**UNIVERSIDADE PAULISTA – UNIP**

**PROGRAMA DE PÓS-GRADUÇÃO EM ENGENHARIA DE PRODUÇÃO**

# *PROCUREMENT* 4.0: desenvolvimento de modelo teórico e análise da contribuição para a economia circular

Tese apresentada ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Paulista – UNIP, para a obtenção do título de Doutor em Engenharia de Produção.

**ROBSON ELIAS BUENO**

**SÃO PAULO**

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**Orientador(es):** Dr. Rodrigo Franco Gonçalves/ Dra. Silvia Helena Bonilla (*in memoriam*)

**Área de concentração:** Gestão de sistemas de operação

**Linha de pesquisa:** Sustentabilidade em sistemas de produção

**Projeto de pesquisa:** Avanços em produção mais limpa e ecologia industrial

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Aprovado em:_____

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## DEDICATÓRIA

Esta tese é resultado de um sonho que muitas vezes foi postergado e desacreditado por mim. Isto somente seria possível se fosse mesmo um sonho... Realmente pensei em desistir por ter enfrentado tantos desafios e obstáculos. E o sonho está se realizando, Deus com sua bondade direcionou os caminhos.

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**EPÍGRAFE**

Acreditei que conseguiria ganhar o jogo e perdi.
Perdi mais de 9 mil lances em minha carreira.
Perdi quase 300 jogos.
Falhei uma e outra vez em minha vida.
E foi por isso que consegui.

*Michael Jeffrey Jordan*

## RESUMO

O objetivo deste trabalho foi o de avaliar os resultados na área do *Procurement*, com base na utilização das tecnologias habilitadoras da Indústria 4.0 e sua contribuição para a Economia Circular. A metodologia utilizada nesta tese foi composta em forma de artigos: o primeiro artigo é uma avaliação dos impactos das aplicações das tecnologias habilitadoras da Indústria 4.0 na área de *Procurement*; o segundo é a validação do modelo proposto em dimensões (competências, gestão, parcerias, processos, sistemas/tecnologias e sustentabilidade); e o terceiro mostra como a área de *Procurement* 4.0 pode contribuir para a economia circular. A tese aponta as formas de aplicação das ferramentas habilitadoras da Indústria 4.0 na área de *Procurement* e retrata como o *Procurement* 4.0 está apto a contribuir com a transição da economia linear para a economia circular nas organizações. Estudos futuros poderão usar o mesmo método, envolvendo mais profissionais de outros países e de outros setores. Existem algumas limitações no estudo, embora ele tenha apontado as tendências das tecnologias e que o modelo conceitual das dimensões faz parte do *Procurement* 4.0.



**Palavras-chave**: *Procurement*. Indústria 4.0. Economia circular. Dimensões.

## ABSTRACT

The objective of this work was to evaluate the results in the Procurement area based on the use of Industry 4.0 enabling technologies and their contribution to the circular economy. The methodology used in this thesis was composed of articles: the first article is an evaluation of the impacts of the applications of Industry 4.0 enabling technologies in the Procurement area; the second is the validation of the proposed model in dimensions (skills, management, partnerships, processes, systems/technologies, and sustainability); and the third shows how the Procurement 4.0 area can contribute to the circular economy. The thesis points out ways of applying Industry 4.0 enabling tools in the Procurement area and portrays how Procurement 4.0 can contribute to the transition from the linear economy to the circular economy in organizations. Future studies could use the same method, involving more professionals from other countries and other sectors. There are some limitations in the study, although it pointed out the trends in technologies and that the conceptual model of dimensions is part of Procurement 4.0.



**Keywords**: Procurement. Industry 4.0. Circular economy. Dimensions.

## UTILIDADE

Os objetivos de desenvolvimento sustentável (ODS) chamam a atenção do mundo com um apelo às ações de proteção ao meio ambiente e ao clima e para acabar com a pobreza, além de outras necessidades, de modo a garantir que as pessoas, em todos os lugares, possam desfrutar de paz e prosperidade.

A Indústria 4.0 está alterando a forma de produzir, sendo utilizada em diversos processos, o que retrata uma conexão de ativos inteligentes e físicos, como produtos e máquinas inteligentes que operam de forma autônoma e criam sistemas autocoordenados. Para ilustrar melhor, o termo "I4.0" foi apresentado pela primeira vez na Feira de Hannover, na Alemanha, em 2011, onde a conexão de todas as partes dos elementos de fabricação em cadeias de dados integradas através da internet tem um efeito significativo na rápida interação entre fornecedores, fabricantes, varejistas e clientes.

Alguns exemplos das ferramentas habilitadoras de tecnologias da Indústria 4.0 que podem ajudar a lidar com os desafios da área de *Procurement* são a internet das coisas (IoT), os sistemas ciberfísicos (CPS), a computação em nuvem (CC), os *big data analytics* (BDA), a robótica, a *blockchain* , a inteligência artificial (IA), a manufatura inteligente e a simulação.

Por intermédio do *Procurement* circular 4.0, que utiliza as ferramentas habilitadoras da Indústria 4.0, as organizações poderão usar seu poder de compra para dar um sinal ao mercado a favor da sustentabilidade, passando a escolher bens e serviços aliando aos critérios atuais quesitos socioambientais, como aspectos econômicos: melhor relação custo-benefício, preço, qualidade, disponibilidade, funcionalidade; aspectos ambientais, contratos públicos ecológicos, ou seja: os impactos do produto e/ou serviço em seu ciclo de vida, produção ou descarte sobre o meio ambiente; e aspectos sociais: efeitos de decisões de compra em questões como erradicação da pobreza, equidade internacional na distribuição dos recursos, condições de trabalho e direitos humanos.

Este trabalho verifica como as diferentes ferramentas habilitadoras da Indústria 4.0 na área do *Procurement*, constituindo o *Procurement* 4.0, com sua contribuição para a economia circular, devem ser direcionadas para contribuir e relacionar-se com os seguintes ODS:

ODS#09 – Indústria, inovação e infraestruturas.

ODS#12 – Consumo e produção sustentáveis: assegurar padrões de produção e de consumo sustentáveis, em que o *Procurement* circular 4.0 contribui para a mudança do atual sistema socioeconômico linear, caracterizado pelo princípio de "produção-uso--descarte", que é insustentável e está causando o esgotamento dos recursos naturais, para uma

economia circular, na qual o modelo circular propõe fechar o ciclo (extrair, transformar, produzir, utilizar e descartar) repensando as práticas econômicas e sociais de modo a aproximar o funcionamento do sistema econômico da forma como a natureza executa seus processos.

ODS#08 – Trabalho digno e crescimento econômico.

ODS#17 – Parcerias e meios de implementação: fortalecer os meios de implementação e revitalizar a parceria global para o desenvolvimento sustentável. A aquisição de materiais para produtos circulares altera o processo de seleção de fornecedores e o modo como as empresas se relacionam com os fornecedores parceiros. A área do *Procurement* tem um papel crucial no entendimento de como os materiais afetam a circularidade do produto final.

## LISTA DE FIGURAS

CAPÍTULO 4 – ARTIGO 3

## LISTA DE QUADROS E TABELAS

## LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

BDA – *big data analytics*

CC – computação em nuvem

CPS – sistemas ciberfísicos

EC – economia circular

EL – economia linear

GPS – sistema de posicionamento global

IA – inteligência artificial

IoS – internet dos serviços

IoT – internet das coisas

ISO – organização internacional para padronização

ODS – objetivos de desenvolvimento sustentável

RFID – identificação por radiofrequência

SCM – gerenciamento da cadeia de suprimentos

**SUMÁRIO**

# 1 INTRODUÇÃO

Enquanto os recentes avanços tecnológicos e a transformação digital trazem uma gama de novos potenciais e oportunidades de negócios, as empresas se veem expostas a tecnologias inovadoras disruptivas e forçadas a acompanhar o acelerado ritmo de mudanças para se manterem competitivas no mercado. No entanto, o erro de muitas organizações é acreditar que a simples adesão a uma determinada inovação tecnológica é garantia de sucesso.

Segundo Thomas Friedman (2017), estamos vivendo em um dos maiores pontos de inflexão da história. As três maiores forças do planeta – a tecnologia, a globalização e as mudanças climáticas – estão todas se acelerando ao mesmo tempo. Em consequência disso, muitos aspectos da nossa sociedade, ambiente de trabalho e geopolíticas vêm assumindo novas formas e necessitam ser repensados.

Observa-se, com relação às organizações, que o meio em que elas operam passa por constantes mudanças econômicas, políticas, legislativas, tecnológicas, das preferências dos clientes e das propostas da concorrência (Moura & Saroli, 2021). O aumento da concorrência global está afetando os negócios de manufatura, pois a competição intensa cria uma pressão sobre recursos escassos, o que afeta a disponibilidade e a competitividade de custo (Feger, 2014).

Constata-se que, ao longo dos tempos, inúmeras revoluções de processos, desencadeadas principalmente por novas tecnologias e por novas formas de perceber o mundo, provocaram mudanças nos sistemas econômicos e nas estruturas sociais (Schwab, 2017). Muitas empresas estão em um processo de revisão constante para encontrar melhores métodos para gerenciar seus dados da cadeia de suprimentos e informações para obter uma vantagem competitiva (Deloitte, 2017).

Nos últimos anos, as organizações enfrentaram mudanças profundas, pois a conectividade mundial e a transferência de informações em tempo real permitem que as empresas invistam em inovação e ideias dentro de sua área operacional, de um lado, e a crescente concorrência, também resultante de novas entradas no setor, de outro, pressiona as empresas a aprimorar sua capacidade de inovação para ficar à frente dos concorrentes dentro dos conceitos de negócios recém-criados (Bienhaus & Haddud, 2018).

O termo “Indústria 4.0” foi usado pela primeira vez em 2011, quando uma associação de representantes da indústria, da política e do mundo acadêmico promoveu a ideia como uma abordagem para melhorar a manufatura alemã (Schwab, 2017).

Destaca-se, com o surgimento das tecnologias habilitadoras da Indústria 4.0

(Zangiacomi et al., 2020; Ivanov & Dolgui, 2020; Bordeleau, Mosconi & De Santa-Eulália, 2020; Calabrese, Levialdi Ghiron & Tiburzi, 2020; Stentoft et al., 2020), que se torna urgente que os sistemas de produção mudem para a produção inteligente (Sony & Naik, 2019a).

Neste contexto, as tecnologias habilitadoras da Indústria 4.0 estão ganhando terreno mais rapidamente e podem alavancar o processo de digitalização em uma ampla gama de sistemas de produção, manufatura e *supply chain* (Chiarini et al., 2020; Wagire et al., 2020; Schroeder et al., 2019).

Para Hermann, Pentek & Otto (2015), são quatro os conjuntos principais de tecnologias habilitadoras para a Indústria 4.0: sistemas ciberfísicos (CPS), internet das coisas (IoT), internet dos serviços (IoS) e fábrica inteligente. Outras tecnologias não devem ser consideradas exclusivamente da Indústria 4.0, pois foram certificadas nas "revoluções" anteriores, como, por exemplo, a comunicação máquina a máquina (M2M), *big data* e a computação em nuvem. Entretanto, essas tecnologias são consideradas habilitadoras da Indústria 4.0.

Entende-se que, mesmo nas indústrias, há resistências internas dada a quebra de paradigma que isso representa, na qual a produção em massa não é mais o único foco. Os objetivos anteriores, voltados para aumentar a eficiência e a produtividade de itens seriados, hoje têm que responder a uma demanda flexível, que aumenta a complexidade de suas tarefas (Chiang, 2016).

Consequentemente, há um forte desejo de implementar várias tecnologias habilitadoras da Indústria 4.0 (Sony & Naik, 2019a; Wagire et al., 2020; Chiarini et al., 2020; Fatorachian, 2021), especialmente em campos relacionados à cadeia de suprimentos. A Quarta Revolução Industrial desencadeou a Indústria 4.0 (I4.0), que revolucionou quase todos os aspectos dos processos de negócios, incluindo atividades de aquisição, o que por sua vez evidenciou o surgimento do conceito de *Procurement* 4.0 (Bag, Surajit et al., 2021).

Verifica-se que aquilo que antes era apenas vender e entregar atualmente é otimização e integração de todas as áreas funcionais da empresa, incluindo marketing, vendas, produção, finanças, recursos humanos e tecnologia da informação, o que se denomina logística integrada, reportada ao sistema intraorganizacional ou a departamentos internos de uma organização. Já a integração da logística vem da visão interorganizacional, que aborda a necessidade de integração entre processos diferentes, ou seja, parceiros externos, como fornecedores e clientes. Assim, é necessário envolver toda a organização na criação de um plano estratégico de logística (Grant, 2013, p. 12).

Justifica-se, pois já se foi o tempo em que a função de compras era considerada uma função de serviço ou simplesmente um "processador de pedidos". Ao contrário, é uma função

crucial, pois o departamento comercial agrega valor à organização por meio do aumento do faturamento (Nicoletti, 2018).

Quanto ao processo específico de compras nas empresas, é possível que essas tecnologias habilitadoras da Indústria 4.0 provoquem a descontinuidade dos processos, sendo essa a maior mudança de todos os tempos, trazendo conectividade, agilidade, saindo de “cadeia de suprimentos” para um “ecossistema de suprimentos” (Schrauf, 2018). O setor de compras denota a aquisição de vários bens ou serviços com base nos termos e condições do contrato (Bag et al., 2020). Os elementos-chave da compra incluem atividades como decidir sobre o contratante aprovado, documentar a compra de matéria-prima e construir e manter um relacionamento cordial com os fornecedores (Moktadir et al., 2020).

Nesse contexto, o *Procurement* 4.0 é a digitalização das atividades de compras para aumentar a eficiência e automatizar o processo (Bienhaus & Haddud, 2018). Em paralelo, o *Procurement* 4.0 representa os avanços mais recentes na área de compras. Essa definição foi introduzida para facilitar a comunicação e a colaboração com a rede de fornecedores (aquisição de saída), a organização interna (aquisição de entrada) e a rede de clientes (aquisição de saída) (Nicoletti, 2018).

A importância e a relevância do tema*Procurement* 4.0 justifica a tese ao desenvolver uma estrutura conceitual apresentada em dimensões, apresentando as formas de aplicação das ferramentas habilitadoras da Indústria 4.0 na área de *Procurement*.

Constata-se que as organizações estão bem posicionadas para promover a sustentabilidade no *Procurement* 4.0. O valor dessa inovação geralmente gira em torno da iniciativa de uma organização que optou por inovar. A inovação não só otimiza o relacionamento entre parceiros e clientes mas também facilita a continuidade dos parceiros. Se as grandes organizações expandem a perspectiva dos membros de uma rede de valor, os benefícios são o compartilhamento de riscos em troca de uma renda mais confiável e suprimentos mais estáveis (Nicoletti, 2018).

A tese também traz como objetivo mostrar como o *Procurement* 4.0 contribui para a economia circular, em que os modelos de negócios podem minimizar o excesso de utilização de recursos naturais escassos e também reduzir o volume de geração de resíduos (Schroeder et al., 2018), e, portanto, as metas de desenvolvimento sustentável (DS) seriam alcançadas por meio dos princípios da economia circular (Ellen MacArthur Foundation, 2016).

## 1.1 Contexto e problematização

A área de *Procurement*, incorporando as tecnologias habilitadoras da Indústria 4.0, alinhadas com os objetivos de sustentabilidade, leva ao aumento da competitividade no contexto da economia circular.

Acredita-se que as tecnologias habilitadoras da Indústria 4.0 continuam sendo um elemento crucial na transição bem-sucedida para um modelo de economia circular, entre elas as tecnologias baseadas na internet das coisas (IoT), como RFID (identificação por radiofrequência), GPS (sistema de posicionamento global), robôs e veículos autônomos, que podem permitir fluxos ininterruptos, seja em questões de informação ou de logística (Demestichas et al., 2020).

Entende-se que aumentar a produtividade, economizar despesas e melhorar a eficiência das empresas com a integração das tecnologias habilitadoras da Indústria 4.0 nos processos de *Procurement* é um tema de estudo pertinente e relevante.

As empresas estão sob crescente pressão para ser mais eficientes, econômicas e sustentáveis no atual ambiente de negócios em rápida evolução. Além disso, à medida que o mundo enfrenta preocupações ambientais e ecológicas, a mudança para uma economia circular está se tornando mais significativa para as empresas. O *Procurement* 4.0 pode ser uma ferramenta para ajudar as organizações a atingir esses objetivos (Corbos et al., 2023).

Nos últimos anos, para operar neste novo ambiente, as cadeias de suprimento estão sendo redesenhadas para acelerar sua mudança de sistemas industriais lineares tradicionais para circulares (Pollice et al., 2018).

Estudos anteriores também destacaram a necessidade de focar na perspectiva de compras ou gerenciamento de suprimentos porque isso consumia uma grande quantidade do orçamento nos setores público e privado. Para preencher essa lacuna, este estudo fornece uma análise do estado da arte para adotar a circularidade nas operações de compras.

No entanto, o *Procurement* necessita ser reformulado. Essa revisão revela os fatores nos níveis micro, meso e macro que ajudam os acadêmicos a criar uma estrutura para a investigação empírica. Da mesma forma, ajuda profissionais, formuladores de políticas e tomadores de decisões a atingir o ODS#12, incorporando a circularidade nas compras.

## 1.2 Questões da pesquisa

Segundo Batran et al. (2017), a realidade é que o ritmo da mudança e a escala de desafios que enfrentamos exigem uma nova abordagem de como fazemos negócios. Em termos simples, exige obter uma maior compreensão do nosso mundo através de análises avançadas de dados,

reagindo rapidamente às situações à medida que surgem e sendo mais abertos à colaboração com terceiros para ajudar a resolver os desafios.

O *Procurement* ocupa uma posição favorecida e, por ter uma visibilidade proveniente do relacionamento com centenas de fornecedores, pode gerenciar o processo que permite a colaboração avançada entre organizações de outra forma autônomas (Batran et al., 2017). No entanto, o desenvolvimento de sistemas do *Procurement* 4.0 não é necessariamente um empreendimento simples (Bienhaus e Haddud, 2018).

Embora predominantemente focadas no controle de custos, as empresas hoje estão procurando romper barreiras para acessar novas tecnologias, novas soluções e novos desenvolvimentos de produtos (Batran et al., 2017). Isso é diferente e novo, e a área do *Procurement* tem a oportunidade de gerenciar e facilitar o processo com fornecedores (Batran et al., 2017) sustentáveis.

A economia circular pode trazer potenciais benefícios para as pessoas dos pontos de vista social, econômico e ambiental (Sharma et al., 2021). O cliente adquire um serviço por tempo limitado enquanto o fornecedor mantém a propriedade do produto e continua incentivado pela manutenção, a durabilidade, a atualização e o tratamento contínuos do produto ao final de seu uso.

O fornecedor tem agora uma responsabilidade e um incentivo econômico para mecanismos de eliminação mais seguros, uma responsabilidade que anteriormente cabia ao utilizador final, muitas vezes sem incentivo financeiro (World Economic Forum, 2022).
Questões necessitam ser respondidas, tais como:

a) Quais são os direcionadores e as teconologias do *Procurement* 4.0?
b) Como o *Procurement* 4.0 contribui para a economia circular?

## 1.3 Objetivos

Esta tese tem como objetivo geral avaliar as características que compõem o *Procurement* 4.0 e como este pode contribuir para a economia circular. Para o cumprimento desse objetivo geral, a pesquisa foi fracionada nos seguintes objetivos específicos:

a) Avaliar o o processo, as tecnologias e as tendências da evolução do *Procurement* para o *Procurement* 4.0.
b) Validar o modelo conceitual do *Procurement* 4.0.
c) Avaliar a contribuição do *Procurement* 4.0 para a economia circular.

## 1.4 Composição da tese

O estudo foi moldado no formato de artigos, visando a proporcionar o fácil entendimento das ideias e promover a compreensão dos objetivos desta tese.

A tese está estruturada em sete capítulos.

- O primeiro capítulo apresenta a introdução e os objetivos geral e específico.
- O segundo capítulo apresenta o referencial teórico, tratando dos conceitos de.
- O terceiro capítulo apresenta os aspectos metodológicos aplicados, definindo os procedimentos adotados na execução dos artigos, os instrumentos e as técnicas de pesquisa utilizadas.
- O quarto capítulo apresenta os resultados, adotando o formato de artigos publicados enviados para congressos, bem como o de artigo em elaboração.
- O quinto capítulo apresenta a discussão.
- O sexto capítulo apresenta as conclusões da dissertação e uma prosposta de trabalhos futuros.
- O sétimo capítulo apresenta as referências utilizadas na tese e apêndices.

# 2 REFERENCIAL TEÓRICO

Como forma de contextualizar o cenário de *Procurement 4.0* (ou compras 4.0), levantamos informações gerais na literatura sobre Indústria 4.0, *Procurement*, *Procurement* 4.0, economia linear, economia circular e objetivos de desenvolvimento sustentável:

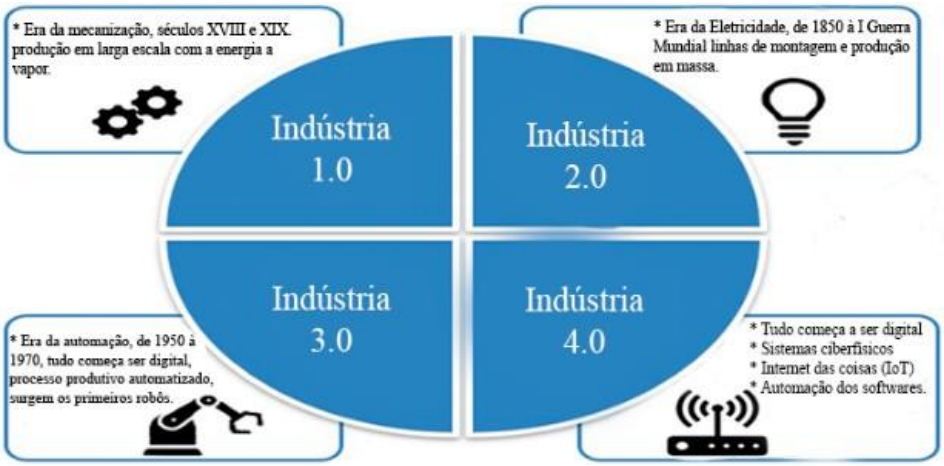
## 2.1 Indústria 4.0

O conceito de Indústria 4.0 surgiu na Alemanha, durante a Feira de Hannover de 2011, propondo um novo modelo de produção para a indústria, possibilitado pelo rápido avanço tecnológico das últimas décadas, principalmente o da internet, com linhas de produção mais eficientes e de menor custo (Gomes, 2016).

Os modelos produtivos da primeira Revolução Industrial, no século XIX, tomavam por base a máquina a vapor, assim como a circulação de bens e serviços. A manufatura e o uso da tecnologia da informação compõem a segunda e a terceira revoluções industriais (Sacomano et al., 2018).

Resumidamente, pode-se dizer: Indústria 1.0 – era da mecanização, com o surgimento da máquina a vapor e a mecanização do trabalho manual, no século XVIII;. Indústria 2.0 – era da eletricidade, com o surgimento da produção em massa e das linhas de montagem nas fábricas, no século XIX; Indústria 3.0 – era da automação industrial, da computação e da eletrônica, no século XX; Indústria 4.0 – era dos sistemas ciberfísicos e das transformações digitais, marcando a quarta e mais nova Revolução Industrial, a partir do século XXI (Grilletti, 2017). A figura 1 apresenta a evolução das revoluções industriais.

Figura 1 – Evolução das revoluções industriais




Fonte: Autor (2023).

Como a automação evoluiu e computadores ofereceram novas possibilidades, a próxima era industrial foi anunciada. Presenciamos o movimento para a Quarta Revolução Industrial, em que mais tarefas serão executadas por máquinas ou inteligência artificial (Batran et al., 2017). A feira de Hannover de 2011 foi o marco do nascimento da Indústria 4.0 e da aplicação de suas tecnologias. Hoje essas tecnologias já são uma realidade que vem acontecendo "passo a passo", transformando significativamente a forma de projetar, produzir, entregar e remunerar a produção (Hofmann et al., 2017).

Vale ressaltar que o processo de implementação das tecnologias habilitadoras da Indústria 4.0 nas organizações é uma tarefa complexa que deve ser gerida por altos executivos, como as normas ISO 9000 e outros projetos importantes. Delegar uma tarefa dessa magnitude representa um sério risco para toda a empresa (Sátyro et al., 2019). O diferencial da Indústria 4.0 caracteriza-se pela evolução do processo de fabricação de uma única célula automatizada para sistemas totalmente automatizados e integrados que se comunicam com outros, contribuindo para maiores flexibilidade, velocidade, produtividade e qualidade dos sistemas produtivos (Hofmann et al., 2017).

Para Rodrigues, Jesus e Schutzer (2016), na Indústria 4.0, em pouco tempo trabalhadores, máquinas e matérias-primas conseguirão comunicar-se em tempo real através de uma rede de internet. Dessa forma, o processo de produção poderá ser realizado por meios digitais em uma fábrica inteligente e aplicado ao ambiente real, onde o trabalhador poderá acompanhar a distância, obtendo informações em tempo real.

Devido a suas características únicas, o objetivo da Indústria 4.0 é aumentar a produtividade e a personalização que são alcançadas através da flexibilização da fabricação e da descentralização por meio da digitalização e da integração da rede de informações, permitindo monitoramento e controle em tempo real (Bonilla et al., 2018).

Sistemas inteligentes reconhecerão automaticamente a procura de determinado material e de maneira independente gerarão uma ordem que é transmitida ao respectivo fornecedor, sem qualquer necessidade de interferência humana. A digitalização pode ser vista como uma evolução (Wisner et. al., 2017).

Dada a interface direta com os fornecedores, o domínio dos contratos poderá trazer inovações a uma empresa, que assim terá a oportunidade de estabelecer uma nova posição dentro de toda a rede (interna e externa) e se tornar estrategicamente relevante. Em um futuro próximo, novas oportunidades digitais, como a disponibilidade de dados em tempo real, levarão à melhoria da gestão do *Procurement* (Pellengahr et al., 2016).

## 2.2 Indústria 4.0 e sustentabilidade

O surgimento da Indústria 4.0 trouxe consigo um número importante de desafios e oportunidades para as organizações em todo o mundo. Para lidar com um ambiente de mudanças tão rápidas, as organizações têm implementado constantemente diferentes tipos de tecnologia e em diferentes estágios (Wamba et al., 2022). A Indústria 4.0 está sendo promovida como um instrumento fundamental para aumentar a produtividade, proporcionando crescimento econômico e sustentabilidade para as empresas (Rosin et al., 2020).

Espera-se que os dados gerados pelas tecnologias habilitadoras da Indústria 4.0 possam ser convertidos em inteligência e trazer benefícios para que essas empresas se mantenham competitivas e sustentáveis (Ahmad et al., 2020), como, por exemplo, a internet das coisas (IoT), para controlar informações, consumo de energia, poluição e desperdício com mais precisão (Cui et al., 2020). Todavia, as tecnologias que sustentam a Indústria 4.0 consomem recursos e energia, impactando negativamente o meio ambiente (Waibel et al., 2017).

A Indústria 4.0 também pode trazer o desequilíbrio nas relações comerciais, pois os grandes fabricantes poderão implementá-la mais rapidamente que os pequenos e médios devido ao alto custo e aos riscos envolvidos (Ghobakhloo & Fathi, 2020). Fornecedores que não se adaptarem ao abastecimento das empresas da Indústria 4.0 tendem a perecer, agravando as desigualdades sociais (Bag et al., 2018).

No anseio de produtividade, desempenho e competitividade, o ser humano está sendo esquecido, a sustentabilidade vem sendo considerada um aspecto secundário e sua dimensão social tem sido subestimada e pouco estudada. A Indústria 4.0 veio para ficar. O mundo está se tornando digital, e é natural que a produção siga o mesmo caminho, mas a sustentabilidade deve ser mais estratégica, de forma a que as pessoas possam associar claramente a Indústria 4.0 à sustentabilidade, contribuindo para o crescimento estável de todos os territórios e evitando o aprofundamento das desigualdades sociais (Sátyro et al., 2022).

No processo de implementação da estratégia das tecnologias habilitadoras da Indústria 4.0, a manufatura deve manter em equilíbrio a sustentabilidade social, econômica e ambiental (Fritzsche et al., 2018). Embora haja evidências de que a Indústria 4.0 contribui para a melhoria da sustentabilidade, novos estudos devem considerar a análise do impacto da dimensão social no futuro da sociedade, especialmente para os funcionários (Varela et al., 2019).

## 2.3 *Procurement*

*Procurement* é uma função essencial no gerenciamento da cadeia de suprimentos

(SCM), que influencia muito o desempenho organizacional (Chen, Paulraj & Lado, 2004; Bag, Wood, Mangla et al., 2020; Bag, Wood, Xu et al., 2020). *Procurement* é um procedimento sistemático para fornecimento de materiais e serviços nos termos e condições especificados de um acordo entre fornecedores envolvidos (Bienhaus & Haddud, 2018).

*Procurement* pode ser definido como a atividade da empresa para obter bens e serviços. Na prática, muitos termos e conceitos são usados na área de compras, como compras, aquisições e gerenciamento da cadeia de suprimentos, por exemplo. No entanto, a literatura não define a diferença entre compra e aquisição, embora alguns autores argumentem que a compra se refere apenas ao processo de ordenamento operacional (Owens, 1998).

De acordo com Weele (2002) "compra é obter de fontes externas todos os bens, serviços, capacidades e conhecimentos necessários para executar, manter e gerenciar as atividades primárias e de apoio da empresa nas condições mais favoráveis".Com a evolução da tecnologia, essa área passou a ser aprimorada. Além de comprar, o setor passou a ter uma função estratégica nas companhias: mais do que *sourcing*, que literalmente quer dizer aquisição, passou a executar a função de *Procurement*, termo que tem origem no latim *procurare* e significa adquirir (Supporte, 2019).

O *Procurement* consiste em um processo que envolve não somente o relacionamento comercial com os fornecedores mas também a pesquisa, o desenvolvimento e a qualificação. Como existe um suporte técnico durante o relacionamento entre as partes, há a necessidade de um aperfeiçoamento dos sistemas de informação, resultando numa integração entre os setores da empresa, clientes e fornecedores (Lima, 2011).

*Procurement* integra a logística e é um processo abrangente de integração de vários subsistemas dos processos de compra ou aquisição entre os quais ocorrerão inúmeras relações (Kapustina et al., 2017).

## 2.4 *Procurement* 4.0

Em uma comparação paralela com a evolução da indústria desde a transformação da energia a vapor em movimento mecânico, o *Procurement* 1.0 suportou funções relacionais básicas que eram em sua maioria manuais e reativas (Guarnieri & Gomes, 2019). O *Procurement* 2.0 girou em torno do desenvolvimento de serviços em uma estrutura integrada de diversos processos. O *Procurement* 3.0 foi baseado no trabalho colaborativo até certo ponto automatizado. Nas arenas comerciais de hoje, o *Procurement* 4.0 oferece suporte à informação aumentada com análises cognitivas e funções adaptativas que formam a Indústria 4.0

(Althabatah et al., 2022).

Na área de *Procurement* 4.0, não há muita literatura (Jahani et al., 2021). Henke e Schulte, por exemplo, citam que a aquisição de parceiros e a camada de interface de soluções de produção oferecem a oportunidade de se posicionar como um fator-chave para o desenvolvimento da Indústria 4.0. Eles postulam várias oportunidades (Henke et al., 2015). Distintas publicações possuem um foco mais técnico (Sundermann, 2013), outras consideram aspectos específicos, como a integração com a área logística (Aslanbas, 2014).

No contexto do *Procurement* 4.0, o setor de suprimentos, como principal interface com o fornecedor, poderá aproveitar novas oportunidades de negócio, deixando de ser um centro de custo para ser um centro de lucro. Isso é possível porque o *Procurement* possui know--how estratégico sobre os fornecedores e seus mercados, uma profunda *expertise* sobre os produtos e serviços que são adquiridos, bem como as alternativas em oferta, incluindo inovações emergentes (Weissbarth et al., 2016).

O *Procurement* 4.0 foi projetado para descrever a evolução da utilização do sistema de compras MRP (Material Requirements Planning) até os dias de hoje, podendo ser visto que o avanço real ocorreu em duas dimensões: em primeiro lugar, o grau de integração funcional e transversal, e em segundo lugar o grau em que os sistemas têm reduzido o trabalho manual nas tarefas de compras, ou seja, a automação (Kagermann, 2013). O transporte de mercadorias é considerado uma atividade fundamental para integrar diferentes mercados. Nesse sentido, espera-se um aumento substancial nas atividades de transporte devido ao crescimento populacional mundial previsto para os próximos anos. A figura 2 demonstra a evolução da área de *Procurement.*

Figura 2: Evolução da área de *Procurement*

| **Evolução do *Procurement*** | | | |
|---|---|---|---|
| ***Procurement 1.0*** | ***Procurement 2.0*** | ***Procurement 3.0*** | ***Procurement 4.0*** |
| Foco no abastecimento;<br>Abatimento no preço;<br>Mínima relação com fornecedores;<br>Atitude reativa. | Foco primário no custo;<br>Qualidade e prazo de entrega negociadas;<br>Maior relação com áreas internas e fornecedores. | Área Estratégicas;<br>Foco nas áreas internas;<br>Envolvimento extremo com fornecedores;<br>Área descentralizada nas operações;<br>Visão para o custo total. | Foco 100% no cliente;<br>Integração total com fornecedores;<br>Foco no valor agregado sobre o custo;<br>Atitude Pró-Ativa;<br>Papel estratégico na empresa;<br>Papel Tático de conexão da rede. |

Fonte: Autor (2023).

O termo *Procurement* 4.0, que em princípio denota a aplicação de técnicas específicas

da Indústria 4.0, é um elemento de novidade, pois pode ser identificado em pouquíssimos trabalhos (Bag et al., 2020). Consideramos este termo de extrema importância no contexto da era digital e uma óbvia necessidade de integração com outros processos de negócio dentro das organizações.

O *Procurement* 4.0 significa desenvolver novas proposições de valor, atender às novas necessidades do negócio e integrar dados em funções e cadeias de valor. Ele exige a utilização desses dados de forma proativa e inteligente, ao mesmo tempo que apresenta processos e ferramentas digitais. Talvez, o que é mais importante, exija a remodelação fundamental da organização de compras e de suas capacidades, para enfrentar os desafios e as oportunidades da expansão da revolução digital global (Deverhum, 2018).

## 2.5 Economia linear

As origens da economia linear datam da Revolução Industrial. No século XVIII, houve um aumento da quantidade, da variedade e da velocidade da produção devido à mecanização e ao desenvolvimento de novos sistemas de produção. Esse crescimento baseou-se no princípio de “pegue-faça-use-descarte” (Andrews, 2015).

Esse modelo aumentou os lucros das empresas, mas funcionou como um sistema de negócio no qual os consumidores se tornaram desperdiçadores e devedores. Pode-se observar o exemplo da indústria de eletrônicos, em que são impostas dificuldades na etapa de desmontagem e a consequente indução do consumidor à compra de um produto novo, geralmente atribuída a danos em componentes e à dificuldade de reparo e/ou substituição de itens do produto defeituoso (Andrews, 2015; Araújo & Queiroz, 2017).

A literatura especializada cita que as práticas de reparo, reutilização e reciclagem eram comuns durante e imediatamente após a Segunda Guerra Mundial, uma vez que os recursos eram racionados ou direcionados para o chamado esforço de guerra. Terminado o período de racionamento, os produtos passaram a ser novamente descartados ao final de sua utilização (Andrews, 2015; Araújo & Queiroz, 2017).

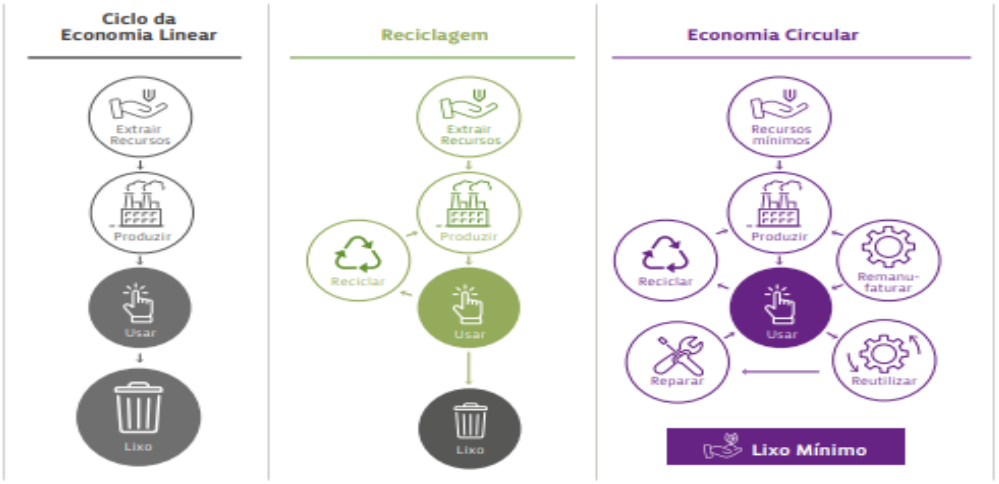
Entre as propostas para uma mudança dos padrões de produção e consumo encontra-se o conceito de economia circular, um modelo que busca a circularidade no uso de materiais e energia de forma intencional desde o projeto dos produtos (Ribeiro & Kruglianskas, 2014).

## 2.6 Economia circular

O modelo de economia circular (EC) surge em substituição ao modelo de economia

linear (EL), o qual se baseia em extração, produção e descarte. Visto que os recursos disponíveis são finitos, a economia circular é uma alternativa para um desenvolvimento sustentável, pois se baseia em eliminar resíduos e poluição desde o início da cadeia produtiva e busca manter os materiais em uso e realizar a regeneração do sistema (Ellen MacArthur Foundation, 2013). A figura 3 faz uma comparação entre a economia linear e a economia circular.

Figura 3 – Ilustração comparativa da economia linear e da economia circular




Fonte: World Economic Forum, DXC Technology (2022). Adaptado.

Pearce e Turner (1990) são reconhecidos como os pioneiros em introduzir o termo "economia circular", considerando as relações entre as funções econômicas e as do meio ambiente, mas a proposta foi mais bem difundida e promovida mundo afora pela Ellen MacArthur Foundation (EMF).

O modelo circular propõe fechar o ciclo (extrair, transformar, produzir, utilizar e descartar) repensando práticas econômicas e sociais de modo a aproximar o funcionamento do sistema econômico da forma como a natureza executa seus processos. O modelo é capaz de reduzir drasticamente a quantidade de novos recursos necessários para a produção, assim como a quantidade de resíduos descartados, mas para isso é necessário estabelecer novas relações sociais (Ellen MacArthur Foundation, 2013).

A economia circular visa a transformar materiais residuais em bens e serviços úteis, aumentando a eficiência dos recursos e eliminando o desperdício em toda a cadeia de valor. Isso pode ser alcançado usando peso leve, durabilidade, eficiência, substituição, ecodesign, simbiose industrial ou locação/aluguel (Witjes & Lojano, 2016).

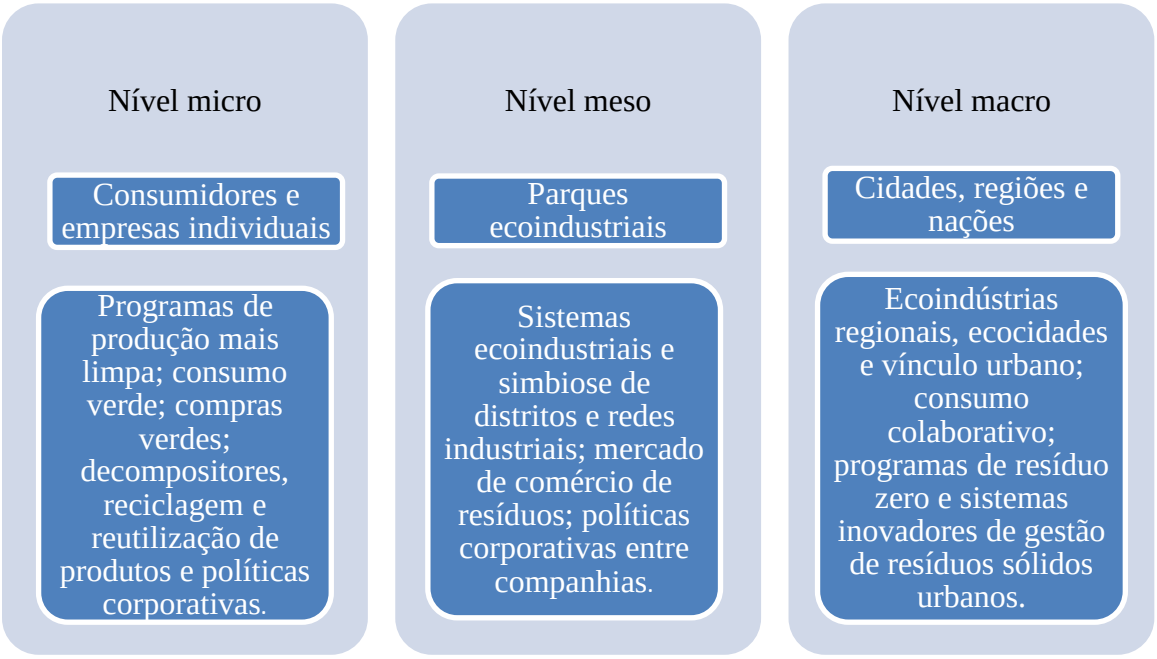
Outra definição detalhada por Geissdoerfer et al. (2017): "A economia circular é um

sistema regenerativo no qual a entrada e o desperdício de recursos, a emissão e o vazamento de energia são minimizados pela desaceleração, o fechamento e o estreitamento dos ciclos de materiais e energia. Isso pode ser alcançado por meio de projeto duradouro, manutenção, reparo, reutilização, remanufatura, reforma e reciclagem".

Segundo Jesus et al. (2018) a economia circular pode ser considerada:

- um conceito integrador para alcançar "congruência limpa", orientando novos arranjos institucionais que correspondam às considerações ambientais sobre o desempenho socioeconômico, promovendo um desenvolvimento técnico-econômico que não depende do consumo de recursos finitos;
- uma estrutura multinível (micro, meso e macro) que reconfigura e redireciona os modelos de produção e de negócio para a resiliência e a sustentabilidade;
- uma noção abrangente que exige ações específicas para minimizar a extração de recursos, maximizar a reutilização, aumentar a eficiência, aumentar a reciclagem de resíduos e o desenvolvimento de novos modelos de negócio. A figura 4 apresenta os níveis de implementação de práticas da economia circular.

Figura 4 – Níveis de implementação de práticas da economia circular




Fonte: Adaptação Ghisellini et al. (2016).

O *Procurement* atua como guardião na cadeia de valor, a aparência do sucesso torna-se diferente em vez de só buscar a economia, os critérios relacionados à pegada ambiental e social tornam-se mais relevantes. A aquisição de materiais para produtos circulares altera o processo

de seleção de fornecedores e o modo como as empresas se relacionam.

Os departamentos de compras precisam entender como os materiais afetam a circularidade do produto final (Deloitte, 2021).

## 2.7 *Procurement* 4.0 e a economia circular

As tecnologias habilitadoras da Indústria 4.0 para o *Procurement* 4.0 são úteis para alimentar informações oportunas e otimizar o processo de aquisição. No entanto, o processo de suprimentos é baseado na estratégia de negócios e operações da empresa, o que pode influenciar ainda mais a intenção de otimizar o processo de aquisição (Srai & Lorentz, 2018).

No entanto, o processo de suprimentos em um ambiente de economia circular é moldado por características de fábricas inteligentes em operações de remanufatura que determinarão o ajuste da tecnologia 4.0. Esse ajuste estratégico reforçado com educação e treinamento contínuos, com o objetivo de atualizar conjuntos de habilidades, mudará a atitude e a mentalidade dos compradores/fornecedores e aumentará a facilidade e a utilidade percebidas do *Procurement* 4.0 para fins de aplicação (Bienhaus & Haddud, 2018).

A abordagem da economia circular pode criar um valor para a organização (Weetman, 2017). Nesse cenário, a gestão estratégica da função de compras sob a visão da economia circular aumenta a eficácia por meio da construção de relacionamentos colaborativos, e isso ajudará a motivar os funcionários a aplicar ainda mais as ferramentas do *Procurement* 4.0 para otimizar os processos de compras (Kusiak, 2018; Majeed & Rupasinghe, 2017; Moeuf et al., 2018).

O *Procurement* 4.0 é composto de talentos, recursos tecnológicos e gerenciamento que podem ser integrados e reconfigurados para aplicar as tecnologias habilitadoras da Indústria 4.0 que melhorará a produtividade da remanufatura e a lucratividade dos negócios de remanufatura durante tempos incertos, a fim de atingir as metas da economia circular para a sustentabilidade (Glas & Kleemann, 2016; Gaustad et al., 2018; Low & Ng, 2018).

Na implementação das tecnologias habilitadoras da Indústria 4.0, o *Procurement* 4.0 busca desenvolver recursos e atender às necessidades do cliente no ambiente da economia circular. Hoje, todo cliente espera uma melhor entrega e um maior nível de confiabilidade dos fornecedores (Bienhaus & Haddud, 2018). Anteriormente, os fabricantes poderiam ter reduzido as incertezas ao não se concentrar na capacitação. No entanto, os tempos mudaram, e as empresas ficaram sobrecarregadas com altos estoques e tensões financeiras, o que as forçou a mudar de estratégia e focar no aprimoramento de capacidades para gerenciar com eficiência o

processo operacional e se transformar em uma economia circular (Bienhaus & Haddud, 2018).

O objetivo da economia circular é aumentar a longevidade dos recursos através do uso do princípio dos três erres (reduzir, reutilizar e reciclar). A otimização do processo de negócios de remanufatura por meio da capacitação tecnológica do *Procurement* 4.0 pode obter maior margem de lucro, tempo de ciclo de fabricação mais curto, maior produtividade e eliminação de desperdícios para apoiar ainda mais a economia circular (Bag et al., 2020).

# 3 METODOLOGIA

O objetivo deste capítulo é apresentar os procedimentos metodológicos, bem como descrever os métodos e instrumentos utilizados nos artigos desenvolvidos para o cumprimento dos objetivos desta tese. Vale ressaltar que se optou por identificar na área do *Procurement* os impactos da Indústria 4.0 e de que maneira o *Procurement* irá auxiliar no desenvolvimento da economia circular.

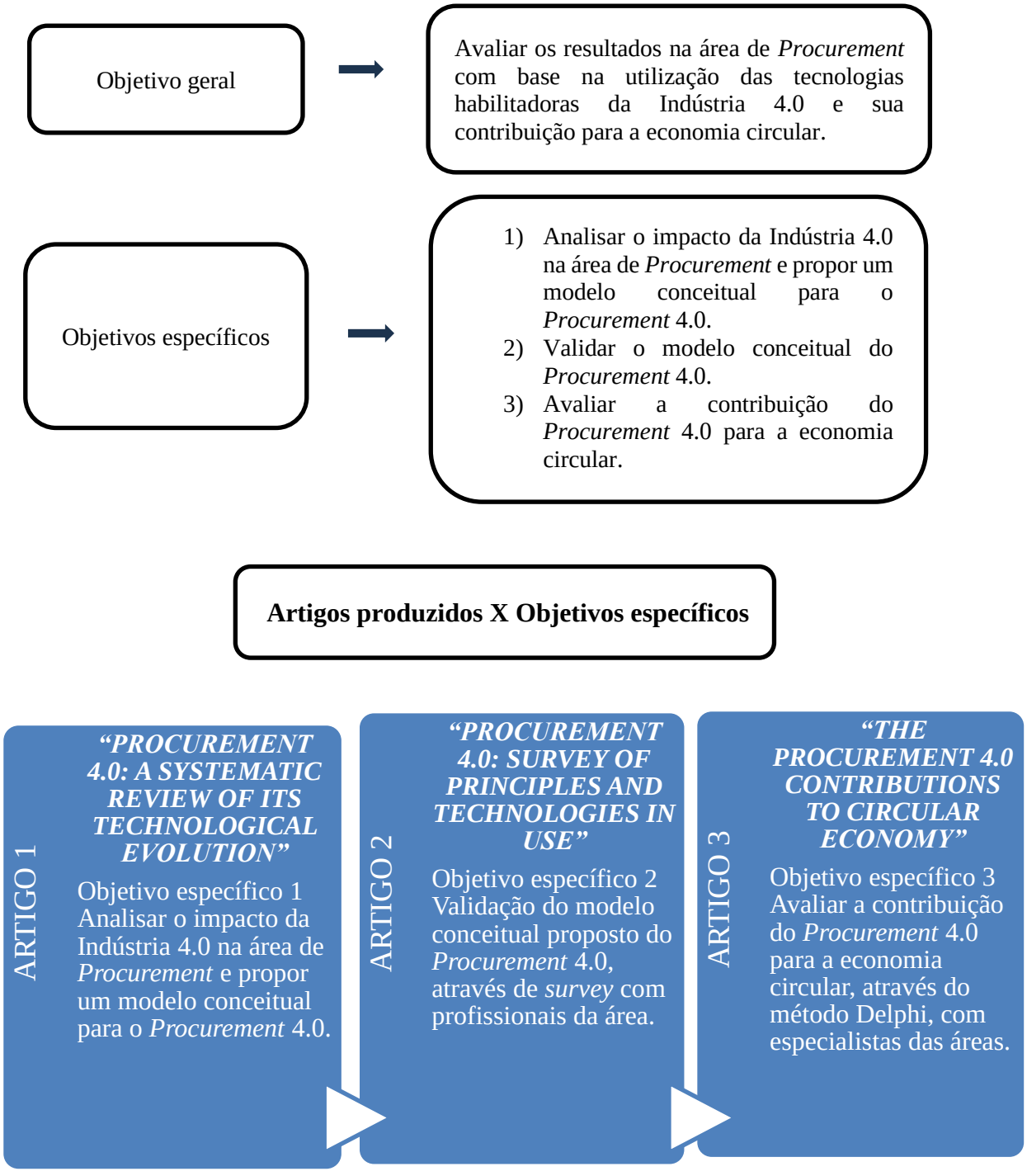
O trabalho se baseia da pesquisa bibliográfica que reside no fato de permitir ao investigador a cobertura de uma gama de fenômenos muito mais ampla do que aquela que ele poderia pesquisar diretamente. Essa vantagem torna-se particularmente importante quando o problema da pesquisa requer dados muito dispersos pelo espaço, sendo a pesquisa desenvolvida com base em material já elaborado, constituído principalmente de livros e artigos científicos. Embora em quase todos os estudos seja exigido algum tipo de trabalho dessa natureza, há pesquisas desenvolvidas exclusivamente a partir de fontes bibliográficas (Gil, 2002).

As pesquisas foram executadas nas principais bases de estudos acadêmicos disponíveis no Programa de Pós-Graduação em Engenharia de Produção da Unip: Ebsco, Google Acadêmico, Scielo, Scopus, Science Direct e Web of Science.

A organização da tese é em formato de artigos, e os resultados das pesquisas realizadas são apresentados por meio de trabalhos aprovados ou submetidos a congressos ou periódicos. Esse método permite a discussão sobre o tema no meio acadêmico em diferentes fóruns e com a contribuição de diferentes pares, a partir das revisões e sugestões durante o processo de aceite dos artigos.

Os artigos apresentados utilizam uma metodologia própria, com o objetivo de melhorar o resultado, em que cada tema abordado permite uma conclusão para inovação do conhecimento e confecção desta tese. A tese é composta de artigos, conforme apresentado na figura 5.

Figura 5 – Disposição dos objetivos e artigos da pesquisa




A primeira etapa do trabalho trata das tecnologias habilitadoras da Indústria 4.0, que estão transformando significativamente a forma tradicional de gestão das cadeias de abastecimento. No entanto, as ferramentas habilitadoras da Indústria 4.0 podem ser caras e não acessíveis e também podem ser implementadas de diversas maneiras. Portanto, os benefícios da implementação dessas ferramentas devem ser esclarecidos antes de investir na digitalização

do processo de *Procurement*. O trabalho foi o de apresentar o modelo conceitual proposto das dimensões (competências, gestão, parcerias, processos, sistemas/tecnologias e sustentabilidade) e motivar as tendências de evolução da área do *Procurement* diante dessas mudanças em tecnologias e transformação digital.

Por fim, os resultados concluem que as seis dimensões propostas no modelo conceitual podem proporcionar uma melhor compreensão da área de *Procurement*, demonstrando as tendências de implementação das ferramentas habilitadoras da Indústria 4.0 relacionadas às diferentes atividades apresentadas pelos autores da literatura.

A segunda etapa do trabalho aborda a evolução da indústria 4.0, com as suas tecnologias digitais e seus impactos na transformação digital dos negócios, bem como na digitalização da área de *Procurement* das empresas. Este artigo tem como objetivo encontrar os princípios e as tecnologias habilitadoras da Indústria 4.0 na área de *Procurement*.

Apresentamos um modelo de dimensões de *Procurement* 4.0 construído teoricamente e buscamos confirmar esse modelo por meio de uma pesquisa realizada com 177 profissionais da área de *Procurement* de diversos setores. Por meio da pesquisa, também foi possível abordar o aspecto dos profissionais que trabalham com esse cenário tecnológico inovador e algumas das tecnologias da Indústria 4.0.

O principal resultado pôde confirmar o modelo conceitual de *Procurement* 4.0 e suas dimensões (competências, gestão, parcerias, processos, sistemas/tecnologias e sustentabilidade), que orientam e podem fornecer um melhor entendimento para a implementação de tecnologias da Indústria 4.0 no área de *Procurement*.

# 4 RESULTADOS

Artigos produzidos durante a vigência do curso:

## 4.1 ARTIGO 1: "PROCUREMENT 4.0: A SYSTEMATIC REVIEW OF ITS TECHNOLOGICAL EVOLUTION"

Artigo aprovado e apresentado no Congresso APMS 2022 – IFIP International Conference Intelligent Manufacturing and Logistics Systems: Turning Ideas into Action. "Digital, Autonomous, Sustainable and Interoperable Systems," Gyeongju, Coreia; 25 a 29 set. 2022 – híbrido on-line/off-line.

Texto original no idioma inglês. O artigo busca responder ao objetivo específico 1: avaliar o processo, as tecnologias e as tendências da evolução do *Procurement* para o *Procurement* 4.0, possibilitando assim desenvolver uma base conceitual para o *Procurement* 4.0.

***Procurement 4.0: A systematic review of its technological evolution***

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**Abstract:** Industry 4.0 is significantly transforming the traditional way of managing supply chains. However, Industry 4.0 tools can be expensive and not affordable and can be implemented in a variety of ways. Therefore, the benefits of implementing these tools should be clarified before investing in digitizing the Procurement process. The objective of the work is to present the dimensions (Competencies, Management, Partnerships, Processes, Systems/Technologies, and Sustainability) and the tools of Ind4.0 motivating the trends of evolution in the procurement area in the face of these changes in technologies and digital transformation. Despite the importance of this issue, few studies have attempted to address the effects of Ind4.0, technologies, and intelligent systems in procurement. To fill this gap, in the applications of Ind4.0 tools a conceptual model was developed to classify different value propositions provided by the different applications of Ind4.0 tools in the internal and external processes of the area.

Finally, the results conclude that the six dimensions proposed in the conceptual model can provide a better understanding of the Procurement area, demonstrating the trends of the implementation of Ind4.0 tools related to different activities, presented by the literature authors.

**Keywords:** Industry 4.0; Procurement 4.0; value proposition; supply chain; digitization.

## 1 INTRODUTION

The new industrial revolution is beginning and is changing the way we live, work, and relate to each other [1]. To meet this new requirement, manufacturing and all processes of companies will need to adapt [2]. The importance of developing and managing innovative procurement strategies is clear [3]. From a historical perspective, procurement has undergone major transitions, especially in recent decades, in the sense that organizations have had to deal with pressures related to cost reduction and increased profits [4].

According to Batran et al. (2017) [5], the reality is that the pace of change and the scale of challenges we face require a new approach to how we do business. Change is continuous: Procurement 4.0 must be able to easily adapt and take advantage of emerging opportunities. It is also an integral and essential component of a larger system within a given organization. Procurement 4.0 can improve supply chain performance by adding values and improving visibility and resiliency.

The idea of Procurement 4.0 and the values aggregated by this concept is a new subject that is rarely addressed and suffers from great uncertainty due to the involvement of complex supply chain activities and multicriteria decision-making [6]. In terms of processes, problems, and solutions in defining how procurement can add value to customers, inside and outside an organization; and how it can help manage relationships, improve processes, and better resource management, both internally and with partners [7].

In this sense, the research questions are: How will the process be different from the current Procurement system to Procurement 4.0? What technologies can be used? What is the tendency of Procurement evolution?

The paper is conceptual to achieve the goal of organizing the literature through a systematic review and evaluating the process, technologies, and trends of the evolution of Procurement to Procurement 4.0.

For this, we carried out a systematic review of the literature and established a conceptual frame (table 1) of Procurement evolution, technologies, and tendencies of Procurement 4.0. The paper is organized as follows: Section 2 presents the background of the review of Industry 4.0 and Procurement concepts; section 3 presents the systematic review method, used to organize and classify the literature into six dimensions; Section 4 presents the results of literature research on Procurement, technologies of industry 4.0 and the respective references; Section 5 presents the discussion and conclusions about the evolution of Procurement to Procurement 4.0, emphasizing process improvements.

## 2 THEORETICAL REVIEWS

### 2.1 Industry 4.0

To contextualize the Procurement 4.0 scenario, we raise information about industry 4.0, digital technologies, and the structure of procurement. Germany brings a new paradigm of industrial production to the world, with the appropriation of digital technology disseminated on the Internet and executed by the Elements Internet of Things [8].

Bonilla et al., (2018) [9], common that due to its unique characteristics, the goal of Industry 4.0 is to increase productivity and customization that are achieved through the flexibilization of manufacturing and decentralization through the digitization and integration of the information network, allowing the real-time monitoring and control.

### 2.2 Procurement and Procurement 4.0

Procurement can be defined as the “business management function that ensures the identification, supply, access, and management of external resources that an organization needs or may need to meet its strategic objectives” [10]. Procurement is a function of procurement of products and services, especially for commercial purposes. Among them are supplier selection, payment terms, contract negotiation, regulatory compliance, analysis, and outsourcing [11]. This is possible because Procurement has strategic know-how about suppliers and their markets, deep expertise in the products and services purchased, and the alternatives on offer, including emerging innovations [12].

Procurement 4.0 connects the organization with its suppliers and enables dynamic cooperation and coordination of the procurement process [13]. Procurement 4.0 includes a range of

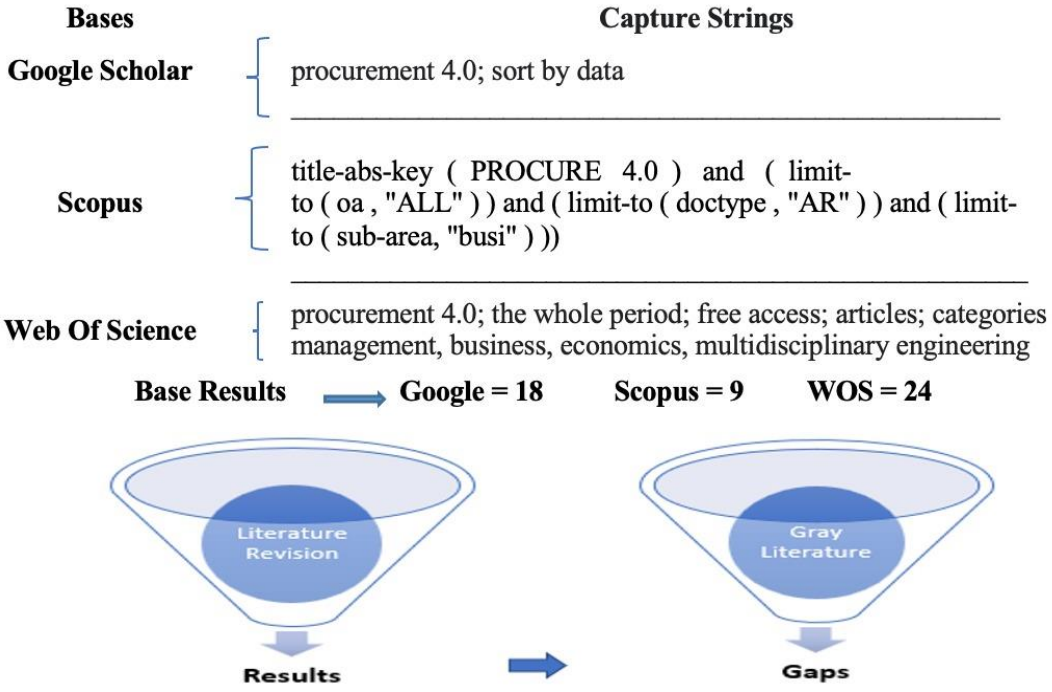
processes and changes within a company as they work to develop new procurement value propositions and incorporate supplier management into purchasing software [14].

According to current literature, Procurement 4.0 can be understood as an intelligent system capable of autonomously detecting material demand, generating your order, and even transmitting the order to the supplier without the need for human involvement [15]. Procurement 4.0 aims to optimize the value provided by the purchasing function [3].

## 3 METHOD

First, we selected the Google Scholar, Scopus, and Web of Science databases. In the second step, we select the keyword applied to collect related articles. The keyword "procurement 4.0" is new to academic literature and the resulting terminology for the new synonym for I4.0 and Supply Chain 4.0. The illustration presents the methodology in figure 1.

**Fig. 1 .** Illustration of the methodology used in this article.




Instead of covering a rigid systematic review, we conducted a review at different levels, looking for text representative of technologies within the Procurement approach, showing a current or potential use in the construction of Procurement 4.0.

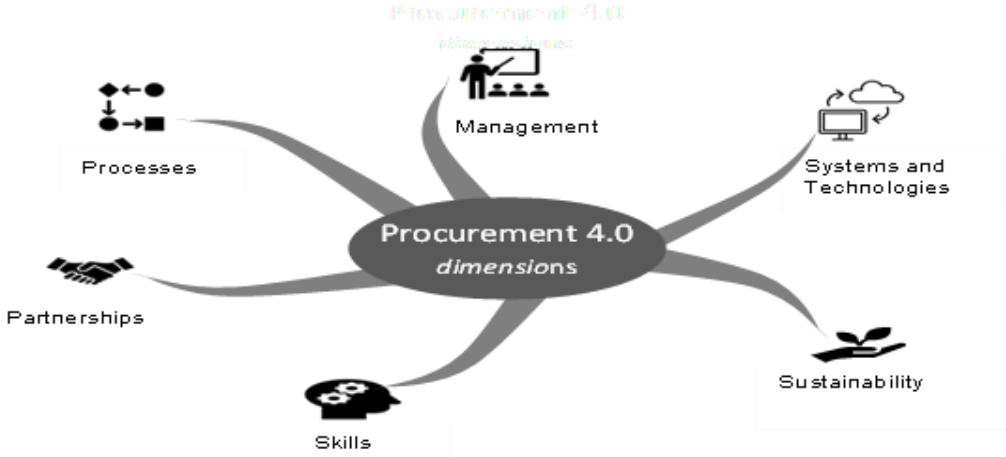
After the analysis of the articles, a gap was presented in the literature presented, of the

term Procurement 4.0 for still being reduced publications, to repair it was used an approach in the gray literature [36], specialized scientific journals and management reports were used to extract technologies applied in various forms and levels of intervention that help to manage this change. Public Procurement cases were discarded because they did not belong to the scope of the search.

For example, Henke and Schulte [16] argue that the acquisition of partners and the interface layer of production solutions offer the opportunity to position itself as a key factor for the development of industry 4.0, postulating several opportunities.

Contributing to this reasoning, Bueno et al. [17] present six essential dimensions for the implementation of Procurement 4.0 that will require a mutation in companies, and their Strategic, Tactical, and Operational planning: Competencies, Management, Partnerships, Processes, Systems / Technologies, and Sustainability. Figure 2: Illustrates the established dimensions of Procurement 4.0.

Fig. 2: Dimensions for Procurement 4.0, based on Bueno et al. [17]**.**




## 4 RESULTS

The intention advocated in this article was to address the six dimensions and technologies of industry 4.0, to present the due rupture [3] of Procurement for Procurement 4.0. The introduction of 4.0 technologies will mean developing new value propositions, meeting new business needs, and integrating data between roles and value chains. Procurement 4.0 include forming service level agreements with suppliers, maintaining the procurement intranet site, frequent design reviews and stakeholder satisfaction surveys, and identifying and implementing opportunities for improvement [15]. Table 1 presents the procurement break for version 4.0.

Table 1: Evolution of Procurement technologies

| Dimensions | Industry 4.0 Tecnologies | Transition in Procurement Operations | Tendences | Authors |
|---|---|---|---|---|
| **Skills** | Cloud Computing, Internet of Things (IoT), Blockchain Technology, Cybersecurity, Big Data Analytics, Advanced Robotics, Virtual/Augmented Reality, 3D Printing, and Additive Manufacturing. | Reduced team workload | Multi talent profiles. | [18] |
| | | | Consultants | [19] |
| | | Creating synergies | Data Analysts (Descriptive analytics to cognitive analytics). | [20] |
| | | | Strategic with the business. | [21] |
| | | Communication | Relationship management and strategic thinking. | [22] |
| **Management** | Cloud Computing, Internet of Things (IoT), Blockchain Technology, Cybersecurity, Big Data Analytics, Advanced Robotics, Virtual/Augmented Reality, 3D Printing, and Additive Manufacturing. | Strategic Positioning | Mastery of proprietary technology. | [18] |
| | | Creation of new business networks | Third party independence. | [19] |
| | | | Process and data integration. | [5] |
| | | Cost reduction | Cost of acquisition and supplier selection. | [24] |
| | | | Higher Profits. | [20] |
| | | More customer-oriented business models | Greater Autonomy. | [21] |
| **Partnerships** | Cloud Computing, Internet of Things (IoT), Internet of Services (Ios), Blockchain Technology, Cybersecurity, Big Data Analytics, Advanced Robotics, Virtual/Augmented Reality, 3D Printing, and Additive Manufacturing | Supplier Administration | Creation of new business networks. Use of blockchains for contract validation. | [18] |
| | | | More agile communication with customers and suppliers. | [19] |
| | | More transparency in the supply chain | Increased transparency of data and information. | [20] |
| | | Proactive Response | Early issuance of outage notices. | [23] |
| | | | Strategic Partners. | [5] |
| | | Risk management | Improved evaluation of customer and supplier data. | [21] |

| | | | | |
|---|---|---|---|---|
| **Processes** | Cloud Computing, Internet of Things (IoT), Internet of Services (Ios), Artificial Intelligence, Simulation, Blockchain Technology, Cybersecurity, Cyber Physical Systems, Big Data Analytics, Advanced Robotics, Virtual/Augmented Reality, 3D Printing, and Additive Manufacturing. | Demand analysis | Digitization of processes and procedures. | [18] |
| | | | Greater efficiency, flexibility, and fast reaction time. | [19] |
| | | Information flow | Automated allows perfect coordination, saving coordination costs. | [13] |
| | | Process standardization | Decreased travel costs and increased speed in decision making. | [20] |
| | | Fast reaction times | Better connections with global supplier network. | [21] |
| **Systems and Technologies** | Cloud Computing, Internet of Things (IoT), Internet of Services (Ios), Blockchain Technology, Simulation, Cyber Security, Big Data Analytics, Advanced Robotics, Virtual/Augmented Reality, 3D Printing, Additive Manufacturing, and Artificial Intelligence. | Improved data quality (greater significance due to information and not just data). | Real-time availability of data and information. | [18] |
| | | Real-time availability of data and information. | Improved data availability, fully computerized. | [19] |
| | | | Increased transparency of data and information. | |
| | | Intelligent behavior | Autonomous Vehicle Routing, Locating Potential Suppliers, Order Scaling, and Lot Storage. | [25], [26] |
| | | Database security | Data sharing, visibility and transparency promotes trust. | [15] |
| | | Fully automated information flow. | Improved evaluation of customer and supplier data. | [21] |

| | | | | |
|---|---|---|---|---|
| **Sustainability** | Cloud Computing, Internet of Things (IoT), Blockchain Technology, Cybersecurity, Big Data Analytics, Advanced Robotics, Virtual/Augmented Reality, 3D Printing, and Additive Manufacturing. | Reduction of costs associated with waste management. | Socially responsible shopping. | [27] |
| | | Sustainable shopping | Cloud data associated with sustainability, such as carbon footprint (environmental) and waste disposal costs (economic) and social aspects. | [28] |
| | | Corporative image | Economic, environmental, and social behaviour depends heavily on your supply chain. | [30] |
| | | Sustainable Production | Flexibility in production volumes. | [19] |
| | | Facilitates compliance with legal requirements. | Acquisitions covering environmental, economic, and social (TBL) elements. | [30] |
| | | | Incorporation of new technologies. | [20] |
| | | It demonstrates the organization's commitment to a sustainability and social responsibility policy. | Perceived Costs/Benefits: Sustainable products play a prominent role in sustainable procurement. | [31] |

## 5 DISCUSSION AND CONCLUSIONS

Despite the emerging literature on this subject, it is notorious that there is a lack of comprehensive and systematic structures, strategies, and approaches for the implementation of Industry 4.0 concepts in the Procurement processes. The literature has in common that the described procurement process was initiated not by a single technology, but by the interaction of various technologies and solutions whose effects created new modes of production, but also influenced organizations, the environment, and social functions, in accordance with [32].

Procurement is no longer a personality-centered function, where professionals in the areamanage everything on their own, using only the knowledge they have acquired over time. Based on the research of the literature presented, the table presented how Industry 4.0 technologies will change the way the Procurement process works and what are the trends of this evolution.

Procurement 4.0 will transform the operation of the Supply Chain. Applicable technologies represented substantial values and aggregated values consist of improving performance in operations associated with purchasing management in supply chains, such as pricing, supplier selection, evaluation, cost-benefit, data collection, and analysis. The presence of digital integration is transforming business processes, both internal and external, with the implementation of Ind.4.0 technologies. Processes and data are increasingly transparent and accessible, intelligence in Procurement 4.0 requires a transformation in the organization in the six dimensions presented.

The adoption of Procurement 4.0 results in autonomy, flexibility, and transparency of operations associated with purchasing management to optimize pricing decisions, supplier management, and purchasing management, or to develop sustainability and data sharing security [33,34]. Given the issues related to the application of Industry 4.0 technologies in Procurement and compared with the existing literature in the area, this article focuses not only on technological trends but proposes a vision of Procurement evolution and tendencies.

However, our reviewed literature does not find a clear concept of Procurement 4.0. Future studies can focus on a conceptual model of Procurement 4.0.

## REFERENCES

1. Kagermann, H.; AnderlR.; GausemeierJ.; Schuh G; Walser. (Eds.) (2016). (“the digital world”) Industrie 4.0 in a Global Context: Strategies for Cooperating with International Partners. Munich: Herbert UtzVerlag.
2. Chiang, W. C. (2016). Development of a lean non-adjusting setup system – A case study of Aluminum rims production. Christian University; Chung Yuan, Taiwan, 2016.104p.
3. Nicoletti B. (2020). Procurement 4.0 and the Fourth Industrial Revolution. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-35979-9_1.
4. Uusitalo, J. (2019). Strategic acquisitions in the face of uncertainty. Master's thesis. University of Jyväskylä, Finland.
5. Batran, A. et al. (2017). A survival guide in a digital, disruptive world. Frankfurt: Campus.

6. Bag, S.; Wood, LC; Mangla, SK; Luthra, S. (2020). Procurement 4.0 and its implications for business process performance in an economy circular. Resource. conservation Recycle, 152, 104502.
7. Nicoletti, B. (2017). Agile Acquisitions. Volume II: Designing and Implementing a Digital Transformation, Springer International Publishing, London, UK, ISBN 978-3-319-61085-6.
8. Kagermann, H., Wahlster, W., Helbig, J.B (2013). Securing the future of German manufacturing industry: recommendations for implementing the strategic initiative INDUSTRIE 4.0. German National Academy of Science and Engineering (ACAT- ECH) Technical Report.
9. Bonilla, SH; Silva, HRO; Terra da Silva, M.; Franco Gonçalves, R.; Sacomano, JB Industry 4.0 and Implications of Sustainability: A Scenario-Based Analysis of Impacts and Challenges. Sustainability 2018. 10, 3740. https://doi.org/10.3390/su10103740.
10. Andrew, K. (2005). "The definition of acquisitions," Chartered Institute of Purchasing and Supply, Australia, pp. 1-7.
11. Chakravarty, Sukriti. (2017). What is the difference between procurement and sourcing? Available at: www.tendersinfo.com/blogs/what-is-the-difference-between procurement-purchasing-and-sourcing.
12. Weissbarth, Robert., Geissbauer, Reinhard., Wetzstein, Jurgen; (2016). Procurement 4.0: are you ready for the digital revolution? Available in: https://www.strategyand.pwc.com/report/procurement-4-digital-revolution. Access on 20/04/2020.
13. Glas, A.H., and Kleemann, P.F.C. (2016). "The Impact of Industry 4.0 on Procurement and Supply Management: A Conceptual and Qualitative Analysis," International Journal of Business and Management Invention, Vol. 5 No. 6, pp. 55–66.
14. PWC Report (2016). Procurement 4.0: Are You Ready for Digital Revolution? Available at https://www.strategyand.pwc.com/report/procurement-4-digital-revolution. Accessed on June 25, 2020.
15. Bienhaus, F., Haddud, A., Bienhaus, F. and Haddud, A. (2018). "Procurement 4.0: factors influencing the digitization of procurement and supply chains." Business Process Management Journal, Vol. 24 No. 4, pp. 965–984.
16. Henke, M., & Schulte, AT (2015). Einkauf und die 4. Industrielle Revolution, BeschaffungAktuell, 62 (3): 20–21.
17. Bueno, R E; Freitas Junior, Moacir De; Da Silva, Marco Aurélio; Lombardi, Império; João Victor Bueno. (2021). THE EVOLUTION OF LOGISTICS: PROCUREMENT 4.0. Production engineering [electronic book]: quality management, production, and operations: volume

2 / Ernane Rosa Martins. organizer. Guarujá, SP: Scientific Digital. ISBN 978-65-5360-036-2_DOI 10.37885/978-65-5360-036-2.

18. Burton, Niul. (2015). Procurement 2025: 10 Challenges that Will Transform Global Sourcing. Disponível em www.industryweek.com/global-sourcing. Acesso em 20/04/2021.
19. Fraunhofer, IML, (2016). The Digitalization of Procurement. Pilot Study Procurement 4.0 Fraunhofer IML BME. Disponível em: https://www.iml.fraunhofer.de/content/dam/iml/en/documents/OE260/Pilot%20Study_Procurement%204-0_Fraunhofer%20IML_BME.pdf - Acesso em 20/04/2021.
20. Biazzin, C. (2017). Inteligência em Compras. GV executivo, v.16, nº6, nov/dez. Supply Chain, Operações e Logística • inteligência em compras. Disponível em: https://bibliotecadigital.fgv.br › article › download.
21. CIPS (2019). Digitalization in Procurement and Supply. Disponível em: https://www.cips.org/PageFiles/138071/CIPS_Digitalisation_of_Procurement_WEB.pdf. Accessed on 02 July 2021
22. Bals, L., Schulze, H., Kelly, S. and Stek, K. (2019). "Journal of Purchasing and Supply Management Purchasing and supply management (PSM) Competencies: Current and future requirements," Journal of Purchasing and Supply Management, Elsevier Ltd, Vol. 25 No. 5, p. 100572.
23. Tripathi, Shubham & Gupta, Manish. (2020). A framework for procurement process re-engineering in Industry 4.0. Business Process Management Journal. ahead-of-print. 10.1108/BPMJ-07-2020-0321.
24. Klunder, T., Niklas, J. and Steven, M. (2019). "Procurement 4.0: How the digital disruption supports cost-reduction in Procurement," Production, Vol. 29, available at: https://doi.org/10.1590/0103-6513.20180104.
25. Pomerleau, Da. (2012). Neural Network Perception for Mobile Robot Guidance; Springer Science & Business Media: Berlin/Heidelberg, Germany, Volume 239
26. Ciula, G.; D'amico, A.; Brano, VL; Traverso, M. (2019). Application of an optimized artificial intelligence algorithm to assess the heating energy demand of non-residential buildings at a European level. Energy, 176, 380-391.
27. Park, H; Stoel, L. (2005). "A model of socially responsible purchasing/supply decision-making processes", international journal of retail & distribution management, vol. 33no.4, pp.235-48.

28. Singh, A.; Kumari, S.; Malekpour, H.; Mishra, N. (2018). Big data cloud computing framework for selecting low carbon suppliers in the supply chain beef supply. J. Clean. Product 202, 139-149.
29. Xie, G. (2016). “Cooperative strategies for sustainability in a decentralized supply chain with competing suppliers.” (“Manufacturer’s cooperation strategy of closed-loop supply ...”) Journal of Cleaner Production, 113, 807-821. http://dx.doi.org/10.1016/j.jclepro.2015.11.013.
30. Meehan, Joanne; Bryd, David. (2011). Sustainable procurement practice. Business strategy and the environment bus. Strat. Env. 20, 94–106 published online 3 May 2010 in Wiley online library (wileyonlinelibrary.com) DOI: 10.1002/bse.678.
31. Brammer, S.; Walker, H. (2011). Sustainable procurement in the public sector: An international comparative study. International Journal of Operations and Production Management. v.31, n.4, p.452-476.
32. Schmidt, R., Möhring, M., Härting, RC, Reichstein, C., Neumaier, P., &Jozinovi Ć, P. (2015). Industry 4.0 potentials for creating smart products: results of empirical research. At the International Conference on Business Information Systems, 16–27. Springer, Cham, Switzerland.
33. Babiceanu, RF; Seker, R. (2016). Big Data and Virtualization for the Fabrication of Cyber-Physical Systems: A Survey of Current Status and Future Perspectives. To compute. Ind. 81, 128-137.
34. Fatorachian, H.; Kazemi, H. (2021). Impact of Industry 4.0 on supply chain performance. Product Plan. To control, 32, 63-81.
35. Neto, G. T. G., Santos, W. B., Endo, P. T., and Fagundes, R. A. (2019). “Multivocal literature reviews in software engineering: Preliminary findings from a tertiary study.” (“Multivocal literature reviews in software engineering ...”) In 2019 ACM/IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM), volume 2019-Septe pages 1–6. IEEE.
36. Côrtes, Pedro Luiz. The Importance of the Grey Literature Available on the Internet for the Areas of Accounting and Business Administration Brazilian Journal of Business Management, vol. 8, no. 20, January-April 2006. pp. 13-22. Álvares Penteado School of Commerce Foundation São Paulo, Brazil.

## **4.2** Artigo 2*:* **“PROCUREMENT 4.0: SURVEY OF PRINCIPLES AND TECHNOLOGIES IN USE”**

Artigo submetido e aceito para publicação ao *International Journal of Procurement Management (*CiteScore2.2 (2022)). Texto original no idioma inglês. O artigo busca responder ao objetivo da pesquisa: Identificar os impactos da Indústria 4.0 na área do Procurement, identificar as possíveis ferramentas e tecnologias que podem alavancar estes processos digitais.

A pesquisa apresenta um modelo proposto de dimensões do Procurement 4.0, construído teoricamente e busca a validação do modelo através de uma survey conduzida com 177 profissionais de Procurement.

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## *PROCUREMENT 4.0: A SURVEY OF ITS PRINCIPLES AND TECHNOLOGIES IN USE*

**Abstract:** This work addresses the 4.0 evolution and its digital technologies and their impacts on the digital transformation of the business, as well as the digitization in the Procurement area of companies. This paper aims to find the enabling principles and technologies of Industry 4.0 in the Procurement area. We present a model of Procurement 4.0 dimensions, theoretically constructed, and we seek to confirm this model through a survey conducted with 177 professionals in the Procurement area from various sectors. Through the research, it was also possible to address the aspect of professionals who work with this innovative technological scenario, and some of the technologies of Industry 4.0. The main result could confirm the Procurement 4.0 conceptual model with the dimensions: Skills, Management, Partnerships, Processes, Systems/Technologies, and Sustainability, that guide and can supply a better understanding for implementing industry 4.0 technologies in the Procurement area.

**Keywords**: Procurement 4.0; Industry 4.0; Procurement Technologies; Procurement Evolution; Procurement Sustainability

### 1 INTRODUCTION

Considering the Industry 4.0 context, the company's acquisition process will increase its corporate value as a driver of innovation in the digital age, connecting critical external knowledge and skills with internal aspects of the business to build its increasingly efficient and competitive supply chains (Joseph et al., 2022).

Technologies related to Industry 4.0 could respond to specific procurement challenges, reducing lead times, improving communication and transparency, and supplying useful information on rigorous management decisions, for example, the outsourcing decision whether to manufacture or buy certain components or even products or services (Corbos et al., 2022). The market has become global, thus forcing the company's operations to keep up to date. The application of information technology/information systems (IT/IS) and outsourcing to operations management has significantly altered the landscape of operations management strategies, techniques, and technologies (Angappa et al.,2012).

According to Schiele (2018), the revolution does not happen exactly when a recent technology emerges, but when there is a change in the organizational model used by this technology. Just remember the production line and the division of labour, which were the factors that drove change.

The concept of Procurement 4.0 looks for a more autonomous, transparent, flexible, agile, and sustainable procurement process, supported by innovative technologies, in association with some new procurement principles to perfect pricing decisions and supply chain (Babiceanu et al.,2016; Fatorachian et al.,2021). But what are the technologies and principles that support Procurement 4.0?

This article aims to show the principles and enabling technologies of Industry 4.0 in the Procurement area. The conceptual model presents a model of dimensions for the implementation of Procurement 4.0, built theoretically, and seeks to confirm this model through a survey conducted with 177 Procurement professionals in different sectors.

## 2 BACKGROUNDS

### 2.1 Procurement and Procurement 4.0

“Procurement” is a process that involves not only the business relationship with suppliers, but also research, development, and qualification. As there is technical support during the relationship between the parties, there is a need to improve the information systems, resulting in integration between the company's sectors, customers, and suppliers (Lima, 2011).

Procurement affects most business functions as it ensures that services and items are procured properly so that companies' processes and projects can proceed efficiently (Heckman, 2020).

The term ‘Procurement 4.0', which in principle denotes the application of specific techniques of 'Industry 4.0', is an element of novelty, as it can be identified in very few works (Bag et al., 2020).

Given its potential to increase productivity, save expenses and improve performance in companies, procurement 4.0 – the integration of digital technology into procurement processes – is a pertinent and relevant study problem. The term procurement 4.0 is a relative novelty and therefore we consider that it needs further investigation, especially in the strategic context of the organization (Corbos et al., 2023).

The pursuit of Procurement 4.0 is the ease of operation that it can provide organizations. In line with this, the reduction of human efforts is also another driver for the implementation of Procurement 4.0, as it leads to zero human error (Bag et al., 2020). Technological advancement and technology requirements implications in the fast-paced environment are other drivers of Procurement 4.0 (Yang et al., 2021).

Procurement 4.0 refers to integrating digital technologies into procurement processes for greater efficiency and performance (Corbos et al., 2023).

"Procurement 4.0" was designed to describe the evolution of the use of the MRP (Material Requirements Planning) procurement system up to the present day, and the real advance occurred in two dimensions: firstly, the degree of functional integration and transversal, and secondly, the degree to which systems have reduced manual work in purchasing tasks, that is, automation (KAGERMANN et al., 2013).The redefinition and restructuring of Procurement 4.0 can be beneficial to organizations' partners and customers (Wuttke et al.,2013).

In the context of "Procurement 4.0," the supply sector as the main interface with the supplier will be able to take advantage of new business opportunities, changing from a cost center to a profit center. This is possible because "procurement" has strategic ability about suppliers and their markets, deep ability about the products and services that are acquired, as well as the alternatives on offer, including emerging innovations (Weissbarth et al., 2016).

"Procurement" integrates logistics and is a comprehensive process of integrating various subsystems of the purchasing or procurement processes between which numerous relationships will occur (Kapustina et al.,2017).

## 2.2 *Procurement 4.0 dimensions: A proposed model*

In a previous work, Bueno et al. (2022), proposed a Procurement 4.0 conceptual model created based on the literature in which the six dimensions: Skills, Management, Partnerships, Processes, Systems/Technologies, and Sustainability, to promote a better understanding of the industry 4.0 technologies implementation in the Procurement area, proving the trends of Industry 4.0 tools related to different activities:

**A) Skills:** In the worker category, Industry 4.0 will lead to a growth in the automation of daily routine assignments, which implies that workers will have to face the fact that their current tasks will no longer exist in the future (Spath et al; 2013). Trading skills remain essential, but the need for these professionals to acquire new ways of thinking about the value chain as part of their skills. Change of buyer's behavior to design value chains (Batran, 2017). Digitally able people to benefit from the opportunities of digitization. Creation of modern job profiles: buyers of renewed categories, specialists in contracts and intellectual property, and data scientists (Geissbauer et al., 2016).

**B) Management:** Industry 4.0 consists of systems and concepts in various areas of knowledge, such as aggregate industrial automation, perfectly integrated production and logistics chains, supply of raw materials and energy, asset management, and industrial complexes, combining domains ranging from the most varied areas of engineering and information technology

(Cesário, 2017). At the management level, the shift to procurement 4.0 is increased global connectivity with multifunctional teams, a real effort to manage to create a work environment that unleashes the potential for creativity and innovation. On the one hand, managers should direct employees during the transformation method to procurement 4.0. On the other hand, it is important to make room for employees to conduct this process of change in their own conduct and to ensure long-term sustainable success (Nicoletti, 2020).

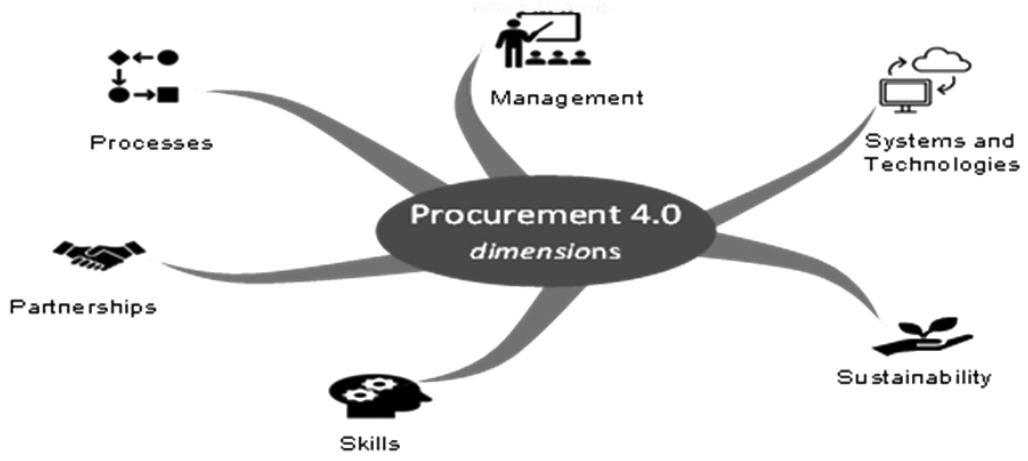
**C) Partnerships**: Procurement 4.0 reflects a thriving emphasis on the importance of partners. Relationships with partners are adapting to cooperate with selected suppliers. The procurement 4.0 activities it should implement are quite different from a few decades ago. Supplier involvement can be a way to facilitate "the speed of development and quality of new products and reduce production costs" (Jean et al., 2014). Procurement 4.0 requires partner development, partner design agreements, use of full-service providers, total cost partner selection, long-term partner relationships, strategic cost management, enterprise resource planning, and integrated internet connections and shared databases as ways to create new values within the supplier network (Rodrigues et al., 2019).

**D) Processes:** Smart machines and computer applications connect all functions and allow an organization to share information in real-time. At the same time, procurement processes need to be simplified. Procurement 4.0 is the addition of technology, information, communication, and automation in procurement support to improve the added value for the customer and for the entire organization (Nicoletti, 2020). "Procurement 4.0" was planned to describe the evolution of the application of the MRP (Material Requirements Planning) purchasing systemto the present day, and progress has occurred in two dimensions: first, the degree of functional and cross-sectional integration, and secondly the degree to which the systems have reduced manual work in procurement tasks, i.e., automation (Kagermann et al., 2013).

**E) Systems and Technologies:** Digital systems and technologies will increase engagement, data analysis, and engagement using tools throughout the procurement value chain, from planning and supply to contract negotiations, order delivery, payment, and supplier management (Batran et al., 2017). Digital technologies have changed the way we connect with customers and offer value. Customer messages and reviews make them much more influential than advertising and celebrities, turning dynamic customer participation into a critical factor in business success (Rogers, 2018). Technologies vary according to the impact and the current technological maturity of each company. Need to define data architecture strategy to define the processes they want to support and their tools. The tools are "a means" and not an "end" (Geissbauer et al., 2016).

**F) Sustainability:** Sustainable acquisition can be defined as the process used to acquire goods and services ('products') to ensure the least impact on society and the environment throughout the product life cycle. The role of the Procurement area in promoting the corporate sustainability agenda is fundamental, given its positioning and ability to influence external organizations in the supply chain (Seuring, 2004). However, the purchasing structures available for assessing the sustainability of suppliers, such as ISO 14001, have a diluted vision of sustainability, focusing only on environmental standards (Corbett et al., 2001). The acronym ESG encompasses the environmental (E), social (S), and governance (G) factors, studies the impact of three levels on corporate value and the results showed that improving ESG performance was conducive to improving corporate market value. Companies with satisfactory performance in ESG are stable and their stock prices are more resilient (Broadstock et al., 2021). Figure 1 presents the six dimensions of the conceptual model.

Figure 1. Conceptual model of the Procurement 4.0 Dimensions. Source: Bueno et al; (2022).




## 3 *METHOD*

A Survey was conducted with the approach of quantitative research using an online questionnaire to collect data with an audience of professionals in the Procurement area from different organizations and segments.

The research questions were based on the conceptual model of dimensions. The questionnaire, based on the conceptual model, consists of seventeen questions in two parts: the former focusses the respondent profile; the latter, with six questions (Appendix A), focus the respondent perception about the Procurement 4.0 dimensions, aiming the model validation. The Skills

dimension was not included in the questionnaire, considering that all the respondents are Procurement professionals, presupposing they have the involved skills.

The sample was built by consulting a professional profile social network, where professionals who claim to be in the procurement area, are from different nationalities and cultures. The survey was conducted using an online survey platform of this same social network. All data stays anonymously saved in the platform's database.

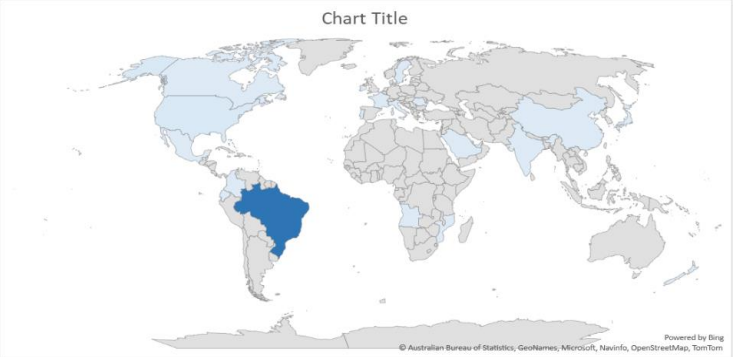
### 3.1 *Reliability*, Representativeness *and Validity*

The research is qualitative since the research was presented to 8,000 professionals in the Procurement area. Sampling is non-probabilistic and voluntary; the study takes an intentional qualitative research approach to analyze the responses collected from 177 professionals in the supply area.

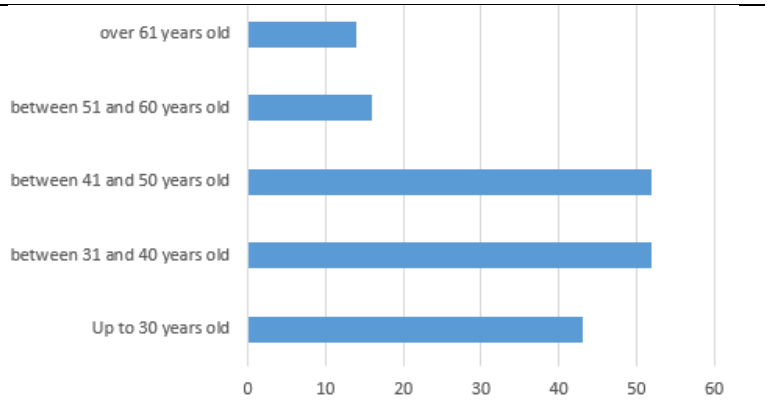
The survey results were presented as a table in the first part the profiles of the interviewees and the companies represented and in the second part the proposed model of the dimensions. The survey focused on a key question: Respondents respond to these statements based on their point of view, experiences, and significant business environment. The answers to these research questions will help find how the dimensions supply a general sign for organizations to pay more attention to the progress of digital transformation.

Focus on the tools and technologies needed to use the potential of digitization and the statements include different communication, collaboration, and support tools. Participants respond to these statements from a general perspective and should not be limited to their position, title, or organization. Below are tables, where figure 2 is the profile of respondents and figure 3 is the profile of respondent organizations?

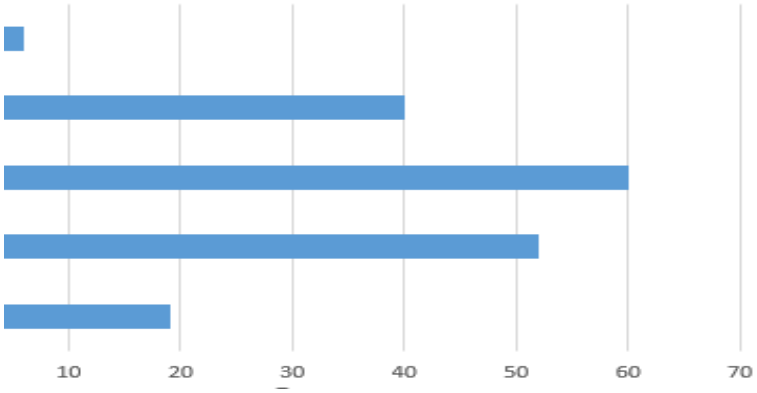
Figure 2. Profile of the respondents

| | |
|---|---|
| Countries |  |

Age group

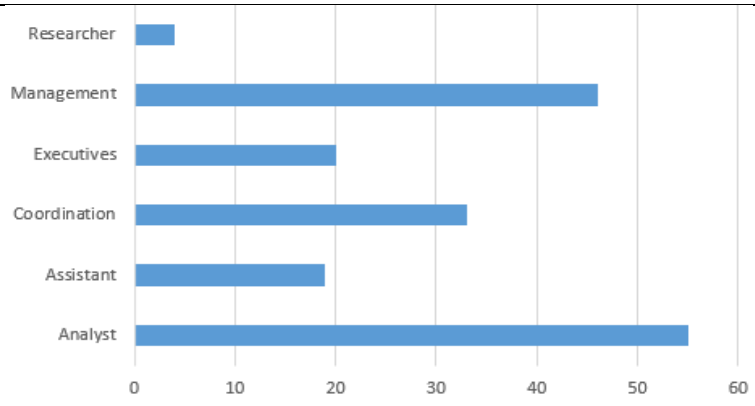



Level of schooling

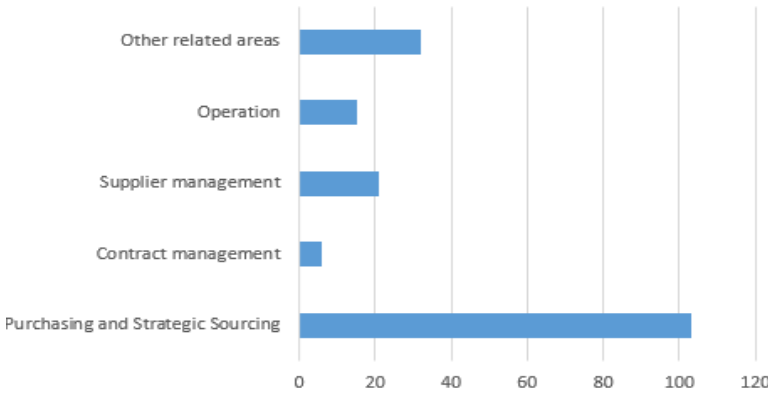



Professional experience


Position Held



Department /Area




## 4 RESULTS

The approach chosen was quantitative research using an online questionnaire to collect data for this study with an audience of Procurement professionals from different organizations and segments. The table presents six questions about the profile of professionals. The Locations question presented responses from the five continents (Table 1).

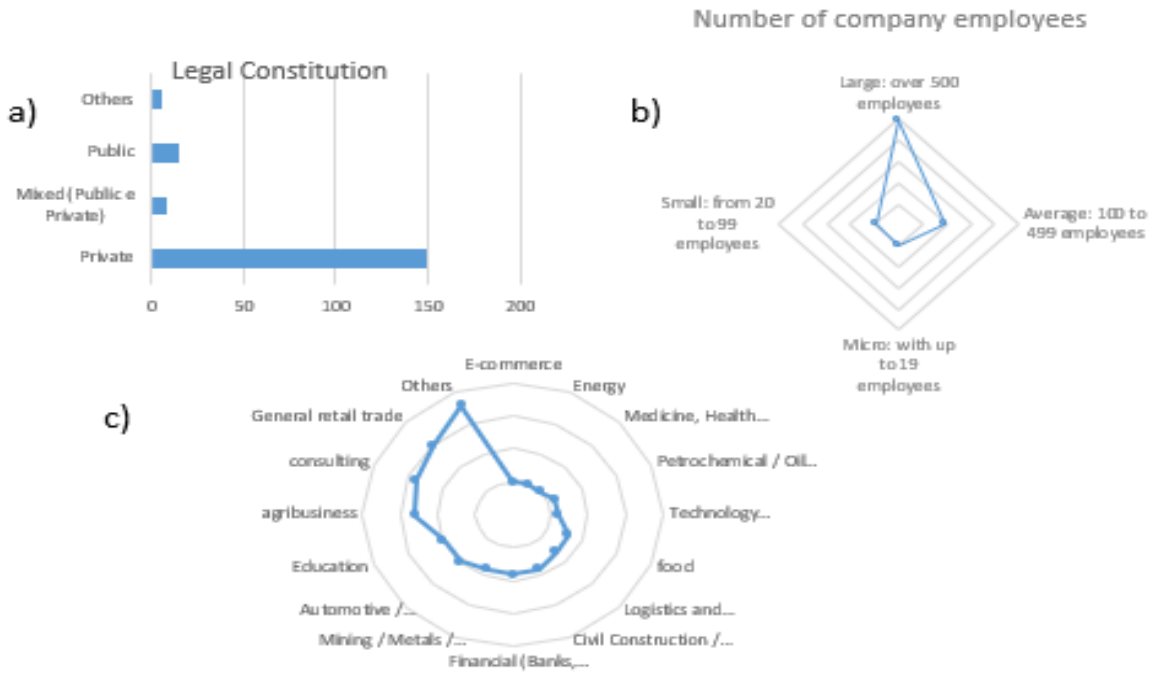
Table 1. Respondent's continent

| **Continent** | **Answers** |
|---|---|
| North America | 6 |
| South America | 150 |
| Asia | 9 |
| Europe | 8 |
| African | 2 |
| Oceania | 2 |

The age presented showed a trend between 31 and 40 years, having a degree of postgraduate years range, having 20 years of higher performance and an experience between the first area, where the main charges are classified as career and management heads in management tasks. Key strategic purchases. Figure 3 presents the profile of the participating organizations.

Figure 3 shows that private companies considered large in several employees over five hundred employees were the ones that took part the most in the survey; we were not able to decide which branch of activity of the respondent companies.

Figure 3. Profile of the participating organizations: a) legal constitution; b) size; c) economic sector




Despite the emerging literature on the subject, comprehensive and systematic structures, strategies, and approaches are lacking for the implementation of the concepts of Industry 4.0 technologies in Procurement processes. The literature has in common that the procurement process described was started not by a single technology, but by the interaction of several technologies and solutions whose effects created new modes of production and influenced organizations, the environment, and social functions (Nicoletti, 2020).

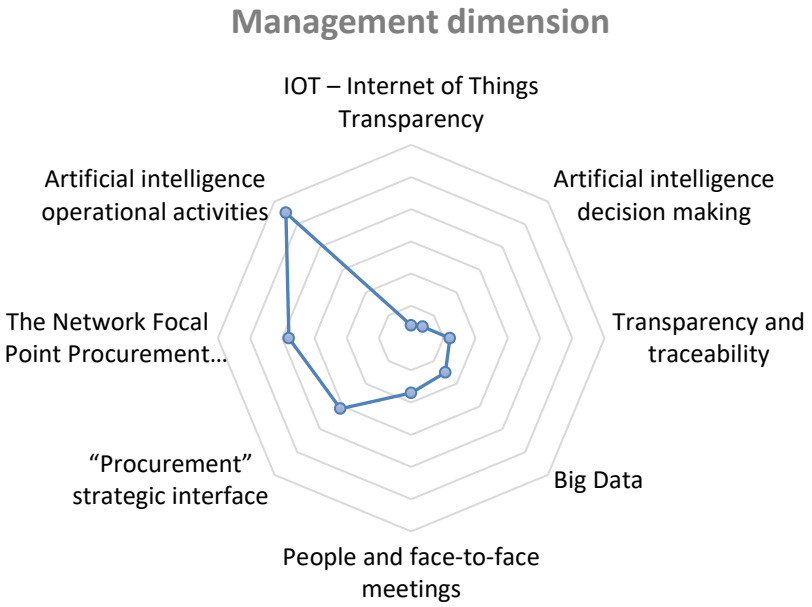
The survey questionnaire was configured to cover the validation of the conceptual model, where the six dimensions are covered, having the technologies of industry 4.0 with a focus on Procurement and its influence on the transformation of Procurement to Procurement 4.0. It is considered in the research:

### 4.1 *Answers to Question 1 – Management Dimension:*

The answers regarding the Management dimension presented an indicator of 31%, that "Artificial intelligence will be able to support my daily activities and reduce operational activities", whereas the literature shows, that Procurement 4.0 will be able to detect the need for purchases using programming production and stock inventories and can autonomously generate an order (Gupta et al.,2014).

Cutting redundant movements, operational activities and communication delays also lead to reduced procurement cycle time and resource optimization (Bag et al.,2019; Knight et al.,2019). Figure 4 presents the order of importance of Industry 4.0 enabling tools.

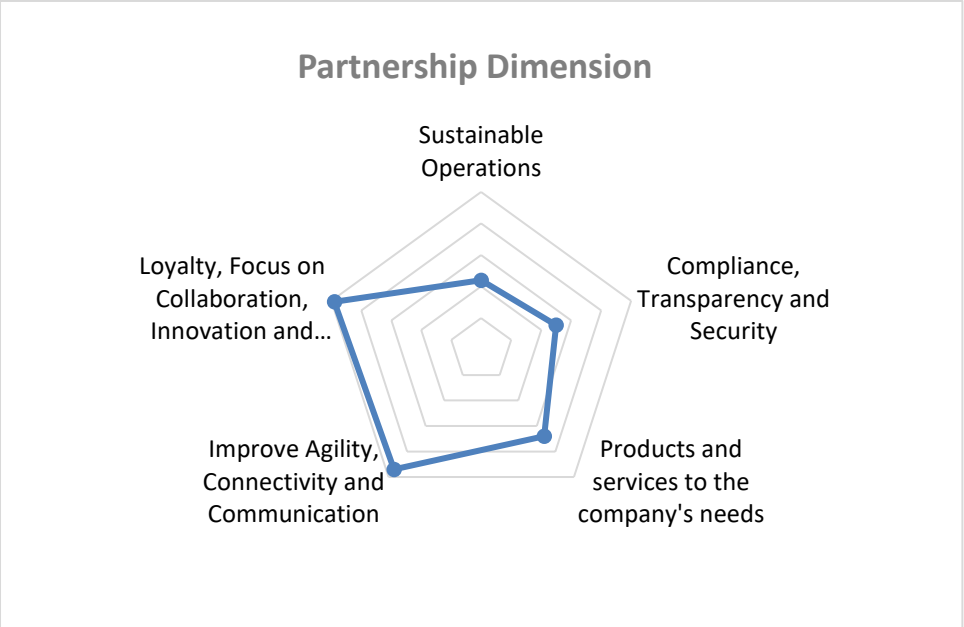
Figure 4. Order of importance of Industry 4.0 tools, showed by respondents in the Management dimension.




**4.2 *Answers to Question 2 – Partnership Dimension:***

The answers referring to the Partnership dimension presented with an indicator of 28%, “Loyalty, Focus on Collaboration, Innovation and Know-How” followed by the answer “Improve Agility, Connectivity, and Communication” with 27%, indicating that the connectivity between buyers and suppliers (partners), organized through digitization, will also raise questions about appropriate governance mechanisms and cybersecurity considerations, including the location of data centers and shopping centers (Srai et al.,2019). The value proposition is the interface with the supplier. Data is shared in real-time to value chain partners. These value chains will become “value networks” (Geissbauer et al., 2016). Figure 5 shows the importance of the main challenge presented by the respondents in the Partnerships dimension.

Figure 5. Order of importance of the main challenge presented by respondents in the Partnerships dimension.



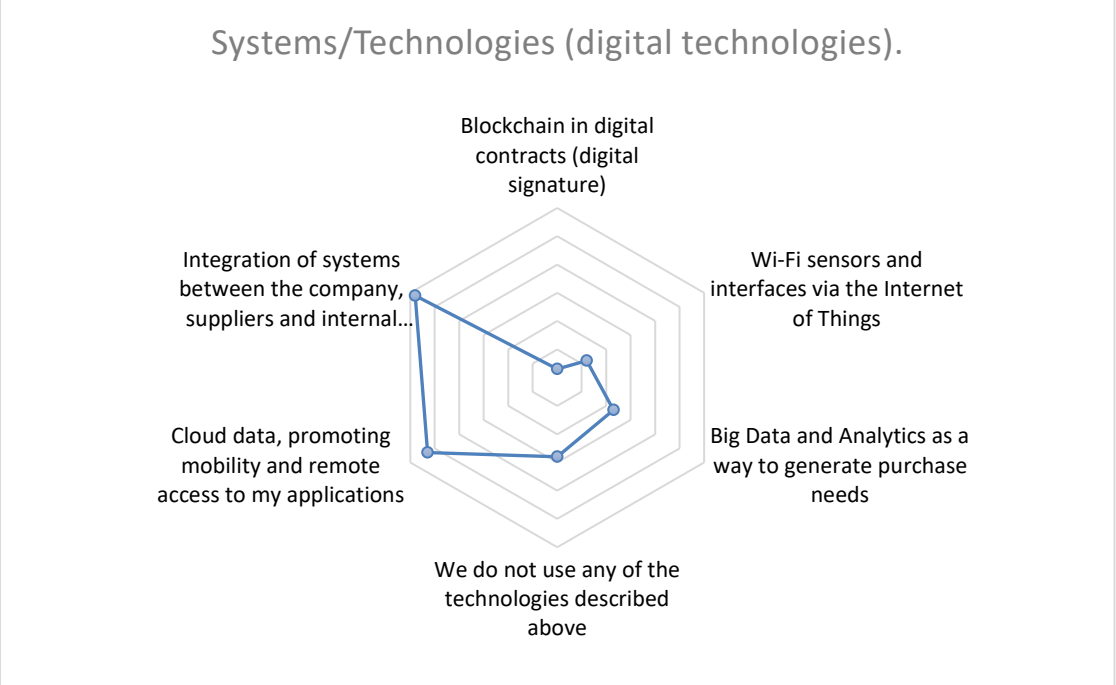

### 4.3 *Answers to Question 3 – Systems and Technologies Dimension:*

In this question referring to the "Systems and Technologies" dimension, the emphasis was on seeing the software, and platforms that will be needed to use the digitalization potential, and checking the answers, it was noticed that the software and platforms complement each other in the adoption of Procurement 4.0.

The information is connected and available online in several interconnected systems, where it is possible to check and evaluate the data used. This requires new types of analytical and technological tools to be used for decision-making (Batran et al.,2017). Procurement 4.0 applications can accelerate procurement transactions by developing information processing capabilities to support the organizational processing of information and data to support a more effective, efficient, and cost-effective organization.

Still, in the Systems and Technologies dimension, digital technologies are needed to use the digitalization potential (focusing on buying processes and procedures), whose order of importance is shown in Figure 6.Regarding the Systems and Technologies dimension, mobile solutions, cloud, and ERP are necessary to use the digitalization potential (focusing on buying processes and procedures) the order of importance is shown in figure 6.

Figure 6. Order of importance of the mobile solutions given by respondents into the dimension System/ Technologies.




Still in the "Systems and Technologies" dimension, the focus was on which technologies would be disruptive and essential to Procurement 4.0, verifying the answers the data technologies stored in the cloud and the integration of ERPs are the most used by the respondents. Digital technologies will help increase collaboration, analysis, and engagement using tools along the entire procurement value chain, from planning and sourcing to contract negotiations, order delivery, payment, and supplier management (Geissbauer et al., 2016).

### 4.4 *Answers to Question 4 – Processes Dimension:*

In the Processes dimension, the focus was on verifying how Procurement 4.0 would effect changes in the area's routines and processes, and the most cited responses were the adoption of leadership awareness, the company's infrastructure, and the adoption of new tasks, creating an essential tripod for the adoption of Procurement 4.0.

Agile and digital organization: Procurement will need to transform itself into an agile business partner characterized by: Digital and agile organizational structure (reduced hierarchy); Digital and agile methods and approaches (design thinking, SCRUM, home office) [13]. Raising awareness of Procurement 4.0 among employees and value chain partners is necessary to improve their understanding of the benefits of Procurement 4.0 and its importance in the

context of the circular economy. Raising awareness increases the intention to perfect procurement processes and platforms, as said by Nicoletti (2020).

In the PROCESSES dimension, the digitization of organizations must follow the following order of importance shown in Figure 7.

Figure 7. Order of the importance of digitization of companies given by respondents in the Processes dimension.

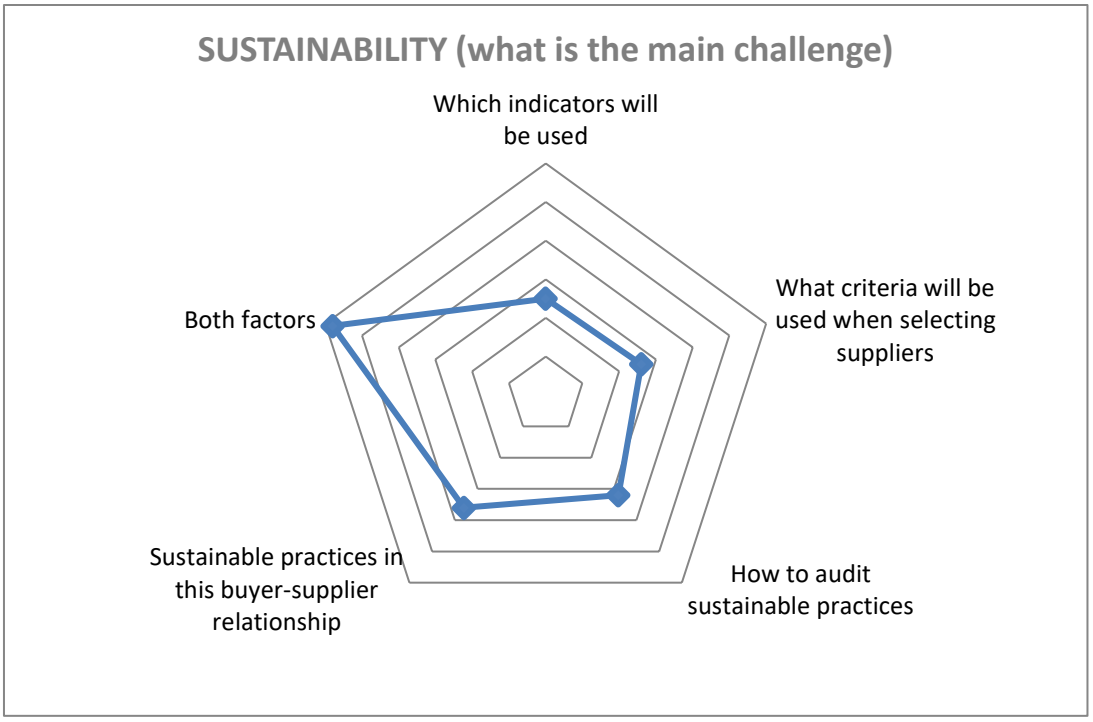

**4.5** ***Answers to Question 5 – Sustainability Dimension:***

In the Sustainability dimension, the focus was to present what would be the main factors for the adoption of sustainability with suppliers (partners) and the main response was that both evaluation factors, such as the audit of sustainable practices, indicators, and sustainable criteria are essential.

Green Public Procurement (GPP) is "[t]he approaches by which organizations integrate environmental criteria at all stages of the procurement process, encouraging the diffusion of environmental technologies and the development of environmentally viable products, through research and choice of results and solutions that have the least possible impact on the environment throughout their entire life cycle". (Commission of The European Communities, 2008).

There is a big push for green procurement in public administration because of its social and community implications (Testa et al., 2016). Directing with the sustainability dimension must be applied in private administration. Figure 8 Shows the order of the importance of the company's integration with suppliers, and respondents in the Sustainability dimension.

Figure 8. Order of the importance of the company's integration with suppliers, and respondents in the Sustainability dimension.

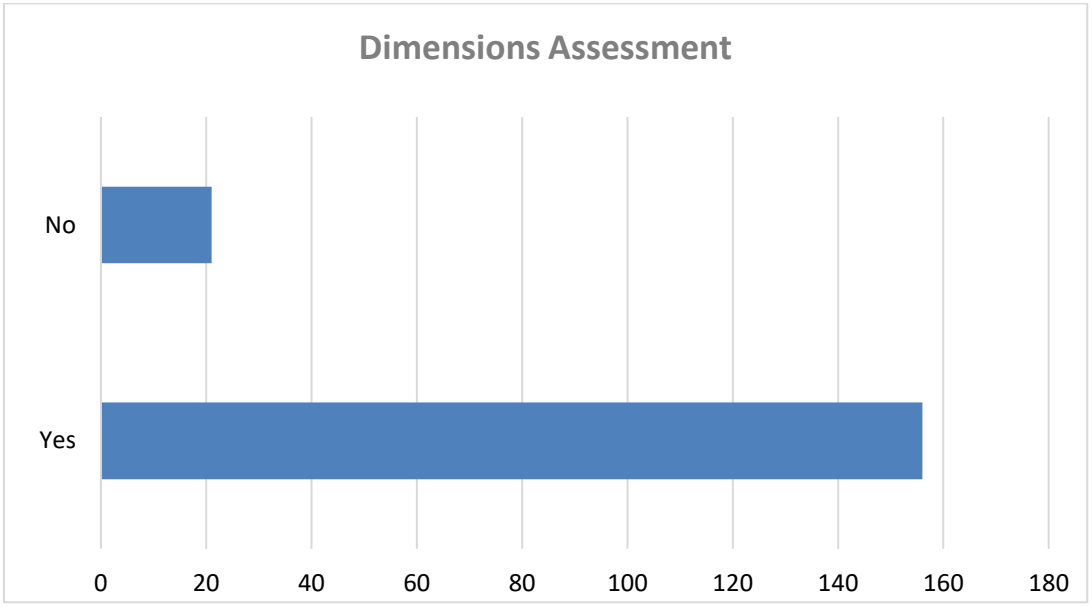



**4.6** ***Answers to Question 6 – Model validation:***

The motivation of the research is that in contrast to Industry 4.0, Procurement focused on the procurement process will be affected by the implementation of Industry 4.0 tools, and with this understanding, the proposed model of Dimensions is essential for the implementation of Procurement 4.0, (Skills, Management, Partnerships, Processes, Systems/Technologies, and Sustainability) and also seek to fill the gap in the literature, can the proposed model be useful in your company?

Based on the answers presented by the interviewees about the conceptual model, which can be used in companies for the implementation of Procurement 4.0, with an index of 88%, and shows that the dimensions have a guiding role in this implementation. Finally, Figure 9 presents the importance of the conceptual model for the implementation ofProcurement 4.0.

Figure 9. Importance of the conceptual model for the implementation of Procurement 4.0.




The industry 4.0 initiative involves a change not only in operations but also in the rest of an organization. A particularly important function here is acquisition. The continuous increase in global sourcing and outsourcing requires not only cross-functional integration but also sophisticated integrative processes across entire organizations as said by Castillo (2016).

## 5 *CONCLUSIONS*

The global trends that affect Procurement areas today are evolving at a rapid pace; the role must focus on corresponding opportunities and respond strongly. While this raises many questions about how to best redefine the role of capturing value, the role will have a strategic role to play. Intelligent technologies and compatible algorithms enable the aggregation, processing, and verification of infinite volumes of data from many heterogeneous sources.

Using all these big data analytics, an organization can improve its knowledge of partners, markets, and customers, predicting market trends and correcting process and product deficiencies. Big data analysis can enable professionals in the field to make better and more informed decisions. The research presented the conceptual model where the dimensions (Skills, Management, Partnerships, Processes, Systems/Technologies, and Sustainability) are found that guide and can provide a better understanding of the implementation of industry 4.0 enabling technologies in the Procurement area.

The research, when presenting the conceptual model of Dimensions, obtained the validation that it is essential for the implementation of Procurement 4.0, according to the response to

the question where the proposed conceptual model was presented and accepted, with an index of 88% of respondents.

The research could not distinguish which area and/or sector of the economy could present a more representative development with the digitization of purchases - Procurement 4.0, not even for the automotive, aviation, and automation segment, which has been the most developed segments of Industry 4.0. The average time of respondents was 10 minutes, which is not advisable because it discourages many respondents (suggested up to 6 minutes). We had 177 accesses to the survey. Legal aspects, privacy, security, and data governance were also not addressed.

This involves a Data Architecture topic that we did not address in this research, and that will be of fundamental value to support Industry 4.0 in companies. We suggest conducting an inverse search and consulting suppliers (or vendors). It is possible that this answer is even more complex and extensive to analyze since the size and number of suppliers are much broader.

## 6 STATEMENTS

The research presented in this paper is a is a revised and expanded version of the research initially presented in a previous paper entitled “Procurement 4.0: A systematic review of its technological Evolution” presented at APMS 2022 Advances in Production Management Systems, Gyeongju, Republic of Korea. The previous version only presented the proposed model, also presented in the section 2.2, and does not include the survey present in this paper.

## REFERENCES

Angappa Gunasekaran, Eric W.T. Ngai. (2012). ‘The future of operations management: An outlook and analyses. International Journal of Production Economics. Vol. 135, Issue 2, 2012, pp. 687-701, ISSN 0925-5273, https://doi.org/10.1016/j.ijpe.2011.11.002. https://www.sciencedirect.com/science/article/pii/S0925527311004646. (Accessed: 15 February 2023).

Babiceanu, RF; Seker, R. (2016). ‘Big Data and Virtualization for the Fabrication of Cyber-Physical Systems: A Survey of Status and Future Perspectives. To compute.’ Ind. 81, pp. 128-137.

Bag, Surajit & Wood, Lincoln & Mangla, Sachin & Luthra, Sunil. (2019) ‘Procurement 4.0 and its implications on business process performance in a circular economy’. Resources Conservation and Recycling 152. 104502. 10.1016/j.resconrec.2019.104502.

Bag, S., Wood, lc, Mangla, Sk, & Luthra, s. (2020). Procurement 4.0 and its implications for the performance of business processes in a circular economy. Resources, Conservation, and

Recycling, vol152, pp.104–502.

Batran, A. Erben, Agnes. Schulz, Ralf. Sperl, Franziska (2017). “Procurement 4.0: A survival guide in a digital, disruptive world.’Campus Verlag Frankfurt/New York. ISBN 978-3-593-50669-2 Print, ISBN 978-3-593-43566-4 E-Book (PDF).

Broadstock, David C. & Chan, Kalok & Cheng, Louis T.W. & Wang, Xiaowei. (2021). ‘The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China’. Finance Research Letters, Elsevier, Vol. 38(C).

Bueno, Robson Elias. Almeida Dos Santos, H. Junior Freitas, Moacir De. Toloi, Rodrigo Carlo. Gonçalves, Rodrigo Franco. (2022). ‘Procurement 4.0: A systematic review of its technological Evolution.’ APMS 2022 International Conference Advances in Production Management Systems. https://www.conftool.net/apms2022/. https://www.apms-conference.org/.

Castillo, F. (2016). ‘Managing information technology.’ Springer International Publishing, Cham, Switzerland.

Cesário, J.M. (2017). Industry 4.0. TLC Brazil: Technology Leadership Council Brazil. Available in: https://www.ibm.com/developerworks/community/blogs/tlcbr/entry/mp283?lang=en. (Accessed: 16 February 2023).

Corbos, Razvan-Andrei & Bunea, Ovidiu-Iulian& Popescu, Ruxandra-Irina. (2022). ‘Organizational readiness for procurement 4.0 in the circular economy: the moderating role on competitiveness.’ Management Research and Practice, Research Centre in Public Administration and Public Services, Bucharest, Romania, vol. 14(2), pages 5-16, June.

Corbett CJ, Kirsch Da. (2001). ‘International Dissemination of ISO 14000 Certification’. Production and Operations Management. 10(3): 327-342.

Commission of The European Communities (2008). Public procurement for a better environment. EU Bruxelles. Available in: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52008DC0400. (accessed 25 February 2023).

Fatorachian, H.; Kazemi, H. (2021) ‘Impact of Industry 4.0 on supply chain performance’ Product Plan. To control, 32, pp. 63-81.

Geissbauer, R.; Weissbarth, R.; Wetzstein, J. (2016) ‘Procurement 4.0: are you ready for the digital revolution?’ Available in: www.strategyand.pwc.com/reports/procurement-4-digital-revolution.(Accessed: 16 March 2023).

Gupta, M. and Narain, R. (2014). ‘A fuzzy ANP-based approach in the selection of the best E-Business strategy and to assess the impact of E-Procurement on organizational performance,’ Information Technology and Management, Vol. 15 No. 4, available at: https://doi.org/10.1007/s10799-014-0208-y.

Heckman, R., (2020). Managing the IT procurement process. Enterprise Operations Management, pp. 367-383, Auerbach Publications.

Jean, R. J. B., Sinkovics, R. R., &Hiebaum, T. P. (2014) 'The effects of supplier involvement and knowledge protection on product innovation in customer-supplier' Journal of Product relationships: A study of global automotive suppliers in China. Journal of Product Innovation Management, 31(1), 98–113.

Joseph Jerome, JJ, Saxena, D., Sonwaney, V. and Foropon, C. (2022), 'Procurement 4.0 to the rescue: catalyzing its adoption by shaping the challenges', Benchmarking: An International Journal, Vol. 29 No. 1, pp. 217-254. https://doi.org/10.1108/BIJ-01-2021-0030.

Kagermann, H., Wahlster, W. and Helbig, J. (2013). Securing the Future of German Manufacturing Industry: Recommendations for Implementing the Strategic Initiative Industrie 4.0. Final Report of the industrie 4.0 Working Group, Acatech— National Academy of Science and Engineering, 678 p.

Kapustina, Larisa M., Chovancová, Mária and Klapita, Vladimír. (2017). 'Application of Specific Theory of Constraints Technique for the Identification of Main Causes of Negative Consequences within Procurement Logistics' LOGI – Scientific Journal on Transport and Logistics, vol.8, no.1, 2017, pp.56-63. https://doi.org/10.1515/logi-2017-0007.

Knight, Caroline & Patterson, Malcolm & Dawson, Jeremy. (2019). 'Work engagement interventions can be effective: A systematic review.' European Journal of Work and Organizational Psychology. 28. 10.1080/1359432X.2019.1588887.

Lima, José Carlos de Souza. (2011). 'A study on the reconfiguration of the purchasing function in companies in the Automotive sector.' ISBN 978-85-7893-864-2. 1st Edition - São Paulo/SP. www.Biblioteca24horas.com. (Accessed: 20 March 2023).

Nicoletti, Bernardo. (2020) 'Procurement 4.0 and the Fourth Industrial Revolution: The Opportunities and Challenges of a Digital World". ISBN 978-3-030-35978-2. https://doi.org/10.1007/978-3-030-35979-9. (Accessed: 21 March 2023).

Rodrigues, M., Sousa, B., & DA Costa, JB (2019) 'The Improvement of the Supply Chain Channel Based on in Digital Transformation: An Exploratory Study in Sustainable Industry 4.0'. 4th Regional Helix Book of Abstracts Parallel Session 4, Porto, Portugal.

Rogers, D. L. (2018) 'Digital Transformation: rethinking your business for the digital age'. São Paulo: Publisher Business Authentic.

Schiele, H. 'How Industry 4.0 is coming to the purchasing sector.' (2018). Available at: https://inbrasc.liveuniversity.com/2018/10/04/como-industria- 4-0-esta-chegando-ao-setor-de-compras/. (Accessed: 21 March 2023).

Seuring S. (2004). ‘Industrial ecology, life cycles, supply chains; differences and interrelationships. Business Strategy and Environment. 13(5):306-319.

Spath.D. Ganschar, O. Gerlach, S. M. Hämmerle, T. Krause E S. Schlund. (2013). “Produktionsarbeit der Zukunft - Industrie 4.0,” Fraunhofer Verlag, Stuttgart.

Srai, J. S., Lorentz, H. (2019) ‘Developing design principles for the digitalization of purchasing and supply management’. J. Purch. Supply Management. 25, 1, 78-98.

Testa, F., Annunziata, E., iraldo, F., & Frey, M. (2016) ‘Disadvantages and opportunities of public procurement greens: an effective tool for sustainable production’ Journal of Cleaner Production, 112, 1893–1900.

Yang, M., Fu, M., and Zhang, Z., (2021). The adoption of digital technologies in supply chains: Drivers, process, and impact. Technological Forecasting and Social Change, vol. 169, pp.120795.

Weissbarth, Robert. Geissbauer, Reinhard., Wetzstein, Jurgen. (2016) ‘Procurement 4.0: Are you ready for the digital revolution?’ Available at: https://www.strategyand.pwc.com/report/procurement-4-digital-revolution. (Accessed: 18 March 2023).

Wuttke, Da, Blome, C., Foerstl, K., & Henke, M. (2013) ‘Managing the adoption of supply chain finance innovation supplies’ empirical evidence from six European case studies. Journal of Business Logistics, 34 (2), 148–166.

## 4.3 Artigo 3: THE PROCUREMENT 4.0 CONTRIBUTIONS TO CIRCULAR ECONOMY

Artigo será submetido a um períodico para análise e publicação. Texto original no idioma inglês. O artigo busca responder ao objetivo da pesquisa: Avaliar a contribuição do *Procurement* 4.0 para a Economia Circular;

Foi utilizado a metodologia Delphi para a elaboração do artigo, construído teoricamente e buscando a opinião de especialistas sobre como a área do *procurement* poderá contribuir com a área da economia circular.

### The Procurement 4.0 contributions to Circular Economy

**Abstract:** The work analyzes the role of *Procurement* 4.0 as a driver of the circular economy. However, the principles of the circular economy are becoming more important every day, impacting the well-established way of working in procurement. The aim of this study is to identify how the Procurement *4.0 area* contributes to the circular process. The results of Delphi demonstrate the potential benefits of Industry 4.0 applications in the role of the *Procurement* area in a

circular economy, optimizing business processes playing a key role in improving the performance of the circular economy. Procurement 4.0, aligned with sustainability goals and incorporating enabling technologies, leads to greater competitiveness in the context of the circular economy in the business environment.

**Keywords:** Circular economy; Procurement4.0; Industry 4.0; Delphi.

## 1 INTRODUCTION

A traditional linear economy follows the “take-make-waste” approach, where natural raw materials are extracted and then turned into products. These products are used for a certain period and eventually discarded as waste (AKTER et al.; 2022). This economic model encourages excessive consumption of material resources, creates unsustainable waste management practices, and creates serious health, biodiversity, and climate problems (ELGHAISH et al.; 2022).

It is estimated that by 2060, the number of material resources consumed worldwide will almost double, from 90 gigatons in 2020 to 167 gigatons, while the number of consumers will increase by three billion by 2030 (ROBERTS et al.; 2022).

Increased global competition is bothering industrial firms, as intense competition creates pressure on scarce resources, which affects their availability and cost competitiveness (FEGER, 2014). Therefore, many companies have investigated the opportunity to develop a circular economy business model.

Circular economy business models can minimize the overuse of scarce natural resources and also reduce the volume of waste generation (SCHROEDER et al., 2018). The ambition to promote the transition from a linear economy to a Circular Economy, decoupling economic growth from resource use, has assumed a central position in the global policy context in recent years. The transition to a circular economy is a global challenge (SADHUKHAN, 2020).

All over the world, there is a scenario of fear with the preservation of the environment, especially with the excessive use of mineral resources and other materials of nature as raw materials for the manufacture of products. This excessive use tends to the scarcity of natural resources and the accumulation of industrial, organic, and other waste, which are mostly treated as waste in the traditional model.

According to Jabbour et al.; (2018), there have been barriers to the full adoption of Circular Economy principles within organizations and supply chains due to misunderstanding of the product life cycle and the scarcity of advanced technology.

However, with the arrival of technology based on Industry 4.0, these principles can be overcome some of the most successful circular companies are those that adopt a diverse set of

capabilities that help enable the transition, such as embedding circular economy principles at the heart of corporate strategy, making understanding of the circular economy part of internal capacity-building programs, adapting systems and processes across business functions, committing to circular innovation, and promoting circular initiatives in the supply chain.

However, if the organization overcomes the implementation barriers, the circular operating model achieved acquires a greater capacity to generate sustainability gains (LECHNER & REIMANN, 2020).

Procurement4.0 involves a competitive strategy and partnership strategy for remanufacturing and recycling materials in the circular economy, where supplier development and supplier inventory management for outsourcing decisions are key to the excellence of remanufacturing operations in the circular economy (BAG et al.; 2020). Companies with a strong procurement strategy and effective Procurement 4.0 review processes are better able to optimize their procurement processes and achieve better circular economy performance (BAG et al.; 2020).

Procurement 4.0 offers advantages such as increased collaboration in the supply chain, the use of hard data in decision-making, and the upskilling of employees, which are essential in the context of a circular economy and in achieving a company's sustainability goals (CORBOȘ, 2023).

Circular Procurement consists of making agreements to ensure that products are produced according to the principles of the circular economy and will be further processed after use. Such products are, for example, designed to be durable, repairable, and recyclable and can, at the end of their life cycle, be broken down into components, materials, or raw materials, which can then be used again in the production chain (CPG, 2017).

The objective of this work is to identify how *Procurement 4.0*, with the use of enabling technologies of Industry 4.0, contributes to the incentive and connection to the processes of the Circular Economy, deriving the following questions:

Q1: Which enabling technologies of Procurement 4.0 can support the transition to the Circular Economy?

Q2. How can *Procurement* 4.0 contribute to the Circular Economy?

## 2 THEORETICAL BACKGROUNDS

### 2.1 Procurement and Procurement4.0

Pooler (1992) numbers three objectives of the *Procurement* area in companies – (1) to control costs; (2) ensure supply savings; and (3) contribute to profit. These objectives increase

the scope of the *Procurement* area in the case of global sourcing procurement since the negotiations involve global suppliers. "*Procurement*" is a business management function.

Purchasing is essentially an acquisition of products and services, especially for commercial purposes. It covers a full range of activities from identifying the need for goods and services to placing them (CHAKRAVARTY, 2017); and business activities (CHAKRAVARTY, 2017). The development of *Procurement* 4.0 systems is not necessarily a simple undertaking (BIENHAUS AND HADDUD, 2018).

The acquisition will enhance its corporate value as a driver of innovation in the digital age by connecting critical external knowledge and skills with internal business aspects to build their supply chains every time.

The term 'Procurement 4.0', which in principle notes the application of specific techniques of 'Industry 4.0', is an element of novelty, as it can be identified in very few studies (BAG et al.; 2020).

We consider this term to be extremely important in the context of the digital age and an obvious need for integration with other business processes within organizations. In addition, the literature has shown us over time how enterprise resource planning (ERP) solutions have created various implementation difficulties, and, as a result, organizations have focused more on managing supplier relationships to achieve success in implementing such solutions (BAG et al.; 2020).

ERP solutions facilitate the transfer of information in real-time to integrate all the organization's activities, which can be useful in the adoption of procurement 4.0 systems. However, the constraints of such an approach have not been studied thoroughly; in addition to the very prohibitive costs, companies need to consider procedures, capabilities, and knowledge to successfully implement such an approach (BAG et al.; 2020).

While the authors have taken important steps to show how the procurement function is particularly important, the literature could benefit from further research in this regard to produce empirical evidence in different contexts and approaches (LEE, 2017).

## 2.2 Principles of the Circular Economy

In 1972, Meadows et al. published a study entitled The Limits to Growth. Commissioned by the Club of Rome, the study projected the future of our global system, systemic relationships, and the evolution of the world's population, industrial production, food, pollution, and resource depletion.

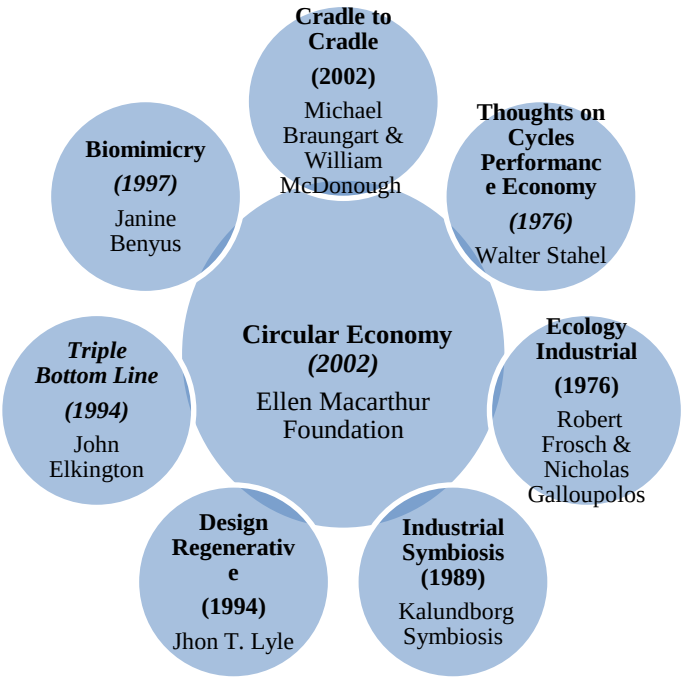
The 1972 report predicted a scenario of "overload and collapse" in the second half of the

21st century, in which our current patterns of production and consumption are extrapolated along with population growth, among others, leading to an unsustainable state for both humanity and the environment.

However, circularity offers a solution to this scenario by using and reusing raw materials more effectively, rather than simply being "consumed". In addition, the Circular Economy will generate an economic system in which there will be a new demand for skilled labor to repair and recycle products, which will contribute positively to average levels of well-being and prosperity.

Pearce and Turner (1990) are recognized as the pioneers in introducing the term circular economy, considering the relations of economic functions to those of the environment, but the formal proposal is well disseminated and promoted worldwide by the Ellen MacArthur Foundation (EMF). There were several definitions of the circular economy, as shown in Figure 1.

Figure 1: Time circle of the main concepts developed worldwide that have emerged for the "Circular Economy".




Source: Authors (2023)

The circular model proposes to close the cycle (Extract, Transform, Produce, Use, and Discard) by rethinking economic and social practices to bring the functioning of the economic system closer to the way nature executes its processes. The model is capable of drastically reducing the amount of new resources needed for production as well as the amount of waste discarded, but to do so it is necessary to establish new social relations (ELLEN MACARTHUR

FOUNDATION,).

Another definition detailed by Geissdoerfer et al.; (2017), the Circular Economy is a regenerative system in which resource input and waste, energy emission, and leakage are minimized by slowing down, closing, and narrowing material and energy cycles. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishment, and recycling."

The Circular Economy (CE) model replaces the Linear Economy (EL) model, which is based on extraction, production, and disposal. Whereas the available resources are finite. Maintaining the current trend of natural resource consumption in this model would cause the available reserves for some materials to be depleted in a few decades, with the risk of making it unsustainable in the long term.

Resources generally used in supply chain activities, new real-time information and communication technologies have increased the ability to manage the flow of materials, contributing to logistics operations in an effective/efficient way, using new tools for geolocation, inventorymanagement, and traceability of the entire product life cycle (VARRIALE et al.; 2021). Figure 2 shows the expected duration of the reserve of some chemical elements,given the currentrate of consumption (COHEN, 2007).

Figure 2: Expected duration of reserves of some chemical elements

| Element | Application | Duration of reserves (in years) if the current consumption rate is maintained. |
|---|---|---|
| Silver | Jewelry and Converters | 29 |
| Antimony | Medicines | 30 |
| Tin | Can and solders | 40 |
| Zinc | Galvanization | 46 |
| Uranium | Energy e Armament | 59 |
| Nickel | Batteries and Turbine Propeller | 90 |
| Tantalum | Cell Phones and Cameras | 116 |
| Aluminum | Construction, cars and others. | 1027 |

Source: Adapted from COHEN, (2007).

The circular economy is an alternative to sustainable development because it is based on eliminating waste and pollution from the beginning of the production chain, seeking to keep materials in use and regenerate the system (Ellen Macarthur Foundation, 2013).

There are three other definitions of the Circular Economy, adopted by the reference institutions in the area, The World Economic Forum presents an industrial model that dissociates revenues from input and material (2014); The European Commission comments that in the circular economy, the value of products, materials and resources is maintained in the economic area, for as long as possible, and the generation of waste minimized (2015) and in the Ellen Macarthur Foundation comments that an economy that provides multiple mechanisms of value creation, which are decoupled from the consumption of finite resources (2013).

The Circular Economy aims to transform waste materials into useful goods and services, increasing resource efficiency and eliminating waste throughout the value chain. This can be achieved by using lightweight, durability, efficiency, replacement, eco-design, industrial symbiosis, or rental/rental (WITJES AND LOJANO, 2016).

According to Jesus et al.; (2018), The circular economy can be considered as:

I) Integrative concept to achieve “clean congruence”, guiding new institutional arrangements that correspond to environmental considerations such as socioeconomic performance, promoting technical-economic development that does not depend on the consumption of finite resources.

II) Multi-level structure (micro, meso, and macro) that reconfigures and redirects production and business models towards resilience and sustainability.

III) An all-encompassing notion that requires specific actions to minimize resource extraction, maximize reuse, increase efficiency, increase waste recycling, and the development of new business models.

## 2.3 Procurement e a Economia Circular: Related works

The *Procurement* Circular has become one of the most recent recommendations for debating environmental sustainability. Focusing on economic growth while also considering the supply shortages of raw materials and energy, as well as the growth of new business models (WITJES AND LOZANO, 2016). In this condition within Supply Chain Management, no other area can play such a fundamental role in the transition to a circular economy than *Procurement Supply Management* (WEETMAN, 2017).

Green buying requires active research (BLOME et al.; 2014). Focusing on circular economy principles, Witjes and Lozano (2016) proposed a public procurement agenda including non-technical and technical descriptions and services/products. The guidelines for the decrease in the use of precious raw materials and complete recovery and less waste production. A circular

economy study by Stern and Stern (2016) talked about green industrial achievements and resource-intensive effectiveness.

The environmental advantages and disadvantages of various product procurement options in industries with possibilities for reuse and recycling. The integration of circular economy principles into SCM has been seen as potentially feasible for managing disruptions in the supply of critical and strategic materials.

Procurement activity in a circular economy will redefine quality, time, and price value (Meehan and Bryde, 2011). A circular economy needs inputs to be technically invigorating and biologically refreshing to mitigate the negative environmental impact (GENOVESE et al.; 2017).

Sprecher et al.; (2017) introduced resilience metrics to quantify the resilience of critical materials supply chains to disruptions based on circular economy principles. On the other hand, Gaustad et al.; (2018) indicated that many companies are not able to allocate the time and resources needed to track these dynamic and complex issues.

They suggested that circularity strategies such as recycling, lean principles, dematerialization, and diversification have significant potential to reduce vulnerabilities in the supply of materials.

## 3 METHODOLOGIES

The work used the Delphi methodology, carried out in three stages, to obtain opinions on how Procurement 4.0 can contribute to the evolution of the Circular Economy. Based on a questionnaire sent to experts in the areas of Procurement and Circular Economy.

In the first stage, the authors contacted the interviewees via e-mail, explaining the objectives, details, contributions, and benefits of the research. At this stage, the names of the interviewees are not disclosed, as described in the instructions.

In the second stage, two questionnaires were made available, using the Google Forms tool, one composed of specific questions from the Procurement area and the other with specific questions from the Circular Economy area, 23 questions for the Procurement area, and 17 questions for the Circular Economy area.

In the third phase, the analysis followed the following steps:

a) Gather all the information generated by the experts.

b) Analysis of the results and cross-referencing of information between the specialists.

c) Evidence supporting the main ideas.

d) Writing of results.

e) Analysis and conclusions.

# 4 RESULTS

Procurement4.0 with Industry 4.0 enabling technologies in procurement processes for greater efficiency and performance. The Circular Economy is a system where waste and pollution are reduced, and resources are conserved through closed-loop supply chains.

In response to the objectives of this work: Q1: What enabling technologies of Procurement 4.0 can favor the transition to the Circular Economy? How can *Procurement* 4.0 contribute to the Circular Economy?

Delphi Procurement will be presented in scenarios, first the Delphi Procurement, then the Delphi Circular Economy, and the scenario of proximity of the areas.

## 4.1 Procurement Scenario

We consider that Procurement involves several processes, including the identification of procurement needs, the establishment of requirements and specifications, the selection of suppliers, the negotiation of contracts and prices, the management of deliverables and quality, as well as the management of risks and conflicts. We admit the following functions of Procurement:

✓ DISCOVERY: This involves the search and selection of suppliers. To choose the best suppliers, it is essential to define objective processes to evaluate, select, and monitor suppliers that offer quality products or services at prices consistent with your needs.

✓ NEGOTIATION: Establishment of agreements, contracts, rules, and parameters for supply, both about contractual aspects (deadlines, price, payment terms) and about the intrinsic aspects of the product/service to be provided (quality criteria, packaging, place of delivery, etc.).

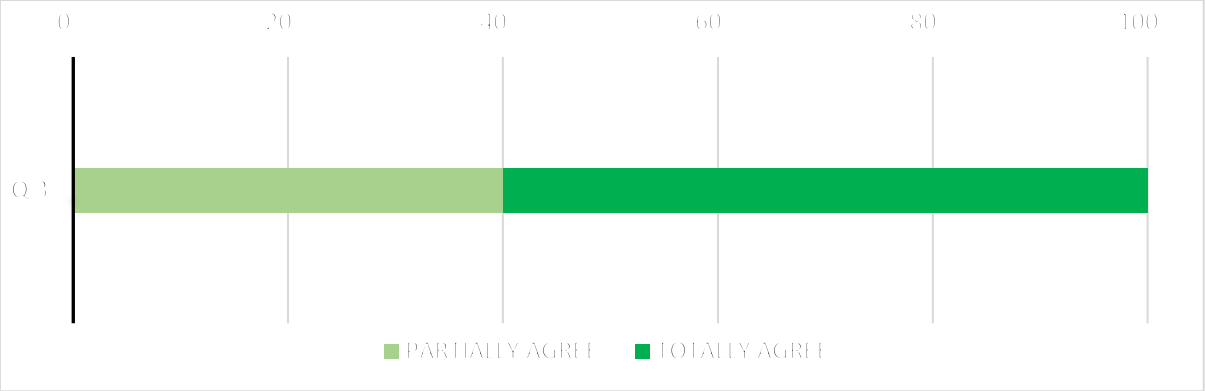
✓ PROCUREMENT: Proposes supplier performance evaluation indicators, necessary to monitor and ensure that suppliers are complying with the terms of the contracts. Procurement defines compliance parameters and rules for the Procurement department. In this way, the Procurement function can be understood as an internal function of Procurement.

Below are the results of Delphi, with experts around Procurement; The approach chosen was qualitative research through an online questionnaire to collect data for this study from an audience of professionals around Procurement.

With the experience of the area, the respondents also contributed that the area can be more comprehensive, such as monitoring the level of services and defining internal requirements, where the purchasing area will understand the demand in-depth, especially in terms of Total Cost of Ownership (TCO).

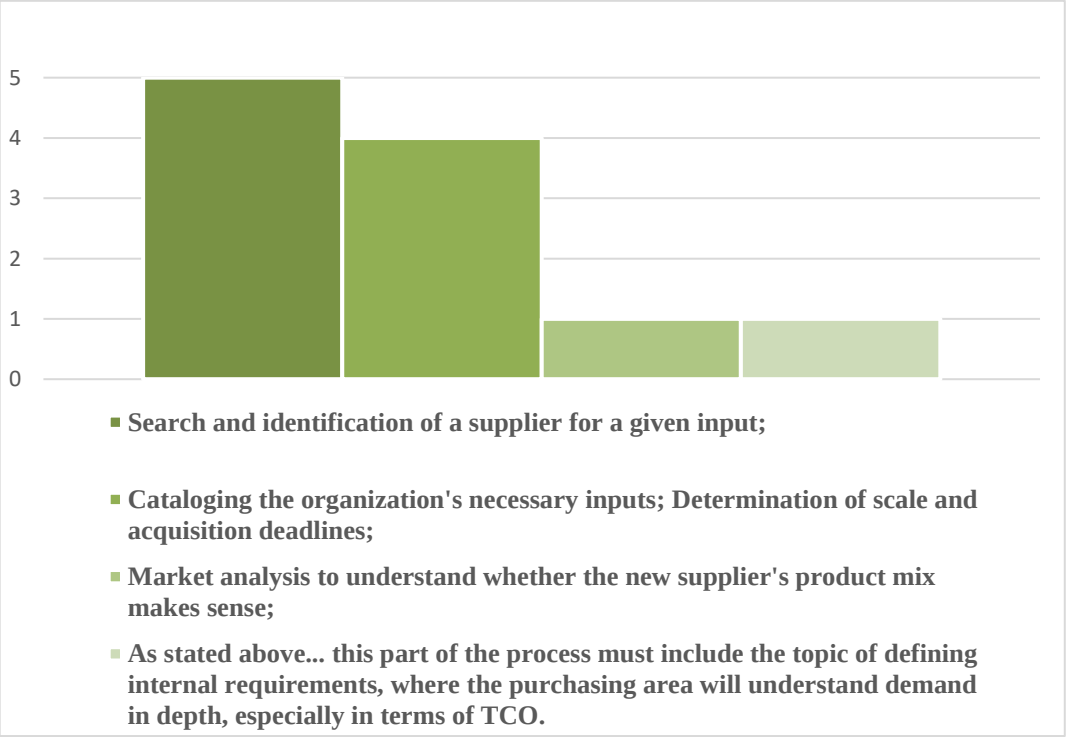
The answers indicate that all respondents agree that the basic functions of Procurement are Discovery, Negotiation, and Procurement, as shown in Figure 3.

Figure 3: The basic functions of Procurement are: Discovery, Negotiation, and Procurement.




Considering that the Discovery function is one of the basic functions of the Procurement area, with the expertise of the respondents, the following tasks were also added: Monitoring the level of services and the issue of defining internal requirements, where the area understands the demand in-depth, especially in the Total Cost of Ownership (TCO) item, being an instrument for analyzing the total costs involved in the acquisition of a product. As shown in Figure 4.

Figure 4: Discovery Role Tasks



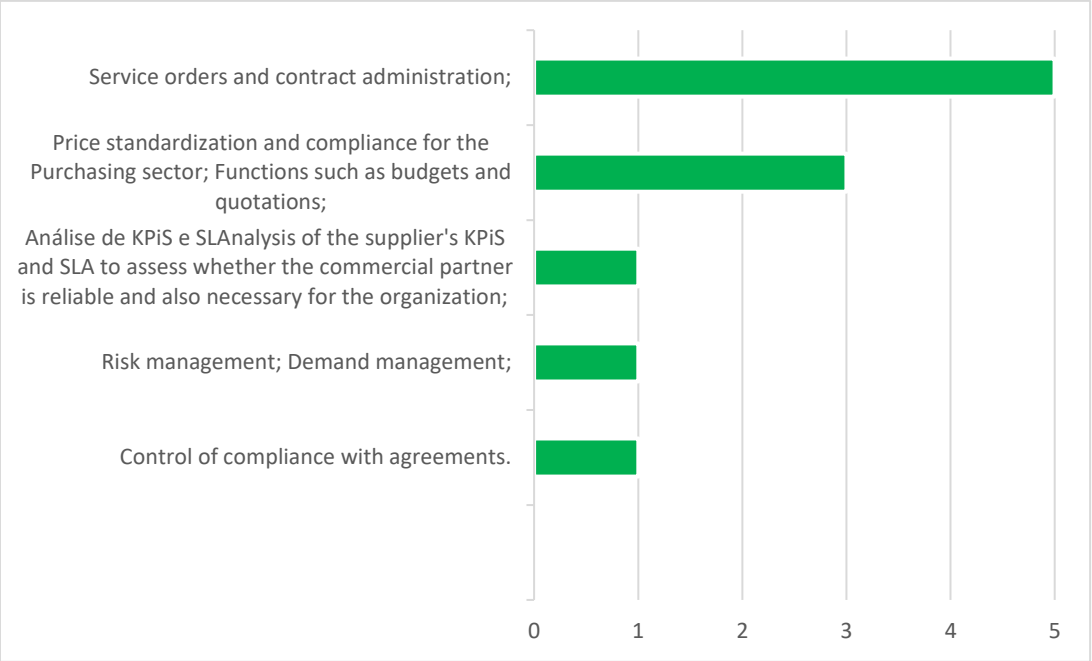
In the Negotiation function, there was an unanimity of tasks, definitions of price rules, deadlines, delivery methods, packaging, quality and compliance standards, and payment methods with the supplier. As a contribution and benefiting from the experience of the respondents, they suggested the inclusion of Total Cost of Ownership (TCO) and Cost Breakdown being an analysis method that enables the understanding of the elements that make up the costs of products or raw materials offered by suppliers. Figure 5 shows the tasks of Negotiation.

Figure 5: Tasks of the Negotiation function


In the Procurement function, among the tasks presented, all respondents pointed out that the main tasks are service orders and contract administration, followed by price and compliance standardization for the area and budgets and quotations tasks.

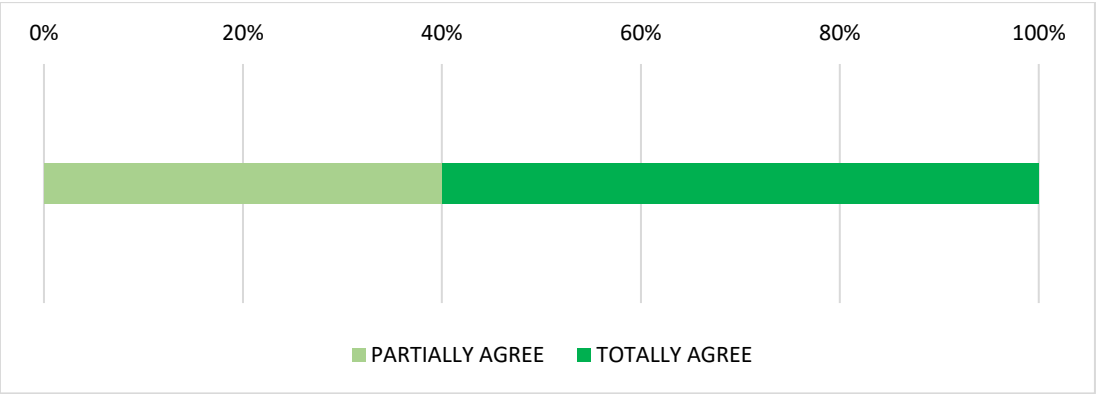
Appreciating the experience of the professionals, the tasks of demand management, risk management, analysis of the KPIs and SLA of the suppliers, and the control of compliance with agreements were added to the Procurement function. Figure 6 shows the functions of Acquisition.

Figure 6: Acquisition Function Tasks




The analysis of the problem points to the emergence of Industry 4.0 enablers, which has resulted in a shorter purchasing cycle, while supplier management, vertical and horizontal corporate integration, and bettering the quality of analytical data are all crucial for success. With individualized, sustainable, flexible, and resilient production, among the respondents pointed out that 60% of the answers totally agreed and 40% partially agreed. Figure 7 shows the importance of Industry 4.0 enabling tools.

Figure 7: Importance of Industry 4.0 enabling tools

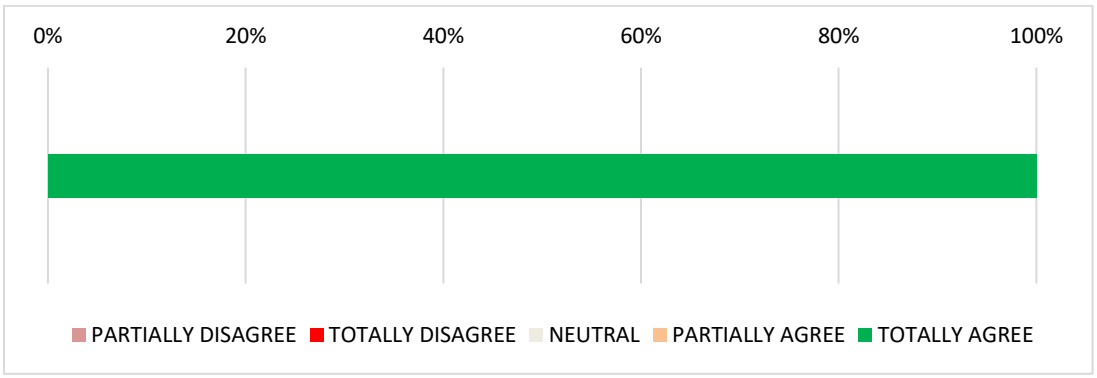



According to the enabling technologies of Industry 4.0, the answers of the experts all agreed that Big Data Analytics is the most used around Procurement, followed by the enabling technologies of Artificial Intelligence (AI), Internet of Things (IoT), Digital Integration and

Blockchain, with Advanced Robotics and Cyber-Physical Systems also being used.

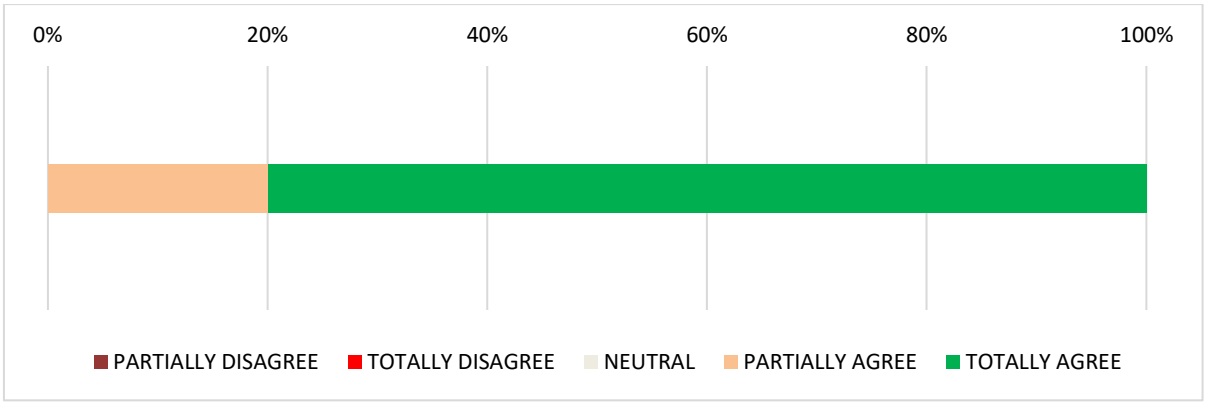
In the area of Procurement, the use of Big Data Analytics is an indispensable element in dealing efficiently and effectively with a large volume of data generated from cyber-physical systems, being an essential tool for the capacity of data processing about speed, variety, and volume, in addition to obtaining insights for decision making. Experts in the field were unanimous in saying that they agree with the statement. Figure 8 shows the unanimous use of Big Data Analytics.

Figure 8: Use of Big Data Analytics




The data analysis involves the data collection activities from all sources, external and internal, to optimize the Procurement area, the data analysis is carried out in a set of Business Intelligence technologies, enabling the detection of patterns in large data sets, to predict future events, predicting supply promptly, inventory reduction and lean operation, with 80% of experts in the field strongly agreeing and 20% partially agreeing. Figure 9 shows the data on the use of Business Intelligence.

Figure 9: Use of Business Intelligence.



The Internet of Things (IoT) is considered one of the main enabling technologies of Industry 4.0, as it ensures interconnectivity between elements and devices, enabling a transparent environment between supplier and buyer, traceability, and trust, about the incorporation of heterogeneous devices from different participants with different functionalities in a unified and real-time network. Procurement experts presented the following results: 60% said they strongly agree with the statement, with 20% saying they partially agree and the other 20% partially disagreeing.

The enabling tools of Industry 4.0, Blockchain is one of these technologies that consists of a decentralized ledger, distributed across nodes, ensuring the recording, and sharing of data in a secure, reliable, and tamper-proof manner, through cryptography. Blockchain can bring reliability and traceability to supply chains and exchange relationships through tokens and smart contracts. It also allows for decentralization and independence from the traditional financial system. The experts pointed out that 60% totally agree with the statement and 40% partially agree with the statement.

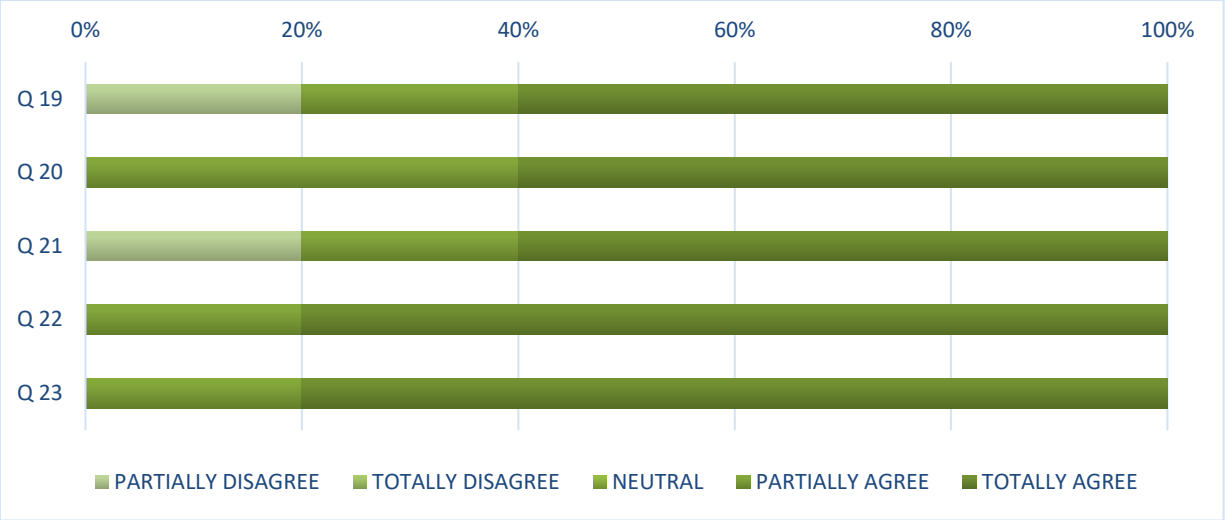
On the issue of Cyber-Physical systems that are responsible for integrating the physical world with the virtual one, they emphasize decision-making in a decentralized way due to the systems and define technology as a system that uses sensors and actuators to collect physical data and act through the interaction between man and machine. The control of physical inventory is one of the essential functions of the Procurement area. Experts on this question answered that 60% strongly agree with the statement, 20% partially agree and the other 20% partially disagree with the statement.

The issue where Artificial Intelligence around Procurement can be applied to contract management, automated supplier discovery, performing a support function for daily administrative business tasks, and serving as support for decision-making. The experts responded that 80% strongly agreed and 20% partially agreed with the statement.

Where Procurement 4.0 is established, a digitalized process is established, which involves activities such as intelligent planning, online self-generation of purchase requisitions, supplier self-selection, automatic generation of purchase orders, automatic release of the purchase order, automatic sending of the order to supplier, online tracking of deliveries and goods, digital signature of proof of delivery, online payment and proof of payment automatically sent to the supplier.

Experts in the field responded that 80% strongly agree with the statement and 20% partially agree with the statement. Figure 10 presents the results of the enabling technologies of Industry 4.0.

Figure 10: Industry 4.0 enabling tools




Experts in the field confirm that enabling technologies of Industry 4.0 are essential to recognize that the adoption of these technologies presents challenges.

The implementation of enabling Industry 4.0 technologies requires significant investments in infrastructure, data management systems, and workforce training. Organizations need to address issues related to data security, privacy, and interoperability when leveraging technologies such as big data and IoT. In addition, the assimilation of multiple technologies can pose compatibility problems and require changes in organizational structures and processes.

To fully harness the potential of Industry 4.0 enabling technologies in procurement, organizations must optimize a comprehensive strategy that organizes the adoption of technologies with their business objectives.

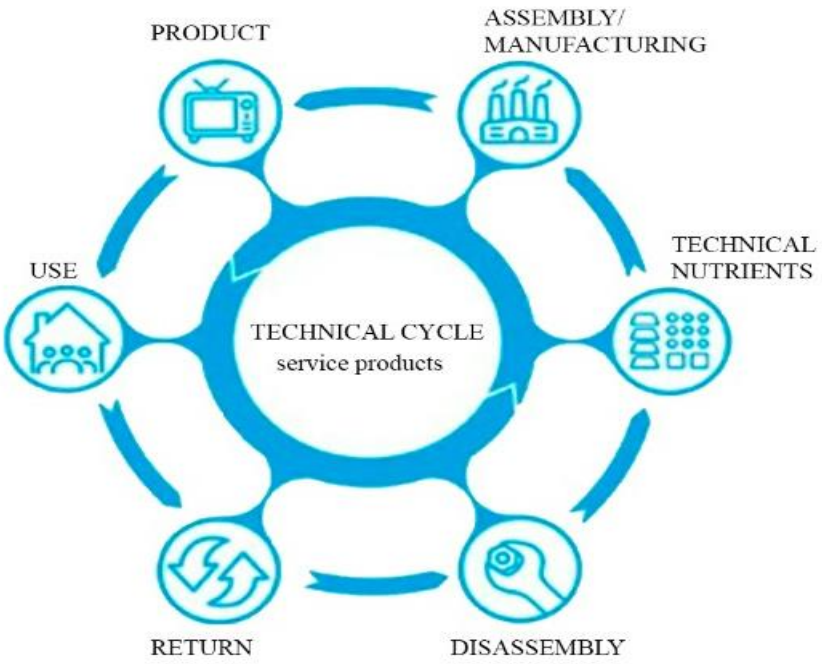
These strategies should consider factors such as organizational culture, change management, and stakeholder engagement.

### 4.2 Circular Economy Scenario

Evaluating the importance of procurement processes and technologies for the Circular Economy, from the point of view of the manufacturing industry.

Thus, please consider your answers based on the technical cycle (Right side, cycles in blue: Share, Maintain/Extend, Reuse/Redistribute, Recycle/Remanufacture/Renew) of the Circular Economy butterfly model (Figure 11).

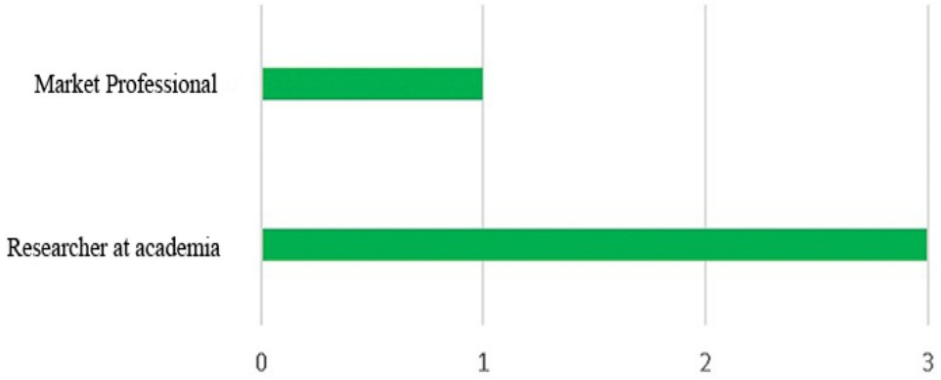
Figure 11. Technical Cycle of the Butterfly Model of the Circular Economy.




Source: Adaptation Circular Idea (2017).

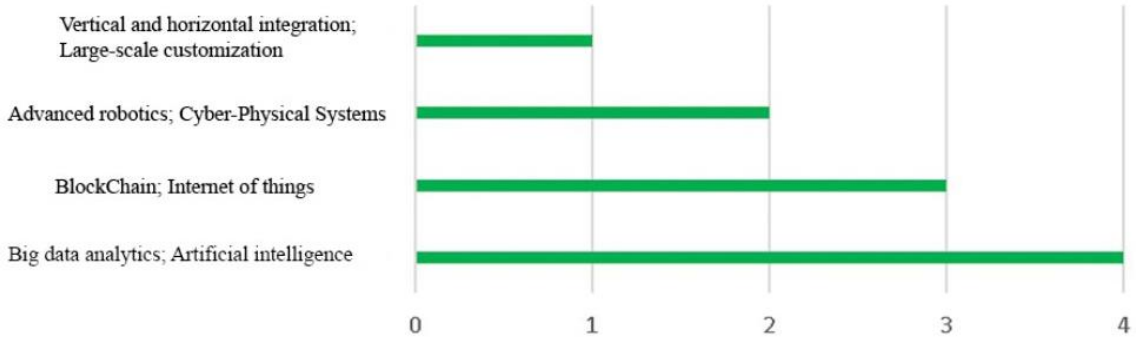
Following are the results of Delphi carried out with experts around Circular Economy, Delphi was composed of 75% of researchers from academia and 25% of professionals from the market. Figure 12 shows the qualifications of the specialists.

Figure 12: Qualification of specialists




Among the enabling technologies of Industry 4.0, are those that offer the potential to assist in the Circular Economy. Figure 13 presents the enabling technologies of Industry 4.0, with an emphasis on the circular economy.

Figure 13: Enabling technologies with an emphasis on the circular economy.




For the concepts of enabling technologies in Industry 4.0, which offer the potential to assist in the Circular Economy, the experts in their entirety pointed to Big Data Analytics and Artificial Intelligence (AI) tools as having the most potential, followed by Blockchain and Internet of Things (IoT), Advanced Robotics and Cyber-Physical Systems and with less potential Vertical and Horizontal Integration and Mass Customization.

The questions asked by circular economy experts, using the Delphi methodology, provided the following answers:

Q1: The transition from the linear economy to the circular economy faces some barriers, which can be classified into four major groups: technical-productive and process barriers, economic and market barriers, regulatory barriers, and social factors. The use of Industry 4.0 enabling concepts and technologies to overcome these barriers is, according to the experts' answers, 50% as important and 50% as fundamental for the transformation to occur.

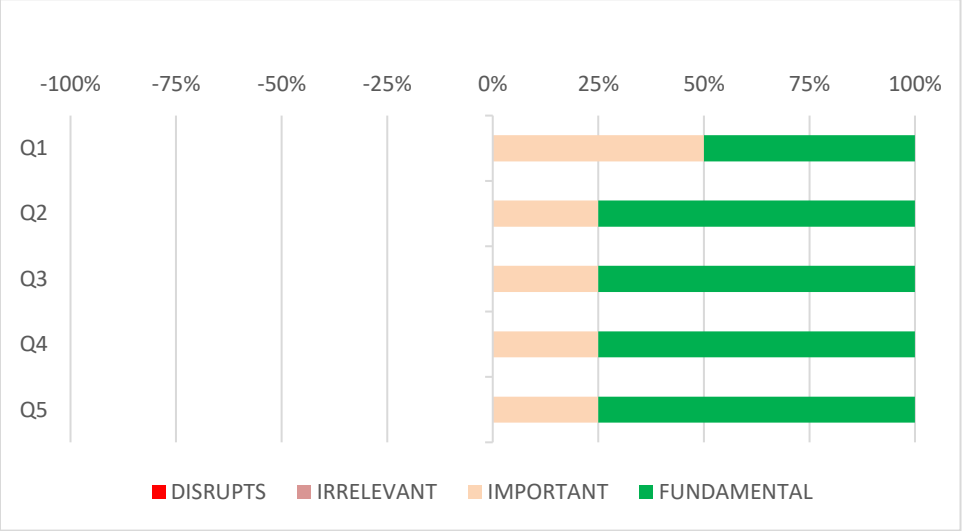
Q2: In the question that considers the Reuse/Redistribute cycle in the implementation of circular processes in the industry, the negotiation with the distributor of the manufactured product is, according to the answers of the experts, with 75% being somewhat difficult and 25% being very difficult.

Q3: Considering the Remanufacturing cycle in the implementation of circular processes in the industry, the discovery of remanufacturing services, with the involvement of the manufacturer, as answers from the experts, 75% think it is critical and 25% believe it is important.

Q4: Still in the Remanufacturing cycle in the implementation of circular processes in the industry, the negotiation with the manufacturer, involving contracts and licenses, spare parts, etc. to recover or remanufacture equipment is, given the answers of the experts pointed out that it is 75% fundamental and 25% think it is important.

Q5: The question that considers the recycling cycle in the implementation of circular processes in the industry, the discovery of a supplier of recycled material or an organization capable of collecting and recycling waste and supplying it in the required volume is, in the opinion of experts 75% is fundamental and 25% believe it to be important. Figure 14 shows the respondents' opinions on the technical cycle.

Figure 14: Respondents' opinion of the technical cycle




On the issue that considers the Sharing cycle in the implementation of circular processes in the industry, understood here as the final consumer of machinery and equipment, the discovery of partners willing to share productive resources is, as the answers of the experts pointed out, that it will be very difficult.

On the question that ponders the maintenance/Extension cycle in the implementation of circular processes in the industry, the discovery of maintenance services, according to the answers of the experts, will be somewhat difficult.

On the issue that reflects the reuse/redistribute cycle in the implementation of circular processes in the industry, the negotiation with the manufacturer of the manufactured product is, according to the answers of the experts, a little difficult.

Considering the four cycles of the Circular Economy, with the establishment of internal rules and parameters of the industry for the establishment of suppliers, presented the following result of the respondents where all agree that the supplier's compliance with the PNRS; Law 12.305/2010 and the Environmental Responsibility of the supplier are the most indicated, followed by the Social Responsibility of the supplier and then the ISO 14.000 Certification.

On the question of the importance of the Procurement area for the Circular Economy, all

respondents pointed out that it has a lot to contribute.

In the question that considers some of the possible applications of Industry 4.0 enabling technologies for the Circular Economy and points out their potential to contribute to the Circular Economy, according to the experts' answers, he presented the following results:

Internet of Things: Possibility of tracking a material or equipment throughout its entire life cycle, as very potential.

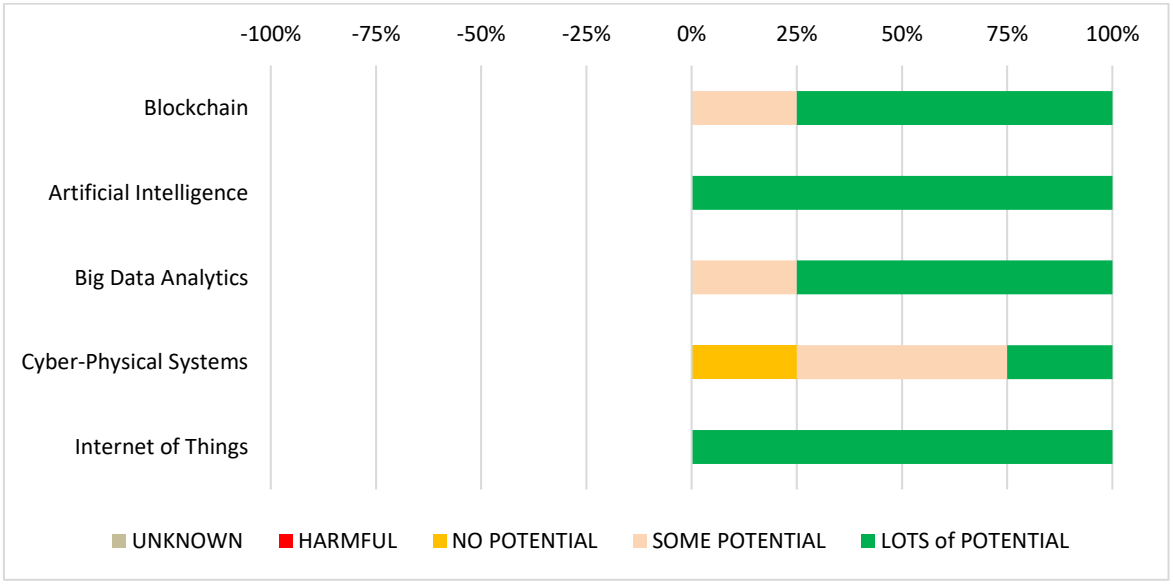
Cyber-physical systems: Digital mirroring of production and logistics processes for simulation or real-time monitoring and control, showed that 50% believe it has some potential, 25% of the answers present it with a lot of potential and 25% demonstrate that there is no potential.

Interaction with Big Data Analytics: Value Creation through the extraction of information from data on production, consumption, and reverse cycles, presented the following results, being 75% believe that there is a lot of potential and 25% believe that there is some potential.

Artificial Intelligence: Automated discovery of partners for sourcing materials, equipment, or services, automated price quotes, and waste identification, presented the following results from the experts with a lot of potential.

Blockchain: Automated negotiation with partners, establishment of digital contracts, creation of alternative means of payment and social currencies, traceability, security, and preservation of transactional records, according to the responses of the experts showed that 75% believe that there is a lot of potential and 25% of the answers presented that there is some potential. Figure 15 shows the potential of enabling technologies for the circular economy.

Figure 15: Potential of technologies for the circular economy

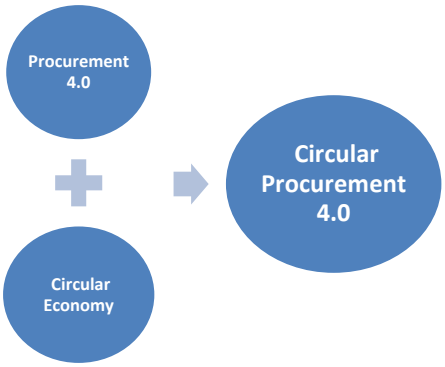


### 4.3 Relationship Between Procurement 4.0 and Circular Economy Scenarios

Delphi was carried out with experts and the data analysis showed proximity that responds to the objectives of the work: Which enabling technologies of Procurement 4.0 can favor the transition to the Circular Economy? How can Procurement 4.0 contribute to the Circular Economy?

One of the advantages of Industry 4.0 enabling technologies in procurement is the ability to leverage real-time data and analytics to gain insights into supplier performance, demand patterns, and market trends, enabling the optimization of strategies, the identification of potential risks, and the management of supplier relationships. Figure 16 exposes the origin of Procurement Circular 4.0.

Figure 16: Origin of Procurement Circular 4.0




Source: Authors (2023).

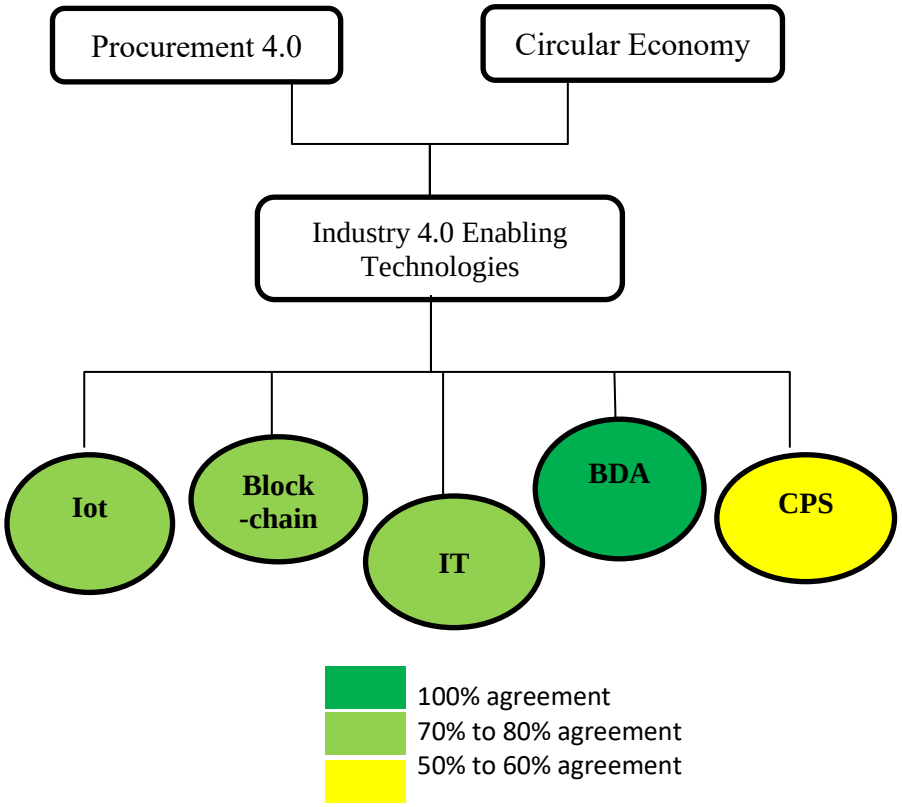
As the analysis of the results of Delphi was carried out with the experts, we realized that there is a proximity between the answers about Procurement and the Circular Economy, for example in the answers about the enabling technologies of Industry 4.0. Table 1 presents the occurrences of responses about technologies that can help about Procurement 4.0 and the Circular Economy.

Table 1. Occurrences of the answers with the enabling technologies of Industry 4.0 that can help about Procurement 4.0 and the Circular Economy, according to the respective experts.

| Technologies | Procurement Specialists | EC Specialists |
|---|---|---|
| Internet of Thinks | 80% | 75% |
| Blockchain | 80% | 75% |
| Artificial Intelligence | 80% | 100% |
| Big Data Analytics | 100% | 100% |
| CPS | 60% | 50% |

The main enabling technology of Industry 4.0 that will have the greatest occurrence of Procurement with the Circular Economy, in the opinion of experts, will be Big Data Analytics. Figure 17 exposes this opinion.

Figure 17: Presentation of the main enabling technology for Industry 4.0 in the opinion of experts.




Source: Authors (2023).

## 5 CONCLUSIONS

Given the above the linear economy is where natural raw materials are extracted and then transformed into products, used for some time, and discarded as waste. In this way, the incentive for the excessive consumption of material resources creates unsustainable waste management practices and creates health, biodiversity, and climate disorders. Thus, it is estimated that in a few decades, the amount of material resources consumed worldwide will almost double.

Considering what has been observed, the increase in global competition is bothering companies as competition has become intense, encouraging companies to investigate the opportunity of a business model using the Circular Economy. Circular economy business models can minimize the overuse of natural resources and reduce the volume of waste generation.

As a result of the above, the adoption of the circular economy within organizations and supply chains has created barriers, due to the misunderstanding of the life cycle of products and the scarcity of advanced technologies. However, with the arrival of Industry 4.0 enabling technologies, these principles can be overcome.

Thus, the Procurement 4.0 area involves competitive strategies and partnerships for remanufacturing and recycling materials in the circular economy. Circular Procurement consists of making agreements to ensure that products are produced according to the principles of the circular economy and will be further processed after use.

Given the reflection presented, the article presented the following objective, which was to identify how Procurement 4.0, with the use of Industry 4.0 enabling technologies, contributes to the incentive and connection to the Circular Economy process, deriving the following questions: Q1: Which enabling technologies of Procurement 4.0 can favor the transition to the Circular Economy? Q2. How can *Procurement* 4.0 contribute to the Circular Economy?
In the answers to the questions presented, the Delphi methodology was used, carried out in three stages, with scenarios and graphs of the analysis of the questions.

As a result of the occurrences of the answers regarding how much the enabling technologies of Industry 4.0 around Procurement can contribute to the evolution of the Circular Economy, the experts unanimously pointed out the Big Data Analytics tool as being the one with the greatest potential for this evolution, followed by the Artificial Intelligence (AI) Blockchain and Internet of Things (IoT) tools. with a slightly lower, but no less relevant, degree of potential.

In answer to the second question, how can *Procurement* 4.0 contribute to the Circular Economy?

The Supplier Management function was presented as the one with the greatest potential for success, as well as the vertical and horizontal integration of companies, with individualized, sustainable, flexible, and resilient production, among the respondents pointed out that 60% of the answers totally agreed and 40% partially agreed.

The limitations of this study were specific to the areas of Procurement and Circular Economy with the use of Industry 4.0 enabling tools, and the study does not allow generalizations, but the results may induce similar research in several other countries on the subject.

Future studies in this area should focus on surveying and addressing practices for the implementation of enabling Industry 4.0 technologies in the areas of Procurement and Circular Economy. Empirical studies and case examples can provide valuable insights into the real-world impact of these enabling technologies, on cost-effectiveness and sustainability.

In addition, it should explore the ethical implications of technologies such as Artificial Intelligence (AI) and Blockchain in Procurement, including privacy issues is essential to ensure reliable adoption.

From all the ideas presented, we conclude that the use of Industry 4.0 enabling tools around Procurement has a high potential for the transition from the linear economy to the circular economy.

## BIBLIOGRAPHIC REFERENCES

AKTER, U.H.; PRANTO, T.H.; HAQUE, A.K.M. (2022). Machine Learning and Artificial Intelligence in Circular Economy: A Bibliometric Analysis and Systematic Literature Review. arXiv:2205.01042.

ALONSO-ALMEIDA, MM, RODRÍGUEZ-ANTÓN, JM, BAGUR-FEMENÍAS, L, PERRAMON, J. (2020). Sustainable development and circular economy: the role of institutional promotion in circular consumption and market competitiveness from a multisectoral engagement approach. Bus Strat Env. 2020; 29: 2803 - 2814. Available at: https://doi.org/10.1002/bse.2544. Accessed on: 20 Mar 2023.

BAG, SURAJIT; LINCOLN C. WOOD; SACHIN K. MANGLA; SUNIL LUTHRA. (2020). Procurement 4.0 and its implications on business process performance in a circular economy. Resources, Conservation and Recycling, Volume 152, 104502, ISSN 0921-3449. Available at: https://doi.org/10.1016/j.resconrec.2019.104502. Accessed on: 25 Mar 2023.

BENYUS, J.; (1997). BY NATURE, Biomimicry-Innovation Inspired. Harper Collins Publishers. New York.

BIENHAUS, F. AND HADDUD, A. (2018), "Procurement 4.0: factors influencing the digitisation of procurement and supply chains", Business Process Management Journal, Vol. 24 No. 4, pp. 965-984. Available at: https://doi.org/10.1108/BPMJ-06-2017-0139. Accessed on: 20 Jun. 2023.

BLOME, C., HOLLOS, D., & PAULRAJ, A. (2014). Green procurement and green supplier development: Antecedents and effects on supplier performance. International Journal of Production Research, 52 (1), 32-49. Available at:10.1080/00207543.2013.825748. Accessed on: 10 May. 2023.

BRESSANELLI, G.; ADRODEGARI, F.; PERONA, M.; SACCANI, N. (2018). Exploring how usage-focused business models enable the circular economy through digital technologies. Sustainability, 10, 639.

BUNEA, OI. (2021). A bibliometric analysis on the link between circular economy and supply chain. Rev. Manager Comp. Int. 22, 555–569.

COHEN, D. (2007). Earth audit. New scientist, v. 194, n. 2605, p. 34-41.

CORBOȘ, RĂZVAN-ANDREI, OVIDIU-IULIAN BUNEA AND DANIEL-CONSTANTIN JIROVEANU. (2023). "The Performance Effects of Strategic Purchasing 4.0 on Organizational Competitiveness in the Circular Economy". Logística 7, no. 1: 13. Available at: https://doi.org/10.3390/logistics7010013. Accessed on 25 Mar. 2023.

CHAKRAVARTY, SUKRITI. (2017). What is the difference between procurement-purchasing and sourcing? Available at: www.tendersinfo.com/blogs/What-is-the-difference-between-procurement-purchasing-and-sourcing/. Accessed in 20 Apr. 2023.

CORBOȘ, RĂZVAN-ANDREI, OVIDIU-IULIAN BUNEA, AND DANIEL-CONSTANTIN JIROVEANU. (2023). "The Effects of Strategic Procurement 4.0 Performance on Organizational Competitiveness in the Circular Economy" *Logistics* 7, no. 1: 13. Available at: https://doi.org/10.3390/logistics7010013.Accessed on 20Feb 2023.

DEMESTICHAS, K.; DASKALAKIS, E. (2020). Information and Communication Technology Solutions for the Circular Economy. Sustainability, 12, 7272.

DE SOUSA JABBOUR, ABL; JABBOUR, CJC; FOROPON, C.; GODINHO FILHO, M. (2018). When the titans meet – Can industry 4.0 revolutionize the wave of environmentally sustainable manufacturing? The role of critical success factors. Technol. Forecast. Chang Society. 132, 18–25.

DE MATTOS, CA; DE ALBUQUERQUE, TLM (2018). Enabling factors and strategies for the transition to a circular economy (CE). Sustainability, 10, 4628.

EUROPEAN COMMISSION (2017), "Public Procurement for a circular economy: Good practice and guidance". Available at: http://ec.europa.eu/environment/gpp/.Accessed on: 20 May. 2023.

ELGHAISH, F.; MATARNEH, S.T.; EDWARDS, D.J.; RAHIMIAN, F.P.; EL-GOHARY, H.; EJOHWOMU, O. (2022). Applications of Industry 4.0 digital technologies towards a construction circular economy: Gap analysis and conceptual framework. *Constr. Innov. 22*, 647–670.

ELLEN MACARTHUR FOUNDATION. (2013). Towards the Circular Economy, Economic and Business Rationale for an Accelerated Transition; Foundation Ellen MacArthur: Cowes, United Kingdom.

FEGER, A.L. R (2014). Creating cross-functional strategic consensus in manufacturing facilities. Int. J. Oper. Prod. Manage., 34 (7) (2014), pp. 941-970.

HAWKEN, P LOVINS, A., LOVINS, L. (1999), “Natural Capitalism”,

GEISSDOERFER, M; SAVAGET, P; BOCKEN, N; HULTINK, E. (2017). “The Circular Economy - a new paradigm of sustainability?”. Cleaner Journal, 143(1), 757-768.

HOBBS, E. (2020). Food supply chains during the COVID-19 pandemic. He can. J. Agric. Econ. /Rev. He can. D'agroeconomie, 68, 171–176.

IDEIA CIRCULAR (2017). Technical Cycle and Biological Cycle. Available at: https://ideiacircular.com/ciclo-tecnico-e-ciclo-biologico/. Accessed on: 10 May. 2023.

JABBOUR, ANA BEATRIZ LOPES DE SOUSA & CHARBEL JOSE CHIAPPETTA JABBOUR & MOACIR GODINHO FILHO & DAVID ROUBAUD. (2018). “Industry 4.0 and the circular economy: a proposed research agenda and an original roadmap for sustainable operations “, Annals of Operations Research, Springer, vol. 270(1), pages 273-286, November.

JESUS, A.; ANTUNES, P.; SANTOS, R.; MENDONÇA, S. (2018). Eco-innovation in the transition to a circular economy: An analytical literature review. Journal of Cleaner Production, 172, 2999e3018.

KUSI-SARPONG, S.; GUPTA, H.; KHAN, SA; CHIAPPETTA JABBOUR, CJ; REHMAN, ST; KUSI-SARPONG, H. (2021). Sustainable selection of suppliers based on industry 4.0 initiatives in the context of implementing the circular economy in supply chain operations. Product Flat. Control, 1–21.

LECHNER, G., & REIMANN, M. (2020). Integrated decision-making in reverse logistics: an optimisation of interacting acquisition, grading, and disposition processes. International Journal of Production Research, 58(19), 5786–5805. Available at: https://doi.org/10.1080/00207543.2019.1659518. Accessed on: 10 May. 2023.

LEE, CKH. (2017). A GA-based optimization model for big data analytics with support for early shipping in Retail 4.0. Int. J.Prod. Res., 55, 593–605.

MASI, D.; KUMAR, V.; GARZA-REYES, JA; GODSELL, J. (2018). Towards a more circular economy: exploring awareness, practices, and barriers from a focal business perspective. Product Flat. Control, 29, 539–550.

MEADOWS, D. H.; MEADOWS, D. L.; RANDERS, J.; BEHRENS III, W. W. The limits to growth & a report for The Club of Rome’s project on the predicament of mankind. New York: Universe Books, 1972.

MEEHAN, J; & BRYDE, D. (2011). Sustainable procurement practice. Business Strategy and the Environment, 20 (2), 94-106. Available at: doi:10.1002/bse.678. Accessed on: 18 Mar. 2023.

MICHELINI, G., MORAES, R., CUNHA, R., COSTA, J., OMETTO, A. (2017), “From Linear to Circular Economy: PSS Conducting the Transition”, 9th CIRP IPSS conference: circular perspectives on product/service systems.

OKANO, MARCELO T; ANTUNES, SAMIRA N; FERNANDES, MARCELO ELOY. Digital transformation in the manufacturing Industry under the optics of digital platforms and Ecosystems. (2021). INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P). Available at: http:/hvnww.ijmp.jor.br v. 12, n. 4, May-June 2021. ISSN: 2236-269X. DOI: 10.14807/ijmp. v12i4.1375.

PEARCE, D. W., AND R. K. TURNER. Economics of Natural Resources and the Environment. Baltimore MD: Johns Hopkins University Press, 1990, 378 pp., Available at: https. Accessed on: 12 Mar 2023.

PISANI, J. A. (2006). Sustainable development – historical roots of the concept. Environmental Sciences, v. 3, n. 2, p. 83-96.

POOLER, H.V. (1992). Global purchasing: reaching for the world. New York, Chapman & Hael.

POLLICE, FABIO; BATOCCHIO, ANTONIO; (2018). The new role of Procurement in a circular economy system. 22nd Cambridge International Manufacturing Symposium University of Cambridge, 27 – 28 September.

POPA, V.N., & POPA, L.I. (2016). Green acquisitions and lifecycle management of industrail products in the circular economy. IOP Conference Series: Materials Science and Engineering. IOP Publishing. Available at:10.1088/1757-899X/161/1/012112. Accessed on: 10 May 2023.

RITTER, T.; PEDERSEN, CL. (2020). Ability to digitize and digitize business models in business-to-business companies: past, present, and future. Brand Ind. control, 86, 180–190.

ROBERTS, H.; ZHANG, J.; BARIACH, B.; COWLS, J.; GILBURT, B.; JUNEJA, P.; TSAMADOS, A.; ZIOSI, M.; TADDEO, M.; FLORIDI, L. (2022). Artificial intelligence in support of the circular economy: Ethical considerations and a path forward. *AI Soc.*1–14.

SADHUKHAN, J.; DUGMORE, T.I.J.; MATHARU, A.; MARTINEZ-HERNANDEZ, E.; ABURTO, J.; RAHMAN, P.K.S.M.; LYNCH, J. (2020). Perspectives on “Game Changer” Global Challenges for Sustainable 21st Century: Plant-Based Diet, Unavoidable Food WasteBiorefining, and Circular Economy. *Sustainability*, *12*, 1976. https://doi.org/10.3390/su12051976.

SCHROEDER, P. K. ANGGRAENI, U. WEBER (2018). The relevance of circular economy practices to the sustainable development goals. J. Ind. Ecol. pp. 1-19.

SPRECHER, B., DAIGO, I., SPEKKINK, W., VOS, M., KLEIJN, R., MURAKAMI, S., & KRAMER, G.J. (2017). Novel indicators for the quantification of resilience in critical material supply chains, with a 2010 rare earth crisis case study. Environmental Science & Tecnology, 51 (7). 3860-3870. Available at: 10.1021/acs.est.6b05751 PMID: 28257181. Accessed on: 10 Jun 2023.

UNICEF. (2015). Sustainable Development Goals. Available at: https://www.unicef.org/brazil/objetivos-de-desenvolvimento-sustentavel. Accessed on: 12 Mar 2023.

VARRIALE, V., CAMMARANO, A., MICHELINO, F., & CAPUTO, M. (2021). Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management. Sustainability (Switzerland), 13(11). Available at: https://doi.org/10.3390/su13116372.Accessed on: 02 May 2023.

VELOSO, C. C.; AGUSTINHO, A. G. S. (2017). Corporate sustainability: smart business strategy: theory and practice. Curitiba: Appris, 111 p.

WEETMAN, C. (2017), "A circular economy handbook for business and supply chains: Repair, remake, redesign, rethink". London, Kogan Page Ltda.

WERNECK, EDUARDO; (2021); AGENDA 2030: The contribution of the SDGs as new development paradigms. Investor Relations Magazine (IR). Available at https://www.revistari.com.br/249/1718. Accessed on: 28 Jun 2023.

WITJES, S., & LOZANO, R. (2016). Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. Resources, Conservation and Recycling, 112, 37-44. Available at: 10.1016/j.resconrec.2016.04.015. Accessed on: 15 Apr. 2023.

YU, Z.; KHAN, SAR; UMAR, M. (2021). Circular Economy Practices and Industry 4.0 Technologies: A Strategic Movement in the Automotive Industry. Bus. Strategic Environment. 31, 796–809.

# 5 DISCUSSÃO

Este capítulo visa a apresentar os resultados dos artigos elaborados, tendo como o objetivo desta tese expor o modo como a implantação das tecnologias habilitadoras da Indústria 4.0 transformou a área do *Procurement* em *Procurement* 4.0 e quais serão as suas contribuições para a economia circular.

O primeiro artigo que compõe esta tese, intitulado "Procurement 4.0: A Systematic Review of its Technological Evolution" atingiu o objetivo específico de avaliar o impacto da Indústria 4.0 na área de *Procurement* e propor um modelo conceitual para o *Procurement* 4.0.

O artigo apresenta a tabela "Evolution of Procurement technologies" (ver seção 4, página 39), que evidencia o modelo conceitual proposto, as tecnologias habilitadoras da Indústria 4.0, as transições das operações de processo de *Procurement* 4.0 e quais as tendências dessa evolução, com base na literatura.

Com processos e dados cada vez mais transparentes e acessíveis, o *Procurement* 4.0 estabelece uma transição na organização tendo como base as seis dimensões conceituais apresentadas. Como resultado, o *Procurement* 4.0 adquire mais autonomia, flexibilidade e transparência nas operações associadas ao gerenciamento de compras para otimizar decisões de preços, gerenciamento de fornecedores e gerenciamento de compras, ou para desenvolver sustentabilidade e segurança de compartilhamento de dados, em concordância com Babiceanu et al. (2016) e Fatorachian et al. (2021).

Esse artigo recebeu uma citação na base Web of Science no artigo "Transformative Procurement Trends: Integrating Industry 4.0 Technologies for Enhanced Procurement Processes", publicado na revista *Logistics-Basel*, vol. 7, n. 3, DOI 10.3390/logistics7030063.

Já o segundo artigo, intitulado "Procurement 4.0: Survey of Principles and Technologies in Use", atingiu o objetivo específico da tese de validar o modelo conceitual proposto do *Procurement* 4.0. O artigo mostra como o modelo conceitual proposto das dimensões – competências, gestão, parcerias, processos, sistemas/tecnologias e sustentabilidade (ver seção 2.2, pág. 48) – orienta e proporciona um melhor entendimento para a implementação das tecnologias habilitadoras da Indústria 4.0 na área de *Procurement*. A *survey* permitiu validar, dentro de limites metodológicos, o modelo conceitual das dimensões e mostrou as tecnologias habilitadoras da Indústria 4.0 que mais se adéquam ao processo de *Procurement* 4.0 nas dimensões do modelo apresentado.

A pesquisa mostrou que a área do *Procurement* focada no processo de aquisição será afetada pela implementação das ferramentas habilidadoras da Indústria 4.0, e com esse

entendimento o modelo exibido em dimensões seria essencial para a implantação do *Procurement* 4.0. Onde o modelo proposto poderá ser proveitoso em sua empresa? Essa questão foi colocada mundialmente a profissionais da área de *Procurement* e, pelas respostas apresentadas, apontou um índice de 88%, o que significa que o modelo conceitual proposto das dimensões tem um papel orientador nessa implementação.

O terceiro artigo, intitulado "Contributions of Procurement 4.0 to the Circular Economy", atingiu o objetivo de avaliar as contribuições do *Procurement* 4.0 para a economia circular, que coincide com o terceiro objetivo específico da tese. Foi desenvolvido com a metodologia Delphi com especialistas das áreas de *Procurement* e economia circular, apresentando cenários de implementação das tecnologias habilitadoras da Indústria 4.0 em ambos os casos e apontando quais mostraram maior proximidade.

No cenário do *Procurement*, as tecnologias habilitadoras da Indústria 4.0 influenciam positivamente a intenção dos compradores de otimizar os processos de negócios, mas a implementação de tecnologias facilitadoras da Indústria 4.0 requer investimentos significativos em infraestrutura, sistemas de gestão de dados e formação de mão de obra. As organizações necessitam abordar questões relacionadas a segurança, privacidade e interoperabilidade dos dados ao aproveitar tecnologias como *big data* e IoT, ainda que a assimilação de múltiplas tecnologias possa apresentar problemas de compatibilidade e exigir mudanças nas estruturas e nos processos organizacionais.

O *Procurement* 4.0 envolve uma estratégia competitiva e uma estratégia de parceria para a remanufatura e a reciclagem de materiais na economia circular, em que o desenvolvimento de fornecedores e a gestão de estoques de fornecedores para decisões de terceirização são fundamentais para a excelência das operações de remanufatura na economia circular (Bag et al., 2020).

Já no cenário da economia circular, o artigo apresentou como resultado as ocorrências de respostas sobre o quanto as tecnologias facilitadoras da Indústria 4.0 na área de *Procurement* podem contribuir para a evolução da economia circular; os especialistas apontaram por unanimidade a ferramenta *big data analytics* como sendo aquela com maior potencial para essa evolução, seguida pelas ferramentas *blockchain* de inteligência artificial (IA) e internet das coisas (IoT), com um grau de potencial ligeiramente inferior, mas não menos relevante.

Na literatura, destaca-se que o desejável é que o *Procurement* 4.0 esteja conectado à economia circular, pois envolve o uso de tecnologias específicas da Indústria 4.0 e pode se tornar parte da implementação de tecnologias digitais que contribuem para atingir metas de sustentabilidade, respaldando o que disse De Sousa Jabbour et al. (2018). O *Procurement*

circular é um conceito relativamente novo, não existe uma definição consensual sobre ele (Pollice, 2018).

A função de compras, por sua vez, já há algum tempo deixou de ser apenas uma atividade de suporte das organizações fabris Uma visão estratégica de compras busca alinhar essa atividade com as metas de sustentabilidade, incluindo as tecnologias digitais.

O artigo 3 traz evidências do contexto do ambiente de negócios, que ainda está prestes a se aproximar da digitalização de atividades para ser mais eficiente, reduzir o consumo de recursos e ajudar a reciclar, apoiando os esforços da economia circular.

Por fim, os resultados do Delphi mostraram que o *Procurement* 4.0 deve incorporar os princípios de circularidade na transição para a economia circular. Embora o *Procurement* 4.0 possa trazer muitos benefícios, conforme apontado por Bienhaus e Haddud (2018), nem sempre fica claro como traduzir as tecnologias em ganhos de desempenho da economia circular.

Após análise da literatura, conclui-se que a economia circular e o *Procurement* 4.0 são dois temas de pesquisa em uma dinâmica emergente e que requerem contribuições significativas para aumentar o nível de conhecimento (Masi et al., 2018; Bunea, 2021). Mais pesquisas serão necessárias para demonstrar como as tecnologias habilitadoras da Indústria 4.0 apoiam as relações de transição para a economia circular.

# 6 CONSIDERAÇÕES FINAIS

Inúmeras empresas ao redor do mundo estão em um processo de revisão constante para encontrar melhores métodos de gerenciar seus dados da cadeia de suprimentos e informações para obter vantagem competitiva.

Revela-se na sociedade, de modo geral, uma revolução tecnológica ao mesmo tempo que ela acontece, e isso provoca mudanças repentinas nos mais diversos setores da sociedade. Destacam-se os termos “Quarta Revolução Industrial” e “Indústria 4.0”, que ao serem anunciados possibilitaram que novas tecnologias e metodologias de gestão e novos relacionamentos entre empresas surgissem no mercado.

Aponta-se que, a partir da implementação dos conceitos da Indústria 4.0, ocorrerá uma mudança cultural e organizacional, de modo geral, bem como a integração vertical e horizontal das empresas, com produção individualizada, sustentável, flexível e resiliente, sendo necessária uma estrutura que funcione bem e em tempo real, visto que os processos são mais ágeis e exigem tomadas de decisão muitas vezes em tempo real. Compreende-se que haverá uma redistribuição de tarefas, papéis e responsabilidades, assim como um novo gerenciamento de materiais e informações, de crescimento em escala e de mudança de escopo.

Percebe-se que a importância e a relevância do tema *Procurement* 4.0, justificam a tese, que desenvolveu uma estrutura conceitual demonstrada em dimensões, apontando as formas de aplicação das ferramentas habilitadoras da Indústria 4.0 na área de *Procurement* e retratando como o *Procurement* 4.0 está apto a contribuir com a transição da economia linear para a economia circular dentro das organizações.

Diante do exposto, propõe-se, para pesquisas futuras, que o tema seja abordado de uma forma consolidada, incluindo as etapas necessárias para implementar o *Procurement* 4.0 no âmbito das tecnologias da Indústria 4.0 e com foco no design organizacional e operacional a favor da sustentabilidade, efetuando a circularidade de produtos.

Existem algumas limitações neste estudo. Os benefícios e desafios utilizados a partir da literatura científica não são extensos. Embora o estudo tenha permitido apontar tendências das tecnologias habilitadoras da Indústria 4.0 e que o modelo conceitual das dimensões faz parte do *Procurement* 4.0, os resultados podem induzir pesquisas semelhantes em vários outros países.

Estudos futuros podem usar o mesmo método, envolvendo mais pessoas de outros países e outros setores, para confrontar os achados deste estudo, além de verificar na prática a influência das tecnologias habilitadoras da Indústria 4.0 sobre a área de *Procurement* e também o modo como a economia circular sofreu a influência do *Procurement* 4.0.

## 7 REFERÊNCIAS BIBLIOGRÁFICAS

ABDALA, V. **"Aumento da expectativa de vida não considera efeitos da covid-19"**. (2022). Repórter da Agência Brasil. Publicado em 25/11/2021, 10:47, Rio de Janeiro.Disponível em: https://agenciabrasil.ebc.com.br/economia/noticia/2021-11/aumento-da-expectativa-de-vida-nao-considera-efeitos-da-covid-19. Acesso em: 31 out. 2022.

ACEMOGLU D. (2012). Introduction to Economic Growth. **Journal Econonomy Theory**, 147 (2), p. 545-550.

AHMAD, S.; MISKON, S.; ALABDAN, R.; TLILI, I. (2020). Towards a Sustainable Textile and Garment Industry: Exploring the Role of Business Intelligence Systems in the Era of Industry 4.0. **Sustainability** 12 (7). Disponível em: https://doi.org/10.3390/su12072632. Acesso em: 30 maio 2023.

AKENJI, L.; BENGTSSON, M. (2014). "Making Sustainable Consumption and Production the Core of Sustainable Development Goals." **Sustainability,** 6 (2), p. 513-529.

ALTHABATAH, AREEJ; MENEZES, BRENNO; AND KERBACHE, LAOUCINE. (2022). **Procurement 4.0: Drivers, Challenges, Remedies, and Benefits.** 5th European International Conference on Industrial Engineering and Operations Management. Rome, Italy, July 26-28.

ANDREWS, D. (2015). The Circular Economy, Design Thinking and Education for Sustainability. **Local Economy**, [s.l.], v. 30, n. 3, p. 305-315.

APEL, H. (2020). Inequality in Development: The 2030 Agenda, SDG 10, and the Role of Redistribution. **Real-World Economics Review**, p. 228.

ARAÚJO, T. D.; QUEIROZ, A. A. F. S. **Economia circular: breve panorama da produção científica entre 2007 e 2017**. In: Encontro Internacional sobre Gestão Empresarial e Meio Ambiente, 19. (2017). São Paulo. Anais [...]. São Paulo: FEA/USP, 2017, p. 1-17.

ASLANBAS, M. (2014). Emporias Procurement Survey 4.0. In: **Emporias Management Consulting** (ed.), Emporias, Quarterly 3, Munique, Alemanha, p. 10-14.

ATTOH, K. A. (2011). "What Kind of Right is the Right to the City?" **Progress Human Geography**, 35, p. 669-685.

BABICEANU, R. F.; SEKER, R. (2016). Big Data and Virtualization for the Fabrication of Cyber Physical Systems: A Survey of Current Status and Future Perspectives. **Computers in Industry**, 81, p. 128-137.

BAG, S.; TELUKDARIE, A.; PRETORIUS, JHC; GUPTA, S. (2018). **Industry 4.0 and Supply Chain Sustainability: Structure and Future Research Directions**. Reference, 28 (5), p. 1410-1450. Disponível em: https://doi.org/10.1108/BIJ-03-2018-0056.

BAG, S.; WOOD, L. C.; XU, L.; DHAMIJA, P.; KAYIKCI, Y. (2020). "Big Data Analytics as an Operational Excellence Approach to Enhance 12. BAG, S. et al. Sustainable Supply Chain Performance." **Resources, Conservation and Recycling** 153, p. 104559. Disponível em: doi: 10.1016/j.resconrec.2019.104559.

BAG, SURAJIT; LINCOLN C. WOOD; SACHIN K. MANGLA; SUNIL LUTHRA. (2020). Procurement 4.0 and its Implications on Business Process Performance in a Circular Economy. **Resources, Conservation and Recycling**, vol. 152, January, p. 104502.

BAG, SURAJIT et al. (2021). "Examining the Role of Procurement 4.0 Towards Remanufacturing Operations and Circular Economy." **Production Planning & Control**, 32.16, p. 1368-1383.

BARI, A. (2017). "Our Oceans and the Blue Economy: Opportunities and Challenges." **Procedia Engineering**, 194, p. 5-11.

BATRAN, ALEXANDER; ERBEN, AGNES; SCULZ, RALF; SPERL, FRANZISKA. (2017). **Procurement 4.0: A Survival Guide in a Digital, Disruptive World.** Campus Verlag Gmbh, Frankfurt / New York. ISBN 9783593506692.

BEISHEIM, M.; SIMON, N. (2018). Multistakeholder Partnerships for the SDGs: Actors' Views on UN Metagovernance. **Glob. Gov**., 24, p. 497-515.

BERNHARDT, J. R.; LESLIE, H. M. (2013). "Resilience to Climate Change in Coastal Marine Ecosystems." **Annual Review of Marine Science**.

BIENHAUS, F.; HADDUD, A. (2018). "Procurement 4.0: Factors Influencing the Digitization of Procurement and Supply Chains." **Business Process Management Journal**, vol. 24, n. 4, p. 965-984. Disponível em: https://doi.org/10.1108/BPMJ-06-2017-0139.

BONAN, G. B. (2008). Base científica das mudanças climáticas. Contribuição do Grupo de Trabalho 1 do Painel Brasileiro de Mudanças Climáticas ao Primeiro **Relatório da Avaliação Nacional sobre Mudanças Climáticas** [Ambrizzi, T.; Araujo, M. (eds.)]. Coppe. Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brasil, p. 1444-1449. ISBN: 978-85-285-0207-7.

BONILLA, S.; SILVA, H.; SILVA, M. T.; GONÇALVES, R. F.; SACOMANO, J. (2018). Industry 4.0 and Sustainability Implications: A Scenario-Based Analysis of the Impacts and Challenges. **Sustainability**, 10, p. 3740.

BORDELEAU, FANNY EVE; MOSCONI, ELAINE; SANTA-EULALIA, LUIS ANTONIO DE. (2020). “Business Intelligence and Analytics Value Creation in Industry 4.0: A Multiple Case Study in Manufacturing Medium Enterprises.” **Production Planning & Control**, 31 (2-3), p. 173-185. Disponível em: doi:10.1080/09537287.2019.1631458.

BOSTON, J.; LAWRENCE, J. (2018). “**Funding Climate Change Adaptation.**” Policy Quarterly, 14 (2).

BUENO, ROBSON ELIAS; ALMEIDA DOS SANTOS, H.; JUNIOR FREITAS, MOACIR DE; TOLOI, RODRIGO CARLO; GONÇALVES, RODRIGO FRANCO. (2022). **Procurement 4.0: A Systematic Review of its Technological Evolution.** APMS 2022 International Conference Advances in Production Management Systems. Disponível em: https://www.conftool.net/apms2022/ e https://www.apms-conference.org/.

BRAND-CORREA, L. I.; STEINBERGER, J. K. (2017). “A Framework for Decoupling Human Need Satisfaction from Energy Use.” **Ecological Economics**, 141, p. 43-52.

BRØNS-PETERSEN, OTTO; GJEDSTED, SØREN HAVN. (2021). Climate Change and Institutional Change: What is the Relative Importance for Economic Performance? **Environmental Economics and Policy Studies**, v. 23, n. 2, p. 333-360.

BRUNDTLAND, GRO HARLEM. (1987). **Report of the World Commission on Environment and Development: Our Common Future.** United Nations. Oslo, 20 March 1987. Disponível em: https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html.

CALABRESE, ARMANDO; GHIRON, NATHAN LEVIALDI; TIBURZI, LUIGI. (2020). “Evolutions’ and ‘Revolutions’ in Manufacturers’ Implementation of Industry 4.0: A Literature Review, a Multiple Case Study, and a Conceptual Framework.” **Production Planning and Control, 0** (0), p. 1-15. Disponível em: https://doi:10.1080/09537287.2020.1719715.

CAMPBELL, A.; CONVERSE, P. E.; RODGERS, W. L. (1976). **“The Quality of American Life: Perceptions, Evaluations, and Satisfactions.”** Russell Sage Foundation. Disponível em: https://doi.org/10.7758/9781610441032.

CARMIN J.; TIERNEY, K.; CHU, E.; HUNTER, L. M.; ROBERTS, J. T.; SHI, L. (2015). “Adaptation to Climate Change.” **Climate change and society: Sociological perspectives**, 16, p. 4-98.

CHAN, S.; WEITZ, N.; PERSSON, A.; TRIMMER, C. (2018). “SDG 12: Responsible Consumption and Production. **A Review of Research Needs**.” Stockholm Environment Institute.

CHAKRAVARTY, S.; GHOSH, S. K.; SURESH, C. P.; DEY, A. N.; SHUKLA, G. (2012). "Deforestation: Causes, Effects and Control Strategies." **Global Perspectives on Sustainable Forest Management**, Intech Open.

CHEN, I. J.; PAULRAJ, A.; LADO, A. A. (2004). "Strategic Purchasing, Supply Management, and Firm Performance." **Journal of Operations Management**, 22 (5), p. 505-523. Disponível em: https://doi: 10.1016/j.jom.2004.06.002.

CHIANG, W. C. (2016). **Development of a Lean Non-Adjusting Setup System. Case Study of Aluminum Rims Production**. Chung Yuan Christian University, Taiwan. 104 p.

CHIARINI, ANDREA; BELVEDERE, VALERIA; GRANDO, ALBERTO. (2020). "Industry 4.0 Strategies and Technological Developments. An Exploratory Research from Italian Manufacturing Companies." **Production Planning and Control 0** (0), p. 1-14. Disponível em: https://doi:10.1080/09537287.2019.1710304.

COJOCARU, T. M.; IONESCU, G. H.; FIROIU, D.; CISMAȘ, L. M.; OȚIL, M. D.; TOMA, O. (2022). "Reducing Inequalities within and among EU Countries. Assessing the Achievement of the 2030 Agenda for Sustainable Development Targets (SDG 10)." **Sustainability**, 14(13), p. 7706. Disponível em: https://doi.org/10.3390/su14137706.

CORBOȘ, RĂZVAN-ANDREI; BUNEA, OVIDIU-IULIAN; JIROVEANU, DANIEL-CONSTANTIN. (2023). "The Effects of Strategic Procurement 4.0 Performance on Organizational Competitiveness in the Circular Economy." **Logistics**, 7, n. 1, p. 13. Disponível em: https://doi.org/10.3390/logistics7010013.

CUI, Y., KARA, S., CHAN, KC, (2020). Manufacturing Big Data Ecosystem: A Systematic Literature Review. Robot. **Computer Integrated Manufacturing**, 62. Disponível em: https://doi.org/10.1016/j.rci.2019.101861. Acesso em: 15 abr. 2023.

CURREN, R. (2009). "Education as a Social Right in a Diverse Society." **Journal of Philosophy of Education**, 43 (1), p. 45-56.

DARWIN, C. (1859). On the Origin of Species by Means of Natural Selection, or Preservation of Favoured Races in the Struggle for Life. London: **John Murray**.

DELOITTE, REPORT. (2017). **The Future of Procurement in the Age of Digital. Supply Networks.** Disponível em: www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-cons-digital-procurement-v5.pdf. Acesso em: 12 jul. 2021.

DELOITTE AG. (2021). **Procurement in a Circular Economy. Benefits Beyond Sustainability.** Disponível em: https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/strategy-operations/deloitte-ch-en-procurement-in-a-circular-economy.pdf.

DEMESTICHAS, K.; DASKALAKIS, E. (2020). Information and Communication Technology Solutions for the Circular Economy. **Sustainability**, 12, p. 7272.

DETOMASI, D. (2014). "The Multinational Corporation as a Political Actor: 'Varieties of Capitalism' Revisited." **Journal of Bussiness Ethics**, 128, p. 685-700.

DEVERHUM. (2018). **Digitalização de compras: uma nova proposta de valor**. Disponível em: deverhum.com.br/blog/digitalizacao-de-compras-uma-nova-proposta-de-valor/. Acesso em: 1 ago. 2021.

DU PREEZ, P. (2012). "The Human Right to Education, the Ethical Responsibility of Curriculum, and the Irony in 'Safe Spaces'". In: **Safe Spaces,** Brill Sense, p. 51-62.

ELLEN MACARTHUR FOUNDATION. (2013). **Towards the Circular Economy, Economic and Business Rationale for an Accelerated Transition**. Ellen MacArthur Foundation, Cowes, United Kingdom.

FATORACHIAN, H.; KAZEMI, H. (2021). Impact of Industry 4.0 on Supply Chain Performance. **Production Planning & Control**, 32, p. 63-81.

FEGER, A. L. R. (2014). Creating Cross-Functional Strategic Consensus in Manufacturing Facilities. **International**, 34 (7), p. 941-97.

FREY, D. F.; MACNAUGHTON, G. (2016). **"A Human Rights Lens on Full Employment and Decent Work in the 2030 Sustainable Development Agenda SAGE Open"**, 6 (2), article 2158244016649580.

FRIEDMAN, THOMAS L. (2017). **Obrigado pelo atraso: um guia otimista para sobreviver em um mundo cada vez mais veloz**. Trad. Cláudio Figueiredo. 1a ed. Rio de Janeiro: Objetiva. Título original: Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations. ISBN 978-85-470-0044-8.

FRIELER, K.; MEINSHAUSEN, M.; GOLLY, A.; MENGEL, M.; LEBEK, K.; DONNER, S. D.; HOEGH-GULDBERG, O. (2013). Limiting Global Warming to 2on °C Is Unlikely to Save Most Coral Reefs. **Nature Climate Change,** vol. 3, issue 2, p. 165-170.

FRITZSCHE, K.; NIEHOFF, S.; BEIER, G. (2018). Industry 4.0 and Climate Change: Exploring the Science-Policy Gap. **Sustainability 10** (12). Disponível em: https://doi.org/10.3390/su10124511.

GAUSTAD, G.; KRYSTOFIK, M.; BUSTAMANTE, M.; BADAMI, K. (2018). "Circular Economy Strategies for Mitigating Critical Material Supply Issues." **Resources, Conservation and Recycling**, 135, p. 24-33. Disponível em: https://doi: 10.1016/j.resconrec.2017.08.002.

GBD GLOBAL BURDEN OF DISEASE. (2017). **"Global, Regional, and National Comparative Risk Assessment of 84 Behavioral, Environmental and Occupational, and Metabolic Risks or Clusters of Risks for 195 Countries and Territories, 1990-2017: A Systematic Analysis for the GBD Study 2017."** IHME. Disponível em: https://www.healthdata.org/research-article/global-regional-and-national-comparative-risk-assessment-84-behavioral-0. Acesso em: 12 nov. 2022.

GEISSDOERFER, M.; SAVAGET, P.; BOCKEN, N.; HULTINK, E. (2017). "The Circular Economy: A New Paradigm of Sustainability?" **Cleaner Journal**, 143(1), p. 757-768.

GHOBAKHLOO, M.; FATHI, M. (2020). Corporate Survival in the Industry 4.0 Era: Empowerment Role of Digitized Lean. **Journal of Manufacturing Technology Management, 31** (1), p. 1-30.

GLAS, A. H.; KLEEMANN, F. C. (2016). "The Impact of Industry 4.0 on Procurement and Supply Management: A Conceptual and Qualitative Analysis**.**" **International Journal of Business and Management Invention 5** (6), p. 55-66.

GLAVIČ, P. (2021). "Evolution and Current Challenges of Sustainable Consumption and Production." **Sustainability**, 13(16), p. 9379. Disponível em: https://doi.org/10.3390/su13169379.

GRANT, DAVID B. (2013). **Gestão de logística e cadeia de suprimentos**. Trad. Arlete Simille. São Paulo: Saraiva.

GRILLETTI, L. (2017). **Indústria 4.0: As oportunidades de negócio de uma revolução que está em curso**. In: Endeavor, ago. Disponível em: https://endeavor.org.br/tecnologia/industria-4-0-oportunidades-de-negocio-de-uma-revolucao-que-esta-em-curso/. Acesso em: 2 maio 2023.

GHISELLINI, P.; CIALIANI, C.; ULGIATI, S. (2016). A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. **Journal of Cleaner Production,** v. 114, p. 11-32. Disponível em: https://doi.org/10.1016/j.jclepro.2015.09.007. Acesso em: 1 dez. 2021.

GIL, ANTÔNIO CARLOS. (2002). **Como elaborar projetos de pesquisa**. 4. ed. São Paulo: Atlas, 2002. Bibliografia. ISBN 85-224-3169-8. Disponível em: https://files.cercomp.ufg.br/weby/up/150/o/Anexo_C1_como_elaborar_projeto_de_pesquisa_-_antonio_carlos_gil.pdf. Acesso em: 10 maio 2023.

GOMES, B. (2016). **Indústria 4.0.** Disponível em: http://www.firjan.com.br/lumis/portal/file/fileDownload.jsp?fileId=2C908A8A555B47FF01557D8802C639A4&inline=1. Acesso em: 27 abr. 2022.

GUARNIERI, P., AND GOMES, R. C. (2019). Can Public Procurement Be Strategic? A Future Agenda Proposition. **Journal of Public Procurement**. Disponível em: https://doi:10.1108/JOPP-09-2018-0032.

HAGENAARS, A. J. (2014). The Perception of Poverty. **Elsevier**, reprint. ISBN 1483296350, 9781483296357, 318 p.

HALKOS, G.; GKAMPOURA, E. C. (2021). "Where do We Stand on the 17 Sustainable Development Goals? An Overview on Progress." **Economic Analysis and Policy**, vol. 70, jun. 2021, p. 94-122.

HALLEGATTE S, R. J.; ROZENBERG, J. (2019). Lifelines: **The Resilient Infrastructure** Opportunity. World Bank Group. International Bank for Reconstruction and Development. The World Bank. 1818 H Street NW, Washington, DC 20433. Disponível em: www.worldbank.org. Acesso em: 2 abr. 2023.

HENKE, M., SCHULTE, A. T. (2015). **Einkauf und die 4. Industrielle Revolution**. Disponível em: https://beschaffung-aktuell.industrie.de/allgemein/einkauf-und-die-4-industrielle-revolution/. Acesso em: 4 mar. 2023.

HERMANN, M.; PENTEK, T.; OTTO, B. **Design Principles for Industrie 4.0 Scenarios: A Literature Review.** Dortmund: Technische Universität Dortmund, 2015. Working Paper, n. 1.

HOFMANN, E.; RUSCH, M. (2017). Industry 4.0 and the Current Status as well as Future Prospects on Logistics. **Computers in Industry**. Elsevier. Disponível em: https://doi.org/10.1016/j.compind.2017.04.002. Acesso em:15 abr. 2023.

HOLTHUS, P.; COUNCIL, M. A. (1999). **"Sustainable Development of Oceans and Coasts: The Role of the Private Sector."** Butterworths. In: Natural Resources Forum, 23, p. 169-176.

HOPE, S. R. K. R. (2019). "Peace, Justice and Inclusive Institutions: Overcoming Challenges to the Implementation of Sustainable Development Goal 16". **Global Change Peace & Security**, 32(1), p. 1-21.

HUGHES, T. P.; BARNES, M. L.; BELLWOOD, D. R.; CINNER, J. E.; CUMMING, G. S.; JACKSON, J. B.; KLEYPAS, J.; VAN DE LEEMPUT, I. A.; LOUGH, J. M.; MORRISON, T. H. et al. (2017). "Coral Reefs in the Anthropocene." **Nature**, 546 (7656), p. 82-90. Disponível em: 10.1038/nature22901.

IEEE (2014). The Institute of Electrical and Electronics Engineers. **Ieee Smart Cities**. Disponível em: http://smartcities.ieee.org/about.html. Acesso em: 11 abr. 2022.

IVANOV, DMITRY; DOLGUI, ALEXANDRE. (2020). “A Digital Supply Chain Twin for Managing the Disruption Risks and Resilience in the Era of Industry 4.0.” **Production Planning & Control 0** (0), p. 1-14. Disponível em: https://doi:10.1080/09537287.2020.1768450.

JAHANI, N.; SEPEHRI, A.; VANDCHALI, H. R.; TIRKOLAEE, E. B. (2021). Application of Industry 4.0 in the Procurement Processes of Supply Chains: A Systematic Literature Review. **Sustainability**, 13, p. 7520. Disponível em: https://doi.org/10.3390/su13147520.

JESUS, A.; ANTUNES, P.; SANTOS, R.; MENDONÇA, S. (2018). Eco-Innovation in the Transition to a Circular Economy: An Analytical Literature Review. **Journal of Cleaner Production**, 172, p. 2999 e 3018.

JOSS, S. (2015). **Sustainable Cities: Governing for Urban Innovation**. Palgrave Macmillan. ISBN: 978-0-333-71703 (hardback); 978-0-333-69346-9.

KAGERMANNa, H.; WAHLSTER, W.; HELBIG, J. (2013). **Recommendations for Implementing the Strategic Initiative Industrie 4.0: Final Report of the Industrie 4.0. Working Group.** Acatech – National Academy of Science and Engineering. Frankfurt, Germany.

KAGERMANNb, H. WAHLSTER, W. HELBIG, J. (2013). **Securing the future of german manufacturing industry: recommendations for implementing the strategic initiative industrie 4.0.** Acatech, National Academy of Science and Engineering. Frankfurt, Germany.

KANBUR R.; RHEE, C.; ZHUANG, J. (2014). **Inequality in Asia and the Pacific: Trends, Drivers, and Policy Implications**. Routledge is an imprint of the Taylor & Francis Group.

KAPUSTINA, LARISA M.; CHOVANCOVÁ, MÁRIA; KLAPITA, VLADIMIR (2017). Application of Specific Theory of Constraints Technique for the Identification of Main Causes of Negative Consequences within Procurement Logistics. **LOGI – Scientific Journal on Transport and Logistics**, vol. 8, n. 1. Disponível em: https://doi.10.1515/logi-2017-0007.

KUSIAK, A., (2018). Smart Manufacturing. **International Journal of Production Research**, 56 (1-2), p. 508-517. Disponível em: https://doi=10.1080/00207543.2017.1351644.

LIMA, JOSÉ CARLOS DE SOUZA. (2011). **Um estudo sobre a reconfiguração da função compras em empresas do setor automotivo.** ISBN:978-85-7893-864-2. Disponível em: www.Biblioteca24horas.com. 1a ed. São Paulo, SP.

LORBER J. (2001). Gender Inequality. Los Angeles, CA: Roxbury. LOVELOCK, J. E.; RAPLEY, C. G. (2007). “Ocean Pipes Could Help the Earth to Cure Itself.” **Nature**, 449 (7161), p. 403.

LOW, J. S. C.; NG, Y. T. (2018). “Improving the Economic Performance of Remanufacturing Systems through Flexible Design Strategies: A Case Study Based on Remanufacturing Laptop

Computers for the Cambodian Market." **Business Strategy and the Environment**, 27 (4), p. 503-527. Disponível em: https://doi:10.1002/bse.2017.

MAJEED, A. A.; RUPASINGHE, T. D. (2017). Internet of Things (IoT) Embedded Future Supply Chains for Industry 4.0: An Assessment from an ERP-Based Fashion Apparel and Footwear Industry. Int. J. Supply Chain Manage, 6 (1), p. 25-40.

MIN, H. (2010). Artificial Intelligence in Supply Chain Management: Theory and Applications. Int. J. Logist. Res. Appl. 13, p. 13-39.

MOEUF, A.; PELLERIN, R.; LAMOURI, S.; TAMAYO-GIRALDO, S.; BARBARAY, R. (2018). The S. Bag, et al. Resources, Conservation & Recycling 152 (2020) 104502 13 Industrial Management of SMEs in the Era of Industry 4.0. Int. J. Prod. Res. 56 (3), p. 1118-1113.

MOKTADIR, MD ABDUL; AHMADI, HADI BADRI; SULTANA, RAZIA; ZOHRA, FATEMA-TUJ; LIOU, JAMES J. H.; REZAEI, JAFAR. (2020). "Circular Economy Practices in the Leather Industry: A Practical Step Towards Sustainable Development." **Journal of Cleaner Production**, 251, p. 119737. Disponível em: https://doi:10. 1016/j.jclepro.2019.119737.

MOURA, G. B.; & SAROLI, L. G. (2021). Sustainable Value Chain Management Based on Dynamic Capabilities in Small and Medium-Sized Enterprises (SMEs). **International Journal of Logistics Management**, 32(1), p. 168-189.

NAKAMURA, J. S.; DELANEY, S. W.; DIENER, E.; VANDER VANDERWEELE, T. J.; KIM, E. S. (2022). "Are All Domains of Life Satisfaction Equal? Differential Associations with Health and Well-Being in Older Adults." **Quality of Life Research**, v. 31, p.1043-1056.

NICOLETTI B. (2018). The Future: Procurement 4.0. **Agile Procurement**, vol. II. Disponível em: https://doi.10.1007/978-3-319-61085-6_8.

NICOLETTI B. (2020). Procurement 4.0 and the Fourth Industrial Revolution. Palgrave Macmillan, Cham. Disponível em: https://doi.org/10.1007/978-3.

NIZAMI, N.; PRASAD, N. (2017). Decent Work: Concept, Theory, and Measurement. Palgrave Macmillan, Singapore.

OJIAMBO, P. O. (2009). "Quality of Education and its Role in National Development: A Case Study of Kenya's Educational Reforms." Kenya Stud. Rev., 1 (1), p. 133-149.

ONUd, (1992). United Nations. United Nations Framework Convention on Climate Change. United Nations, New York.

OWENS, GREGORY; VIDAL, OLIVER; TOOLE, RICK; FAVRE, DONOVAN. (1998). "Strategic Sourcing: Aligning Procurement Needs with Your Business Goals." In: John Gattorna (ed.), **Strategic Supply Chain Alignment: Best Practice in Supply Chain Management**. Hampshire, England: Gower, p. 286.

PANDEY, U. C.; KUMAR, C.; AYANORE, M.; SHALABY, H. R. (2020). "SDG10 – Reduce Inequality Within and Among Countries". Emerald Group Publishing.

PEARCE, D.; TURNER, R. K. (1990). Economics of Natural Resources and the Environment. Baltimore: Johns Hopkins University Press.

PELLENGAHR, KAROLIN; SCHULTE, AXEL T; RICHARD, JUDITH; BERG, MATTHIAS. (2016). Pilot Study on Procurement 4.0: The Digitalisation of Procurement. Fraunhofer iml und bme e.v. Disponível em: www.iml.fraunhofer.de/content/dam/iml/en/documents/oe260/pilot%20study_procurement%204-0_fraunhofer%20iml_bme.pdf. Acesso em: 17 jul. 2021.

POLLICE, FABIO; BATOCCHIO, ANTONIO. **The New Role of Procurement in a Circular Economy System**. (2018). 22nd Cambridge International Manufacturing Symposium University of Cambridge, 27-28 September. Disponível em: https://doi.org/10.17863/CAM.31713. Acesso em: 15 mar. 2023.

QUEIROZ, MACIEL M.; TELLES, RENATO; BONILLA, SILVIA H. (2019). "Blockchain and Supply Chain Management Integration: A Systematic Review of the Literature." **Supply Chain Management: An International Journal**, 25 (2), p. 241-254. Disponível em: https://doi:10.1108/SCM-03-2018-0143.

RANIS, G.; STEWART, F.; RAMIREZ, A. (2000). Economic Growth and Human Development. **World Development**, 28 (2), p. 197-219.

RAVALLION, M. "On Measuring Global Poverty." **Annual Review of Economics**, vol. 12, p. 167-188 (volume publication date August 2020). First published as a Review in Advance on June 10, 2020. Disponível em: https://doi.org/10.1146/annurev-economics-081919-022924.

RIBEIRO, F. M.; KRUGLIANSKAS, I. A. (2014). Economia circular no contexto europeu: conceito e potenciais de contribuição na modernização das políticas de resíduos sólidos. In: Encontro Internacional sobre Gestão Empresarial e Meio Ambiente, 16. São Paulo, anais [...]. São Paulo: FEA/USP, 2014. p. 1-16.

RODRIGUES, LETICIA FRANCISCHINI; JESUS, RODRIGO AGUIAR DE; SCHÜTZER, KLAUS. (2016). Industrie 4.0: uma revisão da literatura. **Revista de Ciência & Tecnologia**, Piracicaba, p. 1-13. Disponível em: https://www.metodista.br/revistas/revistas-unimep/index.php/cienciatecnologia/article/viewFile/3176/1899. Acesso em: 31 mars. 2023.

ROSIN, FRÉDÉRIC; FORGET, PASCAL; LAMOURI, SAMIR; PELLERIN, ROBERT. (2020). Impacts of Industry 4.0 Technologies on Lean Principles. **International Journal of Production Research**, 58:6, p. 1644-1661. Disponível em: https://doi.10.1080/00207543.2019.1672902.

SABERI, S.; KOUHIZADEH, M.; SARKIS, J.; SHEN, L. (2019). Blockchain Technology and its Relationships to Sustainable Supply Chain Management. Int. J. Prod. Res. 57, p. 2117-2135.

SACOMANO, JOSÉ BENEDITO et al.; LIMA, ALESSANDRO WENDEL BORGES et al. (2018). **Indústria 4.0: conceitos e fundamentos**. São Paulo: Blucher.

SAFRIEL, U. (2018). Land Degradation Neutrality (LDN) in Drylands and Beyond: Where Has it Come from and Where Does It Go. **Silva Fennica**, 51 (1B), p. 20-24.

SÁTYRO, WC et al. (2019). Implementação da Indústria 4.0 na Alemanha, Brasil e Portugal: barreiras e benefícios. In: Ameri, F.; Stecke, K.; Von Cieminski, G.; Kiritsis, D. (eds.). Advances in Production Management Systems. Em direção a sistemas inteligentes de gerenciamento de produção. APMS, 2019. Ifip Advances in Information and Communication Technology, vol. 567. Springer, Cham.

SÁTYRO, WALTER CARDOSO; ALMEIDA, CECÍLIA MARIA VILLAS BÔAS DE; PINTO JR., MARCOS JOSÉ A.; CONTADOR; JOSÉ CELSO; GIANNETTI, BIAGIO F.; FERREIRA DE LIMA, ANDERSON; FRAGOMENI, MARCO AURELIO. (2022). Industry 4.0 Implementation: The Relevance of Sustainability and the Potential Social Impact in a Developing Country. **Journal of Cleaner Production**, vol. 337, p. 130456. ISSN 0959-6526. Disponível em: https://doi.org/10.1016/j.jclepro.2022.130456.

SHARMA, NAMYA; KALBAR, PRADIP P.; SALMAN, MUHAMMAD. (2022). Global Review of Circular Economy and Life Cycle Thinking in Building Demolition Waste Management: A Way Ahead for India. **Building and Environment**, vol. 222, p. 109413. ISSN 0360-1323. Disponível em: https://doi.org/10.1016/j.buildenv.2022.109413. Acesso em: 16 mar. 2023.

SCHRAUF, S.; BERTTRAM, P. (2018). **Industry 4.0: Global Digital Operations 2018 Survey.** Disponível em: https://www.strategyand.pwc.com/gx/en/insights/industry4-0.html. Acesso em 2 mar. 2023.

SCHREIBER, BERND; ROLF, JANSSEN; WEAVER, STEPHAN; STEPFAN, PEINTNER. (2016). Procurement 4.0 in the Digital World. Disponível em: https://www.adlittle.com/en/insights/viewpoints/procurement-40-digital-world. Acesso em: 21 jul. 2021.

SCHROEDER, ANDREAS; BIGDELI, ALI ZIAEE; ZARCO, CARLOS GALERA; BAINES,

TIM. (2019). “Capturing the Benefits of Industry 4.0: A Business Network Perspective.” **Production Planning & Control 30** (16), p. 1305-1321. Disponível em: https://doi:10.1080/09537287.2019.1612111.

SCHROEDER, P.; ANGGRAENI, K.; WEBER, U. (2018). The Relevance of Circular Economy Practices to the Sustainable Development Goals. **Journal of Industrial Ecology**. Disponível em: https://1-1.DOI:10.1111/jiec.12732.

SCHULLER, T.; PRESTON, J.; HAMMOND, C.; BRASSETT-GRUNDY, A.; BYNNER, J. (2004). The Benefits of Learning: The Impact of Education on Health, Family Life and Social Capital. Routledge.

SCHWAB, KLAUS. (2017). The Fourth Industrial Revolution. London, United Kingdom: Currency.

SONY, MICHAEL; NAIK, SUBHASH. (2019b). “Key Ingredients for Evaluating Industry 4.0 Readiness for Organizations: A Literature Review.” **Benchmarking: An International Journal,** January, BIJ-09-2018-0284. Disponível em: https://doi:10.1108/BIJ-09-2018-0284.

SRAI, J. S.; LORENTZ, H. (2018). Developing Design Principles for the Digitalisation of Purchasing and Supply Management. J. Purchas. Supply Manage. Disponível em: https://doi.org/10. 1016/j.pursup.2018.07.001.

STEFFEN, W.; ROCKSTRÖM, R. J. K.; LENTON, T. M.; FOLKE, C.; LIVERMAN, D.; SUMMERHAYES, C. P.; BARNOSKY, A. D.; CORNELL, S. E.; CRUCIFIX, J. F.; DONGES, I.; FETZER, S. J.; LADE, M.; SCHEFFER, R.; WINKELMANN, H. J. S. (2018). “Trajectories of the Earth System in the Anthropocene”. **Proc. Natl. Acad. Sci.**, 115 (33), p. 8252-8259. Disponível em: 10.1073/pnas.1810141115.

STENTOFT, JAN; WICKSTRØM, KENT ADSBØLL; PHILIPSEN, KRISTIAN; HAUG, ANDERS. (2020). “Drivers and Barriers for Industry 4.0 Readiness and Practice: Empirical Evidence from Small and Medium-Sized Manufacturers.” **Production Planning and Control** 0 (0), p. 1-18. Disponível em: https://doi:10.1080/09537287.2020.1768318.

STOTT, L.; MURPHY, D. F. (2020). “An Inclusive Approach to Partnerships for the SDGs: Using a relationship lens to Explore the Potential for Transformational Collaboration.” **Sustainability**. Disponível em: https://doi.org/10.3390/su12197905.

STRUBLE, M. B.; AOMARI, L. L. (2003). “Position of the World Dietetic Association: Addressing World Hunger, Malnutrition, and Food Insecurity.” **J. Acad. Nutr. Diet.**, 103 (8), p. 1046.

SUNDERMANN, F. (2013). Einkauf 4.0: Einsparungen durch Zusammenarbeit von Einkauf und Technik. **Pool4Tool** (11), p. 24-28.

SUPPORTE. (2019). ***Procurement*: o setor que vai além das compras**. Disponível em: www.supportelogistica.com.br/blog/procurement-o-setor-que-vai-alem-das-compras/. Acesso em: 20 jul. 2021.

THOMSEN, C. (2013). Sustainability (World Commission on Environment and Development Definition). In: Idowu, S. O.; Capaldi, N.; Zu, L.; Gupta, A. D. (eds.). Encyclopedia of Corporate Social Responsibility. Springer, Berlin, Heidelberg. Disponível em: https://doi.org/10.1007/978-3-642-28036-8_531.

TORTAJADA, C.; BISWAS, A. K. (2018). "Achieving Universal Access to Clean Water and Sanitation in an Era of Water Scarcity: Strengthening Contributions from Academia." **Curr. opin. environ. sustain.**, 34, p. 21-25.

TOV, W. (2018). Well-Being Concepts and Components, Handbook of Subjective Well-Being, p. 1-15.

TSENG, M. L.; TAN, R. R.; SIRIBAN-MANALANG, A. B. (2013). "Sustainable Consumption and Production for Asia: Sustainability Through Green Design and Practice." **J. Cleaner Prod.**, 40, p. 1-5.

TUKKER, A.; EMMERT, S.; CHARTER, M.; VEZZOLI, C.; STO, E.; ANDERSEN, M. M.; GEERKEN, T.; TISCHNER, U.; LAHLOU, S. (2008). "Fostering Change to Sustainable Consumption and Production: An Evidence-Based View." **J. Cleaner Prod.**, 16 (11), p. 1218-1225.

UNDP. (2017). Human Development Report 2011, United Nations Development Program, New York.

VALLEJO, L.; MULLAN, M. (2017). Climate-Resilient Infrastructure: Getting the Policies Right.

VARELA, L.; ARAÚJO, A.; ÁVILA, P.; CASTRO, H.; PUTNIK, G. (2019). Evaluation of the Relation between Lean Manufacturing, Industry 4.0, and Sustainability. **Sustentability,** 11 (5). Disponível em: https://doi.org/10.3390/su11051439.

WAGIRE, ANIRUDDHA ANIL; ROHIT, JOSHI AJAY; RATHORE, PAL SINGH; JAIN, RAKESH. (2020). "Development of Maturity Model for Assessing the Implementation of Industry 4.0: Learning from Theory and Practice." **Production Planning and Control** 0 (0), p. 1-20. Disponível em: https://doi:10.1080/09537287.2020.1744763.

WAIBEL, W., L. P. STEENKAMP, N. MOLOKO, G. A. OOSTHUIZEN (2017). Investigating the Effects of Smart Production Systems on Sustainability Elements. **Procedia Manufacturing,** vol. 8, p. 731-737. Disponível em: https://doi.org/10.1016/j.promfg.2017.02.094.

WAMBA, SAMUEL FOSSO; QUEIROZ, MACIEL M. (2022). Industry 4.0 and the Supply Chain Digitalisation: A Blockchain Diffusion Perspective. **Production Planning & Control. The Management of Operations**, vol. 33, issue 2-3: Towards the Next Generation of Manufacturing: Implications of Big Data and Digitalization in the Context of Industry 4.0, p. 193-210. Disponível em:https://doi.org/10.1080/09537287.2020.1810756.

WANNER, J.; HEINRICH, K.; JANIESCH, C.; ZSCHECH, P. (2020). How Much AI Do You Require? Decision Factors for Adopting AI Technology. In: **Proceedings of the Forty-First International Conference on Information Systems,** December 2020, online, p. 13-16.

WEELE, A. V. (2002). **Purchasing and Supply Chain Management: Analysis, Planning and Practice**. Thompson.

WEETMAN, CATHERINE. (2017). **A Circular Economy Handbook for Business and Supply Chains: Repair, Remake, Redesign, Rethink**. 1a. ed. Kogan Page. ISBN 13 978-0749476755.

WEISSBARTH, ROBERT; GEISSBAUER, REINHARD; WETZSTEIN, JURGEN. (2016). Procurement 4.0: Are You Ready for the Digital Revolution? Disponível em: https://www.strategyand.pwc.com/report/procurement-4-digital-revolution. Acesso em: 20 abr. 2019.

WESLEY, H.; TITTLE, V.; SEITA, A. (2016). "No Health without Peace: Why SDG 16 Is Essential for Health Lancet", 388 (10058), p. 2352-2353.

WHO. (1946). Preamble to the Constitution of the World Health Organization as Adopted by the International Health Conference (adopted in June 19-22, 1946; signed on July 22, 1946; and entered into force on April 7, 1948). New York.

WISNER, J. D.; TAN, K. C.; LEONG, G. K. (2017). **Principles of Supply Chain Management: A Balanced Approach**. Boston: Cengage.

WITJES, S; LOZANO, R. (2016). "Towards a More Circular Economy: Proposing a Framework Linking Sustainable Public Procurement and Sustainable Business Models". **Resources, Conservation and Recycling**, vol. 112, p. 37-44.

WORLD ECONOMIC FORUM, DXC TECHNOLOGY. (2022). **5 Circular Economy Business Models that Offer a competitive advantage.** Disponível em: https://www.weforum.org/agenda/2022/01/5-circular-economy-business-models-competitive-advantage/.

WRIGHT, G.; SCHMIDT, S.; ROCHETTE, J.; SHACKEROFF, J.; UNGER, S.; WAWERU, Y.; MÜLLER, A. (2017). "Partnering for a Sustainable Ocean: The Role of Regional Ocean Governance in Implementing SDG14". Prog: Iddri, Iass, TMG & UN Environment.

YANG, Y.; LIU, B.; WANG, P.; CHEN, W. Q.; SMITH, T. M. (2020). “Toward Sustainable Climate Change Adaptation.” **J. Ind. Ecol.**, 24 (2), p. 318-330.

ZANGIACOMI, ANDREA; PESSOT, ELENA; FORNASIERO, ROSANNA; BERTETTI, MASSIMILIANO; SACCO, MARCO. (2020). “Moving Towards Digitalization: A Multiple Case Study in Manufacturing.” **Production Planning & Control**, 31 (2-3), p. 143-157. Disponível em: https://doi:10.1080/09537287.2019.1631468.

## APÊNDICE

Questões do segundo artigo: "Procurement 4.0: A Survey of its Principles and Technologies in Use"

Questionnaire about the model dimensions:

1. Regarding the impact of digitization, in the MANAGEMENT dimension on organizational performance in your company's Procurement area, it is correct to state:
Artificial intelligence will be able to support my daily activities and decrease operational activities.
Artificial intelligence will take control of the decision-making process.
Big Data within the company's environment may be collected, analyzed, and processed to serve the purchasing area.
IOT – internet of things will help in transparency within the supply chain process.
Transparency and traceability in the process will strengthen the relationship between buyers and sellers and the trust between them.
The "purchasing" function will be a strategic interface to support organizational efficiency, effectiveness and possibly profit.
The Purchasing function will become a focal point of a strategy and innovation network and will support the creation of new business models, products, and services.
People and face-to-face meetings will continue to be important to build trust and relationships between companies.

2. In the PARTNERSHIP Dimension, what is the main challenge when you look at supplier interaction in your company?
Find products and services that are assertive in relation to the company's needs.
Improve Agility, Connectivity and Communication
Focus on Collaboration, Innovation, Know How and Loyalty
Include more Compliance, Transparency and Security in the processes.
Sustainable Operations

3. Regarding the barriers in the PROCESSES dimension, for the digitization of organizations and how to overcome them, it is correct to state:
The existing Infrastructure within my organization can support the digital transformation.
Job roles and/or new job tasks could be migrated or added to the new purchasing role.
Leadership management within my organization supports and encourages creativity and innovation.
My organization's suppliers are already included in the digital transformation process.
The communication structure within my company is lean and flexible.
My organization wants to implement digitization and has no doubts or uncertainties.
My organization has a risk management tool in place regarding digital transformation.
My organization has a clear digital strategy.
Employees in my organization have the resources and understanding to help with the digital

transformation.
Employees in my organization have the appropriate skills for digital transformation.

4. In the SYSTEMS and TECHNOLOGY dimension, the main disruptive digitaltechnologies that can make a difference in the purchasing area are Data in the cloud, big data and Analytics, Internet of Things, Blockchain and Cybersecurity and Horizontal and vertical integration of systems. What is thereach of your digital technologies currently in your company?
We use cloud data, promoting mobility and remote access to my applications.
We use data from Big Data and Analytics to generate new purchasing needs.
We use data captured through sensors and wi-fi interfaces through the internet of things togenerate new purchasing needs.
We use systems integration between the company, suppliers, and internal customers (marketplaces, purchasing systems, ERPs, VMI, etc.)
We use blockchain technology in our digital contracts (digital signature)
We do not use any of the technologies described above.

5. In the SUSTAINABILITY Dimension, what is the main challenge when you look at supplier interaction in your company?
What criteria will be used when selecting suppliers?
How to audit sustainable practices
Which indicators will be used?
What is the understanding of sustainable practices in this buyer-supplier relationship?
Both factors

6. The research motivation is that in contrast to Industry 4.0, Procurement focused on the procurement process will be affected by the implementation of the tools of Ind. 4.0, and with this understanding the proposed Dimensions model is essential for the implementation of Procurement 4.0, (Skills, Management, Partnerships, Processes, Systems/Technologies and Sustainability) and also seeking to fill the gap in the literature, can the proposed model be beneficial in your company?

YES
NO

Questões do terceiro artigo: “The Procurement 4.0 Contributions to Circular Economy”

**Survey**
**Sobre o Procurement**
Sua participação nesta pesquisa dá-se em função de sua expertise na área de *Procurement*. Procuramos aqui aprofundar alguns conceitos básicos sobre *Procurement* e sua evolução para o *Procurement* 4.0, o qual incorpora tecnologias habilitadoras da Indústria 4.0. Consideramos que o *Procurement* envolve vários processos, incluindo a identificação das necessidades de aquisição, o estabelecimento de requisitos e especificações, a seleção de fornecedores, a

negociação de contratos e preços, a gestão de entregas e de qualidade, além do gerenciamento de riscos e conflitos. Admitimos como Funções do Procurement:

✓DESCOBERTA

Envolve a busca e seleção de fornecedores. Para escolher os melhores fornecedores é fundamental a definição de processos objetivos para avaliar, selecionar e acompanhar fornecedores que ofereçam produtos ou serviços de qualidade e preços consistentes com as necessidades.

✓NEGOCIAÇÃO

Estabelecimento de acordos, contratos, regras e parâmetros para o fornecimento, seja em relação a aspectos contratuais (prazos, preço, condições de pagamento), seja em relação aos aspectos intrínsecos do produto/serviço a ser fornecido (critérios de qualidade, embalagem, local de entrega etc.).

✓AQUISIÇÃO

Propõe indicadores de avaliação de desempenho de fornecedores, necessários para monitorar e garantir que os fornecedores estejam cumprindo os termos dos contratos. A aquisição define parâmetros e regras de conformidade para o setor de compras. Desta forma, a função aquisição pode ser entendida como uma função interna do *Procurement*.

2. Está de acordo com o preenchimento e autoriza a divulgação das respostas de forma anônima?
concordo
não concordo

3. O quanto você concorda que as funções básicas de *Procurement* são: descoberta, negociação, aquisição?
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

4. Considerando a função descoberta, ela envolve (pode assinalar mais de uma):
Catalogação de insumos necessários da organização
Busca e identificação de fornecedor para um determinado insumo
Determinação de escala e prazos de aquisição
Outras
Não considero descoberta uma função do *Procurement*

5. Entre as respostas escolhidas, você indicou outras?
Sim
Não

6. Quais?

7. Considerando a função negociação, ela envolve (pode assinalar mais de uma):
Definição das regras de preço
Definição de prazo
Definição de forma de entrega
Definição de embalagem

Definição de padrões de qualidade, conformidade
Definição de formas de pagamento com o fornecedor
Outras
Não considero negociação uma função do *Procurement*

8. Entre as respostas escolhidas, você indicou outras?
Sim
Não

9. Quais?

10. Considerando a função aquisição, ela envolve (pode assinalar mais de uma):
Padronização de preço e conformidade para o setor de compras
Funções como orçamentos e cotações
Ordens de serviço e administração dos contratos
Outras
Não considero aquisição uma função do *Procurement*

11. Entre as respostas escolhidas, você indicou outras?
Sim
Não

12. Quais?

13. O surgimento de ferramentas habilitadoras da Indústria 4.0 significou uma redução no tempo de conclusão do ciclo de compra, ao mesmo tempo que melhorou a qualidade dos dados analíticos, tão importantes no processo de Procurement. A gestão de fornecedores é papel fundamental para o sucesso, bem como a integração vertical e horizontal das empresas, com produção individualizada, sustentável, flexível e resiliente.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

14. Entre as tecnologias habilitadoras da Indústria 4.0, as principais utilizadas em *Procurement* 4.0 são (pode assinalar mais de uma):
*Big data analytics*
Internet das coisas
*Blockchain*
Sistemas ciberfísicos
Inteligência artificial
Integração digital
Robótica avançada
Outras

15. Entre as respostas escolhidas, você indicou outras?
Sim
Não

16. Quais?

17. Na área de *Procurement*, a utilização do *big data* é um elemento indispensável para lidar de maneira eficiente e eficaz com um grande volume de dados gerados a partir de sistemas ciberfísicos, sendo uma ferramenta essencial para a capacidade de processamento de dados em relação a velocidade, variedade e volume, além da obtenção de *insights* para tomada de decisões.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

18. A análise de dados envolve as atividades de coleta de dados de todas as fontes, externas e internas, com o intuito de otimizar a área de *Procurement*; as análises de dados são realizadas em um conjunto de tecnologias de *business intelligence*, possibilitando a detecção de padrões em grandes conjuntos de dados, para prever eventos futuros, prevendo fornecimento em tempo hábil, redução de estoques e operação enxuta.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

19. A internet das coisas é considerada uma das principais tecnologias habilitadoras da Indústria 4.0, pois garante a interconectividade entre elementos e dispositivos, possibilitando um ambiente transparente entre fornecedor e comprador, rastreabilidade e confiança, no que diz respeito à incorporação de dispositivos heterogêneos de diferentes participantes com diversas funcionalidades em uma rede unificada e em tempo real.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

20. O *blockchain* é uma tecnologia que consiste em um livro-razão descentralizado, distribuído em nós, garantindo o registro e o compartilhamento de dados de maneira segura, confiável e à prova de adulteração, por meio de criptografia. O *blockchain* pode trazer confiabilidade e rastreabilidade nas cadeias de fornecimento e relações de troca através de tokens e contratos inteligentes. Permite ainda descentralização e independência do sistema financeiro tradicional.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

21. Os sistemas ciberfísicos são responsáveis por integrar o mundo físico ao virtual, ressaltam a tomada de decisões de maneira descentralizada devido aos sistemas e definem a tecnologia como um sistema que utiliza sensores e atuadores para coletar dados físicos e atuar através da interação entre homem e máquina. O controle do estoque físico é uma das funções essenciais da área de *Procurement*.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

22. A inteligência artificial na área de *Procurement* pode ser aplicada à gestão de contratos e à descoberta automatizada de fornecedores, executando uma função de suporte para tarefas diárias de negócios que são administrativas e servindo de apoio para tomada de decisões.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

23. Com o *Procurement* 4.0, estabelece-se um processo digitalizado, que envolve atividades como: planejamento inteligente, autogeração online de requisições de compra, autosseleção de fornecedor, geração automática de ordens de compra, liberação automática de pedido de compra, envio automático do pedido para fornecedor, acompanhamento online de entregas e mercadorias, assinatura digital do comprovante de entrega, pagamento online e comprovante de pagamento enviado automaticamente ao fornecedor.
Concordo totalmente
Concordo parcialmente
Discordo parcialmente
Discordo totalmente

**Sobre a economia circular**
Figura 1. Diagrama de borboleta, modelo Cradle to Cradle, para compreensão do modelo da economia circular. Fonte: Ellen MacArthur Foundation, 2021. Obtido de https://senaies.com.br/news/economiacircular/.

2. Poderia começar comentando um pouco sobre a sua atuação:
Profissional do mercado
Pesquisador na academia
Outros

3. Qual?

4. Entre os conceitos e tecnologias habilitadoras da Indústria 4.0, quais oferecem potencial para auxiliar na economia circular (pode assinalar mais de uma):
*Big data analytics*
Internet das coisas
*Blockchain*
Sistemas ciberfísicos
Inteligência artificial
Integração vertical e horizontal
Customização em massa
Robótica avançada
Outras

5. Entre as alternativas escolhidas, foi selecionado “Outras”?
Sim
Não

6. Qual?

7. A mudança da economia linear para a economia circular enfrenta algumas barreiras, que podem ser classificadas em quatro grandes grupos: barreiras técnico-produtivas e de processos, barreiras econômicas e de mercado, barreiras regulatórias, fatores sociais. A utilização de conceitos e tecnologias habilitadoras da Indústria 4.0 para a superação dessas barreiras é:
Fundamental
Importante
Irrelevante
Atrapalha/prejudica

8. Considerando o ciclo compartilhar na implementação de processos circulares na indústria, entendida aqui como o consumidor final de máquinas e equipamentos, a descoberta de parceiros dispostos a compartilhar recursos produtivos é:
Muito fácil
Pouco fácil
Pouco difícil
Muito difícil

9. Considerando o ciclo manter/prolongar na implementação de processos circulares na indústria, a descoberta de serviços de manutenção é:
Muito fácil
Pouco fácil
Pouco difícil
Muito difícil

10. Considerando o ciclo reutilizar/redistribuir na implementação de processos circulares na indústria, a negociação com o fabricante do produto manufaturado é:
Muito fácil
Pouco fácil
Pouco difícil
Muito difícil

11. Considerando o ciclo reutilizar/redistribuir na implementação de processos circulares na indústria, a negociação com o distribuidor do produto manufaturado é:
Muito fácil
Pouco fácil
Pouco difícil
Muito difícil

12. Considerando o ciclo remanufaturar na implementação de processos circulares na indústria, a descoberta de serviçosde recondicionamento com o envolvimento do fabricante é:
Muito fácil
Pouco fácil
Pouco difícil
Muito difícil

13. Considerando o ciclo remanufaturar na implementação de processos circulares na indústria, a negociação com o fabricante envolvendo contratos e licenças, peças de reposição etc. para recuperar ou remanufaturar equipamentos é:
Fundamental
Importante

Irrelevante
Atrapalha/prejudica

14. Considerando o ciclo reciclar na implementação de processos circulares na indústria, a descoberta de um fornecedor de material reciclado ou de uma organização capaz de coletar e reciclar resíduos e fornecê-los no volume necessário é:
Fundamental
Importante
Irrelevante
Atrapalha/prejudica

15. Considerando os quatro ciclos da economia circular, a adoção de regras e parâmetros internos da indústria para estabelecimento de fornecedores deve envolver (pode assinalar mais de uma):
Conformidade do fornecedor com a PNRS, Lei 12.305/2010
Responsabilidade social do fornecedor
Responsabilidade ambiental do fornecedor
Certificação ISO14000

16. Como você avalia a importância da área de *Procurement* para a economia circular?
Tem muito a contribuir
Tem pouco a contribuir
Irrelevante
Atrapalha/ prejudica

17. Considere algumas das possíveis aplicações das tecnologias habilitadoras da Indústria 4.0 para a economia circular e assinale seu potencial para contribuir com a economia circular.

| | Desconheço a tecnologia | Prejudicial | Nenhum potencial | Algum potencial | Muito potencial |
|---|---|---|---|---|---|
| Internet das coisas: possibilidade de rastrear um material ou equipamento ao longo de todo o ciclo de vida | ○ | ○ | ○ | ○ | ○ |
| Sistemas ciberfísicos: espelhamento digital de processos produtivos e logísticos para simulação ou acompanhamento e controle em tempo real | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| Interação com *big data analytics*: criação de valor através da extração de informação a partir de dados de produção, consumo e ciclos reversos | ○ | ○ | ○ | ○ | ○ |
| Inteligência artificial: descoberta automatizada de parceiros para fornecimento de materiais, equipamentos ou serviços, cotação de preços automatizada, identificação de resíduos | ○ | ○ | ○ | ○ | ○ |
| *Blockchain*: negociação automatizada com parceiros, estabelecimento de contratos digitais, criação de meios alternativos de pagamento e moedas sociais, rastreabilidade, segurança e preservação de registros transacionais | ○ | ○ | ○ | ○ | ○ |

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## PARECER CONSUBSTANCIADO DO CEP

**DADOS DO PROJETO DE PESQUISA**

**Título da Pesquisa:** Procurement 4.0: Desafios e Tendências
**Pesquisador:** Robson Bueno
**Área Temática:**
**Versão:** 1
**CAAE:** 56280921.0.0000.5512
**Instituição Proponente:** ASSOCIACAO UNIFICADA PAULISTA DE ENSINO RENOVADO OBJETIVO-
**Patrocinador Principal:** Financiamento Próprio

**DADOS DO PARECER**

**Número do Parecer:** 5.324.733

**Apresentação do Projeto:**
adequada

**Objetivo da Pesquisa:**
Explorar o fenômeno da Indústria 4.0 por meio da perspectiva do "Procurement 4.0", desenvolvendo um marco conceitual que envolve dimensões
dos impactos causados e que permita a categorização dos impactos em dimensões

**Avaliação dos Riscos e Benefícios:**
não há

**Comentários e Considerações sobre a Pesquisa:**
A pesquisa utiliza questionário e não fere princípios éticos

**Considerações sobre os Termos de apresentação obrigatória:**
adequado

**Recomendações:**
Não há

**Conclusões ou Pendências e Lista de Inadequações:**
Não há

**Considerações Finais a critério do CEP:**
Ressalta-se que cabe ao pesquisador responsável encaminhar os relatórios parciais e finais da

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**Bairro:** Vila Clementino **CEP:** 04.026-002
**UF:** SP **Município:** SAO PAULO
**Telefone:** (11)5586-4086 **E-mail:** cep@unip.br

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Continuação do Parecer: 5.324.733

pesquisa, por meio da Plataforma Brasil, via notificação do tipo "relatório" para que sejam devidamente apreciadas pelo CEP, conforme Norma Operacional CNS nr 001/12, item XI.2.d.

**Este parecer foi elaborado baseado nos documentos abaixo relacionados:**

| Tipo Documento | Arquivo | Postagem | Autor | Situação |
|---|---|---|---|---|
| Informações Básicas do Projeto | PB_INFORMAÇÕES_BASICAS_DO_PROJETO_1861390.pdf | 17/02/2022 10:33:01 | | Aceito |
| Outros | carta_de_apresentacao_do_projeto.pdf | 17/02/2022 09:50:49 | Robson Bueno | Aceito |
| Projeto Detalhado / Brochura Investigador | Projeto.docx | 17/02/2022 09:44:12 | Robson Bueno | Aceito |
| Folha de Rosto | FolhadeRosto.pdf | 15/02/2022 07:19:08 | Robson Bueno | Aceito |
| TCLE / Termos de Assentimento / Justificativa de Ausência | termo_de_autorizacao_para_pesquisa_em_prontuario.pdf | 19/11/2021 11:40:01 | Robson Bueno | Aceito |
| Declaração de concordância | termo_de_compromisso_do_pesquisador.pdf | 19/11/2021 11:38:12 | Robson Bueno | Aceito |
| Orçamento | orcamento_de_projeto_de_pesquisa.pdf | 19/11/2021 11:37:25 | Robson Bueno | Aceito |
| Declaração de Pesquisadores | intencao_de_pesquisa.pdf | 19/11/2021 11:26:28 | Robson Bueno | Aceito |

**Situação do Parecer:**
Aprovado

**Necessita Apreciação da CONEP:**
Não

SAO PAULO, 31 de Março de 2022

**Assinado por:**
**Bettina Gerken Brasil**
**(Coordenador(a))**

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