UNIVERSIDADE ESTADUAL DE CAMPINAS
Faculdade de Engenharia Mecânica

LUCIO FLÁVIO VASCONCELOS

Influência da Indústria 4.0 na dinâmica do relacionamento comprador-fornecedor: um estudo multisetorial do cenário brasileiro

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Influência da Indústria 4.0 na dinâmica do relacionamento comprador-fornecedor: um estudo multisetorial do cenário brasileiro

Dissertação apresentada à Faculdade de Engenharia Mecânica da Universidade Estadual de Campinas como parte dos requisitos exigidos para obtenção do título de Mestre em Engenharia Mecânica, na Área de Materiais e Processos de Fabricação.

Orientador: Prof. Dr. Jefferson de Souza Pinto

Co-orientador: Prof. Dr. Rosley Anholon

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UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ENGENHARIA MECÂNICA

DISSERTAÇÃO DE MESTRADO ACADÊMICO

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Resumo

O trabalho tem como objetivo analisar a influência da Indústria 4.0 (I4.0) na dinâmica do relacionamento comprador-fornecedor na cadeia de suprimentos nos setores industriais brasileiros como o Automotivo, Químico e Agronegócio. Para alcançar este objetivo duas fases foram conduzidas. A primeira fase teve como objetivo identificar os principais temas e subtemas motores de pesquisas acadêmicas referente à maturidade e modelos de negócios no gerenciamento da cadeia de suprimentos. Nesta fase possível foi identificar as principais forças de ligação entre os temas e subtemas motores, que estão sendo pesquisados e sendo ponto de interesse de pesquisadores acadêmicos nos últimos anos por meio de revisão sistemática da literatura. Na segunda fase, com base no principal tema motor identificado na primeira, Indústria 4.0, foi pesquisada a influência deste tema motor na relação comprador-fornecedor em três setores industriais brasileiros, sendo o automotivo, químico e agronegócios. A pesquisa aplicada com objetivo exploratório utilizou uma abordagem mista - quantitativa e qualitativa - para coleta de dados via *survey*. A amostra do trabalho inclui especialistas e profissionais engajados em seus setores de atuação, e que estão inseridos na transformação industrial. Para a análise dos dados do levantamento foram utilizados métodos multicritério. Pelo método *Analytic Hierarchy Process*, o consenso dos especialistas destacou a importância de relacionamentos com alta interação, em um contexto sistêmico e de forma regular, com colaboração mútua de desenvolvimentos estratégicos entre organizações, com confiança entre compradores e seus parceiros fornecedores na cadeia de abastecimento. Na sequência os dados da pesquisa foram submetidos à análise, por meio do método *Grey Fixed Weight Clustering, e os* resultados refinados pelo método Kernel. Embora os setores automotivo e químico apresentem níveis relativamente mais elevados de maturidade na adoção dos princípios I4.0, o setor do agronegócio fica para trás, indicando graus variados de adoção em diferentes setores. Destarte, conclui-se que a contribuição do trabalho está em apresentar como as tecnologias da Indústria 4.0 e as Tecnologias Digitais influenciam três setores industriais relevantes no Brasil,inovando e aprimorando a compreensão dos estudos acadêmicos em relação ao cenário brasileiro, e ainda sendo base de informação para os responsáveis pela tomada de decisões em suas organizações.

Palavras-Chave: Indústria 4.0; Tecnologias Digitais; Relação comprador-fornecedor; *Analytic Hierarchy Process*; *Grey Fixed Weight Clustering; Método Kernel.*

Abstract

The work aims to analyze the influence of Industry 4.0 (I4.0) on the dynamics of the buyer-supplier relationship in the supply chain in Brazilian industrial sectors such as Automotive, Chemical and Agribusiness. To achieve this objective, two phases were carried out. The first phase aimed to identify the main themes and subthemes driving academic research related to maturity and business models in supply chain management. At this stage it was possible to identify the main connecting forces between the driving themes and subthemes, which are being researched and have been a point of interest for academic researchers in recent years through a systematic literature review. In the second phase, based on the main driving theme identified in the first, Industry 4.0, the influence of this driving theme on the buyer-supplier relationship in three Brazilian industrial sectors, namely automotive, chemical and agribusiness, was researched. The applied research with an exploratory objective used a mixed approach - quantitative and qualitative - to collect data via survey. The work sample includes specialists and professionals engaged in their sectors of activity, and who are involved in industrial transformation. To analyze the survey data, multi-criteria methods were used. Using the Analytic Hierarchy Process method, the experts' consensus highlighted the importance of relationships with high interaction, in a systemic context and on a regular basis, with joint collaboration on strategic developments between organizations, with trust between buyers and their supplier partners in the supply chain. Afterwards, the research data was subjected to analysis using the Grey Fixed Weight Clustering method, and the results were refined using the Kernel method. Although the automotive and chemical sectors show relatively higher levels of maturity in adopting I4.0 principles, the agribusiness sector lags behind, varying degrees of adoption in different sectors. Therefore, it is concluded that the contribution of the work is in presenting how Industry 4.0 technologies and Digital Technologies influence three relevant industrial sectors in Brazil, innovating and improving the understanding of academic studies in relation to the Brazilian scenario, and still being a basis for those responsible for making information decisions in their organizations.

Keywords: Industry 4.0; Digital Technologies; Buyer-supplier relationship; Analytic Hierarchy Process; Grey Fixed Weight Clustering; Kernel Method.

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AHP	*Analytic Hierarchy Process*
CCPG	Comissão Central de Pós-Graduação
CEP	Comitê de Ética em Pesquisa
GCS	Gestão na Cadeia de Suprimentos
GFWC	*Grey Fixed Weight Clustering*
I4.0	Indústria 4.0
QP	Questão de pesquisa
RCF	Relação comprador-fornecedor
TD	Tecnologias Digitais
VE	Variáveis de Escolha
VM	Variáveis de Maturidade

Sumário

1 INTRODUÇÃO

O capítulo apresenta o contexto e o problema de pesquisa, bem como o objetivo geral, e específicos, além da originalidade e relevância, seguida pela caracterização da pesquisa, procedimentos metodológicos e finalizando com apresentação da estrutura do trabalho.

1.1 Contexto

Nos negócios modernos, a competição não é mais entre organizações, mas entre cadeias de abastecimento, então o relacionamento entre duas empresas é vital para o sucesso de cada rede de criação de cadeia de abastecimento de valor (Pathak, 2023), e as Tecnologias Digitais (TD) vêem transformando a tradicional Gestão de Cadeias de Suprimentos (GCS), em cadeias de abastecimento digitais eficientes e inteligentes (Stroumpoulis; Kopanaki, 2022), contudo esta transformação nas atividades industriais enfrenta muitos desafios na introdução da Indústria 4.0 (I4. 0) e das TDs (Sunder *et al*., 2023), pois muitas cadeias de suprimentos ainda são fortemente geridas por sistemas de gestão centralizados, por vezes sem sentido e autônomos (Saberi*et al*., 2019).

Com destacado por Bienhaus e Haddud (2018), o rápido progresso da I4.0 e das TDs o ciclo de vida das eras industriais está menor, forçando as organizações buscarem novas estratégias por meio de uma produção inteligente. E ainda, com o objetivo final de tomar decisões autônomas via inteligência artificial tornando as fábricas mais inteligentes, flexíveis e dinâmicas (Lu, 2017; Eswaran e Bahubalendruni, 2022).

Os sistemas físicos e digitais se fundem na I4.0, abrangendo toda a cadeia produtiva e de produtos, mesmo assim os seres humanos e suas relações dentro e entre as organizações são o que moldam e executam os modelos de negócios (Lasi*et al*., 2014; Chiappetta Jabbour*et al*., 2019). Cabe salientar que a Relação Comprador-Fornecedor (RCF) interligada às estruturas organizacionais, a análise da cooperação torna-se crucial para o desenvolvimento futuro das organizações (Veile *et al*., 2021).

Como a RCF são frequentemente considerados uma relação-base, estas são caracterizados por baixos níveis de envolvimento entre as organizações, pois promovem comportamentos oportunistas (Agarwal e Narayana, 2020). Para que os modelos de negócio possam manter a competitividade num cenário de constante evolução e mudanças é importante avaliar maturidade das organizações (Amaral e Peças, 2021; Bari; Chimhundu e Chan, 2022).

Com isso, a I4.0 está remodelando a RCF na cadeia de abastecimento por meio das TDs (Veile *et al*., 2021), e como apresentado por Delafenestre (2019), as TDs como a inteligência artificial, a tecnologia blockchain, a internet das coisas e o big data estão investigando o potencial do novo modelo de negócios e suas vantagens na GCS. Pois como enfatizado pelas pesquisas de Abdelkafi e Pero (2018), os desafios que a colaboração estratégica entre as organizações enfrentam na GCS e os modelos de negócios são questões vitais para o sucesso em longo prazo nas cadeias de abastecimento (Trkman, Budler e Groznik, 2015).

Com o uso de novas tecnologias, maiores vantagens surgirão na integração das empresas e em toda a cadeia de suprimentos (Schmidt *et al*., 2022) e como exposto por Chen *et al.* (2021), os benefícios de uma gestão eficiente e eficaz proporcionam às organizações maior eficiência e lucratividade, sendo os modelos de negócios existentes diretamente impactados devido à influência dessas mudanças, bem como suas estruturas operacionais e estratégias de gestão e relacionamentos (Ghadge *et al*., 2020).

Em economias em desenvolvimento como o Brasil, a arquitetura para implementação de novas TDs, bem como a definição de padrões terminológicos para auxiliar a implementação da I4.0, vem ganhando força e robustez nos últimos anos (Tortorella *et al*., 2020), todavia o grau de digitalização em cooperação com a RCF difere entre empresas de diferentes portes (Niehoff*et al*., 2022). Mas como ressaltado por Fehr e Rocha (2018) é inerente que as RCF sejam relevantes e façam parte da vida cotidiana entre as organizações nas cadeias de abastecimento.

Algumas barreiras são identificadas em multisetores no Brasil, como a falta de alinhamento estratégico não apenas do lado industrial, mas também do lado governamental no apoio tecnológico, financeiro e acadêmico aos setores industriais (Cordeiro; Reis e Fernandes, 2023). Pois apesar do crescente desenvolvimento da I4.0 dentro das organizações e da academia nos últimos anos, entende-se que os desafios enfrentados pelos trabalhadores decorrentes das tecnologias da I4.0 ainda são limitadas no Brasil (Muniz *et al*., 2023); sendo necessário que o Brasil busque uma “Estratégia de Transformação Digital” (Niehoff *et al*., 2022).

1.2 Problema de Pesquisa

Nesse contexto, este trabalho tem como objetivo analisar as influências da I4.0 na dinâmica da Relação Comprador-Fornecedor (RCF) por meio de uma análise multisetorial do cenário brasileiro, por meio de um questionário aplicado a especialistas atuantes com a temática Indústria 4.0 (I4.0) e as Tecnologias Digitais (TD) em seus respectivos setores de atuação. Atendendo ao disposto, seguem-se as seguintes QP:

QP1: Como está a maturidade das empresas no setor industrial brasileiro em relação à sua adaptação a RCF dentro do contexto da Indústria 4.0?

QP2: Quais são as principais variáveis que orientam a transformação das RCFs no contexto da I4.0 neste cenário?

Este trabalho é apresentado de acordo com o formato alternativo, de acordo comas informações da INSTRUÇÃO CCPG Nº 002/20181, Artigo 2º. Sendo composto por dois artigos, relacionados entre si. O Artigo 1 foi submetido a um periódico internacional da área, sendo publicado;e, o Artigo 2 está em processo de submissão em um periódico de igual ou maior relevância ao Artigo1. O periódico da publicação referente ao Artigo 1, é:

1) *Benchmarking: An International Journal* (ISSN: 1463-5771): Fator de impacto do periódico: 5,6 (2022); https://doi.org/ 10.1108/BIJ-04-2023-0255 (Artigo 1).

1.3 Objetivo Geral

O objetivo deste trabalho consiste em analisar por meio de estudo exploratório, a maturidade das empresas e as principais variáveis que orientam a transformação da relação comprador-fornecedor na cadeia de suprimentos em alguns setores industriais brasileiros como Automotivo, Químico e Agronegócio no contexto da I4.0 e das TDs.

Um dos motivos para analisar esses três setores brasileiros se deve a relevância desses segmentos no contexto da economia industrial brasileira, além da rede de contatos do autor com profissionais formados e atuantes no tema I4.0 e as TDs nesses segmentos.

1.4 Objetivos Específicos

Com base no objetivo geral deste trabalho foram definidos os objetivos específicos:

a) Identificar na literatura as variáveis da I4.0 e das TDs que influenciam a relação comprador-fornecedor na cadeia de suprimentos;
b) Desenvolver uma pesquisa com um questionário (*survey*) para levantamento de dados, a qual em um primeiro estágio é submetida a03 especialistas, conhecedores da temática, para definição do consenso dos pesos na aplicação da sistemática *Analytic Hierarchy Process* (AHP); e consequentemente, aplica-se o questionário em uma amostra de profissionais e desenvolvesse o tratamento dos dados do questionário com um método de análise multicritério;
c) Analisar os dados obtidos com o método de análise multicritério – *Grey Fixed Weight Clustering* (GFWC) e refinados pelo método Kernel*,* a fim de obter as respostas as Questões de Pesquisas (QPs).

1.5 Originalidade e Relevância

O trabalho identificou uma lacuna durante a pesquisa bibliográfica, confirmando sua originalidade, referente à temática desta pesquisa, ou seja, inova ao explorar as influências da I4.0 e das TDs na RCF no cenário brasileiro em três segmentos relevantes: automotivo, químico e agronegócio.

Com base no exposto na introdução, a relevância desta pesquisa contribui para que pesquisadores e *stakeholders* das organizações explorem o potencial da I4.0 e das TDs nos setores industriais brasileiros pesquisados, e conheçam o grau de maturidade na RCF, bem como a relevância das variáveis na cadeia produtiva.

1.6 Método

1.6.1 Caracterização da Pesquisa

A classificação deste trabalho é apresentada no Quadro 1.1.

Quadro 1.1. Classificação da pesquisa do trabalho.

Pesquisa	Classificação
Natureza da pesquisa	Aplicada
Objetivo	Exploratório
Método Amplo	Indutivo e Dedutivo
Estratégia	Pesquisa Bibliográfica e Levantamento de dados (*Survey*)
Abordagem	Mista (qualitativa e quantitativa)
Tempo (corte)	Transversal

Fonte: Elaborado pelo autor (2024).

Esta pesquisa caracteriza-se como aplicada quanto à sua natureza, uma vez que pretender colaborar com análise sobre as influências das I4.0 e das TDs na GCS, tanta para *stakeholders* quanto para os gestores de diferentes níveis dentro das organizações e instituições acadêmicas. Pois, como exposto por Cooper e Schindler (2013), a pesquisa aplicada tem ênfase na resolução prática de problemas, sendo conduzida para revelar respostas a questões específicas, visando resolver questões desconcertantes ou obter novos conhecimentos de natureza experimental ou teórica para pesquisas futuras.

Quanto ao objetivo, este estudo é exploratório, devido à pretensão de compreender como as variáveis empregadas no questionário são percebidas pelos especialistas dos setores estudados neste trabalho. Pois, como descrito por Forza (2002), a pesquisa exploratória ocorre durante os estágios iniciais de uma pesquisa sobre um fenômeno, quando o objetivo é obter informações preliminares sobre um tópico e fornece a base para pesquisas mais aprofundadas.

Este estudo adota um método amplo, que engloba tanto o método indutivo (Artigo 1) quanto o método dedutivo (Artigo 2), proporcionando uma abordagem abrangente para investigar o tema em questão. Inicialmente, para o Artigo 1 é utiliza-se o método indutivo. O método indutivo permite a formulação de conclusões a partir de observações específicas, contribuindo para a geração de conhecimento e compreensão dos fenômenos, conforme definido por Cooper e Schindler (2013). Por outro lado, no Artigo 2 adota-se o método dedutivo. Que segundo Cooper e Schindler (2013), a dedução é uma forma de argumentação conclusiva, baseada nas razões e dados apresentados. Ao utilizar esses métodos amplos, este estudo busca explorar as vantagens de ambos, enriquecendo a análise e fornecendo uma visão completa do tema em estudo.

A estratégia utilizada nesta pesquisa foi um estudo do referencial teórico sobre o tema do trabalho, por meio de uma pesquisa bibliográfica. Que segundo Cooper e Schindler (2013), a exploração do problema é realizada por meio da familiarização com a literatura disponível. Nesta pesquisa, encontrou-se o artigo de Weile *et al.* (2021), que demonstra como as mudanças tecnológicas no contexto da Indústria 4.0 (I4.0) influenciam a Relação Comprador-Fornecedor (RCF).

A coleta de dados via *survey*, foi realizada por questionário via *Google forms* por meio de uma pesquisa *online*. O levantamento de dados via *survey*, é um recurso valioso, pois embora, pesquisas e estudos acadêmicos sejam publicados, raramente mais do que uma fração dos conhecimentos existentes numa área é colocada por escrito. Assim, obter informações de pessoas experientes na área de estudo ou atuação, explorando suas memórias e experiências coletivas, contribui para expansão e compartilhamento do conhecimento (Cooper e Schindler, 2013).

A abordagem desta pesquisa foi mista (qualitativa e quantitativa) pelo interesse de conhecer a opinião dos entrevistados sobre a temática da pesquisa, pois como destacado por Cooper e Schindler (2013),os estudos qualitativos podem ser combinados com estudos quantitativos para aumentar a qualidade percebida da pesquisa, especialmente quando um estudo quantitativo segue um estudo qualitativo e fornece validação para os resultados qualitativos. Endossando a classificação supracitada, Creswell (2009), a abordagem de métodos mistos envolve procedimentos de coleta de dados, análises e a combinação de técnicas quantitativas e qualitativas no tratamento do levantamento de uma pesquisa. Nesse sentido o trabalho em questão envolve essa abordagem mista por combinar desde o início da *survey* até a aplicação das análises multicritério – *Analytic Hierarchy Process* (AHP) e *Grey Fixed Weight Clustering* (GFWC) sendo as análises de frequência baseada em variáveis de escolha, refinada pelo método Kernel.

Do ponto de vista do tempo (corte), esta pesquisa caracteriza-se como transversal, devido à coleta de dados ser realizada em um único momento, como mencionado anteriormente via *Google forms* com especialistas dos setores estudados. Conforme definido por Gil (2017), num único momento com múltiplos respondentes/organizações, ser caracteriza com estudo transversal.

1.6.2 Procedimentos Metodológicos

A base deste trabalho é o segundo artigo mencionado (Artigo 2.2), a ser submetido para um periódico internacional. Este trabalho foi estruturado em cinco etapas, as quais são apresentadas no fluxo da pesquisa na Figura 1.1.

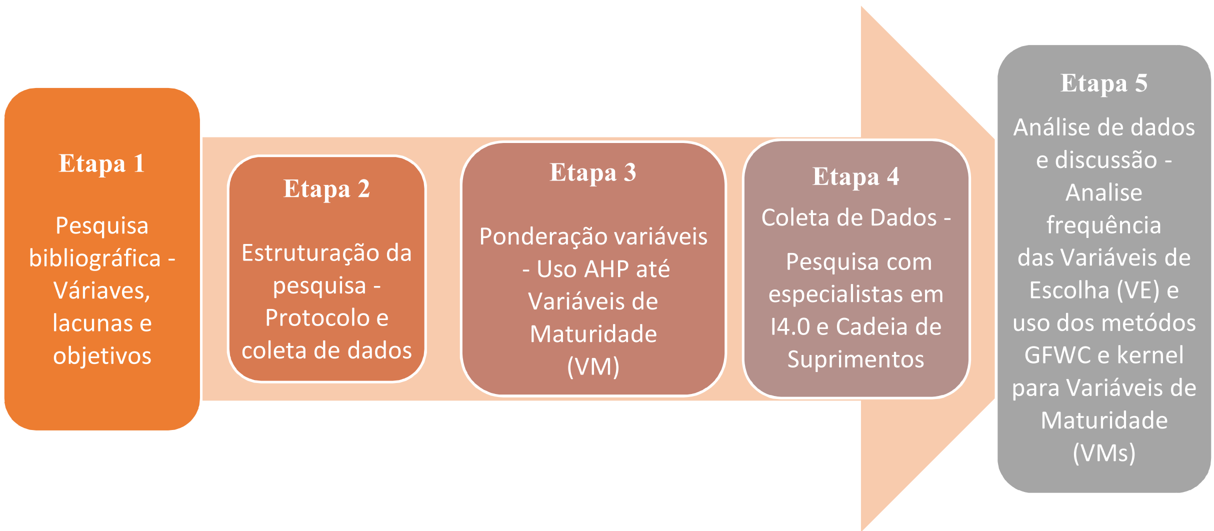

Figura 1.1 – Método da pesquisa de trabalho.
Fonte: Elaborado pelo autor (2024).

As etapas do fluxo da Figura 1.1 são apresentadas nas próximas seções.

1.6.2.1 Etapa 1 – Pesquisa bibliográfica – Variáveis, lacunas e objetivos

A primeira etapa iniciou pela pesquisa bibliográfica para verificar a existência de trabalhos referentes às influências da Relação Comprador-Fornecedor (RCF), termo em inglês

Buyer Supplier Relationship (BSR), na Gestão de Cadeia de Suprimentos (GCS), no que diz respeito à implementação da Indústria (I4.0) e as Tecnologias Digitais (TD) nos setores automotivo, químico e agronegócio no Brasil. Tendo como objetivo estabelecer uma base teórica sobre o tema da pesquisa, dada a natureza exploratória desse estudo, a pesquisa bibliográfica foi realizada nas bases científicas: *Clarivate (Web of Science) Scopus Elsevier, and Google scholar.* Os termos de busca inicialmente utilizados para a pesquisa foram “(("BSR") *OR* ("*buyer supplier relationship*"))”. Na sequência, para refinar as pesquisas, foi adicionado o termo *AND* seguido dos termos de busca “(("I4.0") *or* ("*Industry* 4.0"))” às strings de busca.

Foi encontrada uma lacuna notável, pois dos seis resultados obtidos pela string de busca, nenhuma publicação apresentava à aplicação do método *Analytic Hierarchy Process* (AHP), agregada com o método *Grey Fixed Weight Clustering* (GFWC) com a temática proposta deste estudo. Esta fase da pesquisa bibliográfica mostrou-se fundamental para confirmar a originalidade e relevância, bem como para definir a Etapa 2 deste trabalho.

1.6.2.2 Etapa 2 – Estruturação da pesquisa – Protocolo e coleta de dados

Nesta etapa foi estruturada a construção do instrumento de pesquisa e obtenção de autorização para levantamento de dados via *survey*. Inicialmente, como citado na Etapa 1, a pesquisa bibliográfica foi fundamental para responder o problema de pesquisa desse trabalho, no qual se encontrou o artigo de Weile *et al*. (2021), que demonstra quais variáveis na RCF influenciam a GCS no que diz respeito à implementação da I4.0. Este artigo de Weile *et al*. (2021), suportou a construção deste trabalho por apresentar um estudo recente das variáveis relevantes que influenciam à RCF na I4.0. As variáveis empregadas na pesquisa deste trabalho estão descritas no Artigo 2.2, na seção 2.1 em sua Tabela 1.

Com base no exposto foi elaborado um questionário, conforme Apêndice A, e que possui a concordância dos participantes por meio do Termo de Consentimento Livre e Esclarecido (TCLE). O questionário é estruturado, com 13 perguntas, sendo as cinco primeiras perguntas para caracterização da amostra, as quais são: nome do respondente, segmento de atuação entre os três pesquisados neste trabalho, anos de experiência profissional, contato da rede social do *Linkedin* e e-mail para contato.

As oito perguntas sequentes foram correlacionadas em dois instrumentos de pesquisa, sendo o primeiro desenhado para reunir contribuições de especialistas em I4.0 e RFCs para determinar a importância relativa das Variáveis de Maturidade (VM), estabelecendo assim os pesos para cada VMs em consideração. E o segundo instrumento, Variáveis de Escolha (VE), sendo desenvolvido para coletar dados de outro grupo de especialistas em I4.0 e RCF, a fim de avaliar as indústrias automotiva, química e do agronegócio no Brasil em relação a cada VMs e VEs.

Sendo as oito perguntas apresentadas entre VMs e VEs conforme Artigo 2.2., secção 2.1 na Tabela 1. No qual, três perguntas são relacionadas às VMs, sendo VM1 = Confiança, relacionamento e interação, VM2 = Parcerias e relacionamentos colaborativos para projetos I4.0, VM3 = Evolução ao nível da automação e digitalização nas RFCs, e a cincos relacionadas às VEs são, VE1 = Modo atual de comunicação e contato, VE2 = Condições externas – Dinâmica do mercado, VE3 = Condições externas – Influências macroeconômicas, VE4 = Condições internas – Diferenciação, e por último, a VE5 = Condições internas – Rentabilidade e capacidade de competir.

As cinco perguntas classificadas como Variáveis de Escolha (VE) representam decisões relacionadas à RFC e facilitam a integração de informações contextuais relativas à situação investigada, sendo analisada por análise de estática descritiva. No qual, foram calculadas as frequências das pontuações atribuídas por cada especialista para as VEs, tanto para os setores, quanto para o geral, conforme apresentado no Artigo 2.2, seção 4.1 na Tabela 5 e 6.

E as outras três perguntas classificadas como VMs, foram estruturadas com uma escala *Likert* de 1 a 5, sendo:

1 – Pouco ou nenhuma relevância;

2 – Entre nenhuma e média relevância;

3 – Média relevância;

4 – Entre média e alta relevância; e,

5 – Alta relevância.

Após a elaboração do questionário, seguiram-se as orientações para obtenção de autorização para a coleta de dados, obtendo aprovação com atribuição do Certificado de

Apreciação Ética código CAEE 68574023.2.0000.5404 do Comitê de Ética em Pesquisa (CEP) da Universidade onde foi realizada a pesquisa, conforme ANEXOI.

Para o processo AHP (*Analytic Hierarchy Process)*,a pesquisa foi estruturada em forma de planilha submetida a 03 especialistas conhecedores da temática I4.0 e das TDs, permitindo que estes avaliassem em pares cada variável referente às 03 VMs pesquisadas, conforme método definido por Saaty (2004). Cabe ressaltar que conforme este método, 03 especialistas são suficientes para realizar análise multicritério AHP.

Para este estudo foi definido uma amostragem inicial de 47 respondentes de empresas de grande porte no cenário brasileiro, considerado em média 1/3 de respondentes para cada segmento pesquisado, conforme rede de contatos do autor. O questionário foi enviado via *Google Forms* individualmente para cada participante, tendo obtido 38 respostas. Sendo isto considerado um número positivamente expressivo de respondentes, dado o contexto acadêmico brasileiro em se obter dados via pesquisa.

1.6.2.3 Etapa 3 – Ponderação variáveis - AHP e variáveis de maturidade (VM)

Na Etapa 3, foi utilizado o processo AHP para avaliar a importância relativa das variáveis, que busca realizar uma mensuração relativa em escala absoluta de critérios tangíveis e intangíveis, com base no conhecimento das pessoas envolvidas no processo, para estimar a importância relativa por meio de comparação pareada, sendo capaz de lidar com aspectos qualitativos e quantitativos de um problema de decisão, sendo a mensuração dos ativos intangíveis os principais aspectos matemáticos do método (Saaty, 2004; Saaty, 2013).

Com base no exposto, as três Variáveis de Maturidade (VM) empregadas neste estudo foram estruturadas com seus respectivos elementos para melhor compreensão de cada variável conforme apresentado no Artigo 2.2, seção 2.1na Tabela 1. Então, foi solicitado a cada especialista o preenchimento da Tabela 1.1, a fim de cada par de especialistas inserirem os pesos relativos, chamados de prioridades, para diferenciar a importância dos critérios, conforme os julgamentos no método criado por Saaty (2004), descrito no Artigo 2.2, seção 3.1.3 na Tabela 2. O julgamento reflete as respostas de duas perguntas: qual dos dois elementos é mais importante com respeito a um critério de nível superior, e com que intensidade, usando a escala de 1 a 9, tendo como objetivo fazer agregação do método AHP por meio de média geométrica ponderada.

É importante notar que o elemento mais importante da comparação é sempre usado como um valor inteiro da escala, e o menos importante, como o inverso dessa unidade. Se o elemento linha é menos importante do que o elemento-coluna da matriz, entra-se com o valor recíproco na posição correspondente da matriz. As posições da diagonal serão sempre 1, pois um elemento é igualmente importante a ele mesmo. Para preencher os outros elementos da matriz fora da diagonal, fazem-se os julgamentos e determina-se a intensidade de importância. Para as comparações inversas, isto é, na parte inferior esquerda da matriz, colocam-se os valores recíprocos dos da parte superior direita dela, tendo-se assim a condição $a_{xj} = 1 / a_{xj}$. Onde, neste estudo "j" são direcionadores, "j=j1...j3", e x são os respondentes da *survey*– "x=x1...x38". O método AHP possibilita conhecer a relevância que os três direcionadores pesquisados neste trabalho, por meio da experiência de cada especialista, referente às influências da I4.0 e as TDs na Relação Comprador-Fornecedor (RCF), no cenário brasileiro.

Tabela 1.1. Exemplo - AHP agrupamento e relação de pesos da matriz.

Variáveis de Maturidade (VM)	**VM1**	**VM2**	**VM3**
	Elemento 1	**Elemento 2**	**Elemento 3**
	Critério 1	**Critério 2**	**Critério 3**
VM1	1,0	3	5
VM2	1/3	1,0	9
VM3	1/5	1/9	1,0

Fonte: Elaborado pelo autor (2024).

Conforme exposto no Artigo 2.2, seção 3.1.3 na Tabela 3, foi apresentada a escolha dos 03 especialistas profissionais que participaram no processo AHP, e suas experiências com a temática deste estudo na indústria brasileira e internacional. Conclui-se assim, a seleção destes profissionais mencionados na seção 1.6.2.1, Etapa 1.

Em seguida foram coletados os dados do preenchimento da Tabela 1.1 com cada especialista com seus pesos de julgamento e prioridade preenchida em cada coluna, cujos elementos respeitam a condição $a_{xj} = 1 / a_{xj}$, dita recíproca. Ao final de cada linha foi realizada uma média ponderada, de j1 a j3, sucessivamente para todas as linhas, obtendo-se o peso de critérios *nj.* Na sequência, multiplicou cada valor da primeira coluna da matriz de comparação pela prioridade do primeiro critério e assim sucessivamente para todas as colunas. Então, para cada linha foi realizada uma soma, e na sequência esta soma foi dividida respectivamente por cada peso de critérios *nj.* A somatória do resultado de todas as linhas resultou no valor real denominado λmax (lambda_max), conforme Saaty (2004). E ao utilizar as Equações – Eq. 1 e Eq. 2 foram calculados os índices de consistência, em inglês *Consitency Index* (CI), onde "n" é a ordem da matriz, ou seja, a quantidade número de critérios na matriz. Em seguida calculou-se a taxa de consistência, em inglês *Consistency Ratio* (CR), tendo o Índice aleatório médio AHP, termo em inglês AHP *average Random Index* (RI), conforme Tabela 1.2, sendo utilizado o fator 0,52.

Tabela 1.2. Índice aleatório médio AHP.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Source: Elaborated by Authors adapted based on Saaty (Saaty, 2004).

$$CI = \frac{\lambda max}{(n-1)} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

No Artigo 2.2, seção 4.2 é apresentada na Tabela 7 os pesos de julgamentos atribuídos por cada especialista, e a Tabela 8 apresenta a consolidação dos resultados. Neste estudo o índice obtido de CR foi de 0,35%, ou seja, dentro do limite de menor ou igual a 10%, conforme recomendado por Saaty (2004).A Tabela 9 apresenta os pesos definidos e sua ordem de importância determinada pelo AHP.

Conforme apresentado por Escobar (2004), a inconsistência do grupo é menor que a maior inconsistência individual, razão pela qual o método da média geométrica ponderada resulta em consistência satisfatória em um processo AHP. Neste estudo foi atribuída a agregação das respostas dos três especialistas, confirmando a agregação desse procedimento em estudos que envolvem consistência na tomada de decisão em grupo para AHP.

Com base na sugestão de Forza (2002), a coleta de dados foi obtida por meio de um levantamento (*survey*) que é descrito na próxima seção.

1.6.2.4 Etapa 4 – Coleta de dados - Pesquisa com especialistas

Esta Etapa 4, é seguida da coleta de dados via *survey* com os respondentes dos setores estudados, seguindo as recomendações de Forza (2002).

Como mencionado na seção 1.6.2.1, um questionário foi desenvolvido no *Google Forms* e enviado individualmente para profissionais altamente experientes na área de I4.0, Relação Comprador-Fornecedor (RCF) e gestão da cadeia de suprimentos, e a estruturação do questionário, bem como instrumentos de pesquisas apresentada na seção 1.6.2.2. Um total de 47 potenciais respondentes dos três setores foram convidados a participar deste estudo, e foram obtidas 38 respostas, dado o contexto acadêmico brasileiro em se obter dados via pesquisa, isto é considerado um número positivamente expressivo de respondentes. O perfil dos respondentes é apresentado no Artigo 2.2, seção 3.1.4 na Tabela 4.

Este cenário é base para análise multicritério do método GFWC, que é descrito na próxima seção.

1.6.2.5 Etapa 5 – Análise de dados e discussão – Analise de Variáveis de Escolha (VEs) e uso dos métodos GFWC e Kernel para variáveis de maturidade (VM)

Por fim, nesta última etapa, Etapa 5, é realizada a analise multicritério dos dados por meio do sistema *Grey* para análise dos dados coletados por meio do AHP e do survey. O método *Grey System Theory* (GST), foi desenvolvido por Deng Ju-Long (1982), e apresenta algumas variações, sendo o método *Grey Fixed Weight Clustering* (GFWC), aplicado neste trabalho, por ser adequado para classificar objetos analisados em categorias previamente definidas. Este método foi definido em relação a outros métodos,dentre os quais o de probabilidade estatística e a Análise *Fuzzy*. Pois, o método é apropriado para estruturar situações onde há necessidade de avaliações, análises e apoio à tomada de decisão e outros, por meio de modelagem com dados incompletos com propriedades multivariáveis, mudança de atitudes para melhor e resultados com múltiplas soluções (Liu, Forrest e Yang, 2012). E ainda, aplicado em pesquisas científicas, análise de contextos sociais e econômicos, que demandam estruturação e/ou classificações de cenários com amostra pequena de dados (Golinska *et al*., 2015).

O método GFWC é apropriado, pois possibilita conhecer o nível de maturidade existente na Relação Comprador-Fornecedor (RCF), que influenciam na I4.0 e nas TDs nos segmentos pesquisados no trabalho, por meio de um número limitado de respondentes.

Para este trabalho foi incluso um refinamento dos resultados do GWFC com o uso do *Weight Vector Group* por meio do método Kernel, que segundo Liu *et al*. (2022), é utilizado para tornar mais evidentes as superioridades de cada item, tendo como conceito básico resolver dilema no processo de tomada de decisão de seleção principal, ou seja, as pessoas podem obter um resultado consistente com o modelo de decisão em dois estágios no caso de dilema. No qual, a conclusão da avaliação global é consistente com o resultado do agrupamento, de acordo com a regra do valor máximo.

Como a maioria dos modelos GST são essencialmente modelos lineares, o que limita a aplicabilidade dos modelos Grey, o método Kernel tem como base o modelo multivariado não linear, que contém uma função desconhecida da série de entrada, que pode ser estimada usando a função do kernel (Ma e Liu, 2018).

Cabe ressaltar, que a aplicação método GFWC foi subdividido em seis passos, adaptado por Liu *et al.*(2017), os quais são:

Passo1 – A partir dos dados obtidos de cada respondente é elaborada uma matriz de pontuações de relatórios onde os direcionadores nomeados como critérios no método *Grey*, são classificados como j (j1 a j3); e, os respondentes nomeados como variáveis pelo método *Grey*, como i (i1 a i38). Assim, tem-se a matriz x_{ij}, ou M38x3 (Eq. 3) com base no levantamento de dados realizado via *survey*, para análise multicritério. E ao ponderar os pesos do processo AHP, o valor nj calculado está entre 0 <nj<1, sendo o número 1 o critério mais importante (Golinska *et al*., 2015).

$$M_{38x3} = \begin{bmatrix} i1; j1 & \cdots & i1; j3 \\ \vdots & \ddots & \vdots \\ i38; j1 & \cdots & i38; j3 \end{bmatrix} \quad (3)$$

Passo 2 – Neste passo são definidas as classes "*k"*, também conhecido *clusters* pelo método GFWC, a fim de classificar os direcionadores do estudo. Também foram definidos três grupos de maturidade, adaptado de Golinska *et al.* (2015), os quais são:

a) K=1 – Baixa Maturidade: Há nenhum ou poucos elementos representativos que influenciam a Relação Comprador-Fornecedor (RCF) na Indústria 4.0 (I4.0) e nas Tecnologias Digitais (TD);
b) K= 2 – Média maturidade: Há elementos que influenciam a RCF na I4.0 e nas TDs;
c) K=3 – Alta maturidade: Há elementos que influenciam de forma mais significativa na RCF na I4.0 e nas TDs.

A forma como a técnica GFWC utiliza a definição de cada uma das categorias é apresentada no próximo passo.

Passo 3- Neste passo foram calculadas as funções de possibilidade ou whitenização, em inglês *whitenization,* como é conhecido no método GFWC, para cada classe definida no passo anterior. Pois, conforme Li e Li (2023), as funções de possibilidade são utilizadas para calcular o grau de pertencimento às classes pré-definidas, atribuindo uma pontuação relevante de acordo com cada alternativa a classe.

As funções de possibilidades são empregadas para descrever o grau pelo qual um objeto pode ser classificado em relação às categorias definidas, conforme os critérios de classificação utilizados (Liu *et al*., 2012). Sendo necessário que para cada classe "*k*", a qual os objetos serão classificados, tenha uma função de possibilidades (Liu e Lin, 2011).

Cabe ressaltar, que há três funções de whitenização mais comuns, de acordo com Liu *et al*. (2012), que apresentam ampla adaptabilidade, média adaptabilidade e estreita adaptabilidade. Neste trabalho é correlacionada a palavra adaptabilidade pela palavra maturidade, por ser o objeto deste estudo, bem como, correlacionar a palavra ampla, média e estreita pela palavra alta, média e baixa. Portanto, as funções de possibilidades que são oriundas da análise, e apresentadas na Figura 1.2, são:

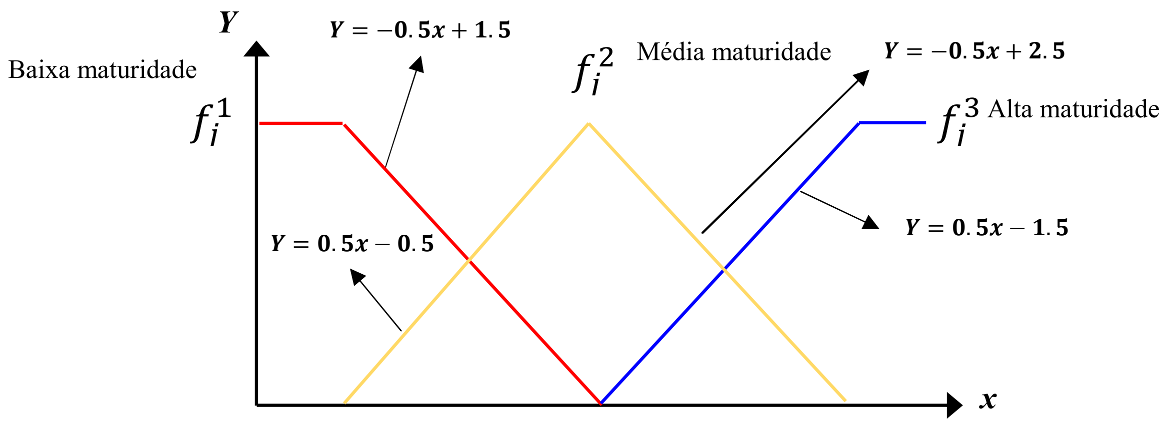

Figura 1.2 – Função de possibilidades usadas no *Grey Fixed Weight Clustering.*
Fonte: Elaborado pelo autor com base em Timóteo *et al.*(2023).

1) A primeira função de whitenização, denominada como baixa, tem os menores valores observados deste estudo e retornam sempre o valor do limite superior de whitenização, até um determinado ponto de inflexão; e, depois passando a diminuir a partir deste ponto, usualmente referenciado pelo valor médio de observação. Dessa maneira, forma-se uma curva, da direita para esquerda, em formato de platô seguido de rampa descendente;
2) A segunda, denominada como média, retorna valor mínimo e, a partir de um ponto de inflexão, começam a retornar valores maiores à medida que o valor de observação se aproxima do valor médio, passando, na sequência a retornar valores menores até chegar ao limite inferior, retornando esse valor a partir deste ponto. Tal curva apresenta formato de um triângulo;
3) A terceira, última função, denominada alta, tem característica oposta à baixa função, retornando valor mínimo até determinado ponto de inflexão, passando a retornar valores cada vez maiores à medida que o valor observado até retornar o valor do limite máximo, mantendo-se nesse patamar a partir de então. O formato dessa função é caracterizado por uma rampa ascendente, da direita para a esquerda, seguida por um platô no valor limite superior de whitenização.

Isto se faz necessário quando o significado dos critérios é diferente e há diferenças entre os valores observados, justificando assim o uso do método GFWC.

Por haver três classes "*k*"definidas para cada função de whitenização, ponderadas pelos pesos dos critérios "*nj*", estes definidos na seção 1.6.2.3, bem como pela soma de cada função. Onden_j^k indica os pesos das variáveis, sendo j as três variáveis desta pesquisa e "*k*" as três classes definidas, e $f_j^k(x_{ij})$ corresponde às funções de possibilidades, conforme Liu *et al*. (2012).

Para mitigar a probabilidade de ser atribuída uma classificação errônea de maturidade a variável de maturidade (VM), e consequentemente sua análise, são atribuídos os percentuais apresentados no Quadro 1.2.

Quadro 1.2. Fatores (percentual) para construção das funções de possibilidades.

Classe	**Função**	**Percentual atribuído**				
		1	**2**	**3**	**4**	**5**
Classe 1 Baixa maturidade	$f_{j=1\_3}^{k=1}$	100%	50%	0%	0%	0%
Classe 2 Média maturidade	$f_{j=1\_3}^{k=2}$	0%	50%	100%	50%	0%
Classe 3 Alta maturidade	$f_{j=1\_3}^{k=3}$	0%	0%	0%	50%	100%

Fonte: Elaborado pelo autor (2024).

Assim, para cada função de possibilidade foram aplicadas as equações descritas por Liu e Liu *et al*. (2012),sendo para baixa maturidade (Eq.4), para a média maturidade (Eq.5) e para a alta maturidade (Eq.6). Conforme a escala de 1 a 5 do Quadro 1.2 e as equações supracitadas são calculadas as funções.

$$f_j^1 = \begin{cases} -0.5\mathrm{x} + 1.5, \mathrm{se}\ 1 \leq \mathrm{x_{ij}} < 3 \\ 0, \mathrm{se}\ 3 \leq \mathrm{x_{ij}} \leq 5 \end{cases} \quad (4)$$

$$f_j^2 = \begin{cases} 0.5\mathrm{x} - 0{,}5\ ,\ \mathrm{se}\ 1 \leq \mathrm{x_{ij}} \leq 3 \\ -0.5x + 2.5,\ \mathrm{se}\ 3 < \mathrm{x_{ij}} \leq 5 \end{cases} \quad (5)$$

$$f_j^3 = 0.5x - 1.5, \text{ se } 3 < x_{ij} \leq 5$$
$$0, \text{ se } 0 \leq x_{ij} \leq 3 \qquad (6)$$

Retomando a análise da Figura 1.2, embora a representação matemática seja idêntica para todas as três Variáveis de Maturidade (VM), o significado das escalas na *survey* de 1 a 5 apresenta diferenças sutis, o que pode gerar nove possíveis funções de possibilidades. Entretanto, isto não afeta o resultado da classificação de maturidade.

Passo 4 – Neste quarto passo é preenchida a matriz com os cálculos obtido da função de possibilidade do passo anterior, e sendo determinados os coeficientes *Grey*.

Na seção 1.6.2.3foi definido o peso dos critérios "*nj"* para cada variável de maturidade (VM), e no Passo1 foi obtida a matriz preenchida dos 38 respondentes "x" com suas respectivas pontuações de 1 a 5para cada uma das três variáveis "j". Ao considerar todos os valores aplicados das três classes "*k*" na função de whitenização, foi possível formar 03 matrizes de dados whitenizados, conforme matriz (Eq. 7).

$$M_{xj}^{k=3} = \begin{bmatrix} M_{1,1}^k & \cdots & M_{1,3}^k \\ \vdots & \ddots & \vdots \\ M_{38,1}^k & \cdots & M_{38,3}^k \end{bmatrix} \qquad (7)$$

Então foi calculado o Coeficiente Grey σ_i^k para cada matriz, conforme Eq. 8, descrita por Liu e Lin (2011).

$$\sigma_i^k = \sum_{j=1}^{m} f_j^k(x_{ij}) * n_j^k \qquad 8)$$

Passo 5 – No quinto passo, toma-se como ponto de partida o resultado de cada matriz (Eq. 8) calculada $M_{xj}^{k=3}$, e analisa-se a classificação das variáveis, referente aos resultados obtidos a partir dos dados fornecidos pelos especialistas da pesquisa. As k classes são definidas de acordo com as funções de possibilidade determinadas no passo 4. Neste estudo, as classes correspondem à maturidade das variáveis da situação em análise segundo os especialistas (i = 38), onde k = 1 é "baixo", k = 2 é "médio" e k = 3 é "alto". Assim, com base nos valores calculados deσ_i^k, a classe k para cada variável e especialistas são determinadas pelo valor de máx. $\{\sigma_i^k\} = \sigma_i^{k*}$, e se então o objeto pertence à classe k*.

As classes "*k*" de maturidade estão apresentadas no Artigo 2.2, seção 4.3 na Tabela 11.

Passo 6 – No último passo, há um refinamento dos resultados do GWFC com o uso do *Weight Vector Group* por meio do método Kernel.

Neste método, assume-se que $\sigma_i^k = \sigma_i^1 \sigma_i^2, \ldots, \sigma_i^s)$,no qual"*s*"é o número de classes de tomada de decisão. Em seguida, os vetores de coeficientes de agrupamento normalizados são calculados usando as Eq.9 e Eq.10.

$$\delta_j^k = \frac{\sigma_i^k}{\sum_{k=1}^{s} \sigma_i^k} \tag{9}$$

$$\sum_{i=1}^{s} \delta_j^k = 1 \tag{10}$$

A seguir, o grupo de vetores de peso com kernel η_k (*k* = 1, 2, ..., *s*) é definido usando a Eq. 11.

$$\eta_k = \left\{ \frac{1}{\sum_{i=2}^{k} \frac{1}{2^i} + \sum_{i=1}^{s-k+1} \frac{1}{2^i}} \right\} \left(\frac{1}{2^k}, \frac{1}{2^{k-1}}, \ldots, \frac{1}{2^2}, \frac{1}{2}, \frac{1}{2^2}, \ldots, \frac{1}{2^{s-k+1}} \right) \tag{11}$$

Finalmente, os vetores de coeficientes de agrupamento abrangentes ponderados ω_j^ksão calculados usando a Eq.12.

$$\omega_j^k = \eta_k \cdot \delta_j^T \tag{12}$$

Assim, com base nos valores de ω_j^k, é possível refinar a alocação de classes do GFWC nos casos em que os resultados são iguais ou muito próximos.

Destarte, os resultados obtidos nesta pesquisa, e decorridos pelo Capitulo 1, seção 1.6.1 e 1.6.2,são apresentados no Artigo 2.2, Capitulo 4, seção 4.1, 4.2 e 4.3.

1.7 Apresentação da Estrutura do Trabalho

Além deste capítulo de introdução que tem por finalidade esclarecer por meio da contextualização as motivações e relevância deste trabalho, é seguido por:

Capítulo 2 - Apresentação de dois artigos sendo primeiro artigo uma abordagem mais abrangente servindo de arcabouço para o segundo artigo base deste trabalho.

Capitulo 3 – Apresenta a discussão dos resultados

Capitulo 4 – Traz as conclusões do trabalho, considerações finais, limitações e trabalhos recomendados.

Encontra-se no final as referências utilizadas, o apêndice e os anexos.

2 ARTIGOS

Esta seção apresenta os dois artigos que compõem esta dissertação e a conexão entre eles será abordado posteriormente.

O primeiro artigo publicado no *Benchmarking An International Journal* (https://doi.org/ 10.1108/BIJ-04-2023-0255) pela *Emerald Insight* intitulado *"Supply chain management maturity and business models: scientific mapping using SciMAT*", tendo como objetivo identificar os temas e sub-temas motores de pesquisas acadêmicas referente à maturidade e modelos de negócios no gerenciamento da cadeia de suprimentos.

O segundo artigo é a base deste trabalho que tem como objetivo analisar a maturidade das empresas e as principais variáveis que orientam a transformação da relação comprador-fornecedor na cadeia de suprimentos em alguns setores industriais brasileiros como Automotivo, Químico e Agronegócio no contexto da I4.0 e das TDs. Este artigo obteve autorização do CEP da Universidade, conforme ANEXO I, e está em processo de submissão a um periódico de igual ou maior relevância que o Artigo 1, com o título preliminar *"Buyer-supplier relationship maturity in the context of Industry 4.0: A multi-sector analysis of the Brazilian landscape"*.

2.1 Artigo 1

Termo de autorização do primeiro artigo publicado no *Benchmarking An International Journal* (https://doi.org/ 10.1108/BIJ-04-2023-0255) pela *Emerald Insight* está no Anexo II.

The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/1463-5771.htm

Supply chain management maturity and business models: scientific mapping using SciMAT

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Abstract

Purpose – Organizations and markets are constantly developing and changing, impacting how organizations create value and manage supply chains. This paper aims to identify the motor themes and subthemes of academic research that relate supply chain management (SCM) maturity and business models (BMs).

Design/methodology/approach – The Science Mapping Analysis Tool (SciMAT) was used to conduct a seven-step bibliometric analysis of 889 documents indexed in the Scopus database clustering by relatedness of works and keywords. The methodological approach included content analysis of the literature, longitudinal analysis and strategic diagram analysis.

Findings – The thematic evolution analysis revealed that three themes drive the studies on SCM maturity and BM: industry 4.0 (motor theme), environmental management (transversal theme) and product management (highly developed and isolated theme). The strategic diagrams and co-word networks allowed to graphically identify the main topics connecting SCM maturity and BM. Considering this connection, the scientific mapping emphasizes the significance and strength of the link between digital technologies, technology management and manufacturing management in Industry 4.0. In addition, the connections between the subthemes revealed that circular economy and green human resource management are important concepts to advance theory and practice on the connection between SCM maturity and BM.

Originality/value – This research extends the knowledge base by providing an analysis of the key themes and the links with subthemes in the literature that relate to SCM maturity and BM. Key studies are analyzed and linked with the key topics identified using the SciMAT software. Future research avenues are outlined, providing new insights to advance theory and practice.

Keywords Supply chain management, Business model, Maturity, SciMAT, Industry 4.0, Sustainability

Paper type Literature review

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1. Introduction

The rapid emergence of innovations and the advancement of digital technologies have resulted in significant changes in the way organizations do business and manage their operations (Ghobakhloo, 2018; Ghobakhloo *et al.*, 2021b). More specifically, digital transformation (DT) has altered how businesses manage their supply chains (Choudhury *et al.*, 2021; Zekhnini *et al.*, 2020) – with direct impact in the field of supply chain management (SCM) – as well as how they create and deliver customer value (Chawla and Goyal, 2022; Singal, 2022) – with direct impact in the field of business model (BM).

On the one hand, DT has transformed traditional supply chains into digital and intelligent supply chains that connect all operations and processes such as product development, purchasing, manufacturing, logistics, suppliers, customers, logistics and services (Stroumpoulis and Kopanaki, 2022). On the other hand, Bellucci *et al.* (2022), Stroumpoulis and Kopanaki (2022) and Saberi *et al.* (2019) emphasize that DT has contributed to revolutionize how BMs are being transformed. Organizations are facing radical change as a result of these transformations, owing to increased global interconnectivity and real-time data and information exchange, which allows organizations to create new BMs and concepts (Bienhaus and Haddud, 2018).

SCM and BM represent two integral facets of modern organizations' operations and strategies. While distinct, these two domains are intricately intertwined, with the effectiveness of one often directly influencing the performance of the other (Di Vaio *et al.*, 2023). In today's dynamic and competitive business landscape, achieving maturity in SCM is not solely about optimizing logistics and operations; it also necessitates aligning these supply chain processes with the overarching BM. SCM maturity refers to the degree of development, efficiency and effectiveness achieved by an organization in managing its supply chain processes and operations (Bach *et al.*, 2023). It signifies the organization's ability to progress from basic supply chain practices to more advanced and optimized approaches (Soares *et al.*, 2021). As organizations advance in SCM maturity, they enhance their capacity to anticipate and respond to market demands, reduce operational inefficiencies, minimize risks, collaborate effectively with partners and ultimately deliver higher value to customers (Caiado *et al.*, 2021), directly impacting their BM.

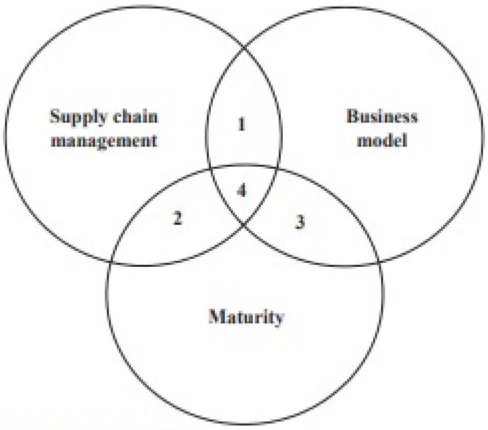
Conversely, the choice of BM profoundly impacts how an organization designs, operates and manages its supply chain. Recognizing the symbiotic relationship between SCM maturity and BM is critical for organizations seeking to thrive in an era characterized by rapid technological advancements, shifting consumer expectations and evolving sustainability imperatives. This exploration delves into the interconnectedness of SCM maturity and BM, shedding light on how advancements in one realm can drive transformative changes in the other and why a holistic approach to these concepts is vital for sustainable business success.

In the context of SCM, BM and maturity research, there are several studies that correlate these concepts two by two, as represented by the areas 1, 2 and 3 in Figure 1.

Research connecting SCM and BM (area 1) can be exemplified by Norris *et al.* (2021) who studied how to integrate sustainable BM in supply chains and Trkman *et al.* (2015) that discuss strategic issues to the long-term success of supply chains through BM modeling. Other examples are Abdelkafi and Pero (2018), which focused on the challenges of strategic collaboration linking SCM and Delafenestre (2019) that investigated the use of digital technologies (e.g. artificial intelligence (AI), blockchain, Internet of Things and big data) in developing new BM in SCM.

Lahti *et al.* (2009) investigated the relationship between SCM and maturity (area 2), highlighting maturity models as valuable management tools for companies to manage their supply chain and set maturity improvement goals. Another example is Sartori and Frederico (2020) who focused on understanding the interrelationships between the dimensions of SCM maturity.

Finally, the relationship between BM and maturity (area 3) can be exemplified by Sehnem *et al.* (2019), who conducted a study aimed at advancing BM maturity levels through process analysis and continuous improvement and by Wagire *et al.* (2021), who focus on technologies to assess BM maturity in the context of industry 4.0 (I4.0).



Source(s): Authors

Figure 1. Representation of the research gap

The research field that integrates SCM, BM and maturity (area 4) is still in its early stages, with very few studies making this connection. Conducting a comprehensive study that connects SCM maturity and BM and delve into their interplay is not only timely but also of paramount importance in today's rapidly evolving business landscape. The need for such a study arises from the realization that these two domains, although distinct in nature, are inherently interdependent and the effectiveness of one profoundly influences the performance of the other (Bach *et al.*, 2023). As organizations strive for SCM maturity, aiming to optimize their logistics, operations and responsiveness, it becomes increasingly clear that this process extends beyond operational efficiency. It encompasses aligning SCM processes with the overarching BM to create a holistic approach to organizational excellence. Conversely, the choice of BM significantly shapes how an organization designs, operates and manages its supply chain, impacting its agility, competitiveness and ability to meet evolving customer demands. With technological advancements, shifting consumer expectations and sustainability imperatives driving transformative changes across industries chains (Chawla and Goyal, 2022; Choudhury *et al.*, 2021), understanding the symbiotic relationship between SCM maturity and BM is not just a matter of academic interest but a strategic imperative for organizations seeking sustainable success. This study aims to fill this gap by providing a comprehensive exploration of these interconnected concepts, shedding light on their intricate dynamics and offering valuable insights for researchers and managers. Thus, the following research question guided this study: What are the motor themes and subthemes of academic research that pertain to the relationship between SCM maturity and BM?

The remainder of the paper is organized in four section in addition to this introduction. Section 2 discuss the main concepts and definition related do SCM, BM and maturity. Section 3 presents the methodological procedures used to conduct this study. Section 4 shows the results and discussions based on the output generated by SciMAT and content analysis. Finally, Section 5 presents the conclusions, discuss limitations and proposes future research.

2. Theoretical background

2.1 Supply chain management

Lalmazloumian *et al.* (2016) define an organization's success as its ability to influence its entire supply chain, thus SCM, in which a group of several organizations, such as suppliers, manufacturers, distributors and retailers, collaborate with a flow of materials and an inverse flow of information, aiming to acquire raw materials with the intention of converting them into final products and delivering them. Frazzon *et al.* (2019), on the other hand, emphasizes how the evolution of intelligent manufacturing processes is modifying and causing profound changes not only in the industry, but also in society, the economy and the environment; as a consequence, this is changing SCM, its value in this chain and thus BMs.

Chen *et al.* (2022) explains how efficient and effective management of practices and activities at SCM improves the quality of goods and materials, allowing organizations to be more efficient and profitable. Lalmazloumian *et al.* (2016) adds agility a critical factor in the competitive environment, as both manufacturing and service companies must adapt quickly in order to meet market requirements and customer expectations. To meet this volatile market demand, the SCM must be agile in order to make these adaptations in an economically viable and timely manner.

As described by Sirisawat and Kiatcharoenpol (2018), environmental issues have become a major issue in various segments of industries in the last decade, so that decision-makers and policy-makers have considered environmental issues of super-relevance in all their organization's activities as they go along throughout their SCM. According to Stroumpoulis and Kopanaki (2022), organizations must develop their supply chain while keeping in mind the social, economic and environmental needs and requirements, as well as the interested parties both inside and outside their environment, where all members can enjoy and benefit from the use of information technologies in conjunction with sustainable development, including within digital supply chains.

As stated by Bressanelli *et al.* (2019), despite being a recipient and still being viewed differently by several academic researchers, the circular economy (CE) as a reliable framework for transforming current BMs towards sustainable development throughout the supply chain and impacted on the approach and SCM strategy due to its concept, basic principles, limitations, advantages and disadvantages at different levels of implementation (Bressanelli *et al.*, 2019). In this context, it is observed that new BMs are emerging and rapidly revolutionizing entire sectors, ranging from industrial to services, as a result of accelerated development via DT and its technologies, thereby changing the entire SCM strategy and conventional guidelines (Mariani and Borghi, 2019).

2.2 Business models

A clear definition of BM is required due to the enormous variety of definitions, not only among academic authors, but also among executives in organizations. A BM, according to Shafer *et al.* (2005), is a representation of a company's underlying core logic and strategic decisions for creating and capturing value within a value network. This definition's simplicity aids in remembering what should always be considered one of the most important aspects of any business, its core logic. This definition will eventually include four key terms. The first key term, core logic, implies that a well-crafted BM aids in the expression and clarification of key assumptions about cause-and-effect relationships and the internal consistency of strategic decisions: the second key term. Indeed, the BM reflects the strategic decisions made. The term value creation and capture refers to two fundamental roles that all organizations must play in order to remain viable over time. Successful businesses create significant value by doing things in ways that set them apart from the competition (Shafer *et al.*, 2005).

Chesbrough and Rosenbloom (2002) designed a BM that acts as a translator between the technical and economic domains. It provides a coherent framework for taking technological characteristics and potentials as inputs and converting them into cost-effective products via customers and markets. As a result, the BM is envisioned as a focusing device that mediates between technological advancement and economic value creation.

Magretta (2002) summarizes two key points in his classic article "Why Business Models Matter" for a possible understanding of what a BM is. The first is that the BM is similar to creating a new story as a variation on an existing one. All new BMs, in this sense, are variations on the generic value chain (doing something plus selling something) that underpins all businesses. The second important point is that business modeling is the managerial equivalent of the scientific method, as it begins with a hypothesis that is then tested in action and revised as needed.

Zott and Amit (2013) emphasize the innovation of the BM in the appropriation of value, and a BM can be defined as the way a company conducts its business in order to meet not only its internal interests, but also all the limits of its sector of activity, with the goals, models, activities of stakeholders and environmental constraints as relevant factors in the design of the BM.

Similarly, Osterwalder and Pigneur (2011) present one of the most used definitions of what a BM can be. In a nutshell, the BM is the logic by which an organization creates, delivers and captures value. The importance of a clear and simple definition stems from the fact that this is a concept that everyone can understand and that facilitates discussion. It is critical to begin at the same point and discuss the same topic. As argued by these authors, the concept should be simple, relevant and intuitively understandable, without oversimplifying the complexities of how businesses operate.

2.3 Maturity

Hellweg *et al.* (2021) defines organizational maturity as the degree to which a process is defined, managed, measured and continuously improved, determining the direction and priorities for future action.

Sari and Nayır (2020) emphasizes the importance of measuring performance in business processes, which can be done by measuring performance or measuring maturity. The first is generally based on the results obtained by the Balanced Scored Card (BSC) example process's performance indicators and the second on verifying effectiveness and efficiency in meeting the organization's existing requirements in its various stages with the goal of improving corporate sustainability. However, it is critical to recognize that, as Amaral and Peças (2021) observed, there are differences between the maturity levels and model attributes for each BM, where levels are the number of steps or stages that the organization must complete before it is ready to implement I4.0 technologies and processes in all internal areas of the organization as well as the supply chain (Amaral and Peças, 2021).

Despite the existence of many maturity models in traditional SCM or even for digital technologies, as Hellweg explains, there is still no agreement on how such a maturity model should be. This may cause the SCM to adapt more quickly in the domain of DT, but it may also present an opportunity to be explored and developed (Hellweg *et al.*, 2021).

The benefits of using maturity models include increased agility, flexibility and availability of products and services, among other things, for organizations that use indices and maturity models as guiding indicators in their decision-making (Basl and Doucek, 2019). As cited by Pigosso and McAloone (2016), maturity measurement models such as the Eco design Maturity Model (EcoM2) have been developed to support manufacturing companies in achieving systematic results and consistent implementation in the development of products and processes, providing sustainable growth for organizations.

For this reason, Hellweg *et al.* (2021) emphasizes that maturity models can serve as a starting point for the digitalization process, because sustainability and digital technologies are indispensable in today's society, and their effects on companies and their businesses are extremely important in SCM.

2.4 Intersections between SCM maturity and BMs

The intersection of SCM maturity and BM represents a critical juncture where the effectiveness of one domain profoundly influences the performance and strategic direction of the other. Achieving maturity in SCM involves the evolution of practices and processes within a network of collaborating organizations, encompassing suppliers, manufacturers, distributors, and retailers, all with the aim of acquiring raw materials, converting them into final products and ensuring their delivery (Bach *et al.*, 2023; Lalmazloumian *et al.*, 2016). Notably, SCM maturity extends beyond operational efficiency; it signifies the organization's ability to progress from basic supply chain practices to advanced and optimized approaches (Soares *et al.*, 2021). As organizations advance in SCM maturity, they gain the capacity to anticipate market demands, reduce operational inefficiencies, manage risks effectively, collaborate seamlessly with partners and ultimately deliver superior value to customers (Caiado *et al.*, 2021). In parallel, the choice of a BM significantly shapes how an organization designs, operates and manages its supply chain. A BM encapsulates a company's core logic and strategic decisions for creating and capturing value within a value network (Shafer *et al.*, 2005). This pivotal role underscores the symbiotic relationship between SCM maturity and BM, where advancements in one domain can instigate transformative changes in the other, emphasizing the necessity for a holistic approach to achieve sustainable business success in today's dynamic and competitive landscape.

Furthermore, the evolution of intelligent manufacturing processes, driven by technological advancements, is causing profound changes not only within industries but also across society, the economy and the environment (Frazzon *et al.*, 2019). Consequently, this transformative wave is exerting a substantial impact on SCM, redefining its value within the broader scope of business operations. Moreover, agility has emerged as a critical factor in the competitive environment, where rapid adaptation to market requirements and customer expectations is essential (Lalmazloumian *et al.*, 2016). The volatile nature of market demand necessitates agile SCM, enabling organizations to make economically viable and timely adaptations (Chen *et al.*, 2022).

The growing significance of environmental concerns has further accentuated the relationship between SCM maturity and BM. Environmental issues have become paramount across various industries, compelling decision-makers and policymakers to consider the environmental impact of their organizational activities throughout the supply chain (Sirisawat and Kiatcharoenpol, 2018). Organizations must now develop their supply chains with a keen focus on addressing social, economic and environmental needs, while considering the interests of internal and external stakeholders (Stroumpoulis and Kopanaki, 2022). Within this context, the integration of information technologies with sustainable development, including within digital supply chains, has become an imperative.

The emergence of the CE as a framework for transforming BMs towards sustainable development has further reshaped the landscape of SCM and its strategic approach (Bressanelli *et al.*, 2019). The CE concept, with its principles, advantages and limitations, has impacted SCM strategies at various implementation levels. This paradigm shift has paved the way for new BMs that are rapidly revolutionizing entire sectors, driven by the accelerated development of DT technologies (Mariani and Borghi, 2019). Consequently, this DT has not only altered the SCM strategy but has also challenged conventional guidelines.

The intersections between SCM maturity and BM represent a dynamic and evolving relationship, wherein advancements in one domain influence and drive changes in the other. As technological advancements, environmental concerns and transformative BMs continue to reshape the business landscape, a holistic approach that recognizes the interconnectedness of these concepts becomes essential for organizations seeking sustainable success.

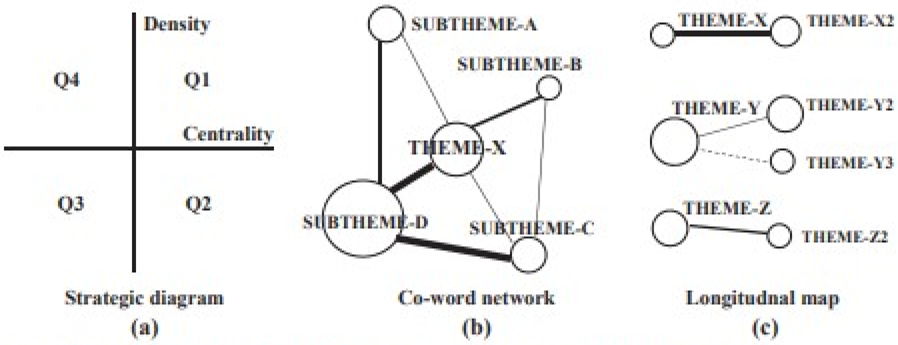
3. Materials and methods

3.1 Science Mapping Analysis Tool

Given the volume and speed with which scientific publications are now produced, scientific mapping studies have gained increased relevance in all knowledge areas (Cobo *et al.*, 2011). In this context, the Science Mapping Analysis Tool (SciMAT) software was created by the "SECABA" group at the University of Granada in Spain, with the aim of improving the visualization of scientific evolution within a specific research area (Castillo-Vergara *et al.*, 2018). This software allows the user to conduct studies based on various bibliometric networks, such as grouping co-word, co-citation of authors, co-citation of journals, co-authorship, bibliography coupling and bibliography coupling of the periodical and bibliography coupling of the author, as well as grouping similar patterns or measures can be linked by strength of association, Equivalence Index, Inclusion Index, Jaccard's Index and Salton Cosine (Cobo *et al.*, 2011).

Currently, the IntellSOK group at the University of Cádiz (Spain) updates and maintains SciMAT, which incorporates all of the modules for carrying out the stages of the analysis flow, assisting researchers from data loading to visualization and interpretation of the output (Moral-Muñoz *et al.*, 2020). According to Furstenau *et al.* (2021), due to its robust pre-processing stage, the SciMAT tool allows for a thorough analysis of the scientific mapping. A frequency and word network reduction is used to identify research topics. The outputs generated by the SciMAT are represented in Figure 2.

A two-dimensional diagram, as shown in Figure 2a (strategic diagram), can be used to represent topics and thematic links through clusters in four quadrants based on density (y axis) and centrality (x axis) values. According to Cobo *et al.* (2012) and Gibbin *et al.* (2023), density can be understood as the degree of development, while centrality represents the degree of importance. Furthermore, these authors explain that the strength of the links is visually represented by the lines connecting the clusters and signifies the intensity of the connection between the themes, with dotted lines indicating weak links and solid, thick lines indicating strong links. In this context, research topics can be classified into four groups based on density and centrality: motor themes (Q1), basic and transversal themes (Q2), emerging or declining themes (Q3) and highly developed and isolated themes (Q4) (Cobo *et al.*, 2011; Kipper *et al.*, 2020). As per López-Robles *et al.* (2019) and Furstenau *et al.* (2020), motor themes hold significance with significant development; basic and cross-cutting themes possess the potential to evolve into motor themes in the future due to their high centrality; emerging or declining themes necessitate a qualitative analysis to ascertain their degree of



Source(s): Elaborated based on Cobo *et al*. (2011) and Furstenau *et al*.(2021)

Figure 2. Visual representation of the outputs generated by SciMAT

emergence or decline; and highly developed and isolated themes represent marginal themes that have diminished in importance due to the emergence of new concepts or technologies.

Figure 2b (co-word network) depicts the thematic network structure, which characterizes the co-occurrence of the research themes and highlights the number of relationships and internal strength between them. The inclusion index is proportional to the line thickness, indicating that the themes share elements (Furstenau *et al.*, 2021).

Regarding Figure 2c (longitudinal map), López-Robles *et al.* (2019) emphasizes that this is useful to understand the evolution path that connects the themes and to identify the conceptual nexus between them. The size of the clusters is proportional to the number of documents related to the theme or subtheme and the links indicate the strength of the connection between the clusters. Solid lines denote clusters that share the main theme, while dashed lines denote cluster elements that do not share the theme.

3.2 Systematic process of data acquisition, organization and analysis

The data of this bibliometric research were obtained in the Scopus database using research strings based on the keywords "supply chain management", "business model" and "maturity", from which the data were extracted in Research Information Systems (RIS) format for analysis by the SciMAT software.

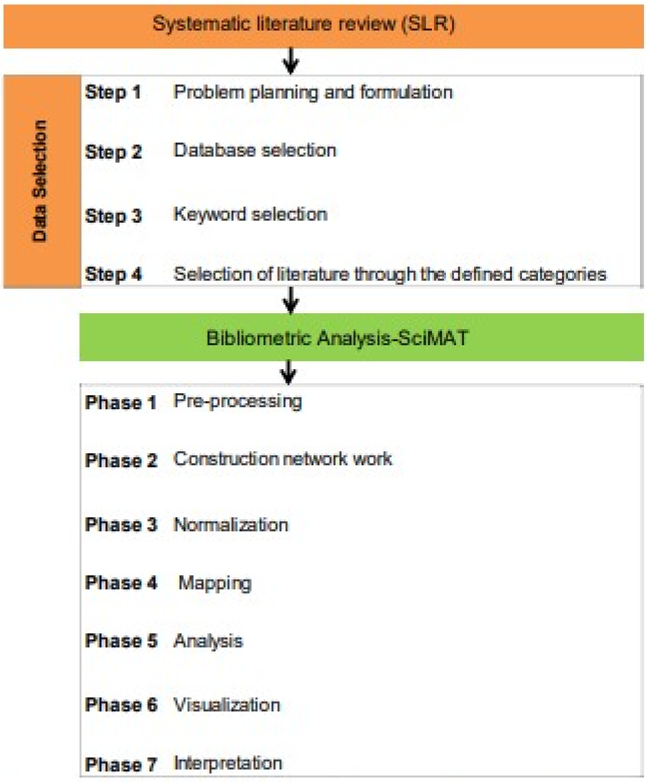
To achieve the objective of this study, the recommendations of Díaz-López *et al.* (2019) were followed to integrate two approaches: systematic literature review (SLR) and bibliometric analysis (Figure 3).

As proposed by Díaz-López *et al.* (2019), the SLR was conducted in four steps. The first step in the study was to plan and formulate the problem, as well as to establish the research question(s). The second step was to identify the best bibliographic databases for document searching. The third step was the selection of keywords, which was one of the most difficult aspects of the research because the number of keywords should not be so large that it restricted the search, but also not so small that it did not present the necessary cut of the search. The fourth step was the final literature selection, which was necessary to ensure a significant and manageable number of relevant selected documents containing the data required to answer the research questions.

Following Díaz-López *et al.* (2019), Figure 4 details these steps and describes the seven phases of the bibliometric analysis.

The data selection process for this study was divided into four steps. The first step defined the scope of the topic to be researched. The second step referred to the selection of the Scopus database, which is characterized by its extensive worldwide and local inclusion of scientific sources, covering journals from additional pertinent databases such as Web of Science, Emerald and ScienceDirect. The third step was to define the keywords search strategy, which involved using the query ("supply chain management") AND ("business model") AND ("maturity") and "all fields" as search location. The strategy of selecting these broad search terms was employed to establish an initial comprehensive database and minimize the risk of excluding important studies in the first search. Thus, the initial search resulted in 1,609 records. The fourth and final step was to critically analyze this initial sample to define the articles to be included in the study. In this step, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher *et al.*, 2009) and the recommendations of Marzi *et al.* (2021), Turzo *et al.* (2022) and Sigahi and Sznelwar (2022) to define the following exclusion criteria (EC): the paper is not available in English, Portuguese or Spanish (EC1); not included in the fields of business and management, accounting, engineering, environmental sciences, social sciences, computer sciences, economics or finance (EC2); not published in a peer-reviewed journal (EC3); does not present a clear connection between SCM, BM and maturity (EC4); only discusses SCM, BM and maturity as part of the

Business models and SCM



Source(s): Elaborated based on Cobo *et al.* (2011) and Furstenau *et al.*(2021)

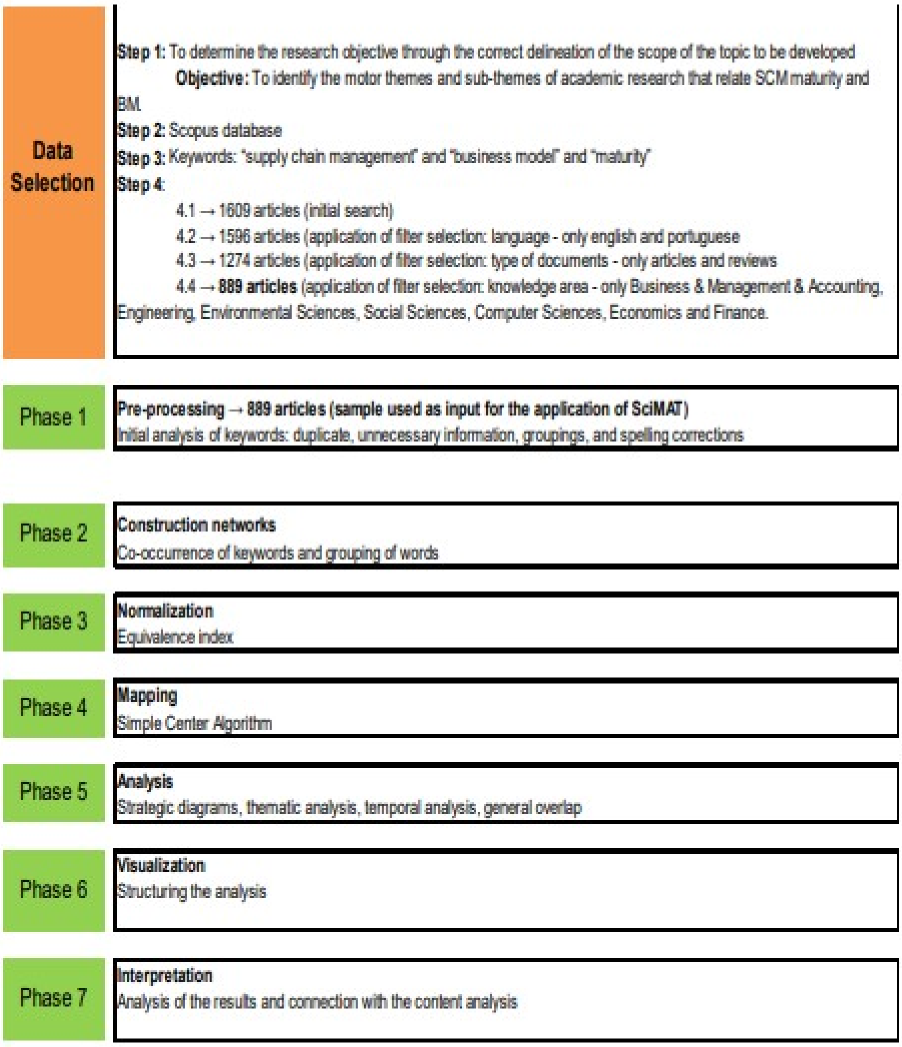
Figure 3.
Research process integrating SLR and SciMAT

future research direction (EC5). EC1 and EC2 were applied using the Scopus database filters. EC3 was verified through the analysis of the journals' websites, whereas EC4 and EC5 were applied by critically analyzing the titles, abstracts and keywords of the articles. This process resulted in final sample of 889 articles which served as the basis for this study. It is important to note that EC4 and EC5 were instrumental in setting the boundaries of the study by including only papers that make contributions to the understanding of the connection between SCM, BM and maturity.

Subsequently, the bibliometric mapping was carried out using the SciMAT software. The first phase involved pre-processing by grouping words that carry the same concept but were originally written in the singular and plural, similar words with one or two character differences were also grouped, and these co-occurring words were grouped in phase two, resulting in a total of 131 groups of words.

In phase 3, the data was normalized and the sample was clustered in the following time periods: 2001–2007, 2008–2012, 2013–2017 and 2018–2022. The selection of the unit analysis in the SciMAT was "author's words", "source's words" and "added words".

In phase 4, the simple center algorithm was used with a maximum network size of 30 and a minimum network size of 2. The options "core mapper" and "secondary mapper" were selected in the sequence in the document mapper. The options "h-index" and "sum citations"



Source(s): Elaborated based on Díaz-López *et al.* (2019)

Figure 4.
Detailed research process integrating SLR and SciMAT

were chosen for quality measures. The SciMAT also included the selection of evolution map, Jaccard's index, overlapping map and inclusion index as parameters.

The software generated the resulting longitudinal and period analysis in phase 5. Phases 6 and 7 allowed for the visualization and interpretation of the results presented in this paper.

4. Results and discussions

4.1 Thematic evolution map

Based on the integrated approach of SLR and SciMAT, the final sample of 889 articles was defined and organized in four periods as shown in Table 1.

Based on the time periods clustered by SciMAT, the thematic evolution map was generated as shown in Figure 5.

The density, centrality and strength of the links between themes and subthemes in the time periods 2001–2007 and 2008–2012 were not sufficient to generate strategic maps. However, in the last decade, when the number of publications significantly increased, the thematic evolution map generated by SciMAT identified the longitudinal connection between "supply chain management" and three clusters: industry 4.0, environmental management and product management. Figure 6 shows the strategic map for this period (2018–2022) and Table 2 shows the values calculated by the SciMAT for each cluster.

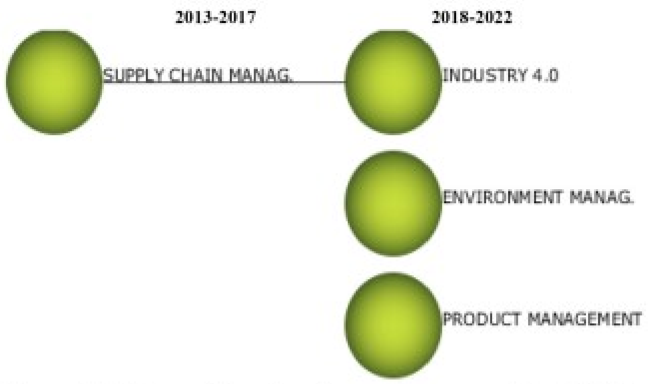
Despite presenting a centricity range of 0.67, the cluster "environmental management" was located in Q2 representing a transversal and basic relevance. This indicates that researchers have been considered topics such as corporate social responsibility (CSR) and socioeconomic responsibility as themes that crosses the majority of discussions on SCM maturity and BM. This reflects the importance of CSR in supporting and structuring modern forms of business management for the benefit of society, with care and focus on the environment, leading organizations to act in a responsible and sustainable manner (Olanipekun *et al.*, 2021). Topics in this quadrant may not be as mature or prominent as motor themes, but they possess high centrality, indicating their potential to become significant in the future. Recognizing these themes is vital for early detection of emerging trends and can inform research and strategy development related to SCM and BM.

By its turn, "product management" present the lowest centricity (0.14) and the highest density (10.65), positioned in Q4 as a highly developed and isolated theme. This indicates that research on product management and development has been conducted by research groups that are not connected with the SCM maturity and BM community, representing an

Time periods clustered by SciMAT	Number of publications
2001–2007	18
2008–2012	32
2013–2017	105
2018–2022	734
Total	889

Source(s): Authors

Table 1. Number of publications grouped by years



Source(s): Elaborated based on the results generated by SciMAT

Figure 5. Thematic evolution map

Source(s): Generated by SciMAT

Figure 6. Strategic map generated by SciMAT for the period 2018–2022

Table 2. Centrality and density values calculated by the SciMAT

Cluster	Centrality	Centrality range	Density	Density range
Industry 4.0	8.23	1	7.94	0.67
Environmental management	3.13	0.67	1.25	0.33
Product management	0.14	0.33	10.65	1

Source(s): Elaborated based on the results generated by SciMAT.

opportunity for increased collaboration and networking. Themes in this quadrant were once significant but have lost importance, often due to the emergence of new concepts or technologies (López-Robles *et al.*, 2019). Recognizing these diminishing themes is crucial to avoid investing resources in areas that are becoming obsolete. It signals the need to shift attention and resources towards more relevant and promising aspects of SCM maturity and BM. In this context, it is important to consider that systematic product development approaches help organizations in the management and standardization of processes in the launch of a new product to meet customer requirements (Salgado *et al.*, 2010). In addition, product-service systems (PSSs) can increase the competitiveness and profitability of an organization and reduce the consumption of material and energy in different supply chain stages creating and delivering enhanced sustainable value (Bocken *et al.*, 2014, 2019).

The only motor theme (Q1) identified was "industry 4.0", which stands out with 303 articles (34.1% of the sample of 889 documents). In the last decade, I4.0 has revolutionized organizations both internally and externally, including strategies for creating and delivering value, as well as managing supply chains, with the goal of improving performance and profitability while ensuring long-term business sustainability (Ching *et al.*, 2022;

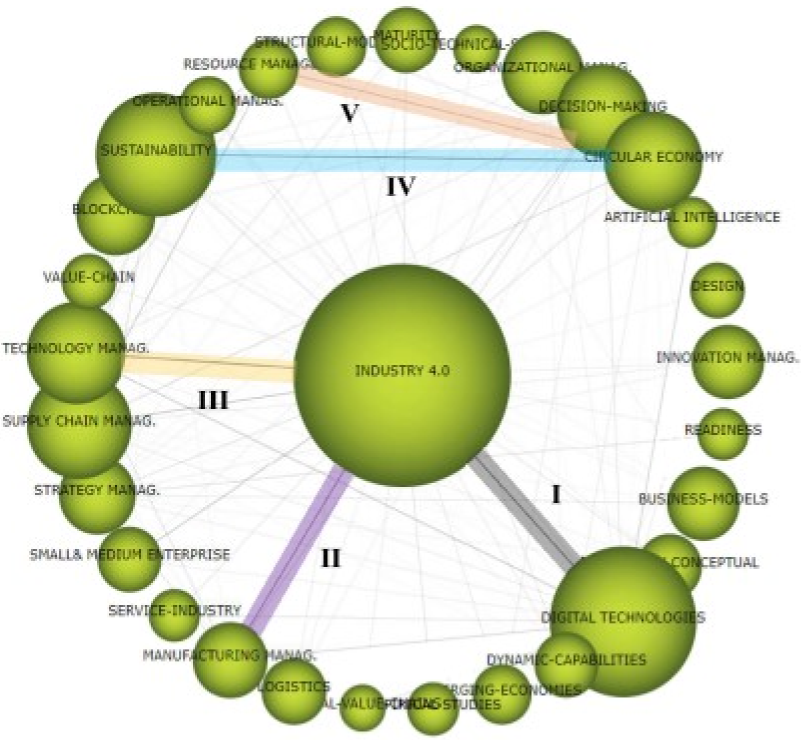
Ghobakhloo *et al.*, 2021a). The cluster "industry 4.0" as a motor theme is an important result as it represents topics that are not only currently significant but also experiencing substantial development. Identifying these motor themes helps researchers and practitioners focus on areas of SCM maturity and BM that are not only important but are actively evolving. It suggests where valuable research efforts should be directed to keep up with industry trends and advancements.

4.2 Network analysis: industry 4.0 as a motor theme

Figure 7 shows the co-word network generated by SciMAT for the motor theme "industry 4.0" highlighting the strongest links.

The links highlighted in Figure 7 represent strong connections not only between the theme engine (industry 4.0) and subthemes (links I, II and III), but also between subthemes themselves (links IV and V).

4.2.1 Links between industry 4.0 and subthemes. The relationship between "industry 4.0" and "digital technologies" (DT) (link I) is related to organizations' increasing demand responsiveness and capacity flexibility, as well as enabling enhanced data coordination and visibility in SCM, facilitating quality in proactive risk management infrastructure planning (Ivanov *et al.*, 2019). This provides context for understanding the connections with "manufacturing management" (link II) and "technology management" (link III), both of which have directly impacted the implementation of I4.0 in improving SCM efficiency and creating mechanisms to capture value in BM (Henríquez *et al.*, 2022).



Source(s): Generated by SciMAT

Figure 7. Connections between "industry 4.0" and subthemes

The content analysis shows that smart manufacturing is a topic that integrates manufacturing and technology management (Ferreira Junior *et al.*, 2022; Leesakul *et al.*, 2022). In fact, smart manufacturing is becoming increasingly important in the advancement of modern industry and economy in I4.0. Smart manufacturing systems can monitor physical processes, creating a digital twin of the physical world and make intelligent decisions via real-time communication and collaboration with humans, machines and sensors, adding value to a variety of products, manufacturing systems and services (Ciccarelli *et al.*, 2022). This includes BM innovation towards sustainable product-service system (PSS) (Zheng *et al.*, 2018) and creating value for both internal actors, such as workers (Demirel *et al.*, 2021; Lum, 2021) and external actors throughout digital supply chain twin (Ivanov and Dolgui, 2021).

The growing relevance of I4.0, DT and smart manufacturing in the scientific literature relating SCM maturity and BM is reflected in practice. General Electric, for example, launched the Industrial Internet of Things (IIoT) concept in the United States of America in 2012, proposing that intelligent machines, advanced analytics and connected people are key elements of future manufacturing, in order to enable more informed decision-making by humans and machines. On a nationwide basis, the most well-known plan was that of Germany, which launched its I4.0 plan in 2013, with the goal of occupying manufacturing industries with machines and intelligent products capable of creating systems and intelligent networks that communicate with each other autonomously (Schwab, 2017). Other examples include Japan, which launched the Industrial Value Chain initiative in 2015 with 30 relevant companies in their industry, combining manufacturing and information technologies to bring smart factories to life; and China, which defined a 10-year plan in 2015 to develop its manufacturing capacity to match that of countries such as Germany and the United States of America (Zhong *et al.*, 2017).

As Ivanov *et al.* (2019) pointed out, these plans have been turned into reality and future production models will necessitate integration throughout the supply chain in a dynamic manufacturing format. Supply partners will need to integrate the digital twins of their operations through technology management, removing functional silos through openness to change, supporting culture, supply chain integration and data transparency in the value chain as I4.0 pervades the entire value chain (Ghobakhloo, 2018).

4.2.2 Links between subthemes. The strongest links between subthemes that compose the network of the motor theme "industry 4.0" include key topics related to sustainable development. The content analysis focusing on the subthemes highlighted in Figure 7 ("circular economy", "resource management" and "sustainability"), allowed to identify trends that influence SCM maturity and BM.

The linear models of production, including resource management systems, widely used in the past and which continue to be used today, have caused immense environmental damage (Korhonen *et al.*, 2018). When considering specific segments of society, usually those most vulnerable, these negative externalities can be extended to social and economic dimensions (Sigahi *et al.*, 2023; UN, 2022). In this context, the convergence of digital technologies with sustainable management and manufacturing practices offers the best possible means for advancing the CE (Haapala *et al.*, 2013; Hapuwatte and Jawahir, 2021; Jawahir and Bradley, 2016).

In this scenario, Enyoghasi and Badurdeen (2021) call researchers to think about the contributions of I4.0 to sustainable development, including SCM and BM, in three dimensions: product, process and systems. Considering these dimensions, the content analysis allowed to identify some contributions in this matter.

At the product level, I4.0 enabling technologies can contribute in different ways to embedding sustainability aspects in SCM and BM:

(1) Big data: reduces the cost of processing components at the end of their life cycle (Ching *et al.*, 2022);
(2) Virtual reality: Improved fault detection and expanded possibilities for improvement before production (Ghobakhloo *et al.*, 2021b; Oliveira Neto *et al.*, 2023);
(3) Computational simulation: product performance improvement based on predictive diagnostics (Bai *et al.*, 2020);
(4) Additive manufacturing: faster and lower cost of R&D, reduced assembly operations, lighter products (Dantas *et al.*, 2021);
(5) Cloud computing: improvement of product management through digital interfaces (Sodhi, 2021);
(6) IoT: improved product cost, quality control, traceability (Enyoghasi and Badurdeen, 2021; Machado *et al.*, 2020).

Considering production processes as an object, these technologies can also promote sustainability at SCM and BM:

(1) Big data: transparency in resource consumption (Dantas *et al.*, 2021; Enyoghasi and Badurdeen, 2021);
(2) Virtual reality: increased process stability due to previous improvements and better workers' training (Bonilla *et al.*, 2018);
(3) Computational simulation: improved resource utilization (Aravindaraj and Rajan Chinna, 2022);
(4) Additive manufacturing: reducing queues between processes and reducing the complexity of manual operations (Ching *et al.*, 2022)
(5) Cloud computing: flexibility of the production planning process (Oliveira Neto *et al.*, 2023);
(6) IoT: improvement in decision-making processes, monitoring and predictive maintenance (Ghobakhloo, 2020; Ghobakhloo *et al.*, 2021b).

From a systemic perspective, the following contributions from I4.0 to sustainable SCM and BM can be mentioned:

(1) Big data: improving demand forecast accuracy (Enyoghasi and Badurdeen, 2021);
(2) Virtual reality: increased organizational efficiency due to the higher qualification of professionals (Mattsson *et al.*, 2020);
(3) Computational simulation: improvement in demand and inventory management (Aravindaraj and Rajan Chinna, 2022);
(4) Additive manufacturing: risk reduction in SCM (Jabbour *et al.*, 2018; Patidar *et al.*, 2023);
(5) Cloud computing: improvement on Green Supply Chain Management (GSCM) (Ching *et al.*, 2022; Jabbour *et al.*, 2018);
(6) IoT: increased SCM efficiency through information and data management such as location, product/production conditions, traceability and availability (Agyabeng-Mensah *et al.*, 2022; Ghobakhloo, 2020; Patidar *et al.*, 2023).

Finally, a specific topic, the human factor, deserves to be mentioned (Bolis *et al.*, 2023; Herrero-Luna *et al.*, 2022; Jabbour, 2011). Particularly, Jabbour *et al.* (2019) focuses on Green Human Resource Management (GHRM), arguing that the "human side" of the CE needs to be looked at more carefully by managers and organizations, once processes of recruitment and selection, training, performance evaluation, rewards and teamwork directly affect how sustainable value is created and delivered through SCM and BM.

4.3 Future research avenues

The results presented in the research paper provide valuable insights into the landscape of SCM maturity and BM, particularly emphasizing the role of I4.0 as a motor theme and the interconnectedness of various subthemes.

Based on that, three research avenues emerged, as shown in Table 3.

4.3.1 Digital technologies and SCM/BM. The strong connections between "industry 4.0," "digital technologies," "manufacturing management," and "technology management" highlight the critical role of technology in SCM and BM. Future studies can explore how the integration of digital technologies influences decision-making, innovation and value creation within supply chains and BMs.

Investigating how IoT technologies influence decision-making processes within supply chains can be of great value for companies and managers. IoT sensors and devices provide real-time data on various aspects of supply chain operations, including inventory levels, shipment status and equipment condition. Understanding how organizations utilize IoT data for decision-making and how it enhances supply chain visibility, agility and responsiveness is crucial. Moreover, exploring the challenges and opportunities that IoT presents in this context can inform best practices.

Another emerging topic is exploring the role of blockchain technology in fostering innovation within BMs. Blockchain has the potential to revolutionize how businesses operate by providing transparent and secure record-keeping. Research can delve into how blockchain

Research avenue	Suggested topics	Key references
Digital technologies and SCM/BM	• Impact of IoT in supply chain decision-making	Ben-Daya *et al.* (2019), Manavalan and Jayakrishna (2019), and Maia *et al.* (2019)
	• Innovation through blockchain in business models	Li *et al.* (2022), Chin *et al.* (2022) and Calandra *et al.* (2023)
	• Value creation through artificial intelligence in manufacturing management	Grover *et al.* (2022) and Dey *et al.* (2023)
Sustainable SCM and BM	• Circular economy implementation in industry 4.0	Bag and Pretorius (2022), Tang *et al.* (2022) and Di Maria *et al.* (2022)
	• Resource efficiency and industry 4.0	Agrawal *et al.* (2022), Hettiarachchi *et al.* (2022) and Kayikci *et al.* (2022)
	• Social responsibility and industry 4.0 adoption	Mukhuty *et al.* (2022) and Govindan (2022)
Human factors and GHRM	• HR skills and competencies for industry 4.0	Sharma *et al.* (2022) and Agarwal *et al.* (2022)
	• HR and employee engagement in sustainability	Brunoro *et al.* (2020), Bolis *et al.* (2023) and Pekaar and Demerouti (2023)
	• Adaptive HR policies and circular business models	Subramanian and Suresh (2022) and Obeidat *et al.* (2023)

Source(s): Authors

Table 3.
Centrality and density values calculated by the SciMAT

facilitates trust among stakeholders, enables new revenue models (e.g. tokenization) and supports innovative BMs such as sharing economies and circular supply chains. Additionally, understanding the challenges and regulatory considerations associated with blockchain adoption is essential.

Researchers can also examine how AI applications impact value creation within manufacturing management. AI-driven technologies, including machine learning and predictive analytics, are transforming manufacturing operations. Research can investigate how AI optimizes production processes, reduces downtime, enhances quality control and supports just-in-time manufacturing. Furthermore, it's essential to assess how these AI-driven enhancements translate into improved value propositions and competitive advantages for organizations.

4.3.2 Sustainable SCM and BM. The subthemes related to sustainability, such as "circular economy," "resource management," and "sustainability," offer a rich area for research. Investigations can focus on how I4.0 technologies enable more sustainable practices in SCM and BM, such as reducing environmental impact, optimizing resource use and promoting social responsibility.

Investigating the integration of CE principles within I4.0-driven supply chains and BMs is paramount. CE concepts aim to minimize waste and promote the reuse, remanufacturing and recycling of products and materials. Research can explore how I4.0 technologies, such as IoT, blockchain and data analytics, facilitate the tracking, tracing and management of products throughout their lifecycle. Additionally, it can assess the economic and environmental benefits of circularity in SCM and BM and identify challenges in transitioning from linear to circular models.

Future research endeavors can focus on examining how I4.0 technologies optimize resource management in supply chains and business operations. I4.0 enables real-time data collection and analysis, which can lead to more efficient resource allocation and reduced resource waste. Research can delve into case studies that demonstrate how technologies like smart sensors, AI and data-driven decision-making contribute to minimizing resource consumption, lowering production costs and enhancing sustainability. Moreover, it can address the potential trade-offs between resource optimization and other business objectives.

Another important research possibility is exploring the social responsibility dimensions of I4.0 adoption in SCM and BM. I4.0 adoption has implications beyond environmental sustainability, extending to social responsibility practices. Research can investigate how organizations consider ethical labor practices, diversity and inclusion and fair supply chain partnerships in the context of I4.0. It can assess the impact of digital technologies on worker well-being, labor rights and community engagement. Additionally, it can explore strategies for organizations to align I4.0 adoption with socially responsible business practices.

4.3.3 Human factors and GHRM. The exploration of human factors and GHRM in the context of CE and sustainable SCM and BM converges with the transformative influence of I4.0. This avenue of research takes on added significance in the I4.0 era as it investigates the crucial human dimension within the technological revolution. As organizations increasingly adopt I4.0 technologies, the role of human resources becomes pivotal in facilitating this transition. Future research can delve into how I4.0 redefines the landscape of human resource (HR) practices, particularly in the context of sustainability and circularity.

Researchers can explore the specific skills and competencies required of HR professionals in an I4.0 environment. This includes proficiency in data analytics, digital literacy and the ability to navigate the complexities of advanced technologies. The study can identify the HR capabilities essential for aligning human capital with the principles of circularity and sustainability.

Investigating the impact of HR practices on employee engagement in sustainability initiatives is paramount. I4.0 can enable real-time monitoring and feedback mechanisms that empower employees to contribute actively to sustainable SCM and BM. Research can delve into strategies for enhancing employee participation in CE endeavors and the role of HR in fostering a sustainability-oriented corporate culture.

The adaptability of HR policies and practices is critical in the dynamic landscape of circular BMs enabled by I4.0. Scholars can examine how HR policies need to evolve to support the adoption of circularity principles, including factors such as flexible work arrangements, performance evaluation criteria and talent acquisition strategies that prioritize CE expertise.

5. Conclusion

The purpose of this study was to identify the motor themes and subthemes of academic research that relate SCM maturity and BM. Scientific mapping analysis was used to achieve this objective. SciMAT showed to be a very useful tool for conceptually organizing the themes relating SCM maturity and BM.

The analysis of thematic clusters in the study revealed distinct patterns in the evolving landscape of SCM maturity and BM. Firstly, the cluster labeled "environmental management" was positioned in Q2, indicating its transversal relevance. This suggests that researchers have recognized the importance of topics like sustainability, CSR and socioeconomic responsibility as overarching themes cutting across discussions on SCM maturity and BM. While not as mature or prominent as a motor theme, these themes exhibit high centrality, signifying their potential for future significance, making early detection of emerging trends crucial. Notably, "I4.0" emerged as the sole motor theme (Q1) with substantial development and relevance, revolutionizing organizational strategies and SCM, underlining the need for researchers and practitioners to focus on actively evolving areas in SCM and BM.

The research presented three significant avenues for future exploration. First, the interplay between digital technologies and SCM/BM, particularly focusing on the influence of technologies like IoT and blockchain on decision-making and innovation, was highlighted. Second, sustainable SCM and BM emerged as a critical area for investigation, encompassing the integration of CE principles, resource management optimization and social responsibility considerations within the I4.0 paradigm. Lastly, the human factor and GHRM gained prominence, addressing the evolving role of HR practices in supporting I4.0 transformations, sustainability and circularity.

Practically, these findings hold significant implications for both researchers and practitioners. Researchers are encouraged to delve into the outlined research avenues to advance knowledge and address critical gaps in the evolving landscape of SCM maturity and BM. By exploring the impact of I4.0, digital technologies and sustainability on decision-making, innovation and value creation, scholars can provide valuable insights to inform business practices. For practitioners, this study underscores the importance of embracing I4.0 technologies strategically. It highlights the potential benefits of these technologies in enhancing supply chain visibility, agility and responsiveness. Moreover, it emphasizes the need for organizations to consider the ethical and social dimensions of I4.0 adoption, aligning technology-driven transformation with sustainability and human resource management practices.

It is also important to note that by emphasizing the role of I4.0, sustainability and the human factor within this context, this study acknowledges the critical importance of aligning business strategies with ethical, environmental and societal considerations. As organizations grapple with the transformational impact of digital technologies and the imperative to operate sustainably, this research contributes to the broader discourse on responsible business practices and innovation, offering insights that extend beyond academic realms to influence real-world decision-making and strategy development.

This study significantly contributes to the existing body of knowledge by providing a comprehensive overview of the thematic landscape at the intersection of SCM maturity and BMs. By employing the SciMAT tool, this research offers a novel perspective on the evolving patterns and interplay between these critical domains. It extends current knowledge by identifying and categorizing thematic clusters, shedding light on emerging trends such as the centrality of sustainability issues and the dominance of I4.0 as a motor theme. Furthermore, the avenues for future research outlined in this paper contributes to offer valuable insights for scholars seeking to deepen their understanding of SCM maturity and BM and address critical gaps in contemporary business practices.

While this study provides valuable insights into the thematic landscape of SCM maturity and BM, it is essential to acknowledge its limitations. Firstly, the research relies on a specific set of academic publications for its analysis, potentially introducing bias based on the selection criteria. Additionally, the study's focus on academic literature might not fully capture the evolving landscape of SCM and BM in practice. Furthermore, the analysis predominantly relies on existing research outputs, limiting the exploration of emerging, non-academic trends in the field. Finally, the study does not delve deeply into regional or industry-specific variations, which could influence the generalizability of findings.

Previous research has often explored SCM maturity and BM as separate domains, with limited attention to their intersection. This study bridges that gap by mapping the thematic clusters that link SCM maturity and BM, revealing previously unexplored connections. It aligns with prior studies in recognizing the significance of I4.0 but extends this understanding by identifying several research topics that deserve attention from both researchers and practitioners. Overall, this study builds upon prior research while introducing novel perspectives that enrich our understanding of SCM maturity and BM in a rapidly evolving business landscape.

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2.2 Artigo 2

Buyer-supplier relationship maturity in the context of industry 4.0: A multi-sector analysis of the Brazilian landscape

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Purpose – This paper investigates the maturity of Brazilian companies in adapting their BSRs in the context of I4.0, encompassing automotive, chemical, and agribusiness sectors.

Design/method/approach – The methodological approach encompassed Analytic Hierarchy Process (AHP), survey, Grey Fixed Weight Clustering (GFWC) and kernel method. The AHP was employed to assign weights to three maturity variables associated with I4.0 impacts on BSRs. This process incorporated the insights of three specialists possessing extensive professional and practical knowledge in the field. Concurrently, 38 experts in I4.0 and supply chain management assessed the maturity level of each variable within the Brazilian context, considering the automotive, chemical, and agribusiness sectors. Subsequently, the weights determined via AHP and the survey data were subjected to analysis using GFWC modeling. The results were refined using the kernel method and complimented by frequency analysis based on choice variables.

Findings – The study reveals that electronic and automated modes of communication dominate BSRs across all sectors, reflecting the increasing reliance on digital technologies within supply chains. External conditions such as market dynamics and regulatory standards significantly shape BSRs, highlighting the importance of sector-specific nuances in managing these relationships effectively. Maturity analysis further illuminates the critical significance of trust, collaborative partnerships, and automation in enhancing BSRs within the context of I4.0. While the automotive and chemical sectors exhibit relatively higher levels of maturity in embracing I4.0 principles, the agribusiness sector lags behind, indicating varying degrees of adoption across different sectors. Understanding these differences is crucial for stakeholders to prioritize efforts and enhance competitiveness in the rapidly evolving landscape of I4.0. These insights offer essential strategies for BSR enhancement amidst I4.0, emphasizing technological innovation, regulatory adaptation, and collaboration for mutual prosperity.

Originality/value – This research breaks new ground by exploring the influence of I4.0 on BSR within key Brazilian industrial sectors. Employing a robust methodological framework suitable for phenomena characterized by data uncertainty and incompleteness, it offers novel theoretical and practical insights for companies to embrace I4.0 technologies on enhancing their BSRs.

Keywords: Industry 4.0; Digital transformation; Supply chain management; Buyer-supplier relationship; Multicriteria decision making.

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1 Introduction

Productive activities entered in a new paradigm in the face of industry 4.0 (I4.0) (Sunder et al., 2023), with technologies capable of making production more intelligent through more assertive, agile and flexible making decision-making (Tortorella et al., 2022).

Physical and digital systems merge in I4.0, covering the entire production chain and products (Ghadge et al., 2020). This sheds light to the relationships within and between organizations, which creates new opportunities for increase corporate performance (Aharonovitz et al., 2018). Particularly, buyer-supplier relationship (BSR) is key as they interconnect with organizational structures, directly impacting the development of organizations and supply chains (Veile et al., 2021, 2022).

BSRs are often considered transaction-based relationships characterized by low levels of involvement between organizations, as they promote opportunistic behaviors (Agarwal & Narayana, 2020). However, recent research has demonstrated how important is to consider them as a key factor in the context of I4.0 (Gottge et al., 2020). Veile et al. (Veile et al., 2021) argues that is necessary to consider external and internal aspects of BSR to understand how I4.0 impacts it. Investigating buyer-supplier dynamics in the I4.0 era is crucial for understanding how trust, communication, and internal and external conditions shape these relationships and influence organizational success. In the competitive landscape of modern markets, BSRs characterized by trustful interactions and shared values are essential for driving innovation, meeting customer needs, and achieving mutual benefits. The integration of I4.0 technologies further emphasizes the importance of effective communication and collaboration between buyers and suppliers, enabling organizations to streamline processes, enhance efficiency, and adapt to dynamic market conditions. Moreover, internal factors such as differentiation, profitability, and competitive strength are significantly impacted by BSRs, with I4.0 technologies offering opportunities to optimize operations, minimize risks, and sustain long-term profitability and competitiveness. As BSRs evolve into cooperative partnerships guided by I4.0 principles, understanding their dynamics becomes paramount for organizations seeking to thrive in the digital age and capitalize on emerging opportunities in the marketplace.

While significant research exists on supply chain and I4.0, there remains a notable gap concerning the nuanced dynamics of BSR within this context. Existing studies have primarily focused on the role of I4.0 technology adoption in supply chain management. For instance, Tortorella et al. (Tortorella et al., 2022) studied the contributions of I4.0 to supply chain performance, while Kumar et al. (A. Kumar et al., 2024) investigated the barriers to implement them. However, limited attention has been given to BSR developed within supply chains and their effectiveness in facilitating collaboration, resolving conflicts, and building trust. Additionally, while some research acknowledges the importance of BSRs, there is a lack of comprehensive understanding regarding the maturity of organizations in different countries (Gameiro &Satolo, 2023). Addressing this gap is crucial for developing practical insights and recommendations for organizations seeking to optimize their BSRs in the era of I4.0, ultimately enhancing their competitiveness and sustainability in dynamic market environments.

Thus, this paper aims to examine the influence of I4.0 technologies on the BSR within the supply chains of key industrial sectors in the Brazilian context, encompassing automotive, chemical, and agribusiness. The following research questions (RQ) guided this study:

- RQ1: How has the implementation of I4.0 technologies impacted BSRs in the Brazilian industrial sector?
- RQ2: What are the main drivers guiding the transformation of BSRs in the context of I4.0 in this scenario?

This study has an exploratory nature and aims to address these questions considering three highly relevant sectors in the Brazilian industrial scenario: automotive, chemical, and agribusiness. Given the importance and influence of these sectors in the country, the findings of the research contribute to understanding the transformations that I4.0 is causing in supply chains, generating conceptual and practical insights for researchers and managers. Furthermore, this study can be important for understanding such impacts more broadly, considering countries with socio-economic and structural characteristics similar to Brazil.

2 Theoretical background

2.1 Buyer-supplier relationship (BSR) in the context of Industry 4.0

In the landscape of increasingly competitive markets, BSRs play a pivotal role, especially within the paradigm of I4.0. Despite the emergent nature of the field, researchers have identified important factors that companies must be aware of. In this context, a key study is Veile et al. (2021), who defined eight drivers explaining how I4.0 reshapes BSRs. In the present study, these drivers were employed as variables and categorized into two types: choice variables (CV) and maturity variables (MV). CVs represent decisions related to BSR and facilitate the integration of contextual information regarding the investigated situation. On the other hand, MVs pertain to elements commonly considered in the day-to-day operations of companies, over which decision-makers wield greater control. They reflect the decision-maker's perception of the current stage of the investigated situation. This forms the conceptual framework of this study, as shown in Table 1

Table 1.Variables related to the impact ofI4.0 on BSR.

Code	Variable	Key explanatory elements
CV1	Current mode of communication and contact	• Communication in the present is typically manual and personal. • Personal and manual contact is prevalent for highly individualized products.
CV2	External conditions – Market dynamics	• Customer needs, competition, and market dynamics are crucial. • Demand for product individuality, quality, and process transparency is increasing. • Competition and market changes greatly impact decisions.

CV3	External conditions – Macroeconomic influences	• Technology enables real-time data exchange and cheaper Big Data analysis. • Regulatory changes demand relationship adjustments. • External trends compel relationship adaptations.
CV4	Internal conditions – Differentiation	• Reshaping BSRs differentiates from competitors. • Accelerating processes leads to shorter delivery times. • Closer collaboration enhances innovation potential.
CV5	Internal conditions – Profitability and ability to compete	• I4.0 decreases costs and boosts profitability. • Reshaping BSRs enhances efficiency and resource allocation. • Strengthening cooperation increases transparency and reduces risks.
MV1	Trust, relationship and interaction	• Trust is vital in BSRs, especially with key suppliers. • Low-trust relationships involve distrust and short-term duration.
MV2	Collaborative partnerships and relationship in I4.0 projects	• BSRs intensify in I4.0 with improved trust and cooperation. • Cooperative partnerships support I4.0 implementation. • Accelerated cooperation integrates suppliers in R&D activities.
MV3	Evolution in the level of automation and digitization in BSRs	• Processes between buyers and suppliers digitize and automate, especially in sourcing and purchasing. • Trust levels vary with product complexity, influencing cooperation intensity. • Systems prepare for real-time data exchange to ensure transparency.

Source: Elaborated by the authors based on Veile et al. (2021).**Note**: MV (maturity variable); CV (choice variable).

Trust, which is related to MV1, is paramount in fostering effective BSRs, especially with key suppliers marked by high purchase volume and strategic significance (Aharonovitz et al., 2018). These relationships transcend transactions, emphasizing shared values, trustful interactions, and long-term collaboration to meet customer needs and drive mutual benefits (Zhang et al., 2023). Joint planning and research activities bolster this collaborative spirit, fostering innovation and value creation. However, trust in BSRs can be fragile, particularly for standardized products where price and efficiency concerns prevail, leading to low trust levels and a short-term focus on cost efficiency and risk mitigation through control measures (Veile et al., 2022).

Guided by the principles of I4.0, BSRs evolve into cooperative partnerships (MV2), fostering strengthened trust bonds and long-term commitments. This enhanced cooperation extends across operations, including the adoption of I4.0 technologies and collaborative problem-solving efforts (Veile et al., 2022). Suppliers assume a pivotal role in research and development, driving innovation and mutual growth (Zhang et al., 2023). Future trends indicate supplier base consolidation, prioritizing quality partnerships over quantity, to achieve economies of scale and scope, ensuring competitiveness and sustainability amidst the evolving landscape of I4.0 (Gameiro &Satolo, 2023).

Communication dynamics in BSRs are evolving due to digitization and automation (MV3). These advancements streamline operative functions like sourcing and purchasing, especially for standardized products (Zhu et al., 2022). Cooperation and trust levels in BSRs vary based on product complexity, with standardized components often sourced through multi-source strategies (Veile et al., 2021). Meanwhile, direct and real-time data exchange ensures transparency, with AI playing a key role in managing transactions (Tortorella et al., 2022). Thus, effective communication strategies are essential for collaboration and efficiency in BSRs, driving competitive advantage and sustainability in the digital age.

In the competitive landscape of modern markets, effective communication is key in fostering robust BSRs, particularly in the era of I4.0 (Gameiro &Satolo, 2023), which is related to CV1. Presently, communication between buyers and suppliers is predominantly manual and personal, relying heavily on analog, non-automated processes through channels such as telephone, email, telefax, events, meetings, and face-to-face interactions (Zhu et al., 2022). This traditional mode of communication persists, especially for highly individualized products or when technical communication equipment is lacking, proving valuable for negotiating contracts, discussing specialized topics, and addressing deviations, particularly during the early stages of a product's lifecycle where systems are not yet established and deviations are frequent (Veile et al., 2021).

External market dynamics (CV2) significantly influence strategic decisions and operational practices (Ghobakhloo et al., 2023). The interplay of customer needs, competition, and market dynamics drives product development and market positioning strategies, emphasizing the shift towards customer-centric approaches (Veile et al., 2021). With I4.0, there's a growing focus on individuality, quality, and transparency, highlighting the need to align strategies with evolving preferences. Furthermore, intensified competition and evolving dynamics demand agile responses, with I4.0 technologies offering opportunities to enhance agility and responsiveness (Gameiro &Satolo, 2023). Leveraging real-time data analytics and advanced communication tools allows stakeholders to anticipate changes, tailor offerings, and optimize processes, underscoring the importance of collaborative and transparent relationships for agile decision-making and strategic alignment in an I4.0-driven marketplace (Schmidt et al., 2023)

Macroeconomic influences (CV3) play a pivotal role in shaping BSRs, driving strategic decisions and operational practices (Veile et al., 2021). Technological advancements enable real-time data exchange and analysis, fostering collaboration and informed decision-making (Tortorella et al., 2022). Regulatory changes, like traceability regulations, require adjustments, promoting closer collaboration and transparency (Sony et al., 2024). External trends, such as specialist shortages and complex global value chains, necessitate adaptive strategies, including strategic partnerships and enhanced coordination. Amidst these challenges, I4.0 technologies offer opportunities to streamline communication, enhance visibility, and build resilience, empowering stakeholders to thrive in a dynamic business environment shaped by macroeconomic forces and I4.0 (Patrucco et al., 2022).

In the context of I4.0, internal conditions such as differentiation (CV4) are pivotal in shaping BSRs and fostering competitive advantage (Veile et al., 2022). Reshaping BSRs through I4.0 technologies offers companies a strategic edge by accelerating processes, shortening delivery times, and enhancing customer satisfaction (Veile, 2023). This heightened efficiency not only positions firms as industry leaders but also cultivates long-term customer loyalty. Moreover, closer collaboration with upstream value creation stages fuels innovation, while bolstering process flexibility and reliability ensures resilience in navigating uncertainties (Tortorella et al., 2022). Ultimately, the evolution of BSRs driven by I4.0 sets the stage for novel business models that enhance competitiveness and sustainability in a dynamic business landscape (Veile et al., 2022).

Other internal conditions, particularly profitability and competitive strength (CV5), are profoundly influenced by BSRs, with I4.0 technologies playing a pivotal role in enhancing both aspects. By streamlining personnel, simplifying processes, and reducing coordination efforts, these technologies optimize operations, leading to cost reduction and improved efficiency, thereby bolstering organizational competitiveness (Gameiro &Satolo, 2023). Moreover, reshaping BSRs to optimize value creation processes aligns with I4.0 principles, allowing companies to leverage advanced technologies for streamlined operations, minimized wastage, and optimized resource utilization, ultimately enhancing profitability and competitive positioning (Ghobakhloo et al., 2023). Strengthening buyer-supplier cooperation enhances cross-company transparency and mitigates risks associated with BSRs, minimizing errors such as incorrect deliveries and storage volatilities and improving operational efficiency and cost-effectiveness (Veile et al., 2022). Additionally, the establishment of risk mitigation measures across company borders, facilitated by I4.0 technologies, contributes to organizational resilience and competitiveness, enabling companies to navigate complex business environments and sustain long-term profitability and competitive advantage (Sonar et al., 2024).

2.2 Brazilian industrial sector and Industry 4.0

There has been a consistent effort worldwide to optimize social and technical systems jointly using digital technologies to align with organizational goals and objectives (Sony et al., 2022). In developing economies like Brazil, the infrastructure for implementing new I4.0 technologies and establishing terminological standards to facilitate their adoption has gained momentum and solidity in recent years (Tortorella et al., 2020). However, the proportion of Brazilian organizations with an advanced level of digitalization in their processes is still deemed to be low (Contieri et al., 2023).

Several barriers have been identified across multiple sectors in Brazil, including a lack of strategic alignment not only within the industrial sector but also within the government in providing technological, financial, and academic support to foster continuous and sustainable development. This deficiency hampers the establishment of technical and organizational foundations essential for the strategic advancement of various Brazilian industrial sectors (Cordeiro et al., 2023).Despite the increasing adoption of I4.0 technologies within organizations and academia in recent years, the challenges faced by workers due to these technologies remain relatively limited in Brazil (Muniz et al., 2023).

In the context of I4.0, there is a growing demand for skilled workers, encompassing not only technical competencies but also soft skills such as problem-solving creativity, research abilities, and social skills like effective communication and networking (Sony et al., 2022). The digitalization resulting from I4.0 fundamentally transforms how organizations manage their processes and routines, leading to the creation of smart factories or organizations proficient in data-driven analytics, predictive maintenance, flexible system configurations, and adaptation to environmental changes (Sunder M. et al., 2023).To address and adapt to this new reality, organizations require professionals equipped with essential competencies, such as systemic thinking and the ability to work with complex problems (Sigahi & Sznelwar, 2023), as characterized by the phenomenon of the fourth industrial revolution, which merges the physical and digital dimensions of production systems (Sony et al., 2022).

2.2.1 Relevance of the automotive sector in Brazilian industry

The automotive sector holds considerable importance within the industrial landscape of Brazil, serving as a significant source of employment and income (Fehr & Rocha, 2018). Its economic, technological, and social impact is profound, generating numerous direct and indirect jobs throughout the country (Maia, Cerra, & Alves Filho, 2010). Brazil hosts plants from all major original equipment manufacturer (OEM) firms, highlighting its pivotal role in the global automotive industry (Marodin et al., 2016). Consequently, suppliers within this sector also hold substantial relevance (Maia, Cerra, & Filho, 2010).

The evolution of relationships between automakers and their suppliers, influenced significantly by the lean philosophy, underscores the importance of information sharing in every transaction between suppliers and buyers (Fehr & Rocha, 2018). While the nature of these relationships may vary from one company to another, maintaining a partnership approach within the supply chain is paramount, especially amidst traditionally transactional dealings (Marodin et al., 2016).

Many companies in the Brazilian automotive industry have established stringent yet collaborative relationships with their suppliers and buyers, recognizing the significance and complexity of their supply chains (Fehr & Rocha, 2018). These manufacturer-supplier relationships within the Brazilian automotive sector can be categorized into direct, behavioral, and environmental relationships, with the duration of these relationships also playing a crucial role (Niehoff et al., 2022). Thus, trust-based BSRs directly impact automotive value chains, making their relevance increasingly evident in everyday operations (Fehr & Rocha, 2018).

According to Niehoff et al. (2022), in line with this transformation, Brazil is actively pursuing a "digital transformation strategy", highlighting the country's commitment to embracing technological advancements in its industrial landscape. These authors pointed out that I4.0 can contribute to supply chain transparency through enhanced data sharing and integration, facilitating collaborative value chains. Thus, given the automotive industry's role as a foundational source of relationship-centric practices, it stands to gain significant competitive advantages (Fehr & Rocha, 2018).

As the automotive sector faces ongoing pressures for cost reduction, quality improvement, shortened product life cycles, market expansion, and enhanced supply chain management performance (Fehr & Rocha, 2018), while I4.0 presents opportunities for enhanced collaboration and competitive advantage (Tortorella et al., 2022), also posing challenges related to digitalization disparities among companies of different sizes (Schmidt et al., 2023).

2.2.2 Relevance of the chemical sector in Brazilian industry

According to Sebrae (2023), Brazil ranks sixth globally in revenue in the chemical industry. Despite its global ranking, the Brazilian chemical industry remains entrenched in industry 2.0 (I2.0) (Joly et al., 2018). Economic barriers present challenges for industries aiming to achieve this new industrial phase in Brazil (Nara et al., 2021). However, it is imperative to pursue avenues that yield short-term results while the Brazilian industrial sector undergoes its technological transition toward a state closer to the envisioned I4.0 standard (Joly et al., 2018).

The primary challenge lies in establishing an organizational framework for the Brazilian chemical industry to effectively map, classify, prioritize, and leverage expertise and human capital in the chemical industry (Sebrae, 2023). These changes represent a crucial stride toward optimizing natural and financial resources, safeguarding the environment and life, and necessitate robust collaboration with academic and technological institutions.

The foremost challenge of smart manufacturing in Brazil, including the chemical industry, lies in fostering direct communication between suppliers and consumers, shifting the focus from product-centric to service-oriented approaches (Joly et al., 2018). Consequently, managers in emerging economies such as Brazil must pursue collaborative industrial practices such as BSRs to foster sustainable development within the context of I4.0 (Nara et al., 2021). Thus, exploring BSR in academic and inter-organizational spheres holds promise for the Brazilian chemical sector.

2.2.3 Relevance of the agribusiness sector in Brazilian industry

Brazil's agribusiness sector holds global prominence due to its vast size and diversity. Recent attention from economists and researchers has focused on digitalization and innovative developments in agriculture, particularly with the widespread adoption of IoT technology, termed "Agriculture 4.0" or "Agro 4.0" (Sonar et al., 2024). This digital transformation of rural areas is especially pertinent for Brazil, where agribusiness plays a pivotal role in the macro economy (Pivoto et al., 2019).

Agriculture 4.0 harnesses new I4.0 technologies tailored for the intricacies of the agricultural industry, presenting vast untapped potential for value addition within agribusiness (Sharma et al., 2024). The adoption of tools and platforms aimed at enhancing effectiveness and productivity, coupled with improved information management throughout the planning, production, and forecasting stages, can yield significant amounts of real-time data from sensors (Trivelli et al., 2019). These data become essential components of Agribusiness 4.0 applications, extracting valuable insights for decision-making from the wealth of data generated by I4.0 technologies (Pivoto et al., 2019).

I4.0 is already well-established in agribusiness, with successful large-scale implementations demonstrating its maturity (Sonar et al., 2024). The exchange of information extends to the national agricultural sector through communication between internet-connected farms. This facilitates information exchange, online discussions about partnerships, contracting, credit, and interactions with public authorities, fostering collaborative knowledge-sharing and connectivity within agribusiness (Spanaki et al., 2021).

Thus, as Brazil's agribusiness sector embraces the opportunities presented by Agriculture 4.0 technologies, exploring collaborative practices and addressing topics like BSR will be instrumental in fostering sustainable growth and resilience within the industry.

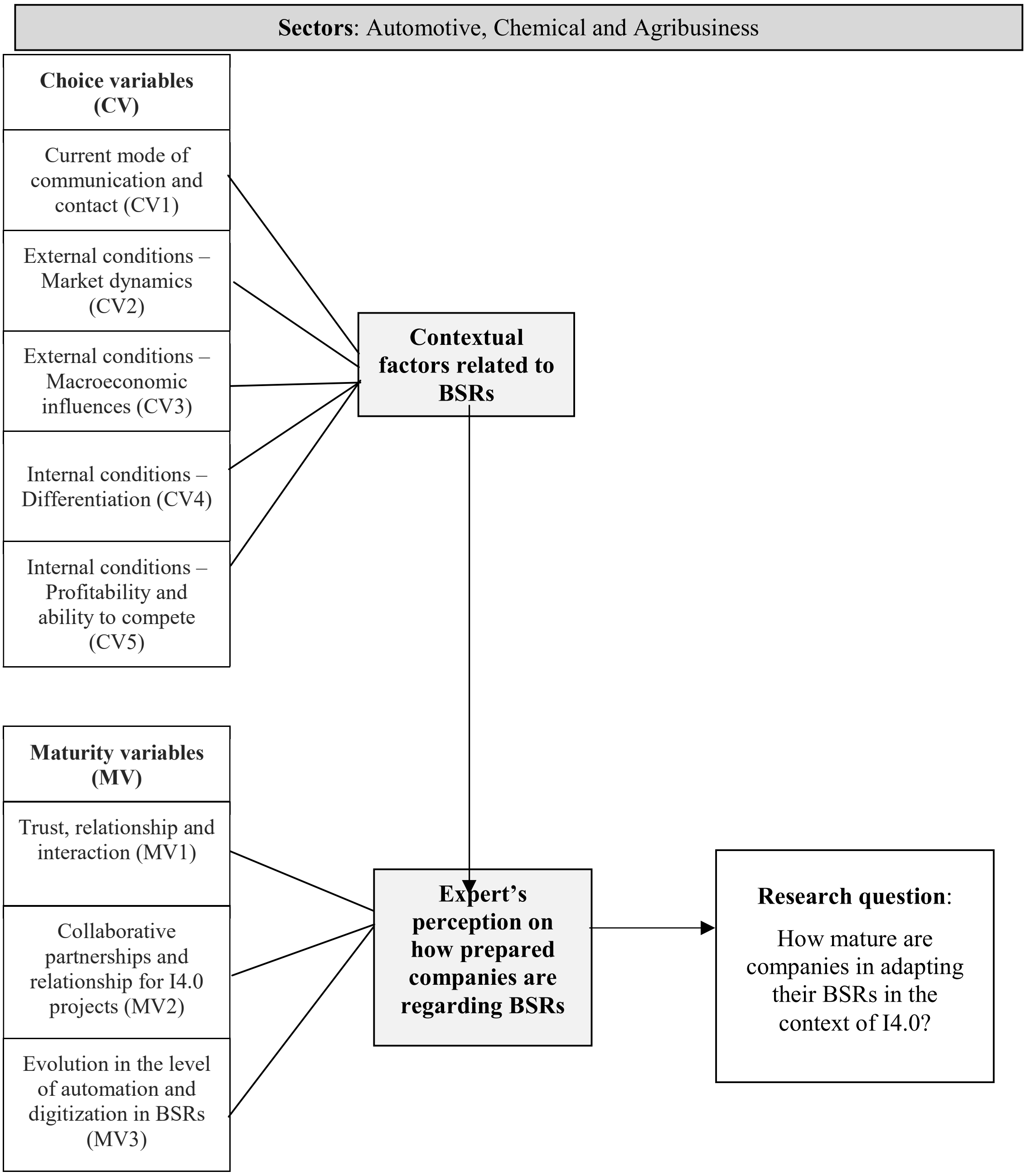
2.3 Research gap and conceptual framework

Despite the existing extensive research on supply chain management and I4.0 (Gameiro &Satolo, 2023; Tortorella et al., 2022), a significant research gap persists regarding the nuanced dynamics of BSR within this framework. While numerous studies have explored the adoption and implications of I4.0 technologies in supply chains, the attention towards

BSR within these contexts remains limited. Existing literature has predominantly focused on the benefits and barriers of implementing I4.0 technologies (Cordeiro et al., 2024; A. Kumar et al., 2024; S. Kumar et al., 2021), neglecting the role of BSR in facilitating collaboration, resolving conflicts, and building trust within supply chains Schmidt et al., 2023; Veile et al., 2021, 2022). Moreover, there is a dearth of research assessing the maturity of BSR initiatives across different countries, hindering the development of comprehensive insights and recommendations for organizations striving to enhance their BSR strategies in the era of I4.0. Addressing this gap is paramount for organizations to navigate the complexities of modern market environments while fostering competitiveness and sustainability.

In this scenario, Figure 1 visually shows the conceptual framework that serves as the basis for this research.

Figure 1 - Conceptual framework and scope of the paper.



Source: Elaborated by the authors.

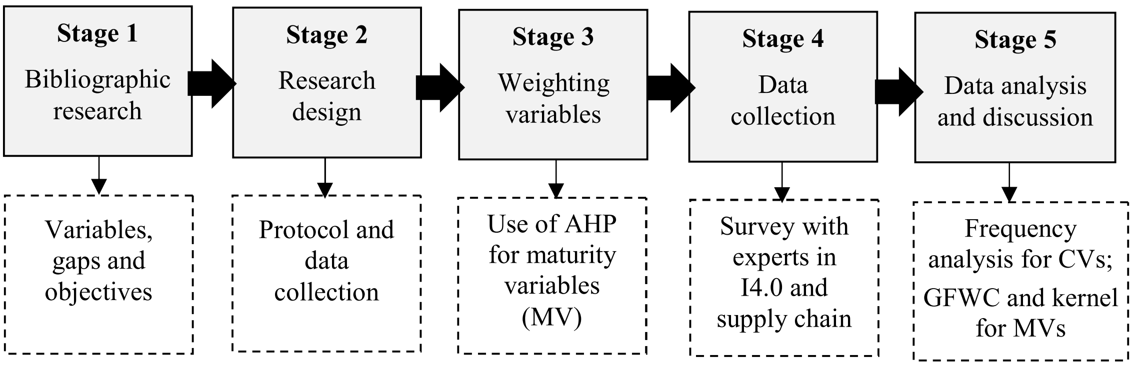
As previously stated, the eight drivers inspired by Veile et al. (Veile et al., 2021) and discussed in Section 2.1 are used as variables to understand the impact of I4.0 on BSRs in the Brazilian context, limiting the scope of research to three relevant industrial sectors, namely automotive, chemical, and agribusiness. The aim is to investigate the maturity of companies in adapting their BSRs in the context of I4.0.

3 Method

3.1 Research Stages

This research was conducted in five stages as depicted in Figure 2.

Figure 2 - Research stages and outputs.



Source: Elaborated by the authors. **Note**: MV: maturity variables; CV: choice variables; GFWC: Grey Fixed Weight Clustering.

3.1.1 Bibliographic research: defining variables, research gap and objectives

The initial phase of this study aimed to establish a theoretical foundation, define variables and identify relevant sectors for investigation.

The theoretical framework involved an analysis of literature related to BSR, I4.0, and supply chain management, with the goal of defining the theoretical constructs that formed the basis of the research. Additionally, given the emerging and incipient nature of the topic, the literature review included the study of methods based on Grey Systems Theory (GST) (Liu, Yang, et al., 2022), which are suitable for analyzing situations with limited available data.

Despite the emergent nature of the field, the literatures on I4.0 and supply chain management are extensive. The literature analysis provided numerous relevant studies that were considered to establish a solid conceptual foundation for the research, particularly the study by Veile et al. (Veile et al., 2021), who defined eight drivers explaining how I4.0 reshapes future BSR. These drivers were used as variables in the present study (see Table 1).

The initial stage was also crucial for identifying relevant sectors for study, particularly within the Brazilian context, by examining how these themes have been discussed in the automotive, chemical, and agribusiness industries. Thus, the bibliographic research was instrumental in clearly defining the research gap and research objectives.

3.1.2 Research protocol and procedures definition

In the second stage, the research instruments were developed and the necessary authorizations for data collection were obtained. This study was approved by the Research Ethical Committee of the university where it was carried out (certificate of approval number 68574023.2.0000.5404).

The first research instrument was designed to gather input from experts in I4.0 and BSR to determine the relative importance of the MVs, thereby establishing the weights for each MV under consideration.

The second research instrument was developed to collect data from other group of experts in I4.0 and BSR in order to assess the automotive, chemical, and agribusiness industries in Brazil against each MV and CV.

Detailed descriptions of these research instruments and the adopted procedures are provided in the subsequent sections.

3.1.3 Application of the AHP

In the third phase, AHP was employed to evaluate the relative importance of the variables. The AHP method is based on the human ability to use knowledge and experience to estimate relative importance through pair-wise comparison, being able to deal with qualitative and quantitative aspects of a decision problem (Saaty & Vargas, 2013).

The AHP combines multidimensional scaling into a one-dimensional scale of priorities (Saaty, 2004), in this way a single number can be assigned to inform the proportionality in the prioritization of alternatives (variables). Therefore, AHP provides ranking order and relative value on an absolute scale for each alternative, considering the objective of the problem and placing the alternatives in descending order of the hierarchy, making use of the principles of decomposition, comparative judgments and synthesis used to evaluate criteria through peer reviews, determining the comparative significance of the criteria (Saaty & Vargas, 2013).

As described by Saaty and Vargas, in addition to being a combination of methodological rigor and ease of use, a highlight of the AHP method is how the decisions represented in a hierarchical way demonstrate the results in a simple and easy to interpret way. This is important because it is possible to apply AHP in a real and practical scenario (Saaty & Vargas, 2013). Within this study, AHP was utilized to assign weights to the variables under consideration.

Table 2 presents scale used in the AHP developed based on Saaty (Saaty, 2004).

Table 2- Scale used in the AHP.

Scale	Description
1	Equally important – The importance for effective relationships between buyer and supplier is the same, as both column and row elements have the same.
3	Moderate importance – Experience and judgment favor slightly one element, with the row being slightly larger than the column, for effective BSRs. In case of a contrary judgment, consider 1/3.
5	High importance – Experience and judgment favor yet another element, with the row having slightly greater importance than the column, for effective BSRs. In case of a contrary decision, consider 1/5.
7	Very high importance – Experience and judgment favor strongly an element, with the line having greater importance than the column, for the effective influence of BSRs. In case of a contrary decision, consider 1/7.
9	Extremely more important – Experience and judgment favor one element in relation to another with a high degree of certainty, with the line having greater importance than the column, for the effective influence of BSRs. In case of a contrary decision, consider 1/9.

Source: Elaborated by authors based on Saaty (2004).

Three professionals with extensive experience in the Brazilian and international industry participated in the AHP (Table 3).

Table 3 - Profile of the specialists participating in the AHP.

Specialist	Professional experience (years)	Experience with I4.0 (years)	Experience in I4.0 implementation in local supply chains	Sector expertise
1	> 35	> 10	Yes	Multi-sectors and Brazilian Government organizations
2	> 28	> 8	Yes	Multi-sectors
3	> 20	> 7	Yes	Automotive sector

Source: Elaborated by the authors.

Specialist 1 holds a master's degree in mechanical production engineering and serves as an expert in implementing process and machine automation within the I4.0 framework. With a focus on the supply chain of the Brazilian automotive industry, Specialist 1 has garnered significant certifications, particularly in manufacturing processes, from a key supplier within the Brazilian automotive chain.

Specialist 2, a mechanical engineer, boasts seven years of experience specializing in the implementation of automation and factory management processes rooted in I4.0 principles. With a dedicated focus on the Brazilian automotive industry's supply chain, Specialist 2 brings a wealth of expertise in driving automation initiatives.

Lastly, Specialist 3, also a graduate in mechanical engineering, has accumulated a decade of managerial experience at Latin America's largest systems company for the automotive sector. Specializing in innovation within the Brazilian automotive market chain, Specialist 3 has spearheaded digitalization and I4.0 adoption efforts. Moreover, as the company's representative to Brazilian governmental bodies, Specialist 3 has played a pivotal role in shaping public policies and advocating for I4.0 advancement within the Brazilian sector.

Based on Saaty's (2004) recommendations, Equations 1 and 2 were used to compute the consistency ratio (CR) for the responses of the experts.

$$CI = \frac{\lambda max - n}{(n-1)} \quad \text{(Equation 1)}$$

$$CR = \frac{CI}{RI} \quad \text{(Equation 2)}$$

CI = consistency index
λmax = maximum eigenvalue
n = matrix dimension- number of criteria in the matrix
RI = AHP average Random Index

The three specialists diligently completed the AHP spreadsheet with full engagement and commitment. The research instrument developed, an electronic spreadsheet, facilitated automatic interaction with consistency index calculations, allowing for real-time review of results. In case of any queries or clarifications, researchers were readily available to provide assistance. Following Saaty's (2004) recommendations, all consistencies should adhere to the quality limit, i.e., CR < 10%.

To aggregate the responses, the geometric mean method was applied. As demonstrated by Escobar et al. (2004), the group inconsistency is smaller than the largest individual inconsistency, validating the effectiveness of the weighted geometric mean method in ensuring satisfactory consistency in an AHP. Consequently, achieving individual consistencies within the recommended limit guarantees the overall group consistency.

3.1.4 Data collection via survey

In the fourth phase, a survey was conducted following the recommendations of Forza (2002).

A questionnaire was developed using Google Forms and sent individually to highly experienced professionals in the field of I4.0, BSR and supply chain management. A total of 47 potential experts from three sectors were invited to participate in this study, and 38 responses were obtained. Table 4 shows the profile of the participants.

Table 4- Profile of the specialists participating in the survey.

Expert (E)	Industry sector	Years ofexperience	Type of experience and background
E1	Automotive	10	Sector-focused
E2	Automotive	8	Sector-focused
E3	Automotive	6	Sector-focused
E4	Automotive	37	Sector-focused
E5	Automotive	6	Multisectoral
E6	Automotive	31	Sector-focused
E7	Automotive	20	Sector-focused
E8	Automotive	30	Sector-focused
E9	Automotive	4	Multisectoral
E10	Automotive	35	Sector-focused
E11	Automotive	20	Sector-focused
E12	Automotive	10	Sector-focused
E13	Automotive	20	Sector-focused
E14	Automotive	17	Sector-focused
E15	Automotive	35	Multisectoral
E16	Automotive	8	Multisectoral
E17	Automotive	20	Multisectoral
E18	Chemical	19	Multisectoral
E19	Chemical	15	Sector-focused
E20	Chemical	15	Multisectoral
E21	Chemical	30	Sector-focused
E22	Chemical	2	Sector-focused
E23	Chemical	37	Multisectoral
E24	Chemical	20	Sector-focused
E25	Chemical	12	Sector-focused
E26	Chemical	20	Multisectoral
E27	Chemical	19	Sector-focused
E28	Chemical	*	Multisectoral
E29	Chemical	12	Multisectoral
E30	Chemical	15	Multisectoral
E31	Chemical	20	Multisectoral
E32	Chemical	15	Multisectoral
E33	Agrobusiness	5	Multisectoral
E34	Agrobusiness	3	Multisectoral
E35	Agrobusiness	35	Multisectoral
E36	Agrobusiness	7	Multisectoral
E37	Agrobusiness	18	Multisectoral
E38	Agrobusiness	20	Multisectoral

Source: Elaborated by the authors. ***Note**: No response obtained from the expert.

The questionnaire consisted of an initial section aimed at presenting research ethics considerations and characterizing the profile of the specialist, followed by questions related to the eight variables (five CVs and three MVs) used to measure the impact of I4.0 on BSRs (see section 2.1). A scale of 1 to 5 was developed for the questions regarding the evaluation of the variables, and each of them was assessed by all participants. The complete questionnaire is presented in the Supplementary Material.

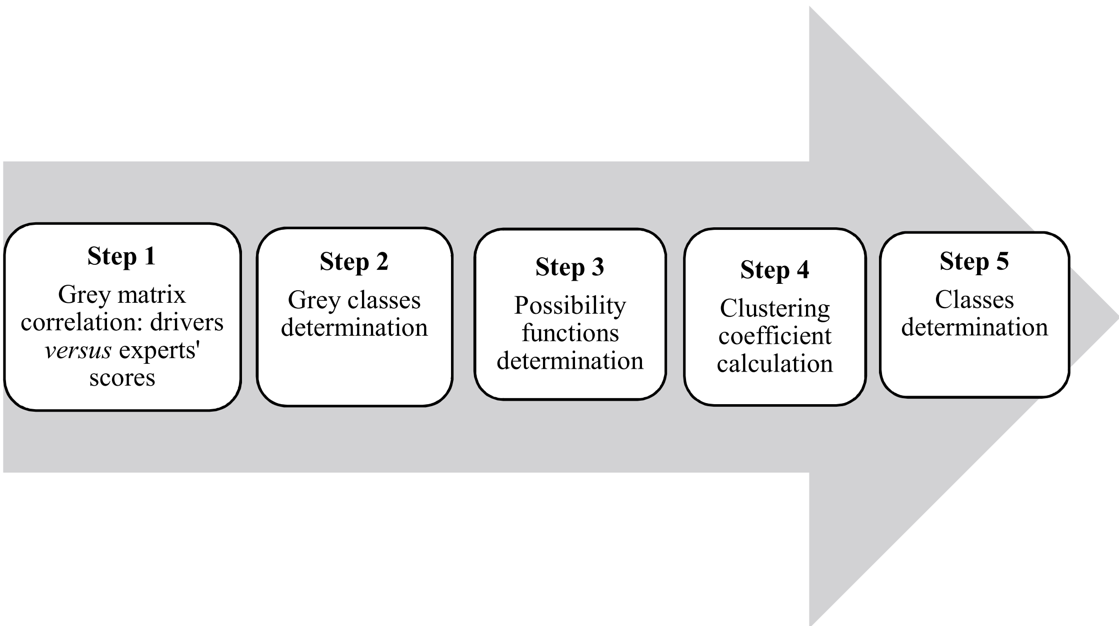
3.1.5 Grey Fixed Weight Clustering Modeling

In the fifth and final phase of the research, the GFWC method was employed to analyze the data collected through AHP and survey. GFWC is grounded on GST developed by Deng Ju-Long (1982), which serves as the theoretical and mathematical foundation for several methods design to analyze incomplete or uncertain information (Golinska et al., 2015). This theoretical basis is therefore appropriate for the present study, as it involves variables and situations that do not have vast consolidated databases; on the contrary, it is necessary to rely on the knowledge of a limited number of specialists (Timóteo et al., 2024).

The GST has gained widespread acceptance and usage in modeling problems involving incomplete data and multivariable properties, spanning various domains including management and engineering (Li & Li, 2023; Prakash et al., 2023).Its effectiveness lies in addressing a gap in statistical analyses by working with small samples and limited information in uncertain systems, thus proving to be a highly applicable method (Liu, Yang, et al., 2022).

It is important to highlight that GFWC is a specific subdivision of GST (Liu, Yang, et al., 2022; Liu & Lin, 2011). Timóteo et al. (2024) developed a GFWC-based decision-making model, which served as the basis for developing the modeling process for this research as illustrated in Figure 3.

Figure 3 - Grey Fixed Weight Clustering modeling process.



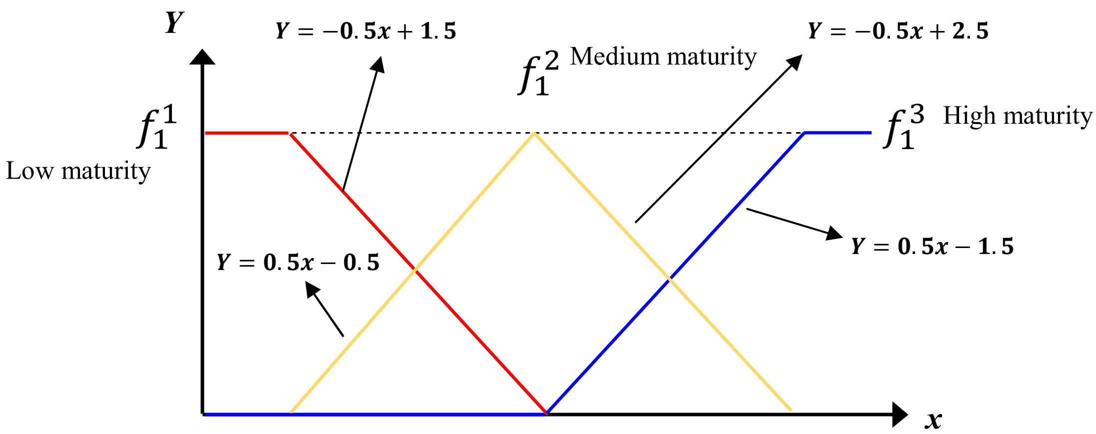
Source: Elaborated by authors based on Timóteo et al.(2024).

In the step 1 of the GFWC process, the three MVs were correlated with the answers collected from the survey with 38 experts, considering the weights resulted from the AHP, i.e., the values of n_j, where $0 < n_j < 1$ and 1 being the most important criterion (Golinska et al., 2015).

In step 2, the grey classes corresponding to each variable were determined. Subsequently, in step 3, the possibility functions were established. According to Li and Li (Li & Li, 2023), possibility functions are utilized to calculate the degree of membership of predefined classes, assigning a relevant score to each alternative based on the class. The construction of a possibility function for a grey number lacks a fixed pattern and relies on the researcher's experience. These authors emphasize that, in practice, due to the multitude of potential decision-making scenarios, researchers must draw upon their expertise and the acquired data to underpin the multicriteria analysis (Li & Li, 2023).

In this study, three possibility functions were considered, where n_j^k indicates the previously defined weights of the variables and $f_j^k(x_{ij})$ correspond to the possibility functions. Figure 4 graphically presents the three possibility functions used in this study.

Figure 4 - Possibility functions used in the GFWC process.



Source: Elaborated by authors based on Timóteo et al. (2024). **Note**: Although the mathematical representation is identical for the three MVs, the meanings of the scales have subtle differences (see Supplementary Material), resulting in a total of nine possibility functions.

After defining all values for each specific possibility function, step 4 involves calculating the clustering coefficient using Equation 3

$$\sigma_i^k = \sum_{j=1}^{m} f_j^k(x_{ij}) * n_j^k \qquad \text{(Equation 3)}$$

$$\text{if } max\{\sigma_i^k\} = \sigma_i^{k*} \text{then the variable belongs to class } k*$$

Lastly, in step 5, the classification of the variables is analyzed, referring to the results obtained from the data provided by the experts in the survey. The "*k"* classes are defined according to the possibility functions determined in step 4. In this study, the classes correspond to the maturity of the variables in the situation under analysis according to the experts (*i* = 38), where *k* = 1 is "low", *k* = 2 is "medium" and *k* = 3 is "high". Thus, based on the calculated values of σ_i^k, the class "*k"* for each variable and experts are determined by the value of $\max\{\sigma_i^k\} = \sigma_i^{k*}$.

3.1.5.1 Weight Vector Group with Kernel

The analysis of the results in step 5 also includes a refinement of the outcomes from GWFC with the use of Weight Vector Group with Kernel. According to Liu et al. (2022), this method is used to make the superiorities of each item more evident.

In this method, it is assumed that $\sigma_i^k = (\sigma_i^1, \sigma_i^2, \ldots, \sigma_i^s)$, where s is the number of classes of decision-making. Then, the normalized clustering coefficient vectors are calculated using Equations 4 and 5:

$$\delta_j^k = \frac{\sigma_i^k}{\sum_{k=1}^{s} \sigma_i^k} \quad \text{(Equation 4)}$$

$$\sum_{i=1}^{s} \delta_j^k = 1 \quad \text{(Equation 5)}$$

Next, the weight vectors group with kernel η_k (k = 1, 2, ..., s) is defined using Equation 6:

$$\eta_k = \left\{\frac{1}{\sum_{i=2}^{k} \frac{1}{2^i} + \sum_{i=1}^{s-k+1} \frac{1}{2^i}}\right\} \left(\frac{1}{2^k}, \frac{1}{2^{k-1}}, \ldots, \frac{1}{2^2}, \frac{1}{2}, \frac{1}{2^2}, \ldots, \frac{1}{2^{s-k+1}}\right) \quad \text{(Equation 6)}$$

Finally, the weighted comprehensive clustering coefficient vectors (ω_j^k) is calculated using the Equation 7:

$$\omega_j^k = \eta_k \cdot \delta_j^T \quad \text{(Equation 7)}$$

Thus, based on the values of ω_j^k, it is possible to refine the allocation of classes from the GFWC in cases where the results are equal or very close.

4 Results

4.1 Results related to the choice variables

Table 5 shows the scores assigned by each expert for the choice variables. Based on that, the frequency of scores for the CVs was calculated, both for the sectors and in general, as shown in Table 6.It is important to recall that the scores represent choices and that meaning of the scores for each CV is different and is detailed in the Supplementary Material.

Table 5 - Scores assigned by the experts for each choice variable (CV).

Expert	Industry sector	Choice variables*				
		CV1	CV2	CV3	CV4	CV5
E_1	Automotive	4	4	4	4	4
E_2		3	3	5	3	5
E_3		5	3	5	4	5
E_4		3	4	4	3	4
E_5		3	1	4	1	4
E_6		3	2	2	2	3
E_7		3	3	4	2	4
E_8		4	2	4	3	5
E_9		3	3	3	4	4
E_{10}		3	3	4	5	4
E_{11}		3	5	5	4	3
E_{12}		3	5	5	2	5
E_{13}		3	2	3	2	4
E_{14}		2	3	5	5	4
E_{15}		3	3	3	2	3
E_{16}		3	3	3	2	3
E_{17}		3	4	2	4	1
E_{18}	Chemical	5	1	3	4	3
E_{19}		3	5	4	4	4
E_{20}		3	3	1	5	1
E_{21}		4	3	3	4	3
E_{22}		3	5	4	4	4
E_{23}		3	1	3	1	4
E_{24}		3	5	3	4	4
E_{25}		3	3	1	1	4
E_{26}		3	3	4	2	4
E_{27}		4	4	2	4	2
E_{28}		2	5	3	1	3
E_{29}		4	4	3	4	4
E_{30}		4	4	3	4	3
E_{31}		2	1	3	2	4
E_{32}		3	1	5	2	3
E_{33}	Agrobusiness	3	2	4	1	3
E_{34}		2	3	5	5	5
E_{35}		3	4	2	1	3
E_{36}		4	5	4	4	4
E_{37}		3	4	3	2	3
E_{38}		3	1	5	3	4

Source: Authors. ***Note**: CV1: Current mode of communication and contact; CV2: External conditions – Market dynamics; CV3: External conditions – Macroeconomic influences; CV4: Internal conditions – Differentiation; CV5: Internal conditions – Profitability and ability to compete.

Table 6 - Percentage of each score for each choice variable (CV).

Industry sector	Score	Choice variables*				
		CV1	CV2	CV3	CV4	CV5
Automotive	1	0.00	0.06	0.00	0.06	0.06
	2	0.06	0.18	0.12	0.35	0.00
	3	0.76	0.47	0.24	0.18	0.24

	4	0.12	0.18	0.35	0.29	0.47
	5	0.06	0.12	0.29	0.12	0.24
Chemical	1	0.00	0.27	0.13	0.20	0.07
	2	0.13	0.00	0.07	0.20	0.07
	3	0.53	0.27	0.53	0.00	0.33
	4	0.27	0.20	0.20	0.53	0.53
	5	0.07	0.27	0.07	0.07	0.00
Agribusiness	1	0.00	0.17	0.00	0.33	0.00
	2	0.17	0.17	0.17	0.17	0.00
	3	0.67	0.17	0.17	0.17	0.50
	4	0.17	0.33	0.33	0.17	0.33
	5	0.00	0.17	0.33	0.17	0.17
General	1	0.00	0.16	0.05	0.16	0.05
	2	0.11	0.11	0.11	0.26	0.03
	3	0.66	0.34	0.34	0.11	0.32
	4	0.18	0.21	0.29	0.37	0.47
	5	0.05	0.18	0.21	0.11	0.13

Source: Authors. ***Note**: CV1: Current mode of communication and contact; CV2: External conditions – Market dynamics; CV3: External conditions – Macroeconomic influences; CV4: Internal conditions – Differentiation; CV5: Internal conditions – Profitability and ability to compete.

4.2 Weights of maturity variables from AHP

As explained in section 3.1.3, the AHP was used to assess the relative importance of the variables, thus assigning weights. The results from the AHP are presented in Table 7.

Table 7 - Results from the AHP for the Specialist 1.

	Variables*	MV1	MV2	MV3
Specialist 1	**MV1**	1.00	3.00	7.00
	MV2	0.33	1.00	2.00
	MV3	0.14	0.50	1.00
Specialist 2	**MV1**	1.00	0.33	0.20
	MV2	3.03	1.00	0.33
	MV3	5.00	3.03	1.00
Specialist 3	**MV1**	1.00	9.00	7.00
	MV2	0.11	1.00	1.00
	MV3	0.14	1.00	1.00

Source: Authors. ***Note**: MVI: Trust, relationship and interaction; MV2: Collaborative partnerships and relationship for I4.0 projects; MV3: Evolution in the level of automation and digitization in BSRs.

As recommended by Saaty (2004), all the consistency ratios (CR) remained below 10%. Specifically, the CRs for Specialists 1, 2 and 3 were 0.4%, 5.7% and 1.34%, respectively.

Based on these results, the aggregation process was performed using the geometric mean method (Escobar et al., 2004), as presented in Table 8, yielding an aggregate CR of 0.35%.

Table 8 - Aggregated result of the AHP considering the three specialists.

Variables*	MV1	MV2	MV3
MV1	1.00	2.07	2.14
MV2	0.48	1.00	0.87
MV3	0.47	1.15	1.00

Source: Authors. ***Note**: MVI: Trust, relationship and interaction; MV2: Collaborative partnerships and relationship for I4.0 projects; MV3: Evolution in the level of automation and digitization in BSRs.

Thus, the weights of the MVs were determined. Table 9 displays the defined weights and their order of importance as determined by the AHP.

Table 9 - Weights and order of importance of the variables.

Code	Variable	Weight	Order of importance
MV1	Trust, relationship and interaction	0.5125	1^{st}
MV2	Collaborative partnerships and relationship for I4.0 projects	0.2338	3^{rd}
MV3	Evolution in the level of automation and digitization in BSRs	0.2537	2^{nd}

Source: Authors.

4.3 AHP and Grey Fixed Weight Clustering modeling and refinement using Kernel

After determining the weights from the AHP for each MV (j = 1 to j = 3) and collecting the responses through the survey (i = 1 to i = 38), the possibility functions $f_j^k(x_{ij})$ were used to calculate the values of σ_i^k for each respondent (i.e., from$\sigma_1^1, \sigma_1^2, \sigma_1^3$ *to* $\sigma_{38}^1, \sigma_{38}^2, \sigma_{38}^3$), corresponding to the k classes. Table 10 presents the calculated values for "low maturity" (k = 1), "medium maturity" (k = 2) and "high maturity" (k = 3), respectively.

Table 10 - Values ofσ_i^k calculated for each expert in the survey.

Expert	k = 1				k = 2				k = 3			
	MV1	MV2	MV3	σ_i^1	MV1	MV2	MV3	σ_i^2	MV1	MV2	MV3	σ_i^3
E_1	0	1	0	0.234	0.5	0	0.5	0.383	0.5	0	0.5	0.383
E_2	0	0	0	0.000	0.5	0	0.5	0.383	0.5	1	0.5	0.617
E_3	0	1	0	0.234	1	0	0.5	0.639	0	0	0.5	0.127
E_4	0.5	0	0	0.256	0.5	0.5	0.5	0.500	0	0.5	0.5	0.244
E_5	0.5	0	0	0.256	0.5	0.5	0	0.373	0	0.5	1	0.371
E_6	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_7	0	0	0	0.000	0.5	1	0.5	0.617	0.5	0	0.5	0.383
E_8	0	0	0	0.000	1	0.5	0	0.629	0	0.5	1	0.371
E_9	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{10}	0	0.5	1	0.371	1	0.5	0	0.629	0	0	0	0.000
E_{11}	0	0	0	0.000	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500
E_{12}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{13}	0	0	0	0.000	0.5	1	1	0.744	0.5	0	0	0.256

E_{14}	0	0	1	0.254	0.5	1	0	0.490	0.5	0	0	0.256
E_{15}	0.5	0	0	0.256	0.5	0.5	0.5	0.500	0	0.5	0.5	0.244
E_{16}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{17}	0	0	0	0.000	0	0	0.5	0.127	1	1	0.5	0.873
E_{18}	0	0	0	0.000	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500
E_{19}	0	0.5	0.5	0.244	0.5	0.5	0.5	0.500	0.5	0	0	0.256
E_{20}	0	0	0	0.000	0	1	1	0.487	1	0	0	0.513
E_{21}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{22}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{23}	0	0	0	0.000	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500
E_{24}	0	0	0	0.000	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500
E_{25}	0	0	0	0.000	0	0.5	0.5	0.244	1	0.5	0.5	0.756
E_{26}	0	0	0	0.000	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500
E_{27}	0	0	0	0.000	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500
E_{28}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{29}	0	0.5	0.5	0.244	0.5	0.5	0.5	0.500	0.5	0	0	0.256
E_{30}	0.5	0.5	0.5	0.500	0.5	0.5	0.5	0.500	0	0	0	0.000
E_{31}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{32}	0	0	0	0.000	1	1	0.5	0.873	0	0	0.5	0.127
E_{33}	0	0	0	0.000	1	1	0.5	0.873	0	0	0.5	0.127
E_{34}	0	0.5	0.5	0.244	0.5	0.5	0.5	0.500	0.5	0	0	0.256
E_{35}	0	0	0	0.000	0.5	0.5	0	0.373	0.5	0.5	1	0.627
E_{36}	0	0	0.5	0.127	1	0.5	0.5	0.756	0	0.5	0	0.117
E_{37}	0	0	0	0.000	1	0.5	0.5	0.756	0	0.5	0.5	0.244
E_{38}	0	0	0	0.000	0.5	1	1	0.744	0.5	0	0	0.256

Source: Authors. ***Note**: MVI: Trust, relationship and interaction; MV2: Collaborative partnerships and relationship for I4.0 projects; MV3: Evolution in the level of automation and digitization in BSRs.

Finally, Table 11 presents, for each expert, the industry sector, the scores assigned to each MV, and the class *k* defined by $max\{\sigma_i^k\} = \sigma_i^k$.

Table 11. Experts' scores for each variable and results obtained from the GFWC.

Expert	**Industry sector**	**Maturity variables***			**σ¹ᵢ**	**σ²ᵢ**	**σ³ᵢ**	**Maturity class (*k*)**
		MV1	**MV2**	**MV3**				
E_1	Automotive	4	3	3	0.234	**0.383**	**0.383**	Medium/High
E_2		3	4	4	0.000	0.383	**0.617**	High
E_3		2	4	5	0.234	**0.639**	0.127	Medium
E_4		4	4	4	0.256	**0.500**	0.244	Medium
E_5		3	4	4	0.256	**0.373**	0.371	Medium
E_6		2	4	4	0.000	**0.756**	0.244	Medium
E_7		3	4	4	0.000	**0.617**	0.383	Medium
E_8		4	5	4	0.000	**0.629**	0.371	Medium
E_9		3	4	4	0.000	**0.756**	0.244	Medium
E_{10}		4	3	4	0.371	**0.629**	0.000	Medium
E_{11}		4	2	2	0.000	**0.500**	**0.500**	Medium/High
E_{12}		3	4	4	0.000	**0.756**	0.244	Medium
E_{13}		4	2	2	0.000	**0.744**	0.256	Medium
E_{14}		2	4	4	0.254	**0.490**	0.256	Medium
E_{15}		4	4	4	0.256	**0.500**	0.244	Medium
E_{16}		2	2	2	0.000	**0.756**	0.244	Medium
E_{17}		3	4	2	0.000	0.127	**0.873**	Medium/High
E_{18}	Chemical	3	4	4	0.000	**0.500**	**0.500**	Medium/High
E_{19}		5	5	4	0.244	**0.500**	0.256	Medium
E_{20}		3	2	1	0.000	0.487	**0.513**	High
E_{21}		4	1	4	0.000	**0.756**	0.244	Medium

E_{22}		3	4	4	0.000	**0.756**	0.244	Medium
E_{23}		3	4	5	0.000	**0.500**	**0.500**	Medium/High
E_{24}		3	1	4	0.000	**0.500**	**0.500**	Medium/High
E_{25}		3	4	4	0.000	0.244	**0.756**	High
E_{26}		4	3	3	0.000	**0.500**	**0.500**	Medium/High
E_{27}		4	2	2	0.000	**0.500**	**0.500**	Medium/High
E_{28}		4	4	4	0.000	**0.756**	0.244	Medium
E_{29}		4	4	4	0.244	**0.500**	0.256	Medium
E_{30}		3	3	4	**0.500**	**0.500**	0.000	Low/Medium
E_{31}		4	4	4	0.000	**0.756**	0.244	Medium
E_{32}		5	3	3	0.000	**0.873**	0.127	Medium
E_{33}	Agrobusiness	3	3	4	0.000	**0.873**	0.127	Medium
E_{34}		5	4	4	0.244	**0.500**	0.256	Medium
E_{35}		4	3	1	0.000	0.373	**0.627**	High
E_{36}		4	4	5	0.127	**0.756**	0.117	Medium
E_{37}		3	4	4	0.000	**0.756**	0.244	Medium
E_{38}		4	4	4	0.000	**0.744**	0.256	Medium

Source: Authors. ***Note**: MVI: Trust, relationship and interaction; MV2: Collaborative partnerships and relationship for I4.0 projects; MV3: Evolution in the level of automation and digitization in BSRs.

Given the tie in the allocation of classes for some experts (E_1, E_{11}, E_{18}, E_{23}, E_{24}, E_{26}, E_{27} and E_{30}), we used the kernel method to refine the analysis. Thus, Table 12 show the results for the normalized clustering coefficient vectors (δ_j^T), the weight vectors group with kernel (η_k), the weighted comprehensive clustering coefficient vectors (ω_j^k) and the resulting refined classes.

Table 12 - Refined classes for the experts with tied allocation of classes.

Values	E_1	E_{11}	E_{18}	E_{23}	E_{24}	E_{26}	E_{27}	E_{30}
δ_j^1	0.234	0	0	0	0	0	0	0.500
δ_j^2	0.383	0.500	0.500	0.500	0.500	0.500	0.500	0.500
δ_j^3	0.383	0.500	0.500	0.500	0.500	0.500	0.500	0
η_1	$^8/_{28}$	$^8/_{14}$	$^8/_{14}$	$^8/_{14}$	$^8/_{14}$	$^8/_{14}$	$^8/_{14}$	$^8/_{56}$
η_2	$^1/_2$	$^1/_4$	$^1/_4$	$^1/_4$	$^1/_4$	$^1/_4$	$^1/_4$	$^1/_4$
η_3	$^8/_{28}$	$^8/_{56}$	$^8/_{56}$	$^8/_{56}$	$^8/_{56}$	$^8/_{56}$	$^8/_{56}$	$^8/_{14}$
ω_j^1	0.298	0.214	0.214	0.214	0.214	0.214	0.214	**0.429**
ω_j^2	0.346	0.375	0.375	0.375	0.375	0.375	0.375	0.375
ω_j^3	**0.362**	**0.429**	**0.429**	**0.429**	**0.429**	**0.429**	**0.429**	0.214
Refined class with kernel	**High**	**High**	**High**	**High**	**High**	**High**	**High**	**Low**

Source: Authors.

5 Discussion

Table 13 summarizes the key information and findings regarding the impacts of I4.0 on BSR in the Brazilian industrial sectors analyzed.

Table 13 - Summary of the key findings and information regarding the maturity of companies in adapting their BSRs in the context of I4.0.

Analytical perspective		Main findings		
AHP	Importance of the variables	Relatively higher	MV1: Trust, relationship and interaction	
		Relatively lower	MV2: Collaborative partnerships and relationship in I4.0 projects	
			MV3: Evolution in the level of automation and digitization in	
	Industrial sector	Automotive	Chemical	Agribusiness
Choice analysis	Scores with highest percentage	CV1: 3 CV2: 3 CV3: 4 CV4: 2 CV5: 4	CV1: 3 CV2: 1, 3 and 5 CV3: 3 CV4: 4 CV5: 4	CV1: 3 CV2: 4 CV3: 4 and 5 CV4: 1 CV5: 3
GWFC and kernel	BSR maturity level (number of experts)	High: 4/17 Medium: 13/17	High: 7/15 Medium: 7/15 Low: 1/15	High: 1/6 Medium: 5/6
Key information	Average experts' experience (years)	18.6	17.9	14.6
	Experts with multi-sector experience	29%	60%	100%

Source: Elaborated by Authors

Based on the key findings, it is possible to develop an integrated analysis of the CVs and MVs, considering the automotive, chemical and agribusiness sectors perspectives. As previously explained, while the results from choice analysis facilitate the integration of contextual information regarding the investigated situation (CVs), AHP, GFWC and kernel help us to better understand the decision-maker's perception of the current stage of the maturity of companies in adapting their BSRs in the context of I4.0.

5.1 Context analysis

Across the automotive, chemical, and agribusiness sectors, certain patterns and variations emerge, shedding light on the multifaceted nature of BSRs in contemporary supply chain management. Firstly, it is evident that electronic and automated modes of communication dominate BSRs across all sectors (CV1). This underscores the increasing reliance on digital technologies for facilitating interactions between buyers and suppliers, reflecting the broader trend towards digitization within supply chains.

External conditions, such as market dynamics (CV2) play a significant role in shaping BSRs, albeit with some sector-specific nuances. In the automotive sector, competition between suppliers emerges as a key external factor, while in the chemical sector, market volatility and dynamics, as well as product quality and transparency, are highlighted. On the other hand, the agribusiness sector emphasizes the role of new suppliers providing innovative solutions. These findings underscore the importance of understanding sector-specific external dynamics in managing BSRs effectively.

Regarding other types of external conditions, such as macroeconomic aspects (CV3), the influence of regulatory standards and digital technologies on BSRs is evident across all sectors. While normative and environmental regulations are consistently noted, the complexity of digital technological solutions varies. In the automotive and chemical sectors, basic digital solutions such as data collection are emphasized, while the agribusiness sector highlights more advanced technologies like artificial intelligence and additive production.

Internal differentiation within BSRs (CV4) is influenced by factors such as value-adding proposals in the automotive sector, process flexibility and reliability in the chemical sector, and faster response times and interactions in the agribusiness sector. These findings underscore the sector-specific priorities and challenges in managing internal dynamics within supply chain relationships.

Lastly, the relevance of I4.0 in reducing costs, increasing efficiency, and creating value is acknowledged across all sectors (CV5). However, the level of relevance varies, with the automotive and chemical sectors indicating higher relevance compared to the agribusiness sector. This suggests differing levels of adoption and integration of I4.0 technologies and principles across sectors.

5.2 Maturity analysis

The results from the AHP illuminate the critical significance of “trust, relationship and interaction” (MV1), which specialists deemed as the most important maturity variable. This finding underscores the pivotal role of trust within BSRs (Aharonovitz et al., 2018), particularly concerning key suppliers, where the establishment and maintenance of trust are essential components (Veile et al., 2021). Furthermore, this sheds light on the detrimental effects of low-trust relationships characterized by distrust and short-term durations (Zhang et al., 2023). To enhance current BSR in the context of I4.0, companies must prioritize initiatives aimed at fostering trust and transparency throughout their supply chain networks (Gameiro &Satolo, 2023; Zhu et al., 2022). This reflects in the importance of the other maturity variables, i.e., “collaborative partnerships and relationship for I4.0 projects”(MV2) and “evolution in the level of automation and digitization in BSRs” (MV3), classified as the 3rd and 2nd by the specialists in the importance ranking, but with weights close to each other. Thus, embracing technological advancements inherent in I4.0, such as real-time data sharing and predictive analytics, can facilitate improved collaboration and communication between buyers and suppliers, ultimately strengthening relationships and driving mutual success in the evolving landscape of this technological revolution (Tortorella et al., 2022).

In a sectoral perspective, starting with the automotive sector, the majority of respondents perceived the sector to have medium maturity in embracing I4.0 principles, with a smaller proportion considering it to have high maturity. This suggests that while the automotive industry has made significant strides in adopting advanced technologies and digitalization in its supply chain operations, there is still room for further growth and improvement.

In contrast, the chemical sector exhibits a more evenly split perception, with a relatively higher number of respondents considering it to have high maturity compared to the automotive sector. This suggests that the chemical industry may have made more progress in integrating I4.0 practices into its supply chain operations, potentially leveraging advanced technologies to a greater extent.

Interestingly, the agribusiness sector shows a different pattern, with only a minority of respondents considering it to have high maturity in embracing I4.0. The majority of respondents perceive the sector to have medium maturity, with a small proportion considering it to have low maturity. This indicates that the agribusiness sector may be lagging behind the automotive and chemical sectors in adopting advanced technologies and practices associated with I4.0.

Overall, these results highlight the varying degrees of maturity in adopting I4.0 principles across different sectors. While the automotive and chemical sectors show relatively higher levels of maturity, the agribusiness sector appears to be at a relatively lower level of maturity. Understanding these differences is crucial for stakeholders in each sector to identify areas for improvement and prioritize efforts to enhance their competitiveness and resilience in the rapidly evolving landscape of I4.0.

It is crucial to note that the interpretation of these findings should take into account that the real benefits generated by I4.0 are not yet clear due to recent and constant development, particularly in developing countries like Brazil(Sebrae, 2023).A general sense of improvement may exist when introducing I4.0 solutions, but the financial benefits take time to be recognized by organizations through increased revenue, budget reduction, or even a new organizational structure aimed at improving competitiveness(Sony et al., 2024). Furthermore, it is also necessary to analyze and understand the effect of this on the supply chain, which requires more comprehensive and in-depth investigation and data availability.

Finally, it is important to highlight the qualification of the experts participating in the study (average experience of 17 years in the topic), which is a key factor due to the data uncertainty related to I4.0. Thus, to enhance the maturity of BSR in the context of I4.0, companies can undertake specific actions tailored to their respective sectors(Marodin et al., 2016; Nara et al., 2021; Niehoff et al., 2022; Pivoto et al., 2019).

6 Conclusion

This research sought to investigate the maturity of companies in adapting their BSRs in the context of I4.0. The findings underscore the varying degrees of maturity among companies in adapting their BSRs within the context of I4.0. While the automotive and chemical sectors demonstrate relatively higher levels of maturity in embracing I4.0 principles, the agribusiness sector lags behind. This indicates differing levels of adoption and integration of I4.0 technologies and practices across sectors. The critical significance of trust, collaborative partnerships, and automation in enhancing BSRs within the context of I4.0 is illuminated, emphasizing the need for stakeholders to prioritize efforts and enhance competitiveness. Overall, the insights provided offer essential strategies for BSR enhancement amidst I4.0, emphasizing the importance of technological innovation, regulatory adaptation, and collaboration for mutual prosperity.

While this study provides some insights, several limitations should be acknowledged. Firstly, although methods suitable for phenomena characterized by data uncertainty and incompleteness (such as I4.0 impacts on BSR) have been employed, it is important to note that the reliance on experts' experience may introduce bias or limited perspectives. Additionally, the survey's focus on 38 specialists, although highly qualified, may not fully capture the diverse range of opinions and experiences within the industries studied. Furthermore, the use of GFWC modeling for analysis could introduce complexities and assumptions that may not fully represent the dynamics of BSRs in practice, such as the meaning of the scales and possibility function.

Future research could address these limitations by expanding the sample size and incorporating diverse stakeholder perspectives, as well as utilizing alternative analytical methods to validate the findings. From a thematic perspective, future studies could further explore the long-term implications of I4.0 on BSRs within the Brazilian industrial context, as well as developing comparative studies using data from other countries. Investigating the sustainability aspect of BSRs in the face of I4.0 advancements could provide valuable insights into how environmental and social factors intersect with technological innovations. Additionally, conducting longitudinal studies to track changes in BSR dynamics over time in response to I4.0 implementation could offer a deeper understanding of the evolution of these relationships. Finally, examining the impact of I4.0 on smaller suppliers within the supply chain ecosystem could shed light on potential disparities and challenges faced by these stakeholders, thus informing targeted interventions to ensure inclusivity and equitable benefits distribution.

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Supplementary Material, applied questionnaire

1 - Agreement to participate in the research

I hereby confirm that I have read the Informed Consent Form (ICF), I am above 18 years of age, and I willingly consent to participate in this research as a volunteer.

2 - Name of the person responsible for filling out the questionnaire.

3 -Specify the industrial sector in which you work.

4 - Years of experience in the field.

5 - Please provide the link to your Curriculum Vitae or LinkedIn profile to help us better understand your background and experience.

6 - Enter your email address if you wish to receive the research results.

From questions 7 to 14, mark the score from 1 to 5 that best represents your experience considering the Brazilian industrial sector in which you operate.

7 -Trust, relationship and interaction:

7.1= There is a relationship **without interaction**, practically non-existent, without trust between buyers and their suppliers in the supply chain.

7.2= There is a relationship **with low interaction**, punctual and irregular, but still without trust between buyers and their suppliers in the supply chain

7.3= There is a relationship **with moderate interaction**, on a regular basis, with trust between buyers and their supplier partners in the supply chain

7.4= There is a relationship **with high interaction**, in a systemic and regular manner, with trust between buyers and their supplier partners in the supply chain.

7.5= There is a relationship **with very high interaction**, in a systemic and regular way, with mutual collaboration of strategic developments between organizations, with trust between buyers and their supplier partners in the supply chain.

8 - Current mode of communication and contact:

8.1= Current contacts between buyers and suppliers in the supply chain are mostly through **personal and manual contact** (without any electronic or automated means).

8.2 = Current contacts between buyers and suppliers in the supply chain are largely being migrated from **personal and manual contact to electronic and automated**.

8.3= Current contacts between buyers and suppliers in the supply chain mostly occur through **electronic and automated contact, such as telephone, email, events, and attendance meetings**.

8.4= Current contacts between buyers and suppliers in the supply chain are mostly being migrated from **electronic and automated contact to digital platforms**.

8.5= Current contacts between buyers and suppliers in the supply chain are **mostly through digital platforms**.

9 - External conditions – Market dynamics:

9.1 = External conditions can largely influence the relationship between buyer and supplier in the supply chain due to **market volatility and dynamics**.

9.2 = External conditions can largely influence the relationship between buyer and supplier in the supply chain due to the **customers' needs and decisions**.

9.3 = External conditions can largely influence the relationship between buyer and supplier in the supply chain due to **competition between suppliers**.

9.4 = External conditions can largely influence the relationship between buyer and supplier in the supply chain through **new suppliers providing new solutions**.

9.5 = External conditions can largely influence the relationship between buyer and supplier in the supply chain through **individual actions in product quality, process transparency and flexibility, and trust**.

10 - External conditions – Macroeconomic influences:

10.1 = The buyer-supplier relationship in the supply chain **is not influenced** by external macroeconomic factors.

10.2 = The buyer-supplier relationship in the supply chain **may be influenced by normative and regulatory standards**;

10.3 = The buyer-supplier relationship in the supply chain **may be influenced by normative, regulatory and environmental standards**;

10.4 = The buyer-supplier relationship in the supply chain **may be influenced by normative, regulatory and environmental standards, and also by basic digital technological solutions for data collection (e.g. Big Data) and monitoring**.

10.5 = The buyer-supplier relationship in the supply chain **may be influenced by normative, regulatory and environmental standards, and also by more complex digital technological solutions such as artificial intelligence, quantum computing, additive production and virtual/augmented reality and digital twin**.

11 - Internal conditions – Differentiation:

11.1 = The most relevant internal differentiation that occurs in the relationship between buyer and supplier in the supply chain **is related to faster response times and interactions**.

11.2 = The most relevant internal differentiation that occurs in the relationship between buyer and supplier in the supply chain **is related to improvements in value-adding proposals**.

11.3 = The most relevant internal differentiation that occurs in the relationship between buyer and supplier in the supply chain **is related to the ability to collaborate for joint innovation**.

11.4 = The most relevant internal differentiation that occurs in the relationship between buyer and supplier in the supply chain **is related to process flexibility and reliability**.

11.5 = The most relevant internal differentiation that occurs in the relationship between buyer and supplier in the supply chain **is related to the emergence of new business models**.

12 - Internal conditions – Profitability and ability to compete:

12.1 = Industry 4.0 is **not relevant** in reducing costs, reducing personnel and coordination efforts, promoting process complexity, increasing efficiency and creating value.

12.2 = Industry4.0 is **lightly relevant** in reducing costs, reducing personnel and coordination efforts, promoting process complexity, increasing efficiency and creating value.

12.3 = Industry4.0 is **moderately relevant** in cost reduction, personnel reduction and coordination efforts, bringing process complexity, increased efficiency and value creation.

12.4 = Industry4.0 is **very relevant** in reducing costs, reducing personnel and coordination efforts, providing process complexity, increasing efficiency and creating value.

12.5 = Industry4.0 is **extremely relevant** in reducing costs, reducing personnel and coordination efforts, promoting process complexity, increasing efficiency and creating value.

13 -Collaborative partnerships and relationship in I4.0 projects:

13.1 = Improvements in the buyer-supplier relationship due to industry4.0, such as closer collaborative partnerships and increased trust, are **not perceived**.

13.2 = Improvements in the buyer-supplier relationship due to industry 4.0, such as closer collaborative partnerships and increased trust, are **lightly perceived**.

13.2 = Improvements in the buyer-supplier relationship due to industry 4.0, such as closer collaborative partnerships and increased trust, are **moderately perceived**.

13.2 = Improvements in the buyer-supplier relationship due to industry 4.0, such as closer collaborative partnerships and increased trust, are **highly perceived**.

13.5 = Improvements in the buyer-supplier relationship due to industry 4.0, such as closer collaborative partnerships and increased trust, are **very highly perceived**.

14 - Evolution in the level of automation and digitization in BSRs:

14.1= In the context of communication and contact platforms in industry4.0, value creation processes, interconnection between several isolated systems and applications from various actors, with an increase in the level of automation and digitalization, **no improvement is perceived**.

14.2= In the context of communication and contact platforms in industry 4.0, value creation processes, interconnection between several isolated systems and applications from various actors, with an increase in the level of automation and digitalization, **little improvement is perceived**.

14.3= In the context of communication and contact platforms in industry 4.0, value creation processes, interconnection between several isolated systems and applications from various actors, with an increase in the level of automation and digitalization, **moderate improvement is perceived**.

14.4= In the context of communication and contact platforms in industry 4.0, value creation processes, interconnection between several isolated systems and applications from various actors, with an increase in the level of automation and digitalization, **high improvement is perceived**.

14.5= In the context of communication and contact platforms in industry 4.0, value creation processes, interconnection between several isolated systems and applications from various actors, with an increase in the level of automation and digitalization, **very high improvement is perceived**.

3 DISCUSSÃO

Este capítulo apresenta as discussões do trabalho, as quais contemplam os resultados que integram os dois artigos apresentados no Capítulo 2.

Como destacado anteriormente, este trabalho é composto de dois artigos. O primeiro artigo é apresentado no Capítulo 2, seção 2.1, e contribui por meio de uma revisão sistemática como o tema Indústria 4.0 (I4.0) e Tecnologias Digitais (TD). E análise a integração das duas temáticas e a relação com a Gestão da Cadeia de Suprimentos (GCS). A revisão sistemática é desenvolvida com o auxílio do *SciMat* (Cobo*et al.*, 2011), e tem como um de seus resultados a relevância das temáticas e suas contribuições na transformação industrial.

Neste contexto como destacado por Ivanov, Dolgui e Sokolov (2019), as TDs aumentam a capacidade de resposta à demanda e a flexibilidade da capacidade das organizações, além de permitir uma nova qualidade de coordenação de dados e visibilidade na gestão da cadeia de suprimentos. Na última década, a I4.0 revolucionou as organizações, melhorando o desempenho e rentabilidade, garantindo ao mesmo tempo a sustentabilidade do negócio em longo prazo (Ching*et al.*, 2022). Por meio da melhoria da eficiência da GCS e da criação de mecanismos para capturar valor nos modelos de negócios (Henríquez, Martínez De Osés e Martínez Marín, 2022), a I4.0 e as TDs otimizaram o gerenciamento de recursos em cadeias de suprimentos e operações de negócios, tendo a relação humana como um papel relevante nesta transformação.

O segundo artigo, base principal deste trabalho, buscou aprofundar o entendimento de como esta relação humana está interagindo na GCS pela transformação da I4.0 e das TDs,em três setores industriais brasileiros, conforme apresentado no Capítulo 2, seção 2.2.

Cabe ressaltar que os resultados obtidos da pesquisa, por meio do processo metodológico descrito neste trabalho Capítulo 1, seção 1.6.2, estão apresentados no Artigo 2.2, em sua seção 4, subseção 4.1, 4.2 e 4.3, e na seção 5, subseção 5.1 e 5.2 do mesmo artigo, no qual estão apresentadas as discussões referentes às Variáveis de Escolha (VE) e Variáveis de Maturidade (VM), deste trabalho.

Destacam-se, nos setores automotivo, químico e agroindustrial, uma complexidade multifacetada na gestão contemporânea da cadeia de suprimentos no que diz respeito às Relações Comprador-Fornecedor (RFC). A predominância de comunicação eletrônica e automatizada reflete uma crescente dependência de tecnologias digitais, evidenciando a tendência geral de digitalização nas cadeias de suprimentos, o que corrobora com Pathak (2023), que identifica os benefícios da transformação digital por meio das TDs, o que direciona as organizações para o futuro com o uso das novas tecnologias.

Condições externas, como as dinâmicas de mercado e os aspectos macroeconômicos, também desempenham papéis significativos na formação das RFCs, embora com nuances específicas em cada setor. Internamente, a diferenciação das RFCs é influenciada por fatores como proposta-de-valor, flexibilidade de processos e tempos de resposta. A relevância da Indústria 4.0 em termos de redução de custos, aumento da eficiência e criação de valor é reconhecida em todos os setores, embora varie em sua importância relativa, indicando diferentes níveis de adoção e integração dessas tecnologias e princípios entre os setores.

Esses insights fornecem uma visão abrangente da dinâmica das RFCs nos setores industriais analisados, destacando a necessidade de adaptação contínua e investimento em inovação para enfrentar os desafios emergentes da cadeia de suprimentos na era da I4.0.

A análise hierárquica de processos (AHP) ressalta a importância crítica da "confiança, relacionamento e interação" (MV1) nas RFCs, especialmente em relação aos fornecedores-chave. A priorização de iniciativas para promover confiança e transparência, juntamente com o avanço na automação e digitalização, impulsiona o sucesso mútuo na era da Indústria 4.0. Do ponto de vista setorial, a percepção da maturidade na adoção dos princípios da Indústria 4.0 varia entre os setores, destacando a necessidade de identificar áreas de melhoria para aumentar a competitividade e resiliência

A experiência significativa dos especialistas envolvidos no estudo, com uma média de 17 anos de atuação, foi essencial para interpretar os resultados e oferecer insights valiosos. Isso contribui para o avanço da maturidade das RFCs no contexto da I4.0, destacando o comprometimento e a qualificação dos profissionais brasileiros, independentemente da sua senioridade e experiência, na adoção das novas tecnologias digitais. Essa dinâmica promove um impacto promissor no desenvolvimento tecnológico a médio e longo prazo para o setor industrial brasileiro.

4 CONCLUSÕES E CONSIDERAÇÕES FINAIS

Este capítulo apresenta as conclusões, as considerações finais, as limitações da pesquisa e as propostas de trabalhos futuros.

4.1 Conclusões

Com base nos artigos apresentados e discussões dos resultados, o objetivo geral do trabalho foi **atingido**. Sendo desenvolvido na pesquisa uma análise de um estudo exploratório, que contempla os principais direcionadores da Indústria 4.0 (I4.0) e das Tecnologias Digitas (TD), que são influenciadores da Relação Comprador-Fornecedor (RCF) na Gestão da Cadeia de Suprimentos (GCS). O estudo foi desenvolvido em alguns setores industriais brasileiros – Automotivo, Químico e Agronegócio.

A contribuição do trabalho está em apresentar um recorte de como a I4.0 e as TDs influenciam três setores industriais relevantes no Brasil, por meio de uma pesquisa estruturada e aplicada à especialistas e profissionais atuantes em seus segmentos de trabalho, e que estão inseridos no cenário da transformação industrial. Para análises é utilizado um método multicritério, a fim de inovar e aprimorar a compreensão dos estudos acadêmicos em relação ao cenário brasileiro. É uma resultante do trabalho, o mesmo ser base de conhecimento para os tomadores de decisões em suas organizações.

Em relação à Questão de Pesquisa 1 (QP1), o Artigo 2.2 na seção 5, apresenta como está a maturidade das empresas em relação à sua adaptação a RCF dentro do contexto da I4.0, no setor industrial brasileiro, no qual os especialistas destacaram por meio do *Analytic Hierarchy Process* (AHP) que o direcionador de Variáveis de Maturidade 1 (VM1) "Confiança, relacionamento e interação", é de grande importância no cenário brasileiro para RCF. O que também é destacado por Kauffman e Pointer (2022), que a acessibilidade e disponibilidade de informações melhoram a velocidade da tomada de decisão, haja vista ter maior nível de confiança e compromisso estabelecidos desde o início da RCF.

Em relação à Questão de Pesquisa2 (QP2), é apresentado no Artigo 2.2 na seção 4.3, na Tabela 13, as principais variáveis que orientam a transformação das RCFs no contexto da I4.0 neste cenário, e os respectivos graus de maturidade obtido por meio da *survey* e aplicação do método multicritério *Grey Fixed Weight Clustering* (GFWC) e método Kernel nos diferentes setores pesquisados. É evidenciado que nos setores pesquisados, em sua maioria, foram classificados com grau intermediário, e poucos com grau alto de maturidade. O que corrobora a este resultado, a relevância que a RCF possui na transformação da I4.0 e nas TDs, conforme Weile *et al.* (2021).

Destarte, as Questões de Pesquisa (QP) foram **atendidas**.

Os objetivos específicos oriundos do objetivo geral também foram **atingidos**, visto que:

a) A caracterização de pesquisa deste trabalho, descrita no Capítulo 1, seção 1.6.1, e os procedimentos metodológicos seção 1.6.2.1 suportaram na identificação na literatura das variáveis da I4.0 e das TDs, que influenciam a RFC na GCS;
b) A pesquisa com questionário (*survey*) para levantamento de dados foi desenvolvida, conforme seção 1.6.2.2 e suportada pelo instrumento de pesquisa apresentada no Apêndice A. Inicialmente, o questionário foi submetido para 03 especialistas, a fim de definir os pesos dos critérios, como descrito na seção 1.6.2.3. Por fim, aplicou-se o questionário em profissionais atuantes nos segmentos pesquisados, conforme seção 1.6.2.4;
c) Os dados obtidos foram analisados por meio do método de análise multicritério GFWC, conforme descrito na seção 1.6.2.5, e as respostas das QPs apresentadas na seção 4.1.

Conforme Cooper e Schindler (2013), a validade é um instrumento de medida que fornece cobertura adequada das questões investigativas de dados referentes aos estudos, relacionados ao conteúdo, critério e constructo, o que confirma o objetivo da mensuração da pesquisa. Em suma, a validade interna é capacidade de um instrumento de pesquisa medir o que se propõe medir; e, a validade externa na capacidade dos dados em serem generalizados entre pessoas, ambientes e tempo.

Portanto, conclui-se que o estudo atinge a validade interna e externa dos seus constructos.

4.2 Considerações Finais

O trabalho apresenta uma visão abrangente do cenário temático na interseção da maturidade na GCS e modelos de negócios ao empregar a ferramenta *SciMAT*. O estudo ofereceu uma nova perspectiva sobre a evolução dos padrões e interação entre esses domínios críticos, o que traz um maior nível de conhecimento sobre tendências emergentes, como a centralidade das questões de sustentabilidade e o domínio das tecnologias da I4.0, fato que destaca o fator humano nesse contexto, como um fator relevante na sustentabilidade desta transformação.

Contudo, como destacado por Veile *et al*. (2021), estudos existentes focam nas implicações que as ferramentas da I4.0 e as TDs tem na GCS, sendo pouco descritas as influências e oportunidades que a RCF proporciona na I4.0 e TDs.E, conforme Pathak (2023), o toque humano é essencial para negociações e gestão de conflitos. Além de ser, um facilitador de novos modelos de negócios e oportunidades de mercado, aumenta a visibilidade e integração entre compradores e fornecedores (Patrucco *et al*., 2022).

No trabalho investigou-se a maturidade das empresas em adaptar suas RFCs no contexto da I4.0. As discussões destacam os diferentes graus de maturidade entre as empresas na adaptação da sua RFC no contexto da I4.0. Embora os sectores automóvel e químico demonstrem níveis relativamente mais elevados de maturidade na adoção dos princípios I4.0, o sector do agronegócio fica para trás. Isto indica diferentes níveis de adoção e integração de tecnologias e práticas I4.0 em todos os setores. A importância crítica da confiança, das parcerias colaborativas e da automação na melhoria das RFCs no contexto da I4.0 é evidenciada, sendo destacada a necessidade das partes interessadas priorizarem os esforços e aumentarem a competitividade. No geral, os conhecimentos fornecidos oferecem estratégias essenciais para melhorar a RFC no contexto da I4.0, destacando a importância da inovação tecnológica, da adaptação regulamentar e da colaboração para a prosperidade mútua.

Este trabalho contribui para ampliar esta perspectiva, e prover conhecimento com uma pesquisa aplicada, na maneira de como é classificado o grau de maturidade da RCF no cenário brasileiro. E ainda, mostra que a formação e a experiências dos profissionais proporcionam a transformação da I4.0 e as TDs, como também, o grau de relevância dos direcionadores neste mercado. Esse cenário corrobora com o exposto por Weile *et al.* (2021),ao destacar que as relações pessoais continuam importantes e o contato pessoal, não se torna supérfluo. Visto que influenciam cada vez mais a RCF, na qual a dependência de fornecedores estratégicos e de sistemas deverá aumentar, especialmente nos fabricantes tradicionais com a introdução das ações da I4.0 e das TDs.

Contudo, é possível apoiar os gestores das organizações na condução de uma estratégia de maior ou menor alocação de recursos para a implementação e desenvolvimento da I4.0 e das TD, prezando pela melhoria e adaptação da abordagem RCF na cadeia de suprimentos. Nesse sentido, este trabalho amplia o conhecimento geral, contribuindo para o nivelamento do conhecimento com base em três importantes segmentos da indústria brasileira.

Um destaque importante é o uso de análises multicritério – AHP e GFWC, mas ainda pouco aplicadas no cenário brasileiro.

A seleção dos especialistas, bem como dos entrevistados consultados, devido às suas experiências profissionais foi de suma importância tanto no AHP para obtenção dos pesos, como na coleta de dados da pesquisa com os profissionais. Por fim, a escolha do método AHP, combinado com o método GFWC e método Kernel mostraram-se adequados para o tamanho da amostra, considerando possíveis imprecisões nas avaliações.

4.3 Limitações da Pesquisa

São limitações da pesquisa desenvolvida no trabalho:

a) O estudo não se aprofunda nas questões regionais ou variações específicas dos setores analisados, o que pode influenciar a generalização das descobertas para outros setores;
b) Foi objetivo pesquisar apenas empresas de grande porte;
c) Por se tratar de um estudo de corte transversal, em consequência da dinâmica do desenvolvimento das Tecnologias Digitais e pela movimentação dos profissionais nos diferentes segmentos de atuação, a pesquisa apresenta um panorama do intervalo de tempo pesquisado.

4.4 Propostas de Trabalhos Futuros

A partir das discussões estabelecidas no trabalho, são propostos os seguintes trabalhos futuros:

a) Desenvolver outro estudo, porém tendo como base uma amostra de respondente de outros países do continente, a fim de estabelecer comparações na percepção da Relação Comprador-Fornecedor;
b) Realizar um estudo da Relação Comprador-Fornecedor, que considere respondentes pertencentes ao contexto de empresas de outros portes e/ou segmentos;
c) Desenvolver um estudo em outro recorte transversal com objetivo de estabelecer uma análise da evolução da temática.

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APÊNDICE A

Questionário da Pesquisa

1 - CONCORDÂNCIA EM PARTICIPAR DA PESQUISA

Declaro que li o TCLE, tenho mais de 18 anos e estou disposto a participar desta pesquisa como voluntário**.**

2_ Nome do responsável pelo preenchimento do questionário:

____

3 – Informe o segmento em que você atua:

____

4 - Experiência em anos no tema:

____

5 - Por gentileza, nos informe seu linkedin para melhor conhecer sua experiência:

____

6 - Informe seu e-mail caso queira receber os resultados da pesquisa posteriormente

____

7 – Relacionamento atual:

7.1= Há um relacionamento **sem interação**, de forma praticamente inexistente, sem confiança entre os compradores e seus respectivos fornecedores na cadeia de suprimento.

7.2= Há um relacionamento **com baixa interação**, de forma pontual e irregular, porém ainda sem confiança entre os compradores e seus respectivos fornecedores na cadeia de suprimento

7.3= Há um relacionamento **com interação moderada**, de forma regular, com confiança entre os compradores e seus respectivos fornecedores na cadeia de suprimento

7.4= Há um relacionamento **com boa interação**, de forma sistêmica e regular, com confiança entre os compradores e seus respectivos fornecedores na cadeia de suprimento.

7.5= Há um relacionamento **com alta interação**, de forma sistêmica e regular, com colaboração mutua de desenvolvimentos estratégicos entre as organizações, com confiança entre os compradores e seus respectivos fornecedores na cadeia de suprimento.

8 - Modo de comunicação e contato atual:

8.1= Os contatos atuais entre os compradores e fornecedores na cadeia de suprimento ocorrem em sua grande maioria através de **contato pessoal e manual** (sem quaisquer meios eletrônicos ou automatizados).

8.2 = Os contatos atuais entre os compradores e fornecedores na cadeia de suprimento estão em sua grande maioria sendo migrados de uma de **contato pessoal e manual para eletrônico e automatizado.**

8.3= Os contatos atuais entre os compradores e fornecedores na cadeia de suprimento ocorrem em sua maioria através de **contato eletrônico e automatizado, como telefone, email, eventos, reuniões presencias.**

8.4= Os contatos atuais entre os compradores e fornecedores na cadeia de suprimento estão em sua maioria sendo migrado de um **contato eletrônico e automatizado para plataformas digitais.**

8.5= Os contatos atuais entre os compradores e fornecedores na cadeia de suprimento ocorrem em sua grande **maioria por meio de plataformas digitais**.

9–Condições externas – Mercado:

9.1 = Em seu segmento de atuação, as condições externas podem influenciar majoritariamente na relação entre comprador e fornecedor na cadeia de suprimento **pela volatilidade e dinâmica do mercado.**

9.2 =Em seu segmento de atuação, as condições externas podem influenciar majoritariamente na relação entre comprador e fornecedor na cadeia de suprimento **pelas necessidades e decisões de seus clientes.**

9.3 =Em seu segmento de atuação, as condições externas podem influenciar majoritariamente na relação entre comprador e fornecedor na cadeia de suprimento **pela concorrência e competição tradicional entre os fornecedores.**

9.4 = Em seu segmento de atuação, as condições externas podem influenciar majoritariamente na relação entre comprador e fornecedor na cadeia de suprimento **por novos fornecedores provendo novas soluções.**

9.5 = Em seu segmento de atuação, as condições externas podem influenciar majoritariamente na relação entre comprador e fornecedor na cadeia de suprimento **pelas ações individuais na qualidade do produto, transparência e flexibilidade dos processos, e pela confiança**;

10 - Condições externas – influência macroeconômica:

10.1 = Em seu segmento de atuação, a relação entre comprador e fornecedor na cadeia de suprimento **não é possível ser influenciado** por fatores macroeconômicos externos.

10.2 = Em seu segmento de atuação, a relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada pelo uso e aplicação de apenas normas regulatórias normativas;**

10.3 = Em seu segmento de atuação, a relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada pelo uso e aplicação de normas regulatórias normativas e ambientais**;

10.4 = Em seu segmento de atuação, a relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada pelo uso e aplicação de normas regulatórias normativas e ambientais, e também por soluções tecnológicas digitais básicas como levantamento de dados -BIG DATA- e Monitoramento**.

10.5 = Em seu segmento de atuação, a relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada pelo uso e aplicação de normas regulatórias normativas e ambientais, e também por soluções tecnológicas digitais mais complexas como inteligência artificial, computação quântica, manufatura aditiva e realidade virtual/aumentada (digital twin).**

11 - Condições internas específicas no segmento atuação – diferenciação:

11.1= Em seu segmento de atuação, a mais relevante diferenciação interna que ocorre na relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada por tempo de respostas e reações mais rápidas.**

11.2= Em seu segmento de atuação, a mais relevante diferenciação interna que ocorre na relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada pela melhoria em propostas de agregação de valor.**

11.3= Em seu segmento de atuação, a mais relevante diferenciação interna que ocorre na relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada por uma colaboração na capacidade de inovações em conjunto.**

11.4= Em seu segmento de atuação, a mais relevante diferenciação interna que ocorre na relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada pela flexibilidade nos processo e confiabilidade.**

11.5= Em seu segmento de atuação, a mais relevante diferenciação interna que ocorre na relação entre comprador e fornecedor na cadeia de suprimento **pode ser maior influenciada por uma possibilidade de surgimento de novos modelos de negócios.**

12- Condições internas específicas no segmento atuação – lucratividade e capacidade de competir:

12.1 = Em seu segmento de atuação, a Indústria 4.0 **não se mostra** relevante na redução de custos, redução de pessoal e esforços de coordenação, diminuindo a complexidade do processo, aumento de eficiência e criação de valor, entre outros.

12.2 = Em seu segmento de atuação, a Indústria 4.0 **se mostra pouco relevante** na redução de custos, redução de pessoal e esforços de coordenação, diminuindo a complexidade do processo, aumento de eficiência e criação de valor, entre outros

12.3 = Em seu segmento de atuação, a Indústria 4.0 **se mostra de forma moderada** na redução de custos, redução de pessoal e esforços de coordenação, diminuindo a complexidade do processo, aumento de eficiência e criação de valor, entre outros

12.4 = Em seu segmento de atuação, a Indústria 4.0 **se mostra relevante** na redução de custos, redução de pessoal e esforços de coordenação, diminuindo a complexidade do processo, aumento de eficiência e criação de valor, entre outros

12.5 = Em seu segmento de atuação, a Indústria 4.0 **se mostra muito relevante** na redução de custos, redução de pessoal e esforços de coordenação, diminuindo a complexidade do processo, aumento de eficiência e criação de valor, entre outros

13 - Relacionamentos na Indústria 4.0:

13.1 = Em seu segmento de atuação, os relacionamentos providos pela indústria 4.0 como estreitamento de parcerias cooperativas e aumento da confiança, **não é percebido melhora**.

13.2 = Em seu segmento de atuação, os relacionamentos providos pela indústria 4.0 como estreitamento de parcerias cooperativas e aumento da confiança, **é pouco percebido melhora**.

13.3 = Em seu segmento de atuação, os relacionamentos providos pela indústria 4.0 como estreitamento de parcerias cooperativas e aumento da confiança, **é igual**.

13.4 = Em seu segmento de atuação, os relacionamentos providos pela indústria 4.0 como estreitamento de parcerias cooperativas e aumento da confiança, **é percebido melhora**.

13.5 = Em seu segmento de atuação, os relacionamentos providos pela indústria 4.0 como estreitamento de parcerias cooperativas e aumento da confiança, **é muito percebido melhora**.

14 - Comunicação e contato na Indústria 4.0:

14.1= Em seu segmento de atuação, as plataformas de comunicação e contatos na Indústria 4.0 possuem processo visando de criação de valor, interligando vários sistemas isolados e aplicações de vários atores, com aumento do nível de automação e digitalização, **não é percebido melhora.**

14.2= Em seu segmento de atuação, as plataformas de comunicação e contatos na Indústria 4.0 possuem processo visando de criação de valor, interligando vários sistemas isolados e aplicações de vários atores, com aumento do nível de automação e digitalização, **é pouco percebido melhora.**

14.3= Em seu segmento de atuação, as plataformas de comunicação e contatos na Indústria 4.0 possuem processo visando de criação de valor, interligando vários sistemas isolados e aplicações de vários atores, com aumento do nível de automação e digitalização, **é igual**.

14.4= Em seu segmento de atuação, as plataformas de comunicação e contatos na Indústria 4.0 possuem processo visando de criação de valor, interligando vários sistemas isolados e aplicações de vários atores, com aumento do nível de automação e digitalização, **é percebido melhora.**

14.5= Em seu segmento de atuação, as plataformas de comunicação e contatos na Indústria 4.0 possuem processo visando de criação de valor, interligando vários sistemas isolados e aplicações de vários atores, com aumento do nível de automação e digitalização, **é muito percebido melhora.**

ANEXO I

Autorização do Comitê de Ética em Pesquisa

CEPUNICAMP
comitê de ética em pesquisa

UNIVERSIDADE ESTADUAL DE CAMPINAS - UNICAMP/CAMPUS CAMPINAS

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Análise multi-setorial brasileira de direcionadores que influenciam o futuro relacionamento comprador-fornecedor na Indústria 4.0: um estudo exploratório

Pesquisador: JEFFERSON DE SOUZA PINTO
Área Temática:
Versão: 2
CAAE: 68574023.2.0000.5404
Instituição Proponente: Faculdade de Engenharia Mecânica
Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 6.076.751

Apresentação do Projeto:
As informações contidas nos campos "Apresentação do Projeto", "Objetivo da Pesquisa" e "Avaliação dos Riscos e Benefícios" foram obtidas do documento Informações Básicas do Projeto nº 2117157, datado em 09/05/2023.

INTRODUÇÃO A Indústria 4.0 (I4.0) torna as fábricas mais inteligentes, flexíveis e dinâmicas (LU, 2017), onde a integração no processo de fabricação é apresentada como um facilitador chave para a revolução industrial e agregação de valor (HERMANN et al., 2016), contudo apesar todas as vantagens encontradas em várias publicações acadêmicas e de toda tração entre os líderes nas organizações para implementação das tecnologias da I4.0, muitos ainda não sabem como adaptar seu processo de fabricação apesar do impacto positivo nos negócios e na melhoria da eficiência produtiva (MONSHIZADEH et al., 2022).Com isso, a I4.0 está remodelando o relacionamento comprador-fornecedor na cadeia de fornecimento através das novas tecnologias digitais. O relacionamento entre as organizações é de supra importância na introdução de novas tecnologias e o presente estudo visa analisar as influencias da Indústria 4.0 em diferentes setores industriais no Brasil; (VEILE et al., 2020) apresenta 8 direcionadores a serem considerados no relacionamento comprador-fornecedor na cadeia de suprimento com a implementação da Indústria 4.0 nas organizações e a presente pesquisa tem por objetivo analisar as influencias destes elementos em

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alguns setores da indústrias brasileiras; sua participação se dará por meio da ponderação dos oito direcionadores citados por (VEILE et al., 2020) a ser realizada em uma reunião com outros participantes.

HIPÓTESE Devido à natureza da presente proposta ser exploratória, os autores avaliam que não se faz necessária a estruturação de uma hipótese, considerando o entendimento de Appolinário (APPOLINÁRIO 2012, p. 78), o qual relata que pesquisas descritivas de levantamento, por exemplo, prescindem deste elemento, ou ainda, aquelas pesquisas cujas perguntas são do tipo "quais as características de?".

METODOLOGIA No estudo serão utilizados os métodos de Análise Hierárquica de Processos (AHP) e Clusterização via Grey System. A AHP será utilizada para ponderar a influencias dos direcionadores apontados por (VEILE et al., 2020) no relacionamento comprador-fornecedor na cadeia de suprimento com a implementação da Indústria 4.0 sendo eles: 1) relacionamento atual, 2) modo de comunicação e contato atual, 3) condições externas – mercado, 4) condições externas – influencia macroeconômica, 5) condições internas específicas no segmento atuação – diferenciação, 6) condições internas específicas no segmento atuação – lucratividade e capacidade de competir, 7) relacionamentos na Indústria 4.0, 8) comunicação e contato na Indústria 4.0. A Análise Hierárquica de Processos (AHP) seguirá as recomendações de Saaty (SAATY, 2004). O tempo estimado de participação dos respondentes no processo AHP é de 1 hora. As ponderações obtidas via AHP serão usadas no modelo de clusterização via Grey System, seguindo as recomendações de Golinska (GOLINSKA et al. 2015) e darão base ao questionário que será utilizado na survey. Para survey, as recomendações de Forza (FORZA, 2002) serão seguidas. O tempo estimado de participação dos respondentes na survey é de 10 minutos.

CRITÉRIOS DE INCLUSÃO Para ser incluído na lista de possíveis participantes do processo AHP, o acadêmico deve demonstrar em seu Currículo Lattes conhecimento apurado relacionado ao tema "Indústria 4.0". Para ser incluído na lista de possíveis participantes da survey, o profissional deve demonstrar experiência e conhecimento no tema "Indústria 4.0", por meio das informações relatadas nas redes sociais profissionais.

CRITÉRIOS DE EXCLUSÃO Serão excluídas da pesquisa informações incompletas coletadas e os dados de participantes que por motivos pessoais (ou quaisquer outros motivos) ordenarem a exclusão de seus dados, mesmo após o período de coleta. Entendemos que o participante tem este direito se assim desejar. Esse fato foi esclarecido no processo de consentimento.

Objetivo da Pesquisa:

OBJETIVO PRIMÁRIO O presente estudo de desenvolvimento para pesquisa de Mestrado tem por objetivo analisar as influencias no relacionamento comprador-fornecedor na cadeia de suprimento com a implementação de tecnologias digitais da Indústria 4.0 em alguns setores industriais brasileiros. Tal estudo será conduzido em caráter exploratório.

OBJETIVO SECUNDÁRIO A partir do atendimento do objetivo primário, e da consolidação do conhecimento a partir da pesquisa, desenvolver um artigo científico para publicação em periódico da área.

Avaliação dos Riscos e Benefícios:

RISCOS Não há riscos previsíveis associados a esta pesquisa. Destacamos, entretanto, que existem os riscos característicos do próprio ambiente virtual, meios eletrônicos e/ou atividades não presenciais em função das limitações das tecnologias utilizadas, bem como limitações que nos impedem assegurar total confidencialidade e ausência de violação de informações. Assim, caso sinta qualquer tipo de desconforto, você tem o direito de não responder ou procurar os responsáveis pela pesquisa para esclarecer dúvidas. Você não deve participar do estudo se sentir qualquer desconforto em fornecer as informações solicitadas. Destacamos mais uma vez que a reunião ocorrerá de forma online e não será gravada. Você tem o direito de não responder qualquer questão, sem necessidade de explicação ou justificativa para tal, podendo também se retirar da pesquisa a qualquer momento. Destacamos ainda que seguiremos todas as recomendações do ofício denominado "Orientações para procedimentos em pesquisas com qualquer etapa em ambiente virtual".

BENEFÍCIOS Não há benefícios diretos. Como benefícios indiretos da pesquisa, o estudo ajuda a consolidar informações importantes sobre como a Indústria 4.0 está remodelando o relacionamento comprador-fornecedor na cadeia de fornecimento através das novas tecnologias digitais, proporcionando resultados que podem ser utilizados por gestores de novas empresas e futuros pesquisadores.

Comentários e Considerações sobre a Pesquisa:

Foram postados na Plataforma Brasil os seguintes documentos:

1) PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2117157.pdf em 09/05/2023 23:00:38

2) CARTA_RESPOSTA_Projeto_CEP_Lucio_Flavio_Vasconcelos_RA_232_055.pdf em 09/05/2023 22:58:23

3) Convite_Objetivo_Especifico_2.pdf em 09/05/2023 22:57:50

4) Convite_Objetivo_Especifico_1.pdf em 09/05/2023 22:56:43

5) Projeto_CEP_Lucio_Flavio_Vasconcelos_RA_232_055_Ajustado_CARTA_RESPOSTA.pdf em 09/05/2023 22:55:33

6) Carteirinha_Unicamp_Aluno_Lucio_Vasconcelos.pdf em 09/04/2023 15:23:36

7) Carteirinha_Unicamp_Prof_Dr_Jefferson.pdf em 09/04/2023 15:22:55

8) Projeto_CEP_Lucio_Flavio_Vasconcelos_RA232055.pdf em 09/04/2023 15:21:37

9) TCLE_2.pdf em 09/04/2023 15:21:14

10) TCLE_1.pdf em 09/04/2023 15:21:02

11) Questionario_google_form.pdf em 06/04/2023 16:34:52

12) AHP_Matrix.pdf em 06/04/2023 16:33:59

13) Cronograma_CEP.pdf em 06/04/2023 16:31:46

1 4) Folha_capa_CEP_CONEP_Pesquisa_envolvendo_seres_humanos_Jefferson_de_Souza_Pinto_2795859.pdf em 06/04/2023 16:29:37

Dos documentos mencionados acima, entende-se que o projeto tem como equipe os pesquisadores:

* Prof. Dr. Jefferson de Souza Pinto (Orientador, Responsável Principal)

* Lucio Flávio Vasconcelos (Orientando)

* Prof. Dr. Rosley Anholon (Membro da equipe)

A finalidade da pesquisa é desenvolvimento de projeto de mestrado.

O projeto tem o orçamento de R$ 500,00 (quinhentos reais), com financiamento próprio.

O projeto propõe a realização de uma análise exploratória de direcionadores que potencialmente influenciam como evoluirá o relacionamento entre compradores e fornecedores no contexto da Indústria 4.0.

Está prevista a coleta de dados de 18 a 38 participantes.

Considerações sobre os Termos de apresentação obrigatória:
Vide campo abaixo "Conclusões ou Pendências e Lista de Inadequações"

Recomendações:
1. Nas cartas convite (item 1 de "pendências"), recomenda-se que descreva que TCLE significa "Termo de Consentimento Livre e Esclarecido".

Conclusões ou Pendências e Lista de Inadequações:
1. Os protocolos de pesquisa que contemplem a coleta de dados em ambiente virtual (no caso, das ginastas participantes) deverão se adequar ao Ofício Circular Nº2/2021/CONEP/SECNS/MS1 de 24/02/21 (http://conselho.saude.gov.br/images/Oficio_Circular_2_24fev2021.pdf).
Diante disso, solicitamos que seja anexado o convite que será disponibilizado para os

participantes da pesquisa, sendo que:

RESPOSTA: Obrigado pelo comentário. Os convites que serão enviados aos participantes da pesquisa encontram-se a seguir. Os convites variam dependendo do objetivo específico ao qual respondente esta associado.

CONVITE OBJETIVO ESPECÍFICO 1_Respondentes Participantes
Caro (a) XXXXXX.
Gostaríamos de convidá-lo (a) para participar de um projeto de pesquisa denominado "Análise multi-setorial brasileira de direcionadores que influenciam o futuro relacionamento comprador-fornecedor na Indústria 4.0: um estudo exploratório". De maneira mais específica, você esta sendo convidado para participar de um estudo cujo objetivo especifico é analisar os direcionadores que influenciam as indústrias brasileiras, no seu segmento de atuação. No link apresentado a seguir, você será direcionado para o Google Forms onde encontrará o link para o TCLE2_Respondentes Participantes (que apresenta maiores detalhes e instruções sobre a pesquisa).
https://docs.google.com/forms/d/1Qgea98mDiJ2zXE8wgdhgTotwG-nU-BCZxQK-zuvQVB4/edit?ts=642c244d
Leia o TCLE cuidadosamente e caso manifeste concordância em participar da pesquisa ao assinalar a caixa de seleção no Google Form, você será direcionado às perguntas. Caso não concorde, basta fechar a guia de seu navegador. Ressaltamos que você tem o direito de não responder a qualquer questão, sem necessidade de explicação ou justificativa para tal. A qualquer momento e sem nenhum prejuízo, você poderá retirada seu consentimento de utilização dos dados na pesquisa e, caso isso ocorra, enviaremos resposta de ciência de seu interese em retirar seu consentimento. Para participar da pesquisa, é preciso ter mais de 18 anos.
Destacamos que será utilizada nessa pesquisa a plataforma GoogleForms, ferramenta para a qual conhecemos a política de privacidade para coleta de informações pessoais,2 compartilhamento dessas informações com parceiros comerciais para oferta de produtos e serviços de maneira a assegurar os aspectos éticos. Ao assinalar que concorda com os termos e ao responder o questionário, você manifesta sua anuência para com a pesquisa e concorda com a divulgação dos resultados da mesma; destacamos que na divulgação dos resultados do estudo seu nome e o da organização para a qual trabalha não serão citados.

Desde já agradecemos a atenção.
Professor Dr. Jefferson de Souza Pinto, Lucio Flavio Vasconcelos e demais integrantes da equipe do projeto.
****
CONVITE OBJETIVO ESPECÍFICO 2 – Respondentes AHP_ participantes do processo
Caro (a) XXXXXX.
Gostaríamos de convidá-lo (a) para participar de um projeto de pesquisa denominado "Análise multi-setorial brasileira de direcionadores que influenciam o futuro relacionamento comprador-fornecedor na Indústria 4.0: um estudo exploratório". De maneira mais específica, você esta sendo convidado para participar de um estudo cujo objetivo especifica é auxiliar na coleta das informações e no cálculo das consistências das respostas segundo a teoria de Saaty.
No link apresentado a seguir, você será direcionado para o Google Forms onde encontrará o link para o TCLE1_Respondentes AHP (que apresenta maiores detalhes e instruções sobre a pesquisa).
https://docs.google.com/forms/d/1Qgea98mDiJ2zXE8wgdhgTotwG-nU-BCZxQK-zuvQVB4/edit?ts=642c244d
Leia o TCLE cuidadosamente e caso manifeste concordância em participar da pesquisa ao assinalar a caixa de seleção no Google Form, você será direcionado às perguntas. Caso não concorde, basta fechar a guia de seu navegador. Ressaltamos que você tem o direito de não responder a qualquer questão, sem necessidade de explicação ou justificativa para tal. A qualquer momento e sem nenhum prejuízo, você poderá retirada seu consentimento de utilização dos dados na pesquisa e, caso isso ocorra, enviaremos resposta de ciência de seu interese em retirar seu consentimento. Para participar da pesquisa, é preciso ter mais de 18 anos.
Destacamos que será utilizada nessa pesquisa a plataforma GoogleForms, ferramenta para a qual conhecemos a política de privacidade para coleta de informações pessoais, compartilhamento dessas informações com parceiros comerciais para oferta de produtos e serviços de maneira a assegurar os aspectos éticos. Ao assinalar que concorda com os termos e ao responder o questionário, você manifesta sua anuência para com a pesquisa e concorda com a divulgação dos resultados da mesma; destacamos que na divulgação dos resultados do estudo seu nome e o da organização para a qual trabalha não serão citados.
Desde já agradecemos a atenção.
Professor Dr. Jefferson de Souza Pinto, Lucio Flavio Vasconcelos e demais integrantes da

equipe do projeto.

ANÁLISE: Pendência atendida.

1.1.a. Qualquer convite individual deve esclarecer ao candidato a participante de pesquisa, que antes de responder às perguntas do pesquisador disponibilizadas em ambiente não presencial ou virtual (questionário/formulário ou entrevista), será apresentado o Termo de Consentimento Livre e Esclarecido (e o Termo de Assentimento, para menores de idade) para a sua anuência.

RESPOSTA: A informação é evidenciada no convite que será apresentado aos participantes no email, que se encontra nesta carta resposta, no item 1.

ANÁLISE: Pendência atendida.

1.1.b. O convite para a participação na pesquisa deverá conter, obrigatoriamente, link para endereço eletrônico ou texto com as devidas instruções de envio, que informem ser possível, a qualquer momento e sem nenhum prejuízo, a retirada do consentimento de utilização dos dados do participante da pesquisa. Nessas situações, o pesquisador responsável fica obrigado a enviar ao participante de pesquisa, a resposta de ciência do interesse do participante de pesquisa retirar seu consentimento.

RESPOSTA: O convite apresentado no item 1 possui link para o Google Forms no qual existem explicações sobre o envio das respostas e também o link para o TCLE. De modo a ficar mais explícito sua recomendação, ajustamos o termo no TCLE e trazemos a informação diretamente para o próprio convite, como consta.

ANÁLISE: Pendência atendida.

1.1.c. Esclarecemos ao pesquisador que de acordo coma a Resolução 466/12, a eticidade da pesquisa implica em respeito ao participante da pesquisa em sua dignidade, autonomia e garantias de plena liberdade em participar ou recusar a participação em qualquer fase da pesquisa. Portanto, solicitamos que seja mencionado no projeto de pesquisa que o participante será abordado no máximo duas vezes, e caso não concorde em participar da pesquisa, e-mails e convites online não serão mais disparados para estes participantes.

RESPOSTA: A informação a seguir foi inserida no projeto, como solicitado: "Cada participante será abordado no máximo duas vezes, e caso não concorde em participar da pesquisa, e-mails e convites online não serão mais disparados para estes participantes".

ANÁLISE: Pendência atendida.

Considerações Finais a critério do CEP:

- O participante da pesquisa deve receber uma via do Termo de Consentimento Livre e Esclarecido, na íntegra, por ele assinado (quando aplicável).

- O participante da pesquisa tem a liberdade de recusar-se a participar ou de retirar seu consentimento em qualquer fase da pesquisa, sem penalização alguma e sem prejuízo ao seu cuidado (quando aplicável).

- O pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado. Se o pesquisador considerar a descontinuação do estudo, esta deve ser justificada e somente ser realizada após análise das razões da descontinuidade pelo CEP que o aprovou. O pesquisador deve aguardar o parecer do CEP quanto à descontinuação, exceto quando perceber risco ou dano não previsto ao participante ou quando constatar a superioridade de uma estratégia diagnóstica ou terapêutica oferecida a um dos grupos da pesquisa, isto é, somente em caso de necessidade de ação imediata com intuito de proteger os participantes.

- O CEP deve ser informado de todos os efeitos adversos ou fatos relevantes que alterem o curso normal do estudo. É papel do pesquisador assegurar medidas imediatas adequadas frente a evento adverso grave ocorrido (mesmo que tenha sido em outro centro) e enviar notificação ao CEP e à Agência Nacional de Vigilância Sanitária – ANVISA – junto com seu posicionamento.

- Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara e sucinta, identificando a parte do protocolo a ser modificada e suas justificativas e aguardando a aprovação do CEP para continuidade da pesquisa. Em caso de projetos do Grupo I ou II apresentados anteriormente à ANVISA, o pesquisador ou patrocinador deve enviá-las também à mesma, junto com o parecer aprovatório do CEP, para serem juntadas ao protocolo inicial.

- Relatórios parciais e final devem ser apresentados ao CEP, inicialmente seis meses após a data deste parecer de aprovação e ao término do estudo.

-Lembramos que segundo a Resolução 466/2012 , item XI.2 letra e, "cabe ao pesquisador apresentar dados solicitados pelo CEP ou pela CONEP a qualquer momento".

-O pesquisador deve manter os dados da pesquisa em arquivo, físico ou digital, sob sua guarda e responsabilidade, por um período de 5 anos após o término da pesquisa.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2117157.pdf	09/05/2023 23:00:38		Aceito
Outros	CARTA_RESPOSTA_Projeto_CEP_Lucio_Flavio_Vasconcelos_RA_232_055.pdf	09/05/2023 22:58:23	LUCIO FLAVIO VASCONCELOS	Aceito
Outros	Convite_Objetivo_Especifico_2.pdf	09/05/2023 22:57:50	LUCIO FLAVIO VASCONCELOS	Aceito
Outros	Convite_Objetivo_Especifico_1.pdf	09/05/2023 22:56:43	LUCIO FLAVIO VASCONCELOS	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_CEP_Lucio_Flavio_Vasconcelos_RA_232_055_Ajustado_CARTA_RESPOSTA.pdf	09/05/2023 22:55:33	LUCIO FLAVIO VASCONCELOS	Aceito
Outros	Carteirinha_Unicamp_Aluno_Lucio_Vasconcelos.pdf	09/04/2023 15:23:36	LUCIO FLAVIO VASCONCELOS	Aceito
Outros	Carteirinha_Unicamp_Prof_Dr_Jefferson.pdf	09/04/2023 15:22:55	LUCIO FLAVIO VASCONCELOS	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_CEP_Lucio_Flavio_Vasconcelos_RA232055.pdf	09/04/2023 15:21:37	LUCIO FLAVIO VASCONCELOS	Aceito
TCLE / Termos de	TCLE_2.pdf	09/04/2023	LUCIO FLAVIO	Aceito

Assentimento / Justificativa de Ausência	TCLE_2.pdf	15:21:14	VASCONCELOS	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_1.pdf	09/04/2023 15:21:02	LUCIO FLAVIO VASCONCELOS	Aceito
Outros	Questionario_google_form.pdf	06/04/2023 16:34:52	LUCIO FLAVIO VASCONCELOS	Aceito
Outros	AHP_Matrix.pdf	06/04/2023 16:33:59	LUCIO FLAVIO VASCONCELOS	Aceito
Cronograma	Cronograma_CEP.pdf	06/04/2023 16:31:46	LUCIO FLAVIO VASCONCELOS	Aceito
Folha de Rosto	Folha_capa_CEP_CONEP_Pesquisa_envolvendo_seres_humanos_Jefferson_de_Souza_Pinto_2795859.pdf	06/04/2023 16:29:37	LUCIO FLAVIO VASCONCELOS	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

CAMPINAS, 24 de Maio de 2023

Assinado por:
Renata Maria dos Santos Celeghini
(Coordenador(a))

ANEXO II

Autorização Artigo 1 - *Benchmarking An International Journal*

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This is a License Agreement between Lucio Flavio Vasconcelos ("User") and Copyright Clearance Center, Inc. ("CCC") on behalf of the Rightsholder identified in the order details below. The license consists of the order details, the Marketplace Permissions General Terms and Conditions below, and any Rightsholder Terms and Conditions which are included below.

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Order Date	25-Apr-2024	Type of Use	Republish in a thesis/dissertation
Order License ID	1477332-1	Publisher	EMERALD GROUP PUBLISHING LIMITED
ISSN	1463-5771	Portion	Chapter/article

LICENSED CONTENT

Publication Title	Benchmarking : an international journal	Country	United Kingdom of Great Britain and Northern Ireland
Article Title	Supply chain management maturity and business models: scientific mapping using SciMAT	Rightsholder	Emerald Publishing Limited
Date	01/01/1998	Publication Type	Journal
Language	English		

REQUEST DETAILS

Portion Type	Chapter/article	Rights Requested	Main product
Page Range(s)	26	Distribution	Worldwide
Total Number of Pages	26	Translation	Original language of publication
Format (select all that apply)	Print, Electronic	Copies for the Disabled?	No
Who Will Republish the Content?	Author of requested content	Minor Editing Privileges?	No
Duration of Use	Life of current and all future editions	Incidental Promotional Use?	Yes
Lifetime Unit Quantity	Up to 499	Currency	USD

NEW WORK DETAILS

Title	Masters dissertation	Institution Name	UNICAMP - State University of Campinas
Instructor Name	Lucio Flavio Vasconcelos	Expected Presentation Date	2024-04-18

ADDITIONAL DETAILS

Order Reference Number	N/A

The Requesting Person / Organization to Appear on the License	Lucio Flavio Vasconcelos

REQUESTED CONTENT DETAILS

Title, Description or Numeric Reference of the Portion(s)	1463-5771
Editor of Portion(s)	Vasconcelos, Lúcio Flavio; Sigahi, Tiago F.A.C.; Pinto, Jefferson de Souza; Rampasso, Izabela Simon; Anholon, Rosley
Volume / Edition	N/A
Page or Page Range of Portion	26
Title of the Article / Chapter the Portion Is From	Supply chain management maturity and business models: scientific mapping using SciMAT
Author of Portion(s)	Vasconcelos, Lúcio Flavio; Sigahi, Tiago F.A.C.; Pinto, Jefferson de Souza; Rampasso, Izabela Simon; Anholon, Rosley
Issue, if Republishing an Article From a Serial	N/A
Publication Date of Portion	2023-11-21

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"Order Confirmation" is the confirmation CCC provides to the User at the conclusion of each Marketplace transaction. "Order Confirmation Terms" are additional terms set forth on specific Order Confirmations not set forth in the General Terms that can include terms applicable to a particular CCC transactional licensing service and/or any Rightsholder-specific terms.

"Rightsholder(s)" are the holders of copyright rights in the Works for which a User obtains licenses via the Marketplace platform, which are displayed on specific Order Confirmations.

"Terms" means the terms and conditions set forth in these General Terms and any additional Order Confirmation Terms collectively.

"User" or "you" is the person or entity making the use granted under the relevant License. Where the person accepting the Terms on behalf of a User is a freelancer or other third party who the User authorized to accept the General Terms on the User's behalf, such person shall be deemed jointly a User for purposes of such Terms.

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ii) No License granted shall in any way: (i) include any right by User to create a substantively non-identical copy of the Work or to edit or in any other way modify the Work (except by means of deleting material immediately preceding or following the entire portion of the Work copied) (ii) permit "publishing ventures" where any particular anthology would be systematically marketed at multiple institutions.

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B) use is limited to not more than 25% of the text of a book or of the items in a published collection of essays, poems or articles;

C) use is limited to no more than the greater of (a) 25% of the text of an issue of a journal or other periodical or (b) two articles from such an issue;

D) no User may sell or distribute any particular anthology, whether photocopied or electronic, at more than one institution of learning;

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C) use is limited to not more than the greater of (a) 25% of the text of an issue of a journal or other periodical or (b) two articles from such an issue;

D) no User may sell or distribute any particular materials, whether photocopied or electronic, at more than one institution of learning;

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15) **Miscellaneous.**

a) User acknowledges that CCC may, from time to time, make changes or additions to the Service or to the Terms, and that Rightsholder may make changes or additions to the Rightsholder Terms. Such updated Terms will replace the prior terms and conditions in the order workflow and shall be effective as to any subsequent Licenses but shall not apply to Licenses already granted and paid for under a prior set of terms.

b) Use of User-related information collected through the Service is governed by CCC's privacy policy, available online at www.copyright.com/about/privacy-policy/.

c) The License is personal to User. Therefore, User may not assign or transfer to any other person (whether a natural person or an organization of any kind) the License or any rights granted thereunder; provided, however, that, where applicable, User may assign such License in its entirety on written notice to CCC in the event of a transfer of all or substantially all of User's rights in any new material which includes the Work(s) licensed under this Service.

d) No amendment or waiver of any Terms is binding unless set forth in writing and signed by the appropriate parties, including, where applicable, the Rightsholder. The Rightsholder and CCC hereby object to any terms contained in any writing prepared by or on behalf of the User or its principals, employees, agents or affiliates and purporting to govern or otherwise relate to the License described in the Order Confirmation, which terms are in any way inconsistent with any Terms set forth in the Order Confirmation, and/or in CCC's standard operating procedures, whether such writing is prepared prior to, simultaneously with or subsequent to the Order Confirmation, and whether such writing appears on a copy of the Order Confirmation or in a separate instrument.

e) The License described in the Order Confirmation shall be governed by and construed under the law of the State of New York, USA, without regard to the principles thereof of conflicts of law. Any case, controversy, suit, action, or proceeding arising out of, in connection with, or related to such License shall be brought, at CCC's sole discretion, in any federal or state court located in the County of New York, State of New York, USA, or in any federal or state court whose geographical jurisdiction covers the location of the Rightsholder set forth in the Order Confirmation. The parties expressly submit to the personal jurisdiction and venue of each such federal or state court.

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