UNIVERSIDADE PAULISTA

INTERNET DE SERVIÇOS PARA INOVAÇÃO EM MODELOS DE NEGÓCIOS E TRANSFORMAÇÃO DIGITAL:

Aplicação para Indústria 4.0 e Agricultura 4.0

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

JACQUELINE ZONICHENN REIS

SÃO PAULO

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Orientador: Prof. Dr. Rodrigo Franco Gonçalves

Área de concentração: Gestão de Sistemas de Operação

Linha de Pesquisa: Redes de Empresas e Planejamento da Produção

Projeto de Pesquisa: Gestão do conhecimento e formação de núcleos e redes no empreendedorismo de inovação

JACQUELINE ZONICHENN REIS

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DEDICATÓRIA

Dedico este trabalho ao meu marido Fábio e ao meu filho Bernardo, por abdicarem da minha presença em vários momentos, mas por uma boa causa: a conclusão do meu doutorado.

À minha mãe Marieta (in memoriam) e ao meu pai Milton (in memoriam), por terem me deixado o maior legado que foi o incentivo aos estudos.

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EPÍGRAFE

Pode-se dizer que o trabalho científico é como a vida
Sempre parte de lacunas que precisam ser trabalhadas em uma questão de pesquisa
Cada um segue seu método para respondê-la e colhe seus resultados
Mas no final sempre fica a pergunta: "Afinal, qual foi minha contribuição"
Seja ela qual for, ela não se finda aqui; continua em trabalhos futuros

Jacqueline Zonichenn Reis

RESUMO

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. Na verdade, as tecnologias são de pouca valia se não estiverem fundamentadas em modelos de negócio apropriados que definam as suas estratégias de marketing e captura de valor. Uma das inovações tecnológicas, relevante por ser considerada um dos pilares da Indústria 4.0, é a Internet de Serviços. A Internet de Serviços pode ser definida como um ecossistema em que objetos inteligentes e serviços de diferentes provedores são encontrados, contratados, usados e remunerados on-line. Apesar da relevância do tema Internet de Serviços, ainda é escasso na literatura o estudo sobre um modelo de negócios correlato. Nesse contexto, esta tese tem por objetivo avaliar como a Internet de Serviços é utilizada para a transformação digital e inovação em modelos de negócio em diferentes setores econômicos, como a Indústria 4.0 e Agricultura 4.0. Trata-se de uma pesquisa exploratória, que utiliza a revisão sistemática da literatura para definir o estado-da-arte e criar um framework de modelos de negócio em Internet de Serviços. Somam-se à pesquisa teórica, estudos de casos múltiplos que exploram a aplicação da Internet de Serviços na Indústria 4.0 e a avaliação da criação de um modelo de negócios no campo da Agricultura 4.0. Como resultado, tem-se um esclarecimento do papel da Internet de Serviços, através da caracterização de suas subáreas e seus potenciais campos de aplicação. Além da contribuição teórica para a literatura, existe a contribuição prática, principalmente através do framework de modelos de negócios baseado em Internet de Serviços, que pode ser replicado em diversos contextos da transformação digital.

Palavras-chave: Internet de Serviços. Modelo de negócios. Transformação digital. Indústria 4.0. Agricultura 4.0.

ABSTRACT

While recent technological advances and digital transformation bring a range of new business potentials and opportunities, companies find themselves exposed to disruptive innovative technologies and forced to keep pace with the dynamic changes to remain competitive in the market. However, the mistake of many organizations is to believe that the simple adherence to a certain technological innovation is a guarantee of success. In fact, technologies do not worth if they are not grounded in appropriate business models that define their marketing and value capture strategies. One of the emerging technologies, important for being considered a pillar of the Industry 4.0, is the Internet of Services. The Internet of Services can be defined as a new business environment where intelligent objects and services from different providers are found, contracted, used, and remunerated online. Despite the relevance of the Internet of Services theme, the study of a related business model is still scarce in the literature. In this context, the present study aims to evaluate how the Internet of Services is used for digital transformation and business model innovation in different economic sectors such as Industry 4.0 and Agriculture 4.0. This is an exploratory research, which uses a systematic literature review to define the state-of-the-art and create a framework for business models in Internet of Services. Added to the theoretical research, multiple case studies have been carried to explore the application of the Internet of Services in Industry 4.0 and the evaluation of a business model construct in the field of Agriculture 4.0. As a result, there is a better understanding of the role of the Internet of Services, through the characterization of its sub-areas and its potential fields of application. In addition to the theoretical contribution to the literature, there is a practical contribution, mainly through the framework of business models based on the Internet of Services, which can be replicated in different contexts of digital transformation.

Key-words: Internet of Services. Business model. Digital transformation. Industry 4.0. Agriculture 4.0.

LISTA DE ABREVIAÇÕES, SIGLAS E SÍMBOLOS

IA – Inteligência Artificial

APP – *Application*

BM – *Business Model*

BMI – *Business Model Innovation*

CPS – *Cyber-Physical Systems*

ERP – *Enterprise Resource Planning*

ESB – *Enterprise Service Bus*

FINTECH – *Financial Technology*

IaaS – *Infrastructure-as-a-Service*

ICT – *Information and Communication Technology*

IoS – *Internet of Services*

IoT – *Internet of Things*

IT – *Information Technology*

OT – *Operational Technology*

MES – *Manufacturing Execution System*

MSB – *Manufacturing Service Bus*

OECD – *Organisation for Economic Co-operation and Development*

OPC UA – *Open Communication Standard*

PLC – *Programmable Logic Controller*

PPC – *Production Planning and Control*

RAMI 4.0 – *Reference Architectural Model Industrie 4.0*

QoE – *Quality of Experience*

QoS – *Quality of Service*

QoUE – Quality of User Experience

RFID – *Radio Frequency Identification*

SaaS – *Software-as-a-Service*

SOA – *Service-Oriented Architecture*

SOC – *Service-Oriented Computing*

SOMA – *Service-Oriented Manufacturing Architecture*

TI – Tecnologia da Informação

TIC – Tecnologia da Informação e Comunicação

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1.1 Contexto e problematização

O processo de inovação no século XXI se destaca pela rapidez dos avanços tecnológicos. A infraestrutura de Tecnologia da Informação e Comunicação (TIC) ganha um papel substancial em catalisar o crescimento econômico e a transformação digital, especialmente com um maior acesso à internet através das telecomunicações móveis (APPIAH-OTOO; SONG, 2021). Ghasemaghaei e Calic (2020) apontam que a velocidade dos dados passa a desempenhar um papel mais importante na melhoria do desempenho da inovação das empresas do que outras características, como o próprio volume de dados.

Com a crise causada pela pandemia do COVID-19, a transformação digital se intensificou, afetando desde o trabalho, que passou a ser remoto, até o atendimento on-line aos clientes, passando pela reinvenção da cadeia de suprimentos, uso de inteligência artificial (IA) e aprendizado de máquina para melhorar as operações. Tal disrupção criou espaço para empreendedores digitais, transformando a sociedade nas pequenas, médias e grandes economias (MCKINSEY & COMPANY, 2021).

O Banco Mundial (WORLD BANK, 2022) destaca que o impacto da crise do COVID-19 varia significativamente entre países e setores. Algumas áreas, como o turismo e o setor imobiliário, devem levar mais tempo para se recuperarem aos níveis pré-crise; enquanto áreas como *e-commerce*, serviços e tecnologia da informação já expandem suas participações relativas na economia.

A cada dia, novos softwares e soluções são desenvolvidos na internet, provendo serviços virtuais, conectando pessoas e objetos do mundo real. Tais serviços oriundos de múltiplas redes convergem em um ecossistema complexo chamado Internet de Serviços (IoS) (XU *et al.*, 2020).

A IoS tem sido abordada como um componente fundamental da Indústria 4.0 em conjunto com a Internet das Coisas (IoT) e os sistemas ciberfísicos (CPS) (ALCÁCER; CRUZ-MACHADO, 2019; HOFMANN; RÜSCH, 2017; KAGERMANN; WAHLSTER; HELBIG, 2013; SATYRO *et al.*, 2017). No entanto, ainda falta clareza sobre como estas tecnologias de fato contribuem para o processo de inovação na Indústria 4.0 (ALCÁCER; CRUZ-MACHADO, 2019).

Além disso, tanto na Indústria 4.0 como em outros setores, as aplicações de IoT e CPS vêm sendo bastante discutidas, enquanto a IoS ainda é pouco abordada. Em pesquisas relacionadas aos avanços da Agricultura 4.0, por exemplo, as tecnologias mais exploradas são o sensoriamento remoto e a rastreabilidade (KLERKX; JAKKU; LABARTHE, 2019). Entretanto, Lezoche *et al.* (2020) lembram que novos serviços poderiam surgir de uma integração nas cadeias agroalimentares, se uma plataforma integrada apoiasse seus vários participantes. Em um ambiente caracterizado pela inovação tecnológica, as ideias e os modelos de negócios tradicionais não trazem mais vantagens competitivas (SMITH, 2020).

Bouncken, Kraus e Roig-Tierno (2019) ressaltam que o desafio das empresas no processo de inovação consiste em integrar as diversas tecnologias digitais e a sua aplicação em novos modelos de negócio. Burstrõm *et al.* (2021) apontam dificuldade ainda maior quando tecnologias emergentes afetam indústrias já maduras e abordam desafios das indústrias de manufatura tradicionais ao integrar a inteligência artificial (AI). Com a presente tese, busca-se explorar tal questão no âmbito da IoS, ao avaliar como essa inovação pode ser aplicada nos campos da manufatura e da agricultura.

Saarikko, Westergren e Blomquist (2020) explicam que a aplicação adequada da tecnologia no conjunto de alternativas estratégicas e oportunidades de criação de valor que uma empresa pode adotar é o elo que a transformação digital busca integrar. No entanto, as mudanças digitais nas organizações, em suas práticas de negócios ou em seus produtos e serviços, acabam sendo tratadas como fins em si mesmas, quando deveriam ser meios para um fim.

Priyono, Darmawan e Witjaksono (2021) corroboram a ideia de que o erro de muitas organizações é acreditar que a simples adesão a uma determinada tecnologia é garantia de sucesso. Na verdade, as inovações tecnológicas são de pouco valor sem modelos de negócios apropriados. Um bom modelo de negócios pode até mesmo tornar uma tecnologia inferior mais bem-sucedida, dependendo de como for aplicada estrategicamente e agregar valor. “O design e a implementação de novos modelos de negócios têm o potencial de serem mais eficientes do que a própria inovação tecnológica” (TEECE, 2010).

Durante a ascensão da internet e dos negócios eletrônicos, em meados dos anos 1990, o termo “modelo de negócios” ou *“business model”* (BM) se tornou popular entre as organizações para definirem as suas estratégias de marketing e captura de valor. No início do século XXI, a necessidade de adaptação dos modelos de negócio pelas organizações e pelas diferentes indústrias, devido à constante evolução tecnológica, trouxe o novo termo “inovação de modelo de negócios” ou *“business model innovation”* (BMI) (FOSS; SAEBI, 2017).

Apesar das várias terminologias e da falta de uma taxonomia uniforme para a construção de um modelo de negócios, uma abordagem aceita tanto na literatura como na prática é o *Business Model Canvas,* desenvolvido por Osterwalder e Pigneur (2010) (GÜNZEL; HOLM, 2013; REMANE *et al.*, 2017). Sua representação de modelo de negócios pode ser descrita como um conjunto de nove blocos de construção inter-relacionados que abordam quatro metacomponentes, a saber: proposta de valor, criação de valor, entrega de valor e captura de valor (GÜNZEL; HOLM, 2013).

O Canvas foi utilizado por Dijkman *et al.* (2015) para propor aplicações no campo da IoT. Kerzel (2021) aplicou o Canvas para definir os aspectos relevantes ao integrar sistemas de AI em empresas, enquanto Fatima *et al.* (2021) fizeram o mesmo para aplicar AI no setor público. O Canvas foi utilizado como referência também em modelos de negócio para sustentabilidade (CARDEAL *et al.*, 2020) e economia circular (LÜDEKE- FREUND; GOLD; BOCKEN, 2019). Apesar da sua ampla utilização, o Canvas ainda não foi aplicado para avaliar um modelo de negócios baseado em IoS, e esse é um dos *gaps* que a presente tese procura explorar.

Ranta, Aarikka-Stenroos e Väisänen (2021) explicam que a pesquisa sobre modelo de negócios é ainda baseada em estudos conceituais e de revisão, levando a uma falta de compreensão de como as tecnologias digitais permitem que empresas individuais em ambientes da vida real melhorem seus fluxos de recursos e criação e captura de valor, para, assim, possibilitar o processo de BMI. As estratégias de transformação digital têm quatro dimensões essenciais: uso de tecnologias, mudanças na criação de valor, mudanças estruturais e aspectos financeiros; portanto, no processo de BMI, deve-se buscar identificar e concretizar elementos atribuídos a essas quatro dimensões (MATT; HESS; BENLIAN, 2015).

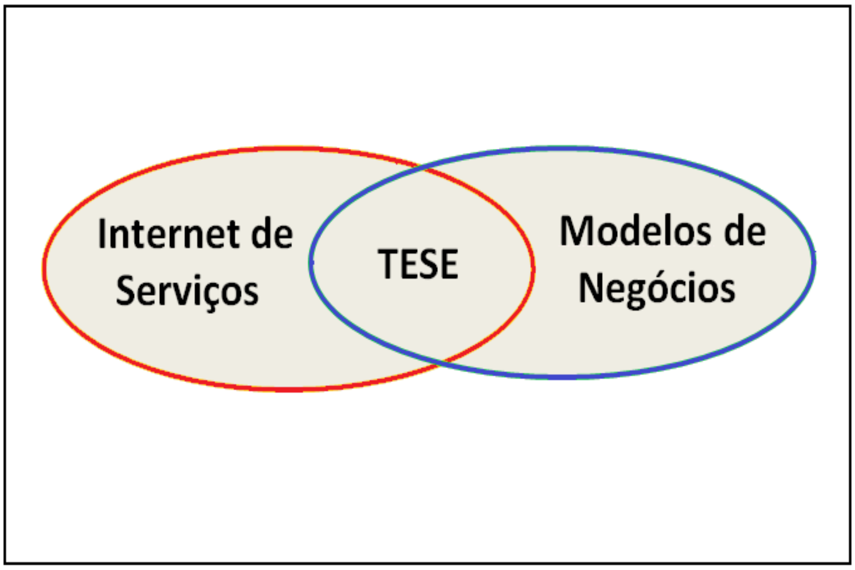
Priyono, Darmawan e Witjaksono (2021) sugerem que os recursos dentro e fora das organizações estejam conectados e disponíveis para serem mobilizados para apoiar o processo de BMI. Para permitir isso, a alta administração das empresas deve preparar os recursos necessários com antecedência. IoS pode fornecer soluções para tais desafios, porém a literatura correspondente também é escassa.

Embora falte um consenso na literatura sobre uma definição para IoS, ela pode ser compreendida como um novo ecossistema de negócios, em que serviços interorganizacionais são oferecidos e utilizados pelos participantes da cadeia de valor (HERMANN; PENTEK; OTTO, 2016).

Uma perspectiva de ecossistemas de serviços em modelos de negócios pode oferecer ricas implicações para a estratégia das empresas (WIELAND; HARTMANN; VARGO, 2017), porém pouco se sabe sobre como uma mudança em direção a modelos orientados a serviços afeta o modelo de negócios existente das empresas e qual seria a estrutura para apoiar o novo modelo de negócios (SCHIAVI; BEHR, 2018). Os desafios estão relacionados à adaptação dos modelos de negócios ao cenário de serviços, como a reconfiguração das cadeias de valor, a customização e as novas formas que os modelos de negócios vão adotar, e o compartilhamento de recursos na rede de empresas que operam em cadeias de abastecimento flexíveis (GRABOWSKA; GAJDZIK; SANIUK, 2020).

Apesar da relevância do tema Internet de Serviços, ainda é escasso na literatura o estudo sobre um modelo de negócios correlato. Há, ainda, espaço de estudo na área para uma melhor compreensão deste fenômeno e é esta lacuna que se busca explorar com a presente tese. A Figura 1 ilustra a delimitação do tema.

Figura 1 – Delimitação do tema de pesquisa



Fonte: Elaborada pela autora.

O ponto de partida da tese é a descrição da Internet de Serviços e do Modelo de Negócios como atores centrais, e, ao se explorar tal intersecção, busca-se contribuir para o entendimento da aplicação desta inovação.

1.2 Objetivos

O objetivo geral da pesquisa é avaliar como a Internet de Serviços é utilizada para inovação em modelos de negócio em diferentes setores econômicos, como a Indústria 4.0 e a Agricultura 4.0.

Para a realização do objetivo geral, a pesquisa foi dividida nos seguintes objetivos específicos:

1. Organizar uma agenda de pesquisa a partir do estado da arte sobre modelos de negócios baseados em Internet de Serviços;
2. Caracterizar os campos de aplicação da Internet de Serviços;
3. Avaliar como a Internet de Serviços pode ser aplicada na prática, para promover a flexibilidade dos processos produtivos na Indústria 4.0;
4. Propor um framework para criar um modelo de negócio baseado em Internet de Serviços na Agricultura 4.0.

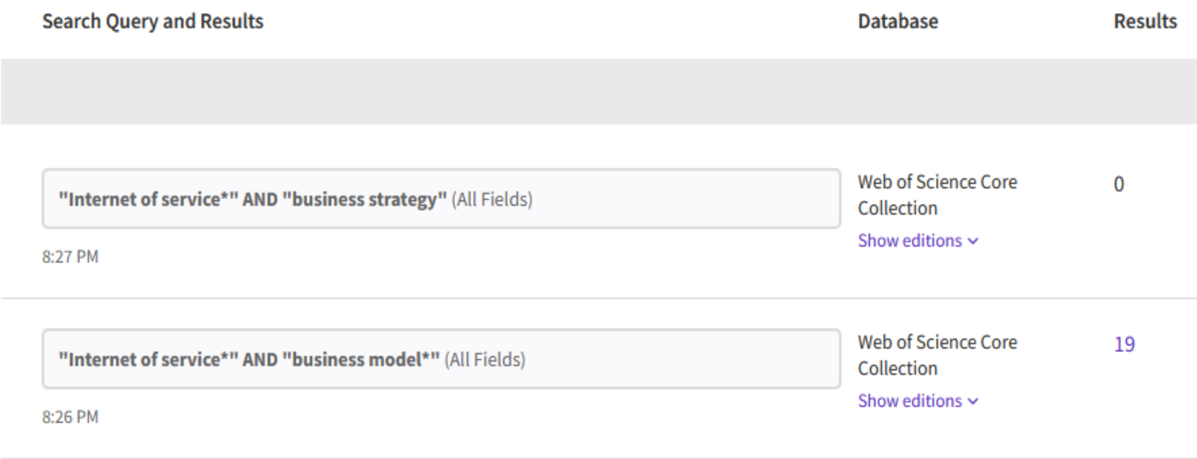
1.3 Justificativa

A transformação digital muda as formas de trabalho, funções e ofertas de negócios causadas pela adoção de tecnologias digitais, especialmente com o avanço da internet (APPIAH-OTOO; SONG, 2021; PRADHAN; MALLIK; BAGCHI, 2018).

A IoS é considerada, juntamente com IoT e CPS, um dos pilares fundamentais para a Indústria 4.0 (ALCÁCER; CRUZ-MACHADO, 2019; HOFMANN; RÜSCH, 2017). No artigo que registra o lançamento da Indústria 4.0 pelo Governo Alemão (KAGERMANN; WAHLSTER; HELBIG, 2013), a Internet de Serviços é colocada como um elemento-chave para a Indústria 4.0 e para a criação de novos modelos de negócio a partir desse novo paradigma. Apesar de o termo *Business Model* aparecer 25 vezes no artigo, existe um *gap* em abordar a relação direta entre esses dois temas, “Modelo de Negócios” e “Internet de Serviços”.

A escassez de artigos sobre modelos de negócios em IoS na literatura é evidenciada pelo baixo retorno de resultados nas principais bases da literatura científica. Como exemplo, tem-se na Figura 2 o resultado de busca na base *Web of Science* utilizando a string “Internet of Service*” AND “business model”. Na pesquisa feita em janeiro de 2022, o retorno foi de 19 artigos. Explorando também a “Internet de Serviços” com a string “Estratégia de Negócios”, nenhum resultado é obtido.

Figura 2 – Resultado da busca de pesquisa



Fonte: Elaborada pela autora.

Embora a internet seja o principal impulsionador do aumento do interesse nos modelos de negócios e do surgimento de uma literatura sobre o tema, a pesquisa sobre o modelo de negócios ainda é evasiva e não fornece discussões sistemáticas sobre os desafios que representa (FOSS; SAEBI, 2017). Devido à falta de ferramentas e métodos para auxiliar na concepção e no processo de BMI, profissionais geralmente seguem um método de experimentação de tentativa e erro (KING; GROBBELAAR, 2020). A mudança de um modelo orientado a produtos para um orientado a serviços leva a novas oportunidades de receita possíveis, mas também traz desafios durante a criação de novos modelos de negócios (SCHIAVI; BEHR, 2018).

King e Grobbelaar (2020) ressaltam que um modelo amplamente aceito e utilizado como ferramenta para a construção de modelos de negócios é o *Business Model Canvas.* Pesquisas futuras deveriam utilizar essa ferramenta como base para criação de novos modelos de negócios que expandam os modelos de digitalização e servitização, hoje mais centrados na organização e pouco projetados para a adoção de um ecossistema de serviços como a IoS (KING; GROBBELAAR, 2020).

Estudos podem promover a expansão da IoS em qualquer área, considerando que o domínio dos serviços não se restringe aos serviços mais tradicionais, como educação, hospitalidade e saúde. Também aparece em indústrias tradicionais orientadas para o produto, como a manufatura, o setor de construção e a agricultura.

Considerando os *gaps* e as propostas de pesquisas futuras encontrados na literatura, fica evidenciada a carência de um modelo de negócios baseado em IoS e como ele pode ser aplicado em diferentes campos de inovação.

1.4 Organização do trabalho

Este trabalho está dividido em capítulos da seguinte forma:

O Capítulo 1 apresenta a Introdução do trabalho, na qual os temas centrais do trabalho são contextualizados.

O Capítulo 2 traz a Fundamentação Teórica, apresentando a evolução e os conceitos dos temas principais.

O Capítulo 3 aborda a Metodologia utilizada na pesquisa. A tese é composta por artigos que buscam atender aos objetivos específicos propostos.

O Capítulo 4 apresenta a produção bibliográfica com os seguintes artigos em seu formato original de submissão e/ou publicação:

Artigo 1 – *"Business Models for the Internet of Services: State of the Art and Research Agenda"*

Artigo 2 – *"Using Internet of Services to stablish Service-Oriented Manufacturing Architecture model on Industry 4.0"*

Artigo 3 – *"Internet of Services-based business model – A case study in the livestock industry"*

O Capítulo 5 discute os resultados obtidos com a pesquisa.

O Capítulo 6 traz as conclusões.

2 REFERENCIAL TEÓRICO

2.1 Inovação

O conceito de inovação se tornou objeto de estudo e aplicação desde meados do século passado. Em 1942, o economista austríaco Joseph Schumpeter, em seu livro *Capitalismo, Socialismo e Democracia*, usou o termo “destruição criativa” para descrever a entrada inovadora dos empreendedores na formação de riqueza e no desenvolvimento econômico, destruindo, assim, o valor das empresas estabelecidas que se beneficiavam de algum poder de monopólio (SCHUMPETER, 1973).

A inovação passou, então, a ser referenciada como uma premissa para a manutenção da competitividade. Para Drucker (1987), mesmo as empresas de grande porte e bem estabelecidas precisam inovar para sobreviverem e prosperarem. Segundo Porter (1989), o sucesso de uma estratégia genérica no fornecimento de vantagem competitiva está em garantir que a cadeia de valor da empresa apoie com sucesso sua estratégia em agregar maior valor a seus produtos e serviços que os concorrentes. Porter (1993) acrescenta, ainda, que essa competitividade depende da capacidade da empresa de inovar. As empresas atingem a vantagem competitiva através das iniciativas de inovação, novas tecnologias e novas formas de execução.

À medida que a tecnologia substitui o trabalho braçal, os indivíduos buscam novas atividades produtivas. Em paralelo, as empresas buscam se firmar em áreas onde a produtividade e a lucratividade tem maior potencial fazendo com que novos modelos de negócios se expandam. O Manual de Oslo, de 2018, destaca que as empresas realizam constantemente mudanças em produto e processo e buscam novos conhecimentos. Inovações de produto são as que envolvem mudanças significativas nas potencialidades de produtos e serviços. Incluem-se bens e serviços totalmente novos e aperfeiçoamentos importantes para produtos existentes. Já as inovações de processo representam geralmente mudanças significativas nos métodos de produção e de distribuição (OECD; EUROSTAT, 2018).

Existem dois tipos de inovação com relação ao nível de disrupção: a radical e a incremental. A inovação radical engendra rupturas mais intensas, enquanto a incremental promove a continuidade do processo de mudança. A inovação radical consiste em uma transformação com características inéditas e com grande impacto que causa uma disrupção e onde o grau de incerteza ocorre em maior grau. Em um ambiente mais volátil, a empresa pode precisar introduzir rapidamente novos produtos, buscar novos mercados e introduzir novas tecnologias, métodos de produção e métodos organizacionais (SCHUMPETER, 1973).

A maior conscientização da importância da inovação fez com que ela fosse incluída não só na agenda dos gerentes de empresas, mas também na agenda política das cidades e dos países desenvolvidos. O desenvolvimento econômico, tradicionalmente medido apenas pela performance de multinacionais ou grandes corporações, atualmente se baseia também na abertura de pequenas e médias empresas e no fomento de novos negócios. Muitas startups e empresas estão melhor posicionadas no mercado por trabalharem com parcerias, sendo os clientes também verdadeiros parceiros no fomento à inovação (ROCHA; OLAVE; ORDONEZ, 2020).

2.2 Transformação digital

Com os avanços da Tecnologia da Informação e Comunicação (TIC) que se intensificam no início do século XXI, os efeitos na economia e no processo de transformação das empresas são constantes (APPIAH-OTOO; SONG, 2021). As novas formas de tecnologias que lidam com a transformação digital trazem profundas mudanças e afetam não só os modelos de negócios, produção, consumo, transporte e entrega, mas também os aspectos sociais e culturais da sociedade.

A transformação digital é definida como uma mudança nas formas de trabalho, funções e ofertas de negócios causadas pela adoção de tecnologias digitais em uma organização ou no ambiente operacional da organização (PARVIAINEN; TIHINEN, 2017).

Anteriormente, as estratégias digitais se concentravam no gerenciamento da infraestrutura de TI dentro de uma empresa, com impacto limitado na condução de inovações e no desenvolvimento de negócios. Isso porque as estratégias de TI apresentam roteiros centrados no sistema para os usos futuros das tecnologias em uma empresa, mas eles não representam necessariamente a transformação de produtos, processos e aspectos estruturais que acompanham a integração de tecnologias. As estratégias de transformação digital assumem uma perspectiva diferente e buscam objetivos diferentes. Vindo de uma perspectiva centrada nos negócios, essas estratégias focam na transformação de produtos, processos e aspectos organizacionais, devido às novas tecnologias. Seu escopo é mais amplamente projetado e inclui explicitamente atividades digitais na interface ou totalmente ao lado dos clientes (MATT; HESS; BENLIAN, 2015).

O processo de transformação digital não deve ser limitado à TI, também pelo fato de uma única área, seja TI ou marketing, não possuir sozinha os braços necessários para serem os únicos inovadores. A transformação digital é uma construção coletiva. É importante garantir o comprometimento de toda a organização e garantir que o desenvolvimento tecnológico seja garantido tanto na estratégia quanto na prática. Tal movimento, no entanto, implica ter uma visão clara do negócio e dos processos da empresa, incluindo as práticas corporativas, normas e valores empresariais, além disso, requer liderança e endosso da alta administração (SAARIKKO; WESTERGREN; BLOMQUIST, 2020).

Acompanhando a evolução para o digital, novos movimentos levam a internet para uma fase em que tudo e todos estão interconectados. As empresas precisam estar atentas ao fato de que o consumidor, hoje, está constantemente na internet, fazendo compras on-line e trocando mensagens nas redes sociais. A marca que deseja se relacionar com o consumidor precisa estar em todos os pontos de contato que a presença digital permite.

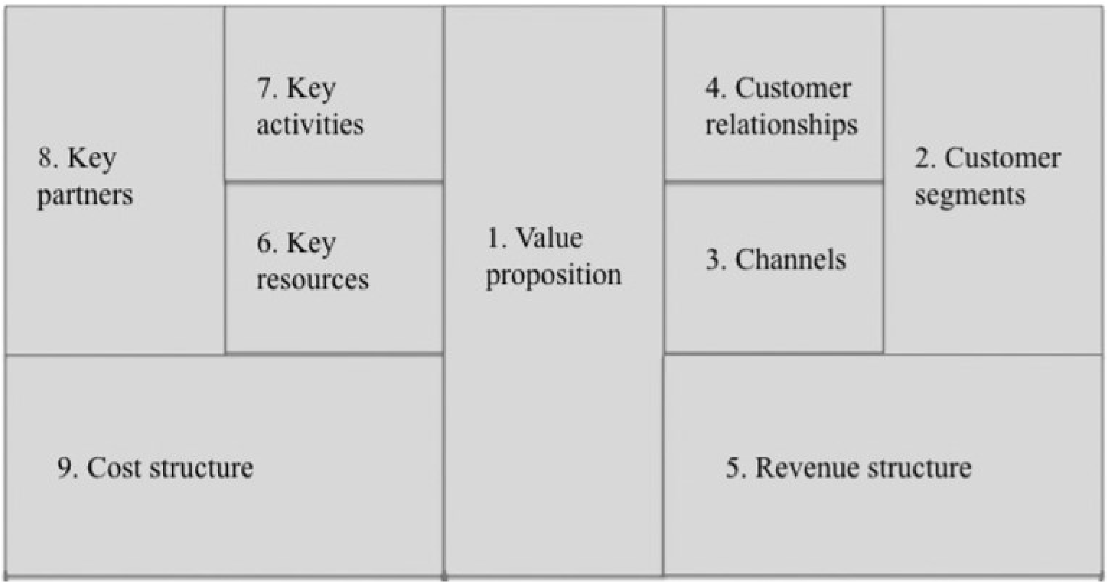
Para uma transformação digital, o acesso à tecnologia em si raramente é o problema. Ao invés disso, é a capacidade de desenvolver e implementar rapidamente modelos de negócios digitais viáveis que está no cerne da questão (HESS *et al.*, 2016).

2.3 Modelo de negócios (BM)

Um modelo de negócios é uma ferramenta conceitual que contém um conjunto de objetos, conceitos e suas relações, com o objetivo de expressar a lógica de negócios de uma empresa específica. Para tanto, a empresa deve considerar quais conceitos e relacionamentos permitem uma descrição e representação simplificada de qual valor é fornecido aos clientes, como isso é feito e com quais consequências financeiras (OSTERWALDER; PIGNEUR; TUCCI, 2005).

Uma abordagem de modelo de negócios aceita, tanto na pesquisa, quanto na prática, é o Business Model, que foi introduzido por Osterwalder e Pigneur (2010). Sua representação de modelo de negócios, que pode ser descrita como um conjunto de nove blocos de construção inter-relacionados, é mostrada na Figura 3.

Figura 3 – Business Model Canvas



Fonte: Osterwalder e Pigneur (2010).

Os nove blocos de construção são: (1) A proposta de valor do produto oferecido ao mercado; (2) o(s) segmento(s) de clientes atendidos pela proposta de valor; (3) os canais de comunicação e distribuição usados para alcançar os clientes e oferecer-lhes a proposta de valor; (4) as relações estabelecidas com os clientes; (5) os fluxos de receita gerados pelo modelo de negócios (constituindo o modelo de receita); (6) os principais recursos necessários para tornar o modelo de negócios possível; (7) as principais atividades necessárias para executar o modelo de negócios; (8) os principais parceiros e suas motivações para participar do modelo de negócios; e (9) a estrutura de custos resultante do modelo de negócios.

O modelo de negócios descreve quatro dimensões essenciais: proposta de valor, criação de valor, captura de valor e entrega de valor. A análise desses elementos centrais é crucial para projetar a solução com base nas funções principais (GÜNZEL; HOLM, 2013).

Independentemente da diversidade de contribuições e entendimentos atuais, pesquisadores e profissionais concordam que todas as empresas precisam de um modelo de negócios (GÜNZEL; HOLM, 2013). Embora nem sempre seja claro por que um modelo de negócios específico é bem ou malsucedido, é geralmente aceito que um modelo de negócios que funcione bem é essencial para o sucesso de qualquer organização comercial, seja um novo empreendimento ou uma empresa estabelecida (MAGRETTA, 2002).

2.4 Inovação em Modelo de negócios (BMI)

No início do século XXI, a constante evolução tecnológica remete à necessidade de adaptação dos modelos de negócio pelas organizações e pelas diferentes indústrias através do termo "inovação de modelo de negócios" ou "business model innovation" (BMI) (FOSS; SAEBI, 2017). A organização de estruturas de negócios e tecnologias emergentes para a geração de inovação passa a ser agenda prioritária dos gestores (BOUNCKEN; KRAUS; ROIG-TIERNO, 2019).

Embora apareçam terminologias e taxonomias diversas para a construção de um modelo de negócios, são considerados basicamente os mecanismos de "criar, entregar e capturar valor", que refletem os componentes compreendidos na literatura, tanto de BM como de BMI (FOSS; SAEBI, 2017). Tais funções aparecem como as grandes áreas do modelo Canvas e podem ser descritas como (1) Proposta de Valor, que é a agregação de valor de serviço ou produto; (2) Criação de Valor, que define a estrutura da cadeia de valor para criar e distribuir a oferta; (3) Entrega de Valor, que cobre os segmentos de clientes atendidos pela proposta de valor; os canais de comunicação e distribuição utilizados para chegar aos clientes; e (4) Captura de Valor, que estima as estruturas de custos e receitas, atendendo à proposta de valor e à estrutura da cadeia de valor escolhida (GÜNZEL; HOLM, 2013).

Similarmente às quatro áreas do modelo Canvas, as estratégias de transformação digital têm quatro dimensões essenciais: uso de tecnologias, mudanças na criação de valor, mudanças estruturais e aspectos financeiros; portanto, no processo de BMI, deve-se buscar identificar e concretizar elementos atribuídos a essas quatro dimensões (MATT; HESS; BENLIAN, 2015).

Apesar do advento da BMI revelar campos interessantes de aplicações, como servitização, inovação aberta e capacidades dinâmicas, pouco se sabe sobre como uma mudança em direção a modelos orientados a serviços afeta o modelo de negócios existente da empresa e qual seria a estrutura para apoiar o novo modelo de negócios (SCHIAVI; BEHR, 2018). A transformação de modelos de negócios baseados em produtos para modelos de negócios centrados em serviços obriga as empresas a diferenciar o alinhamento da sua cadeia de valor, definir novas decisões estratégicas para enfrentar a concorrência, redefinir a estrutura organizacional e alterar os fatores de sucesso de suas aplicações. As proposições de valor, fluxos de receita e tecnologias continuam os principais determinantes dos modelos de negócios de produtos inteligentes e conectados.

Remane *et al.* (2017) explicam que uma opção eficiente para o BMI é aprender com as soluções existentes. No entanto, os vários entendimentos do conceito de modelo de negócios são muitas vezes confusos e contraditórios, com as coleções disponíveis incompletas, sobrepostas e estruturadas de maneira inconsistente.

Importante para o processo de BMI ser bem-sucedido é que os recursos dentro e fora das organizações estejam conectados e mobilizados para apoiar o processo. Para isso, a alta administração das empresas deve preparar os recursos necessários, envolvendo toda a organização (PRIYONO; DARMAWAN; WITJAKSONO, 2021).

2.5 Operações de Serviços

A partir da década de 1970, um desenvolvimento de grande importância ocorre na área de gestão de operações. Pesquisadores e práticos que antes davam exclusiva atenção às operações fabris passam a se importar também com operações de serviços (CORRÊA; CORRÊA, 2011).

Um serviço pode ser definido como uma mudança na condição de uma pessoa ou de um bem, resultante da atividade de uma organização e com acordo prévio do beneficiário desta mudança (HILL, 1999).

De acordo com Costa Neto e Canuto (2010), “a história da Economia ao longo do tempo registrou paulatinamente uma migração de mão-de-obra, capital e importância do setor primário, a agricultura, para o secundário, a indústria, e para o terciário, os serviços”. Esta migração para o setor de serviços é característica do final do século XX, quando a demanda por serviços cresceu continuamente devido a diversos fatores, tais como: automação industrial, urbanização, maior tempo de lazer, mudanças socioeconômicas, entre outros.

Corrêa e Corrêa (2011) ressaltam que os serviços passam, então, a serem relevantes como arma competitiva, mesmo para operações de manufatura. Com a evolução tecnológica mais disponível dos produtos, torna-se mais difícil para uma empresa se diferenciar com base nas características intrínsecas de seus produtos físicos.

A partir de uma mudança na orientação estratégica, algumas empresas passam a adotar uma “lógica dominante de serviço”, defendendo a visão de que o processo de produção é inteiramente baseado em serviços – a empresa compraria serviços dos fornecedores e entregaria serviços aos clientes. Serviço aqui é definido como o uso de conhecimento e habilidade para beneficiar o cliente e pode ser realizado de maneira indireta ou direta, isto é, com ou sem o suporte de um produto (WIELAND; HARTMANN; VARGO, 2017).

Nesse novo contexto, paralelamente ao surgimento de novos serviços resultantes do processo de servitização de empresas de manufatura, surgem as plataformas de serviço, que reúnem tecnologias e conceitos de serviço, baseados em inovações como Mobilidade, Big Data, Internet das Coisas e Internet de Serviços (REIS; PETRONI; GONÇALVES, 2019). As plataformas de serviço atendem às demandas dos clientes, oferecendo serviços de forma mais proativa, integrada, voltada para o cliente e orientada por dados, e entregando os serviços por meio de interfaces virtuais, contínuas, dinâmicas e compartilhadas (MONTAUDON-TOMAS; PINTO-LÓPEZ; YAÑEZ-MONEDA, 2020).

Como a tecnologia da informação permite a comunicação onipresente com o cliente e muitos dados sobre os consumidores, abre-se uma gama de possibilidades para as empresas repensarem produtos, serviços e estratégias.

2.5.1 Diferenças entre bens e serviços

Segundo Juran (2004), qualquer atividade de produção resulta em um produto, mas existem três categorias, a saber:

- Bens: coisas físicas, tangíveis, como lápis, carro, televisão etc.;
- Serviços: resultados intangíveis, como educação, consulta médica etc.;
- *Software*: termo não enquadrável nas categorias anteriores, como ERP, sistemas operacionais, portal na internet etc.

Corrêa e Corrêa (2011) também lembram da categoria *software,* ao questionar a dicotomia da tangibilidade ou intangibilidade na diferenciação entre operações fabris e de serviços. De forma simplista, bens são tangíveis e os serviços intangíveis. Mas existem situações limítrofes, como o *software*. *Software,* por ser intangível, poderia ser categorizado como serviço, entretanto, pode-se listar *software*, corrigir *software*, transportar e estocar *software*.

Além dessa questão da tangibilidade, outras diferenças entre bens e serviços são listadas no Quadro 1.

Quadro 1 – Diferenças entre bens e serviços

Bens	Serviços
Tangíveis, têm existência física	Intangíveis, não têm existência física
Executados ao longo de um processo de produção	Executados instantaneamente ou em curto espaço de tempo
Podem ser estocados e transportados	Não podem ser estocados e transportados
Produção antecede o consumo	Produção simultânea com o consumo
Produção fora do alcance do cliente	Produção com participação física ou virtual do cliente
Formas de produção, em geral, homogêneas	Heterogeneidade na produção
Fácil avaliação da qualidade	Difícil avaliação da qualidade

Fonte: Costa Neto e Canuto (2010).

Para Bowen (2002), mesmo que no processo tenha produtos físicos envolvidos, a performance do serviço é essencialmente intangível. Fato é que bens e serviços estão cada vez mais agregados. Assim como a compra de um serviço quase sempre está associada a bens físicos, a aquisição de um bem é geralmente acompanhada de um serviço. A transformação da economia baseada em produto na chamada economia de serviço faz com que o marketing de serviço ganhe foco. Como sugerido pela lógica dominante de serviço, cada vez mais e, inevitavelmente, todo o marketing se assemelhará ao marketing de serviço (VARGO; LUSCH, 2017).

2.6 Internet de Serviços (IoS)

O termo IoS foi trazido pela primeira vez por Christoph Schroth e Till Janner, em 2007 (SCHROTH; JANNER, 2007). Segundo eles, a IoS surgiu da convergência de outros dois conceitos: Web 2.0 e SOA (Arquitetura Orientada a Serviços). A intersecção desses dois campos é a noção de reaproveitamento e composição de recursos e serviços existentes. Enquanto SOA e Web services possibilitam a aquisição de serviços por meio de diferentes canais, seu principal objetivo é prover a infraestrutura tecnológica para a IoS, que é a perspectiva técnica de um ecossistema mais complexo.

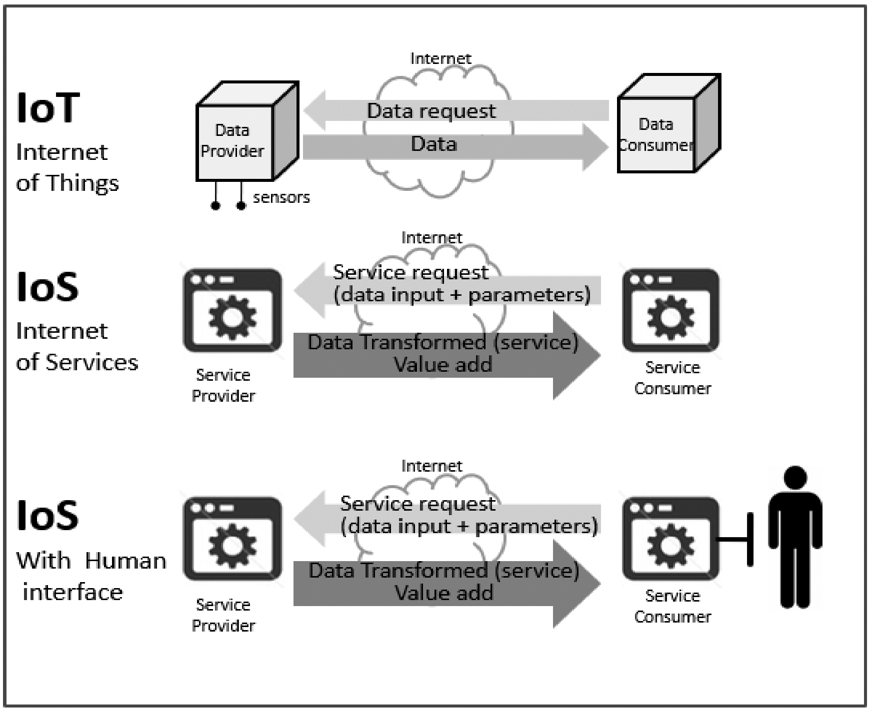
Na literatura científica, IoS apresenta várias definições, alternando sempre entre um viés técnico e um viés de negócios. Dois dos conceitos de Internet de Serviços que são voltados para negócios são: “Ecossistema de negócios colaborativo ou mercado global onde serviços oferecidos por diversos provedores (terceiros) são oferecidos, descobertos e consumidos em uso combinado (orquestração de serviços)" (BUCCHIARONE *et al.*, 2017; GIVEHCHI *et al.*, 2017; KRITIKOS; PLEXOUSAKIS, 2014) e "A Internet do Futuro, que detecta e usa informações contextuais para se adaptar perfeitamente a um cenário imprevisível e permite a configuração *ad-hoc* ou a configuração de novos modelos de negócios" (BALAKRISHNAN; SANGAIAH, 2017). E entre os conceitos de Internet de Serviços voltados para TI, temos:

> Computação orientada a serviços ou baseada em SOA (Arquitetura Orientada a Serviços), em que a composição de serviços é o principal facilitador na reutilização de serviços heterogêneos da Web como blocos de construção para criar aplicativos de valor agregado (BUCCHIARONE *et al.*, 2017).

A IoS é considerada um componente importante da Indústria 4.0, em conjunto com a IoT (ALCÁCER; CRUZ-MACHADO, 2019; HOFMANN; RÜSCH, 2017; KAGERMANN; WAHLSTER; HELBIG, 2013; SATYRO *et al.*, 2017). Enquanto na IoT os objetos inteligentes se comunicam e cooperam em tempo real, via IoS, serviços internos e interorganizacionais são oferecidos e usados pelos participantes da cadeia de valor (HERMANN; PENTEK; OTTO, 2016).

Conforme ilustrado na Figura 4, IoT e IoS funcionam de forma diferente.

Figura 4 – Conceitos de IoT e IoS



Fonte: Adaptado de Reis *et al.* (2021).

A IoT estabelece a comunicação entre "coisas", como máquinas ou equipamentos, por meio da internet. Uma "coisa" solicita dados de outra "coisa", que envia os dados, e a única informação necessária para esta comunicação é o endereço como a identificação de ambas as partes, dada pelo protocolo de internet (IP). Na maioria das vezes, a "coisa" que está provendo dados usa sensores para fornecer esses dados em tempo real. Por outro lado, a "coisa" consumidora de dados pode utilizar atuadores para atuar no ambiente físico.

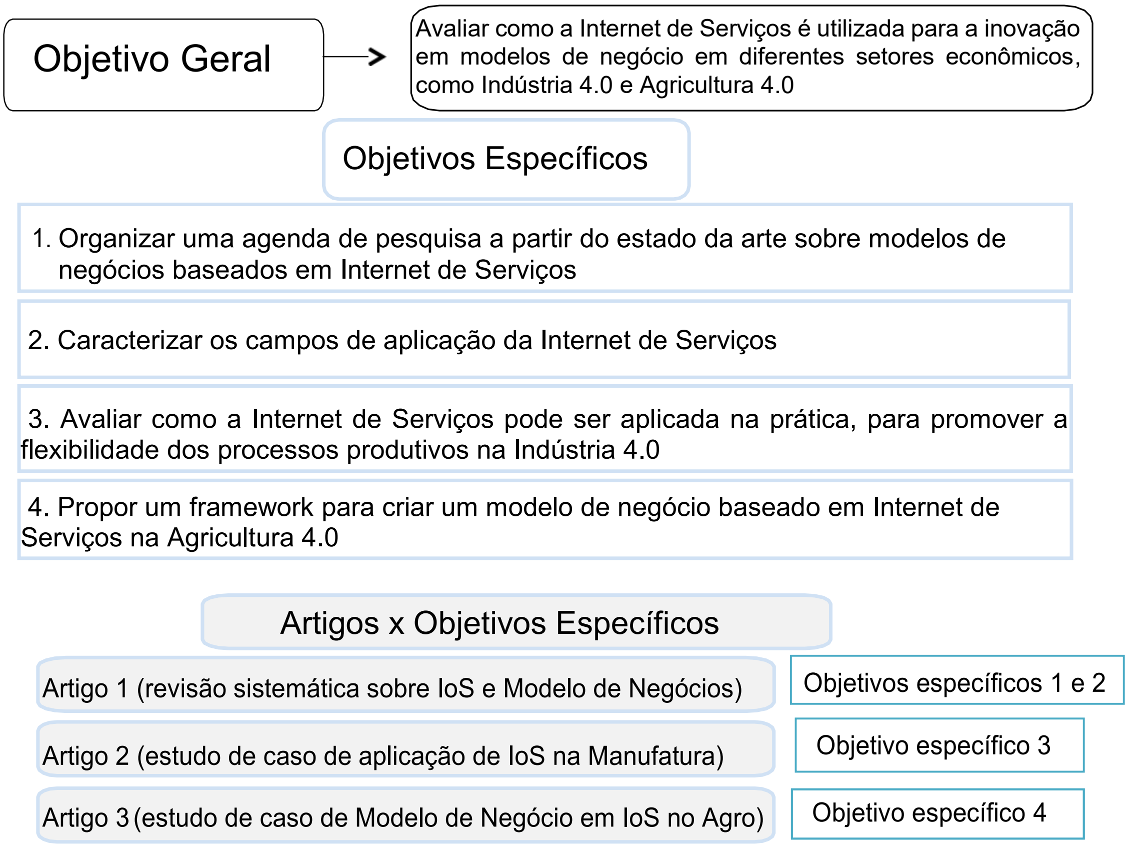
O conceito de IoS vai além da simples comunicação de dados, pois, quando o consumidor do serviço solicita o serviço de um provedor, a solicitação inclui dados de entrada e parâmetros que podem modificar e personalizar a resposta, retornando informações de valor agregado. Os serviços de provedor e consumidor podem operar automaticamente ou com usuários humanos, por meio de uma interface homem-máquina (H-M), para que os usuários finais insiram os dados de entrada e leiam as respostas. Sistemas automatizados também podem invocar os serviços para acessar funções fornecidas remotamente por outros provedores.

O principal objetivo da IoS é apresentar tudo como um serviço na internet, incluindo aplicativos de software, a plataforma para desenvolver e entregar esses aplicativos, e a infraestrutura de rede. Em comparação com serviços técnicos, o desenvolvimento de soluções para a IoS é algo mais elaborado, pois os serviços são intangíveis, muitas vezes inseparáveis, bipolares, híbridos e variáveis, ostensivos no que diz respeito à propriedade, têm interações de longa duração e são dissociados (CARDOSO; VOIGT; WINKLER, 2009).

3 METODOLOGIA

O trabalho se baseia em pesquisa qualitativa e sua estrutura está em formato de artigos, sendo cada um dos objetivos específicos explorado em um artigo, conforme colocado na Figura 5.

Figura 5 – Composição dos objetivos e artigos da pesquisa



Fonte: Elaborada pela autora.

A primeira etapa do trabalho apresenta uma revisão sistemática da literatura sobre modelos de negócios para IoS. Segundo Kitchenham (2007), a revisão sistemática da literatura é um meio de identificar, avaliar e interpretar os estudos relevates disponíveis para uma questão particular de uma pesquisa, um tópico de uma área ou um fenômeno de interesse (KITCHENHAM, 2007). Para realizar essa busca, foi utilizada a string booleana “Internet of service*” AND “business model*”. Como resultado da pesquisa, 23 estudos diferentes são apresentados, categorizados por subáreas da IoS e também por campos de aplicação. A compilação dessa etapa da pesquisa tem como resultado o primeiro artigo que compõe a tese.

A segunda etapa do trabalho consiste em avaliar como a Internet de Serviços pode ser aplicada na prática, em um chão de fábrica, para promover a flexibilidade no processo de produção na Indústria 4.0. A partir de um modelo teórico representativo da Internet de Servços, baseado no seu fundamento que é o SOA, foi utilizada a metodologia de estudo de caso para avaliar se o modelo teórico pode ser verificado na prática. A metodologia de estudo de caso é frequentemente utilizada na área de Gestão de Operações para melhor compreender uma determinada condição, problema ou solução adotada na unidade de análise. O estudo de caso tem duas propostas de pesquisa: no modo indutivo, para criar teoria; no modo dedutivo, para avaliar em condições reais uma teoria ou modelo (BARRATT; CHOI; LI, 2011). Nesta pesquisa, o estudo de caso foi utilizado no modo dedutivo.

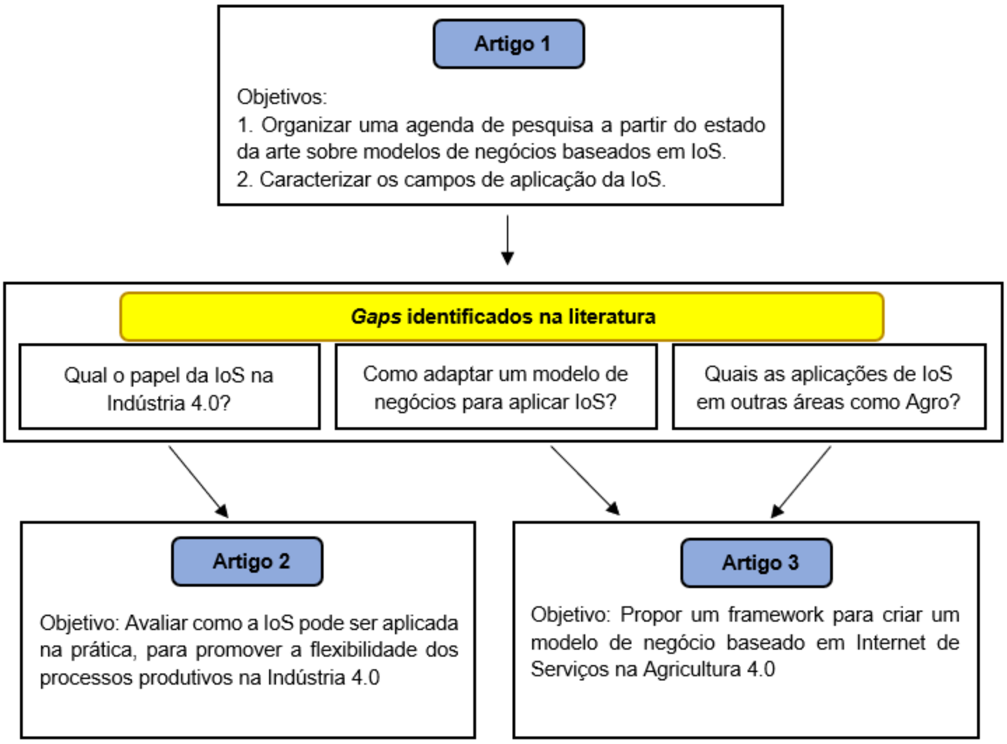
Dois casos representativos da Indústria 4.0 foram selecionados para verificar se o processo de manufatura no chão de fábrica corresponderia ao modelo teórico. Os dois estudos de caso foram realizados de acordo com uma metodologia de pesquisa de caso conhecida (VOSS; TSIKRIKTSIS; FROHLICH, 2002), que consiste em entrevistas semiestruturadas com funcionários das organizações e observação realizada *in loco*. Em um primeiro momento, o modelo conceitual foi apresentado aos entrevistados para eles verificarem se correspondia ao fluxo de produção real. Em um segundo momento, foram feitas visitas às fábricas. A observação foi feita no chão de fábrica (observação da produção em tempo real), com o objetivo de entender como a IoS tem sido usada no fluxo de produção. Desse estudo, foi concebido o segundo artigo da tese.

Na terceira etapa do trabalho, foi proposto um framework para a criação de modelos de negócios baseados em IoS no campo da Agricultura 4.0. O framework foi criado com base na revisão da literatura e avaliado por um estudo de caso único, devido à escassez de modelos de negócios relacionados diretamente à aplicação da IoS. O estudo de caso único normalmente explora oportunidades para explicar um fenômeno em um cenário de circunstâncias raras (EISENHARDT; GRAEBNER, 2007). O estudo de caso foi realizado de acordo com uma metodologia já conhecida (VOSS; TSIKRIKTSIS; FROHLICH, 2002), consistindo em entrevistas semiestruturadas com o CEO da empresa e seguindo o modo dedutivo para validação da teoria (VOSS; GODSELL; JOHNSON, 2015). Dessa forma, o framework de um modelo de negócios baseado em IoS foi elaborado e comparado ao negócio real da empresa, resultando no terceiro artigo da tese.

4 PRODUÇÃO BIBLIOGRÁFICA

Este capítulo apresenta a produção bibliográfica com os artigos que compõem a tese, em sua formatação original de submissão ou publicação. A Figura 6 ilustra a organização da pesquisa e o papel de cada artigo.

Figura 6 – Artigos da pesquisa



Fonte: Elaborada pela autora.

A partir do artigo 1, que busca o estado-da-arte sobre modelos de negócios para IoS e seus campos de aplicação, alguns *gaps* são identificados na literatura científica. Um deles é a falta de clareza sobre o papel da IoS na Indústria 4.0, que é citado como o seu principal campo de aplicação. Para endereçar este *gap*, o artigo 2 busca avaliar como a IoS pode ser aplicada na manufatura para promover a flexibilidade dos processos produtivos – flexibilidade essa que seria uma proposta da Indústria 4.0 para a transformação digital, visando a manufatura avançada.

Outras duas lacunas encontradas na revisão sistemática são a falta de um modelo de negócio baseado em IoS e a aplicação desta inovação em outras áreas de atuação, além da Indústria 4.0. O artigo 3 busca cobrir esses dois *gaps*, ao propor um framework para criação de modelo de negócio baseado em IoS utilizando um estudo de caso no campo da Agricultura 4.0.

4.1 Artigo 1

O artigo *“Business Models for the Internet of Services: State of the Art and Research Agenda”* foi elaborado pelos autores Jacqueline Zonichenn dos Reis, Rodrigo Franco Gonçalves, Márcia Terra Silva e Nikolay Kazantsev, e publicado no periódico *Future Internet,* em fevereiro de 2022.

Esse artigo atende ao primeiro e segundo objetivos específicos da pesquisa: 1) Organizar uma agenda de pesquisa a partir do estado da arte sobre modelos de negócios baseados em Internet de Serviços; 2) Caracterizar os campos de aplicação da Internet de Serviços.

A concepção do artigo responde aos *gaps* iniciais e ao problema da pesquisa, que seria: apesar da relevância atribuída à IoS, sua contribuição para o processo de inovação em modelos de negócios ainda não é clara. Além disso, ainda é escasso na literatura científica um estudo sobre o tema. A importância desse artigo para a pesquisa, portanto, é a busca do estado da arte sobre modelos de negócios baseados em IoS, e suas áreas de aplicação.

O método escolhido foi a revisão sistemática da literatura (KITCHENHAM, 2007) como meio de identificar os estudos relevantes disponíveis. Para realizar a busca, foi utilizada a string booleana “Internet of service*” AND “business model*”. A pesquisa foi realizada em agosto de 2021, nas bases de dados Web of Science e Scopus, excluindo os artigos duplicados e versões curtas de conferências das últimas publicações em periódicos. Como resultado, 23 estudos são apresentados, categorizados por subáreas de IoS e por campos de aplicação.

Uma das contribuições do artigo é a taxonomia de categorias que classificam a IoS em quatro subáreas, a saber: infraestrutura, operação de serviços, aplicações de negócios e aplicações sociais.

Outra contribuição é que, a partir deste artigo, alguns *gaps* iniciais são confirmados e novos *gaps* são identificados. Os *gaps* relevantes para a tese proposta seriam: a falta de clareza sobre qual o papel da IoS na Indústria 4.0; a falta de um modelo de negócio baseado em IoS; e quais seriam as aplicações da IoS em outros campos de inovação, como por exemplo na Agricultura 4.0.

No artigo, também se destacam oportunidades de aplicações de IoS em diferentes áreas e direcionamentos para pesquisas futuras através da proposta de uma agenda de pesquisa.

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Review

Business Models for the Internet of Services: State of the Art and Research Agenda

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Abstract: The relevance of the Internet of Services (IoS) comes from the global reach of the Internet into everyone's home and daily activities and from the move from a manufacturing-based economy to a service-based economy. The IoS is seen as a new ecosystem where service providers and consumers explore their business networks for service provision and consumption. The scientific literature refers to IoS as an important cornerstone for Industry 4.0 and Future Internet; thus, it becomes relevant to study how IoS interacts with business models. Nevertheless, there is a lack of clarity on such an intersection. Moreover, a systematic review of IoS-based business models is still missing. This paper aims to make a systematic review of IoS-based business models and their application fields. We included studies from Scopus and Web of Science databases, we excluded duplicated papers and short conference versions of the later full paper journal publications. Twenty-three different studies are presented, categorized in the sub-areas of IoS, and then by the fields of applications. The main finding highlights the opportunities of IoS applications in different fields, offering directions for future research on this new arena.

Keywords: Internet of Services; business model; services; innovation

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1. Introduction

While the technological advances in the more recent past have opened up a range of new business opportunities [1], both enterprises and software vendors have struggled with the fact that the ICT (Information and Communication Technologies) systems, mostly acquired for more extended periods of time, are exposed to disruptive innovative technologies which have to be rapidly introduced in order for companies to remain competitive in the market [2]. Furthermore, the success of companies in achieving their goals depends on how they integrate the different digital technologies into their business models [3].

New software and services are being developed at an impressive speed and deployed on the Internet, along with virtualized services that connect real-world physical resources. Services from multiple networks converge into a complex ecosystem called the Internet of Services (IoS) [4].

The IoS gains relevance in the scientific literature as an important cornerstone of Future Internet [5], and Industry 4.0, coupled with the Internet of Things (IoT) [1,6]. Through the IoS, the cross-organizational services are offered and used by the value chain participants [7].

A service ecosystems perspective on business models offers rich implications for an enterprise's strategy [8]. Recent research, though, raises problems in regard to "the adaptation of business models to services scenarios, such as the reconfiguration of value chains, the customization and new forms that business models will adopt, and the sharing resources in the network of companies operating under flexible supply chains" [9]. The IoS may provide solutions for such challenges; however, the corresponding literature is scarce.

While there is a great focus on IoT, there is a lack of clarity on IoS applications and contributions to the business ecosystem. Research is needed for a business model to adopt an IoS ecosystem perspective, instead of firm-centric models as servitization and digitalization. Moreover, a systematic literature review regarding IoS and its correlation with business models is still missing.

In this sense, the aim of this paper is to highlight the research directions in the field of IoS-based business models. The study presents the results of a systematic literature review correlating the keywords Internet of Services and business model. Twenty-three different studies are presented as well as the problem they address and proposed solution. The review allows identifying the state of the art and the possible gaps addressed by a research agenda.

2. Theoretical Foundation

2.1. Internet of Services

While humans first delivered services to humans, technological advances over the years allowed computers to deliver services to humans.

The term IoS-based service is used to identify services discovered, ordered, and provided through the Internet [10]. When there is a service request, the requester informs specifications to the provider, that customize the feedback, returning value-added result. Both requester and provider can operate automatically or with humans through a human–machine interface. Furthermore, automated systems can also invoke the services to access functions provided remotely by business providers [10].

An example of an IoS-based service would be a value-added service package of a system used for monitoring public lighting poles, connected to the city's municipality network. In addition to light intensity measurements on each light pole, this system collects other environmental parameters such as CO_2 level, temperature, noise, etc. Then, through the IoS, third-party service providers can use the collected data to optimize or offer new services to people who are connected, such as secure access to homes, predictive maintenance, sustainability applications, etc.

The IoS is seen as an ecosystem that allows services vendors and consumers to collaborate across organizations via the Internet, increasing the popularity of business services in the business markets [11].

Christoph Schroth and Till Janner first coined the term in 2007 [12]. According to them, the IoS is a result from the merge of two other components: Web 2.0 and Service-Oriented Architecture (SOA). The confluence of these two areas reveals the idea of composing and reutilizing services as they were flexible modules.

While SOA and Web services enable service procurement through different channels, their main goal is to provide the technological infrastructure for the IoS, which is a more complex ecosystem.

The main goal of IoS is to present everything as a service on the Internet, such as the software applications, the platform for development and delivery, and the network infrastructure [13]. Nevertheless, developing solutions for the IoS is more elaborate since services are intangible, often inseparable, immersive, bi-polar, hybrid, variable, ostensible concerning ownership, have long-running interactions, and are decoupled [14].

For some authors, IoS is a "future internet that detect, and use contextual information for seamlessly adapt to an unpredicted scenario" [5,15].

Within the IoS, service providers work collaboratively to offer and deliver services. A service-based value network may cover the entire lifecycle, from R&D to operations, passing through the design, marketing, sales, production, and delivery of a service. All the areas should interactively cooperate to add value to the service. Value is created from the collaboration among the different stakeholders: the company, its customers, intermediaries and suppliers [10].

2.2. Business Model

A business model is a "conceptual tool containing a set of concepts and relationships to express a business logic. It must consider which relationships allow a description and representation of what value is provided to customers, how this is done, and the financial consequences" [16].

The business model has been employed mainly in trying to address or explain three phenomena: (1) e-business and the use of information technology in organizations; (2) strategic issues, such as value creation, competitive advantage, and firm performance; and (3) innovation and technology management [17].

Although there is a consensus on how important a business model is for the business' success, the literature has yet to conceptualize what business models do and how they intend to create new structures for an innovative market [8]. The emerging Business Model Innovation (BMI) literature raises new applications as servitization, open innovation and dynamic capabilities [18]. Nevertheless, "little is known about how a shift toward service-driven models affects the firm's existing business model and the structure to support the new business model" [19].

Despite the various terminologies and the lack of a uniform taxonomy for building a business model, an approach accepted both in the practice and literature [20–23] is the Business Model Canvas developed by Osterwalder & Pigneur (2010) [24]. It identifies nine building blocks or components including customer segments, value proposition, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure.

The Business Model Canvas representation is understood as interrelated building blocks that address the four meta-components: value proposition, value creation, value delivery and value capture [20].

The analysis of the business model dimensions is crucial for designing a solution considering the key functions of an organization. "The mechanisms for creating, delivering, and capturing value reflect components that are well understood in the BM and BMI literatures—namely, value proposition, target segments, value chain organization, and revenue capture mechanisms" [18].

Instead of explaining business solely through individual activities such as marketing and R&D, or through mechanisms influencing business outcomes such as value chain or pricing, the research on business models highlights the development of holistic, multi-dimensional, system-level business model frameworks [17].

There are several types of business models for digital services, which present different payment methods and exploited properties. Among the examples discussed by Øverby and Audestad [25], there is the subscription model in which users pay a fee for using the service, like in the massive online game World of Warcraft. There is the freemium model, when some users receive the service for free while others pay for using the service, e.g., Spotify. There are the multisided digital mediation platforms, such as Airbnb, in which the users pay for the mediation services provided by the platform.

3. Materials and Methods

A systematic literature review was carried out to identify the state-of-the-art Internet of Services and the interaction with business models. The systematic review is a means of identifying, evaluating and interpreting all available research relevant to a particular research question or phenomenon of interest [26].

We studied two research questions:

What is the state of the art of Internet of Services-based business models?
What is their classification based on the application field?

This review followed the PRISMA (http://www.prisma-statement.org/ (accessed 28 January 2022)) guidelines which employs a method for conducting the review, such as Systematic Literature Review. PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses, which focuses on the reporting of reviews evaluating the effects of interventions, but can also be used as a basis for reporting systematic reviews with objectives other than evaluating interventions [27]. Figure 1 shows the PRIMA flow diagram for the systematic review.

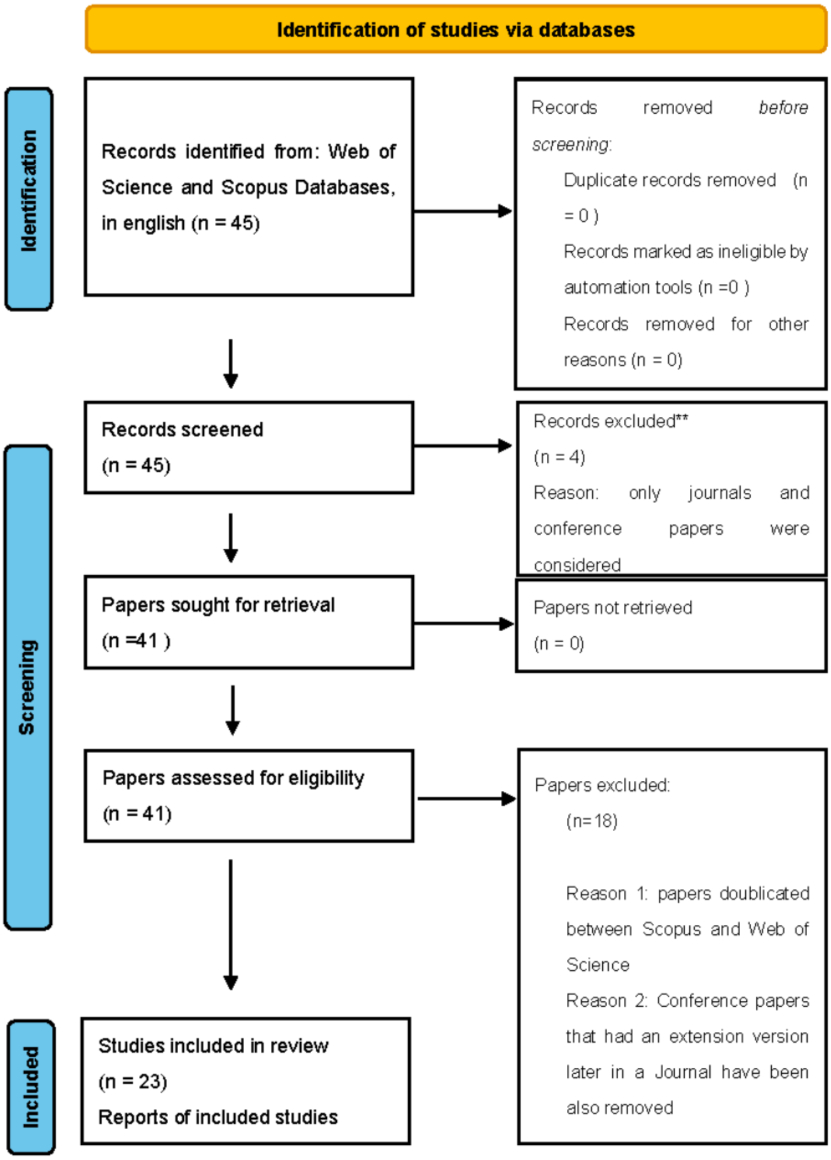

Figure 1. PRISMA 2020 flow diagram for systematic reviews

To conduct this search, we used the Boolean string "Internet of service*" AND "business model*" and followed the steps as listed in Table 1, searching the Web of Science and Scopus bases. The use of the asterisk * right after the words "service" and "model" guarantees that the word appears in singular or in plural in the search results. Publication and journal databases were searched in English on 1 August 2021.

All co-authors looked at how the processes underpinning the review and made suggestions if necessary. From the first result of 45 papers, only journals and conference papers were considered, since peer review is a typical indicator of quality in research. This resulted in a total of 41 candidate papers. We removed duplicated papers (14 papers in WoS were duplicated with findings from Scopus) and 4 conference papers that had an extended version in Journals, resulting in a total of 23 papers.

Table 1. Boolean strings and including/excluding criteria for the research.

Step	String	Finds		
		Scopus	WoS	Total
#**1**	"Internet of service*" AND "business model*"	30	15	45
#2	"Internet of service*" AND "business model*" (Journals and Conference papers only)	26	15	41
	First selection:	34 candidate papers		
Step	Including/Excluding Criteria	Finds		
#3	Removed duplicated papers (14 papers in WoS were duplicated with findings from Scopus)	27		
#4	Removed 4 conference papers that had an extended version in Journals. The respective Journal versions were included.	23		
	Final selection:	23 selected papers		

All the twenty-three studies were examined and distributed under categories of the problem they mainly address, their contributions and gaps. This answered the first research question regarding the state of the art of IoS. Next, the papers that focus on business were also categorized by fields of application to answer the second research question.

4. Results

The very first papers that explore the concept of IoS show that this kind of services have to combine and correlate information technology (IT), operational, and business aspects of forming the IoS [28]. The IoS consists of participants, an infrastructure for services, business models, and the services themselves [10]. Moreover, in order to form the Internet of Services, services have to be described in a way that the business dimension and the technology dimension gather [2].

From all these concepts, it is possible to infer that, besides the infrastructure to support the IT aspects, and the service operation that covers the operational aspects, the IoS needs a business application to exist. Nevertheless, as long the papers start exploring more the IoS-based services, we conclude that the IoS can have a business or social application depending on the participants and their goals.

As a result, we propose a taxonomy of categories that classify the IoS in four sub-areas, namely, infrastructure, service operation, business applications, and social applications.

Next, the selected studies have been divided into these four categories (Table 2). Each paper was placed in only one category according to its focus.

The categories are further explained according to the content of the selected studies and the contributions of current literature.

Table 2. List of selected studies by topic category.

#	Selected Study	Infra	Service	Business	Social
P1	King and Grobbelaar (2020) [29]. Industry 4.0 and business modem innovation			X	
P2	Suseendran et al. (2020) [30]. Banking and FinTech embraced with IoT devices			X	
P3	Cheng et al. (2018) [31]. Design for reducing device high load in industrial networks	X			
P4	Lokshina et al. (2018) [32]. IoT and big data analysis services for third parties				X
P5	Vukanović (2018) [33]. The influence of ICT megatrends on global megatrends	X			
P6	Cozmiuc and Petrisor (2018a) [34]. Industry 4.0 by Siemens: steps made today			X	
P7	Cozmiuc and Petrisor (2018b) [35]. Industry 4.0 by Siemens: steps made next			X	
P8	Komarov et al. (2016) [36]. How IoT influences building social web				X
P9	Zhang et al. (2016) [37]. Energy dialogue with industry 4.0			X	
P10	Chao (2016) [38]. E-services in e-business engineering		X		
P11	Komarov and Khokhlova (2015) [39]. Development of business model for social WoS				X
P12	Huang et al. (2013) [11]. BSNet network-based model for service-oriented business		X		
P13	Armando et al. (2013) [40]. Trustworthy Opportunistic Access to the IoS	X			
P14	Papadakis et al. (2012) [41]. Leveraging the content of Social Networks				X
P15	Arrieta (2012) [42]. Developing a tool for migration of non-SaaS applications to SaaS	X			
P16	Weiner and Weisbecker (2011) [43]. Framework for design of business models in IoS	X			
P17	Kett (2010) [44]. A business model approach for service engineering in IoS	X			
P18	Ruiz-Agundez et al. (2010) [45]. Addressing the billing needs of Internet of Services		X		
P19	Woitsch et al. (2010) [46]. Design, manage and execute service based on open models	X			
P20	Pasic (2010) [47]. Delivering trust, security, privacy for the internet of services	X			
P21	Wang et al. (2010) [48]. Monitoring model for business-oriented service operation		X		
P22	Cardoso et al. (2009) [10]. Service engineering for the Internet of Services			X	
P23	Cardoso (2009) [28]. The Internet of Services	X			

Table 3 brings the number of papers per topic category. Each category is better explored in the following sub-sections.

Table 3. Number of papers by topic category.

Topic Category		Number of Papers
Infrastructure		9
Service Operation		4
Application	Business	6
	Social	4

4.1. Infrastructure

An IT infrastructure for service delivery has to be provided to technically enable the business to participate in IoS [28] (P23).

Among the papers that focus on infrastructure, Cardoso [28] (P23) starts highlighting the importance of good technical infrastructure to make the IoS scalable and support business services. Pasic [47] (P20) explores technical solutions to the problems posed by managing security and trust. Trust, security, and privacy play a significant role for developing IoS solutions, since the services have to be loosely coupled and globally distributed [47] (P20).

Software-as-a-Service (SaaS) models are considered important features of the Internet of Services [49]. SaaS models offer a service-oriented and shared IT infrastructure that serves customers with service packages and flexible access via easy-to-use internet interfaces [50]. Arrieta [42] (P15) presents a tool supported methodology for business assessment when transforming a traditional service application to SaaS. Many characteristics need to be considered, such as architecture, platform, language, and the target SOA environment. Technically, SaaS applications are built up from SOA, but not all SOA applications are SaaS [42].

The literature review reveals a focus on a user-centric SOA in which the end-users would gain more empowerment for programming and exploiting the Web Services. However, the evolution of web-based service front ends falls short of end-user expectations and SOA remained on a technical layer hidden to end users [51].

IoT takes a prominent role in service applications, so the term IoS is often coupled with IoT. IoS is referred to as a globalization of service-oriented solutions, where Web services are offered by different providers [52]. When IoT starts to reproduce this scenario for millions of interconnected devices, a few issues start to be addressed in service domain as the lack of interoperability among such different sources of information. Known problems are the service composition, heterogeneity of physical communication, security, diversity of protocols and other challenges to effectively explore the communication between physical devices and enterprise software systems [53]. Software companies have been focused on standardizing the application programming interfaces (APIs) that enable basic commands and data transfer among IoT devices.

From a service composition perspective, room for improvement in artificial intelligence-based automatic service descriptions generation will require researchers to develop more ontologies and design more effective machine learning methods for semantic expression, classification, and matching. The process of defining requirements and determining the optimal selection of physical objects through web services could be described as a typical service composition problem that integrates IoT and IoS domains [54].

In regard to the challenge of interoperability among SOA applications, Cheng et al. [31] (P3) state it has been addressed by the Open Platform Communication Unified Architecture (OPC UA), a network transmission architecture that uses a peer-to-peer transmission method.

Besides the software, hardware devices and telecommunications also play an important role in the infrastructure for service delivery. Vukanović [33] (P5) highlights ICT-digital media megatrends, mainly the use of wearable sensors transmitting a large amount of data via mobile devices and computers. Armando et al. [40] (P13) address the adoption of the software-defined networking (SDN) as the potential solution to the on-demand connection among mobile devices, while Cheng et al. [31] (P3) propose a method for scheduling multiple periodic requests for reducing the high load of computing devices.

Scientific research in the following ICT fields will continue increasingly developing in the future: computer generated images, immersive and virtual reality, augmented reality, 5G wireless communications, ambient technology, IoT, nanorobotics, AI, geo targeting, 3D printing, predictive analytics, biometric sensors, big data analytics, etc. [33].

The theme of infrastructure goes beyond and reaches the software tools for business model development. Kett's work [44] (P17) focused on the need to develop different business models through the service description language, such as USDL, so that the business model could provide necessary information about services functionalities. Weiner and Weisbecker [43] (P16) defended the same argument introducing a business model ontology and a corresponding software approach to support the design of business model alternatives. Woitsch et al. [46] (P19) introduce the idea of the open models' paradigm applied for service models, aiming to motivate to share services models openly.

4.2. Service Operation

The service operation contains two phases that are essential for the IoS: discovery/invocation and execution. Discovery and invocation refer to the technology used to find and request a service. The execution describes how the service is performed. In terms of execution, the services can be carried out by humans, with conjunction of human and automated devices, or solely automated. The difference in the IoS is that the discovery and invocation are always ICT-based [10].

"Designing services is not only a technical undertaking; it is the job of analyzing the business environment and business processes and identifying business functions that could be implemented as a service" [10].

Service operation studies the new Business/Operations Support System possibilities of, for instance, fraud management, customer usage, rating and billing, marketing, client resource management. Ruiz-Agundez et al. [45] (P18) mention the different pricing schemes that represent how the service client will be charged (e.g., pre-paid, post-paid, time-based, volume-based) and focus on fraud management and in the customer usage or experience.

When the IoT starts to play a more important role in service applications, the quality of service (QoS) gains focus, owing to the practical issues in integrating the commodity objects and the technology underlying the IoT become more challenging [53].

The QoS describes aspects used to evaluate the degree that a Web service meets specified quality requirements in a service request, such as usability, efficiency, reliability, and performance, and managerial aspects such as ownership, provider, contract, and payment [55]. Moreover, the subjective quality of the system perceived by the end-users is called quality of user experience (QoUE), also named quality of experience (QoE) [5]. QoS-based scoring algorithm rates each requirement by comparing its characteristics with the monitored service call records, while a QoE-based approach would focus on past user decisions [52]. Wang et al. [48] (P21) propose a metamodel to observe QoS metrics and implement a service monitor system to execute the monitoring.

During dynamic selection and composition, services are combined to create new added-value services to respond to the consumer's request. The environment creates the service request, so a service-oriented business ecosystem (SOBE) proposed by Huang et al. [11] (P12) could translate it into abstract composition requests that refer the service process and the QoS of every service. Chao [38] (P10) raises that domain ontologies are needed to provide a coherent and context-rich environment and method. Such operation will support discovery and intelligent approaches based on AI to classify services to facilitate service matching. AI is also the approach used by Bucchiarone et al. [15] to solve composition problems of real-world complexity in dynamic applications that heavily depend on the execution environment's run-time parameters.

4.3. Business Applications

In the IoS ecosystem, service providers, organizations and enterprises offer business services. Business services respond to requests from consumers or other services.

The studies previously categorized in business applications topic were distributed by fields of applications, according to the focus of the respective papers (Table 4).

Table 4. Selected studies by field of application in business.

Selected Study	Fields of Business Applications		
	Manufacture (Industry 4.0)	Financial Services	Marketplace
King and Grobbelaar (2020) [29] (P1)	X		
Suseendran et al. (2020) [30] (P2)		X	
Cozmiuc and Petrisor (2018a) [34] (P6)	X		
Cozmiuc and Petrisor (2018b) [35] (P7)	X		
Zhang et al. (2016) [37] (P9)	X		
Cardoso et al. (2009) [10] (P22)			X

- Manufacture/Industry 4.0

Industry 4.0 could be divided into CPS (Cyber-physical systems), IoT, IoS, and the Smart Factory [1].

Because innovation industries are challenged by high mix, high volume, and high complexity, Cozmiuc and Petrisor [35] (P7) research how Industry 4.0 can support integrated supply chains and eco-systems of partners that bring new business models. In addition, King and Grobbelaar [29] (P1) corroborate that future research may explore how servitization business models can be used and designed to embrace Industry 4.0.

For Cozmiuc and Petrisor [34] (P6), the shopfloor will become a network of self-organizing decision-making agents by transforming all machines into CPS, which form the IoT and IoS within Industry 4.0. The idea matches the concept of IoS as a future internet allowing an ad hoc configuration of services, not relying on pre-determined network infrastructure [56].

Opportunities for new business models also emerge by means of new energy utilization technologies such as electric heating equipment, electrified rail transit, electric vehicles, etc. [57]. Zhang et al. [37] (P9) promote the deployment of smart grid in substitution of electricity for direct consumption of primary energy such as coal, gasoline, and diesel. Coupled with CPS, IoT and IoS, the formation of smart grid and added value streams gradually evolve towards global energy interconnection by opening a dialogue with Industry 4.0.

- Financial services (Fintech)

FinTech introduces a new service of tools and products for the emergent businesses through the IoS. Banking FinTech works with capital valuation, trading, investment, and asset valuation and provides new improving accounting systems compared to existing financial technology. The motivation of banking FinTech service is to reduce the human errors and increase banking business transaction and accessing [30] (P2).

As per Suseendran et al. [30] (P2), the banking and financial sectors create a new way of collecting valuable information about the customers through IoT sensor devices using smartphones. The bank can analyze the usage of services to increase and decrease the points of presence. Additionally, since customer information is stored in devices, the bank uses this opportunity to help in identifying customer's business needs. The IoS is a worldwide connector; therefore, the cyber attacker can easily access the targeted user's data because third-party services are unprotected. There are positive features in innovative financial technology: blockchain and crypto currencies, an alternative payment system, and FinTech technology and banking solutions. Nevertheless, the threats related to the FinTech essentials are adverse effects in the FinTech financial service sector.

- Marketplaces

Marketplaces for products enable business interaction between providers and consumers of physical goods. Cardoso et al. [10] (P22) explain that "in the IoS vision, services are tradable goods that their providers can offer on service marketplaces to make them available for potential consumers". On a service marketplace, different service providers that previously agree with the contractual rules may be accepted to offer their services. Providers may vary in size and specialization, enabling a competing and collaborating ecosystem of services.

Startup companies have been producing and bringing to the marketplace innovative goods and services. They generate value added in the form of services that they expose to the community. These services may be purchased and consumed, in some form, by the public or may be further aggregated by other service providers [58].

4.4. Social Applications

There are applications that provide other aspects of the social dynamics to the end users and can also be transformed into services over the internet [41].

The studies previously categorized in social applications topic were distributed according to their fields (Table 5).

Table 5. Selected studies by field of social application.

Selected Study	Fields of Social Applications		
	Healthcare	Smart Environment	Social Networks
Lokshina et al. (2018) [32] (P4)	X	X	
Komarov et al. (2016) [36] (P8)		X	X
Komarov and Khokhlova (2015) [39] (P11)		X	
Papadakis et al. (2012) [41] (P14)			X

- Healthcare

Healthcare is one of the main categories of organizations that can benefit from ICT advances as it will be personalized and involve the use of wearable sensors transmitting a large amount of patient data via mobile devices and computers [32] (P4).

Moreover, the trend of an ageing population will result in increased need for healthcare-monitoring ICT solutions for older people manage their health and consequently prevent health decline and detect near-fall events [59]. There are three key tasks facing the global healthcare system: reducing rising costs, improving quality and results, and expanding access [33].

Lokshina et al. [32] (P4) assess business opportunities applying IoT and Big Data-driven services for third parties. When massive amounts of data become accessible and understandable, the health organizations can subsequently use them, and the implications are enormous for civic life and personal health. Hospitals collect a large amount of patient data, so that information can be connected to a central or aggregated intelligence-management structure that allow for deep, complex analysis. The distribution of drugs and monitoring of blood pressure is observed regularly, so this data could be channeled into activities to improve care, reduce the length of stays in the hospital, and lower the transmission of diseases and infection rates.

Healthcare systems give people the opportunity to access their own health data through smartphone and collaborate in their own healthcare process, while provide public health surveillance [59].

- Smart Environment

Smart Environment raises important social applications, and governments are interested in using the latest technologies to promote the best social climate to their citizens. It includes smart homes, smart cities, office, and plant, all integrated into the environment [32] (P4).

Komarov and Khokhlova [39] (P11) focus on IoS connection with the IoT. The IoS suggests that every connected system has its own API, and a large amount of data produced by things can be shared with the data consumers, i.e., apps, people, or other items. Komarov et al. [36] (P8) bring an IoT influenced smart home business model in which a protocol connects the related devices (refrigerators, washers, microwaves, smartphones, TVs, etc.) and opens access for other vendors to get on board. Such a model can be expanded to cover home-energy, or "eco-home applications" through the partnerships with third-party service providers.

Lokshina et al. [32] (P4) also raise business opportunities in smart environment through the IoT and big data. Information platforms offering comprehensive public transportation information can be developed using open data released by the government together with data collected from the Internet to provide up-to-date information for users. A large customer base can be built for use with advertising and other add-on features. Using a digital business model, the application can be offered at no cost for users with its main source of revenue from mobile advertisements. Collaborators include complementary service providers, such as food delivery and taxis, which rely on location-based technology and generate revenue through service charge.

- Social Networks

Social networks are a potential market for services owing to the volumes of amateur content generated. Moreover, the abundance of subjective content of social network makes it ideal for mining the opinion of its users towards products or services. Papadakis et al. [41] (P14) list possible applications for providers that wish to raise resources from social networks for new services: journalists can monitor the activity of a group of users who are related to a particular topic or a location; producers can cast supporting actors for a play taking advantage of the fact that in social networks the users already provide information and photographs; TV commercial producers may locate a place where they can have the shooting, sending out the description and getting back options close to the target location.

Users of social media typically gather into communities based on some common interests. Their interactions inside these online communities follow several interesting patterns. Komarov et al. [36] (P8) provided an agent-based model simulation showing that companies might manipulate human behavioral patterns through smart things cooperation and social effects. As a result, a required usage setting trend could be created, leading to a business model of a social web of services, which would be the network of shared services by people and devices via social networks.

However, social networks present challenges to the applicability of traditional sentiment analysis techniques, due to their sparse, multilingual, and noisy content [41]. In addition, information security, information privacy and legitimacy are obstacles that must also be considered [36] (P8).

5. Discussion

Through this systematic literature review, we aimed to answer two main research questions:

RQ1. What is the state of the art of Internet of Services-based business models?

To answer the first research question, we analyzed the selected studies and their developments in IoS by dividing them into four categories according to their focus: infrastructure, service operation, business applications, and social applications.

As it is closely-related with technologies paradigms, the review reflects important scenario movements on the Internet environment and on ICT over the past decade.

By offering business functions as web services, it is possible to "break up enterprise boundaries and harmonize services of diverse development platforms. Business services can be made openly available and reusable for supporting collaborative business processes by service orchestration or choreography" [60].

From the categorization in Table 1, it is noticed that the focus of the first papers was much more on IT infrastructure. Although the term "business model" was often mentioned in the papers, the content was mainly on SOA, software functions, and how web services should work through the applications [11,42–44,46,47] (P12, P15, P16, P17, P19, P20), likely the technical prerequisites to make the business feasible but not a discussion on the business or IoS-based business model.

Apart from technical aspects, important questions arise regarding who the suppliers of such services are, how the value capture guarantee that billing and revenue are well structured, and which are more sustainable alternatives for suppliers of such services [61].

From a business perspective, there is a need of understanding how value is created through business services. "A special emphasis has to be given to the generation of new business models for all stakeholders (i.e., service providers, aggregators, and consumers) and corresponding incentive mechanisms" [10] (P22). However, the value creation, which is one of the main functions of a business model [20], rarely appears among the selected papers that address the business applications.

For Komarov and Khokhlova [39] (P11), the phenomena of the IoS concern different spheres, yet the focus has been placed on its connection with the IoT. Bachara et al. [53] and Chao [38] (P10) state that the IoS is an extension of the IoT, poised to take e-service markets to the next stage.

While IoT emerged in the business literature [62–64], the IoS research remained among the developers' software engineers [49], focused on the infrastructure and appropriate programming codes to develop applications [15,51,52,65].

Although the focus changed from the pure IT infrastructure to a business view in the studies that cover the business and social applications, the authors still emphasize the services being potentialized by the IoT and how IoT is an important infrastructure for IoS [30,32,36,39] (P2, P4, P8, P11). In the Industry 4.0 scenario, the CPS gains the same relevance to form the IoS [29,34,35] (P1, P6, P7). The studies explain the business or social application through the technological aspect but lack in the business and organizational aspects.

By analyzing the types of business model studied by Øverby and Audestad [25], the ones that have already a digital mediation platform and exploit the network collaboration, could apply to IoS if some other IoS features are explored. One example is Airbnb, a C2C digital platform that would be stronger if they applied some of the IoS features to shape their existing business model. Additionally, the different payment methods could be combined for value capture in an IoS-based business model, such as subscription, pay-per-use, or ad-based free.

Considering the low number of papers that correlate IoS and business model, there is still a gap in understanding how to construct an IoS-based business model. There is a lack of a detailed view of the business model to support the concept of IoS in creating, delivering, and capturing value to customers. Efforts are still focused on the IT level. Little work has been completed at the business level.

RQ2. What is their classification based on application field?

Regarding the application fields, it is noticed that the role IoS, the heartwood of Industry 4.0, is not entirely clear in this scenario. It would be important to assess how IoS is applied for advanced manufacturing. Manufacturing progressive concepts such as digitalization, standardization, flexibility, customization, real-time responsibility, predictive maintenance, are moving to Industry 4.0, which involves decision making, self-optimization, self-configuration. However, further research and development still needs to be undertaken.

There is a line of research focusing on digitalization and servitization within Industry 4.0. Frank et al. [66] study the connection between Industry 4.0 and servitization, presenting a conceptual framework that analyze the role of digitalization and servitization within the product-firm, while Gebauer et al. [67] discuss the paradox of firms that invest in digitalization and servitization but not earn the expected return. It happens when firms do not study the business model well and all its components, mainly the value proposition. While digitalization and servitization combine digital and services capabilities to facilitate internal growth, the IoS covers the external growth, which is an important view that companies neglect while innovating their business models [67]. Coupled with CPS and IoT, IoS would be a business model proposal that is still being researched and developed to reach Industry 4.0 [35] (P7). R King and Grobbelaar [29] (P1) corroborate that, instead of only firm-centric models as servitization and digitalization, researchers should consider a business model to adopt an ecosystem perspective.

Healthcare and Smart Environment appear as important IoS domains for social applications [32,36,39] (P4, P8, P11). In most countries, one of the largest providers of services is the government. Governments are interested in using the latest technologies to promote the best social climate for their citizens. However, the legal framework of the latest technologies is still considered rather vague or absent to a certain extent. Such issues as standardization, service design architecture and models, as well as data privacy and security create management and governance problems.

The technological advances may also change the future of food production and bring more sustainable alternatives. The innovative systems driven by the CPS, IoT, and IoS start to evolve the rural food production, allowing the automation, communication and digitalization of value chains [68]. The solutions already in place are IoT-based, which enable the smart logistics and traceability with applications for controlled environment and food supply chain tracking [69,70]. An opportunity in this field would be mapping the platforms used by the different stakeholders to propose new services through collaborative networks [71].

From a social applications perspective, the papers that mention the IoS as a trend for business models are conceptual and focus on IoT as an important infrastructure for social applications but do not clarify the IoS role on such business models. Important to shed a light on IoS contribution for business model construction.

6. Research Agenda

Questions around the mapping between the real world of business models and the IoS-based services are still unresolved. Although there is some correlation between business model and IoS in the literature, such intersection is still unexplored. Most research focuses on the infrastructure needed for the IoS environment. Moreover, the papers that describe the IoS are mainly theoretical and bring a few examples of business and social applications.

Based on the presented literature review, we propose a research agenda. The research agenda is composed of two main research streams: (1) exploring the business model meta-components for an IoS adoption, and (2) exploring the IoS application fields. The two research streams are also presented in Table 6 with the respective supporting literature.

Table 6. Research agenda.

Research Stream	Research Question	Supporting Literature
Exploring the business model meta-components for IoS adoption	How to adapt the business model and its structure for applying IoS, regarding value proposition, value creation, value delivery and value capture?	[8,10,25,74]
	How the shift toward IoS-based business model meets social motivations and customer value proposition while being compliant with data privacy and security?	[36,41]
Exploring the IoS' application fields	Which would be an IoS-based business model archetype in traditional service sectors like healthcare and education?	[32,72]
	How to expand the business model in manufacturing sector for an IoS ecosystem perspective, shaping the firm-centric models as servitization and digitalization?	[29,35,67,73,74]
	What is being applied for innovations toward IoS-based business model in agri-business sector?	[68,71]

6.1. Exploring Business Models Meta-Components for IoS Adoption

Future research could investigate the development of business models by organizations for an effective IoS adoption. Figure 2 shows the four sub-areas of IoS proposed in the presented study (infrastructure, service operation, business applications and social applications), interlocking with the business model's four meta-components (value proposition, value creation, value delivery and value capture) [20]. The intersection is the IoS-based business model, which can be better explored in future research.

The widely accepted Business Model Canvas [24], which covers the four areas placed in the second circle of Figure 2, is rarely associated with the IoS. In the present review, considering the papers that explore business or social applications, only Komarov et al. [36] (P8) presented a Business Model Canvas which is an IoT-influenced Smart Home business model. The main goal of their research was to check how the raising number of internet-connected devices influence users.

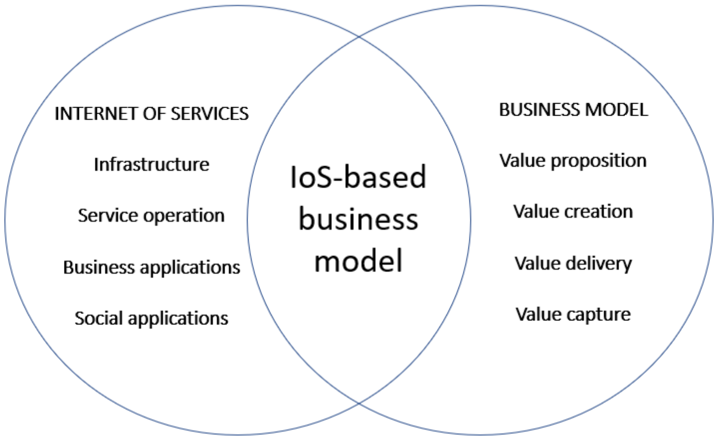

Figure 2. IoS-based business model.

A service ecosystems perspective on business models proposes that "service marketing strategy be less focused on traditional marketing and instead work on the relationship and conversation among the involved stakeholders. A collaborative service-oriented approach has to be embraced to actively explore the rich strategic implication from a service ecosystem" [8]. Consequently, studies that explore how the enterprises are innovating in their business models' value proposition, creation, and delivery for a service ecosystem, allow the expansion of this theme.

Considering the social applications emerging as an IoS domain, another possible future study is the elaboration of research about the social motivations behind a business model innovation. Moreover, analyzing what the customers want and need becomes crucial to develop an IoS-based business model that meets the requirements for a best service delivery. Companies should offer services and solutions that more effectively address their customers' needs [67], always considering their data privacy and security to avoid creating management and governance problems.

6.2. Exploring the IoS' Application Fields

Future studies could promote the IoS expansion in any field that have not yet been assessed in relation to IoS-based business models, considering the service dominance is not restricted to the more traditional services as education, hospitality, and healthcare. It also appears in traditional product-oriented industries such as the manufacturing, building sector, and agriculture.

In traditional service sector, there is a range of applications. In healthcare, "the IoS, as a new concept of Internet evaluation, depends not only on technological solutions but also on service innovations in the field of new value propositions where a patient-centered model is needed. Such a model would consider patient preferences, values, and the need for information as the leading characteristics of care. Patient and medical unit engagement is an essential prerequisite for the new value proposition development process" [72]. Similar research topics could be studied in other services, such as education.

In manufacturing, the IoS role is not totally clear and there are challenges in addressing an IoS-based business model. Jiao et al. [73] question "how to customize products and services to user requirements while producing products of "zero lot size" and "mass production costs". Despite the relevance of the IoS as a pillar for the Industry 4.0 [1,6], the relationship between IoS and business model is not deeply covered by the current scientific research. Although there are theoretical archetypes for data-driven business models in Industry 4.0 [74], they can be further developed to address the IoS and its features.

In agri-business, Lezoche et al. [71] highlight the diversity of stakeholders integrating agri-food chains, and suggest that an integrated platform could support the several players in delivering new valuable services.

7. Conclusions

The IoS is seen as a new ecosystem where service providers and consumers explore their business networks for service provision and consumption. IoS has characteristics that distinguish it, which is the foundation in SOA and modularity, besides a context-aware expected behavior that places it in a Future Internet scenario. Although the IoS plays an important role on business through an innovative way of service offering, there is a gap in scientific literature in covering IoS-based business models and this is what the present review aims to exploit.

A systematic search methodology allowed us to identify 23 studies that were published in journals or proceedings that discuss advances in IoS domain. As a first contribution of the presented study, we proposed a taxonomy to classify the IoS in sub-areas which are: infrastructure, service operation, business applications, and social applications. The selected studies were categorized in these four sub-areas, and then by the application fields. Research could also derive the archetypes of IoS-based business models across the industries, what is an opportunity for future work.

The review showed that most of papers explore the technical infrastructure that will allow the services being offered through the Internet, but lack on a detailed view of an IoS-based business model to support the concept of IoS in creating, delivering, and capturing value to customers. There is room for future research in investigating the role that IoS plays in business, not only coupled with IoT and CPS as the literature often mentions it. Moreover, it is also important to explore other application fields where IoS appears rather than Industry 4.0. The study highlights the opportunities of IoS applications in different fields and present a research agenda for future studies on IoS-based business models.

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4.2 Artigo 2

O artigo *"Using Internet of Services (IoS) to stablish a Service Oriented Manufacturing Architecture (SOMA) model on Industry 4.0"* foi elaborado pelos autores Jacqueline Zonichenn dos Reis, Rodrigo Franco Gonçalves e Márcia Terra Silva. O artigo foi submetido em dezembro de 2021 a um periódico internacional e se encontra em processo de revisão por pares.

Esse artigo atende ao terceiro objetivo específico da pesquisa: 3) Avaliar como a Internet de Serviços pode ser aplicada na prática, para promover a flexibilidade dos processos produtivos na Indústria 4.0.

Com os resultados da revisão sistemática realizada no artigo 1, verifica-se que a Manufatura na Indústria 4.0 é o principal campo de atuação da IoS. No entanto, há uma falta de clareza na literatura sobre como a IoS pode ser aplicada na prática em um chão de fábrica, para promover a flexibilidade na produção.

A estratégia escolhida para o segundo artigo foi a de estudos de caso a partir de um modelo teórico. No modelo, nomeado SOMA (*Service-Oriented Manufacturing Architecture)*, a IoS é caracterizada através de um dos seus fundamentos técnicos que é o SOA (*Service-Oriented Architecture*). O SOA, por sua vez, tem como um dos elementos o ESB (*Enterprise Service Bus*), que é um barramento de serviços. O modelo ilustra como IoS e SOA podem fornecer flexibilidade de produção no nível de PPC (*Production Planning and Control*). A ideia é a de que máquinas e robôs seriam serviços sendo invocados de forma *ad-hoc* pelos insumos e produtos inacabados até o final da linha de produção, trocando dados e instruções através de um barramento de serviços.

Dois casos representativos da Indústria 4.0 foram selecionados para se verificar a adequação do processo de manufatura no chão de fábrica ao modelo teórico. Os dois estudos de caso foram realizados de acordo com uma metodologia de pesquisa de caso conhecida (VOSS; TSIKRIKTSIS; FROHLICH, 2002), que consiste em entrevistas semiestruturadas com funcionários das organizações e observação realizada *in loco*.

Ao se verificar a aderência do modelo teórico SOMA nas duas empresas de manufatura, dois cenários diferentes foram encontrados, e concluiu-se que a IoS se adequou em um processo de produção flexível da Indústria 4.0, mas não em um processo de produção em massa.

A contribuição desse artigo é tratar a lacuna de qual seria o papel da IoS na Indústria 4.0, uma vez que a IoS é citada com frequência na literatura científica como um elemento fundamental deste processo de inovação e transformação digital para a manufatura avançada.

Com esse artigo, foi possível conceituar com mais clareza a IoS e exemplificar, através da elaboração de um modelo teórico-conceitual, como atender às mudanças no plano de produção de um chão de fábrica, contribuindo, assim, para uma produção mais flexível e customizada.

Abstract

The manufacturing industry has been reshaping its operations using digital technologies for a smart production towards a more customized demand. Nevertheless, the flexibility to attend the production plan changes in real-time is still challenging. Although the Internet of Services (IoS) has been addressed as a key element for Industry 4.0, jointly with the Internet of Things (IoT) and Cyber-Physical Systems (CPS), there is still a lack of clarity about the IoS contribution for advanced manufacturing. Through bibliographical research and a theoretical model named SOMA – Service Oriented Manufacturing Architecture, two important concepts may explain the IoS role from a design level: SOA - Service-Oriented Architecture – and ESB - Enterprise Service Bus. The paper aims to validate the adherence of such a theoretical model SOMA in two manufacturing companies that have been already engaged in the Industry 4.0 employing a case study,. As main results, it was concluded that IoS, represented by the SOMA model, could suit in one case of Industry 4.0 flexible production process but not in a mass production one. Considering the scarcity of research that exemplifies the IoS contribution, the present paper critically assesses a real manufacturing scenario.

Keywords: Internet of Services, Industry 4.0, Service-Oriented Architecture, Service Bus

1. Introduction

The first three industrial revolutions have brought essential changes in manufacturing, from steam engines to automated electrical and digital production [1]. It has evolved due to mechanization, electricity, and Information Technology, respectively [2].

In 2011, the German Federal government introduced a new program called Industry 4.0, intending to strengthen and direct manufacturing advances through the application of Information and Communication Technologies (ICT) [2–5].

By encouraging the introduction of the Internet of Things and Services into the manufacturing environment [2]. Through such advanced application of information and communication systems in manufacturing, the factory environment might become smart. In order to attend to customers' needs and desires, the production process should have flexibility, reduced setup time, small batch sizes, and mass customization [6].

Nevertheless, after some time that Industry 4.0 was first coined, companies are still looking for the best approach and trying to understand this new paradigm, mainly because there is a need for clarification of Industry 4.0 related concepts and technologies [3].

Among the technologies that evolve Industry 4.0, the main ones would be the Cyber-Physical Systems - CPS, Internet of Things – IoT, and Internet of Services – IoS [2, 5, 7, 8]. While CPS and IoT deal with tangible sensors, actuators, and objects [9], the IoS covers an abstract set of functionalities from a more intangible standpoint which is natural from services [10]. In scientific literature, the applications of IoT and CPS in Industry 4.0 are exhaustively discussed; however, there is still a lack of clarity on how the IoS fulfills the Industry 4.0 requirements on a manufacturing shopfloor scenario.

By exploring the root of the IoS concept and its correlation with Industry 4.0, the main foundation is SOA - Service-Oriented Architecture [11]. SOA is a logical model that reorganizes logical applications into a set of interacting services centered on service orientation [12]. The service orientation has two principles: (1) Interface related principles, which are related to technology neutrality and protocol standardization, and (2) design principles, which address the real business needs and make services adaptable, easy to use, and manage [13]. The present paper aims to cover the design principles.

Another concept enabling SOA, thus enabling IoS, is the ESB (Enterprise Service Bus). ESB is the service registry that enables a fully integrated and flexible end-to-end SOA by describing the service requestors, service providers, and operations through the information flow [14].

In order to bring value to customers, Industry 4.0 produces an increased number of product types and looks for smaller production batches. However, the vast number of setup changes, in addition to the inevitable production scheduling adjustments, can be a burden for the operator and the production control. Imagine the production schedule is a sequence of operations requirements linked to the machine, and one batch is inserted. The operator has to identify that, modify the machine setup and amend the production schedule. The idea of service inherent to SOA's design principles and ESB use can reverse the rationality. In this case, the process requirements are linked to the product, and at the different workstations, it "requests" the necessary operation, enabling reconfiguration through adapting or changing production requirements [15].

Although there is solid research on service-oriented architectures for developing and exploring methodologies in order to achieve higher flexibility in manufacturing, the assessment of a service-oriented model in a real manufacturing scenario is still missing.

The research question is: How could the IoS improve the production flexibility and product customization at the shopfloor?

It has been assessed the role of IoS in a smart factory shopfloor, employing a case study, and extending the study of the Service-Oriented Manufacturing Architecture (SOMA) model [16] through its evaluation and validation in a real manufacturing scenario. The proposed SOMA model [16] is a conceptual model about how IoS and SOA can provide production flexibility at the PPC (Production Planning and Control) level.

This paper aims to validate applying an IoS-based SOMA model in a flexible manufacturing shopfloor regarding flexible PPC, small size (or unitary) batches and product customization. The expected impact is a better response to the unexpected changes of customer demands which is one of the goals of Industry 4.0 for smart production.

2. Literature review

2.1. ***Industry 4.0***

The term Industry 4.0 was rooted in the German Federal government´s strategy in 2011 [2]. Such initiative had the aim of strengthening the manufacturing by advanced application of information and communication systems.

Industry 4.0 is defined as a collective term for technologies and concepts of value chain organization [5]. Among this set of technologies, the protagonist would be CPS, IoT, and IoS [2, 5, 7, 8].

CPS are sensors and actuators that monitor physical processes and create a virtual copy of the physical world [9]. Over the IoT, CPS communicate and co-operate with each other and humans in real-time. The CPS and the IoT are linked with the IoS, which present the distributed intelligence, completing this complex eco-system. Through the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain [5]. Consequently, the demand for interoperability among all systems, devices, and processes from factory shop floor up to the enterprise and business systems - is rapidly growing [17].

The promoters of the German program explain that Industry 4.0 involves the technical integration of IoT and IoS as enablers to create networks, incorporating the entire manufacturing process that converts factories into a smart environment [2].

Industry 4.0 is called to pull applications and push technologies enabling the future factories [18]. The leading technologies are Internet-based, as the IoS, favored by new developments in computational power, leading to cloud computing and services. “These technologies have the potential to give rise to a new generation of service-based industrial systems whose functionalities reside on-device and in-cloud” [19]. Other technologies would be: Big Data, Simulation, Augmented Reality, Cybersecurity, Additive Manufacturing, and Autonomous Robots [3].

Within the Industry 4.0 concept, "the Internet and supporting technologies serve as a backbone to integrate physical objects, human actors, intelligent machines, production lines, and processes across organizational boundaries to form an intelligent, networked agile value chain" [19].

*2.2. **Internet of Services***

The term Internet of Services was raised from the convergence of other two concepts: Web 2.0 and SOA [11]. The intersection of these two fields is the notion of reusing and composing existing resources and services.

Web 2.0, the first concept, is characterized by four aspects: interactivity, social networks, tagging, and web services [20].

- The interactivity comes from AJAX (Asynchronous JavaScript and XML) technologies that allow the communication and dynamic manipulation of data between a server and the web browser.
- Social networks, based on shared interests, make the information from each network available in different ways.
- Tagging allows users to add a keyword as a tag to certain web content, making this tag easily reachable when searched by other users.
- Web services allow that other software makes use of the features offered by a web application, being available not only to people but also to machines.

The second concept that forms the IoS is the SOA [11]. SOA is a way of designing and building a set of Information Technology applications where application components and web services make their functions available on the same access channel for mutual use. In order to satisfy these requirements, services should be [12]:

- Technology neutral: they must be invoked through standardized lowest common denominator technologies that are available to almost all IT environments. This implies that the invocation mechanisms (protocols, descriptions, and discovery mechanisms) should comply with widely accepted standards.
- Loosely coupled: they must not require knowledge or any internal structures or conventions (context) at the client or service side.

- Support location transparency: services should have their definitions and location information stored in a repository such as UDDI and be accessible by various clients that can invoke the services irrespective of their location.

Besides this more technical foundation based in SOA, the IoS also has a business connotation. From a business standpoint, IoS is seen as a collaborative business ecosystem or global market where services from diverse providers are offered, discovered, and consumed in combined use [17, 21, 22]. It is also seen as a future Internet that detects and uses contextual information to adapt perfectly to an unpredicted scenario, allowing the ad-hoc configuration of new IT business models [23–25].

2.3. ***Service-Oriented Architecture - SOA***

The SOA can also be explained through two different perspectives. From a business standpoint, it represents a set of services that improve the capability of the enterprise to conduct business with customers and suppliers. From a technology point of view, it is a project philosophy characterized by modularity, separation of concerns, service re-use and composition, and a new programming method based [26].

Web Services technology constitutes the main vehicle for the SOA. Web Service is defined as “a software system designed to support interoperable machine-to-machine interaction over a network” [27]. It has an interface described in a machine-process format that informs what the service does and how to call its functions. Web services delivery functionalities (called *services*) offer simple input and output interfaces, hiding the internal structure and programming language used by other web services or software applications [27].

Through the concept of SOA, new applications can be assembled from the available components and services. In analogy to Lego™, grouping these elementary and inter-connectable entities allows for building complex systems, which are modular, reconfigurable, and evolvable. The reconfiguration is achieved due to the easy re-organization of the entities and the services they provide, reflected by the modification of the connections between the devices presented in the system [28].

The integration of devices into the business through SOA has been considered a promising approach to connect physical objects and to make them available to IT systems. This can be achieved by running instances of web services on these devices, enabling them to interact and create an IoS that enables service-oriented manufacturing [29]

In SOA, all applications in an organization can offer and consume services in a unique and integrated communication channel, called Enterprise Service Bus, as a simple way to facilitate integration [30]

2.4. ***Enterprise Service Bus – ESB***

The ESB is a software architecture that has a set of key characteristics [31]:

- To message routing and control across enterprise components
- To decoupling various modules by asynchronous messaging, replacing point to point communication with the typical bus architecture
- To promote reusability of utility services, reducing the number of redundant services across the enterprise
- To provide transformation and translation of messages to allow easy integration of legacy applications
- To provide an engine for workflow execution

The definition of service is broad; it is not restricted by a protocol, such as SOAP (Simple Object Access Protocol) or HTTP (Hypertext Transfer Protocol), which connects a service requestor to a service provider. Though all these standards are major contributors to the ESB/SOA evolution, it does not require the service to be described by a specific standard such as WSDL (Web Services Description Language). However, all these standards are major contributors to the ESB/SOA evolution. A service is a software component that is described by meta-data, which a program can understand. The metadata is published to enable the reuse of the service by components that may be remote from it. It needs no knowledge of the service implementation beyond its published meta-data [14].

The ESB enables the SOA by providing the connectivity layer between services. Descriptions of the services available from a service provider can be made accessible to developers at the service request, possibly through shared development tools. The ESB formalizes this publication by providing a registry of the available services for invocation and the service requestors that will connect to them. The ESB is the connectivity layer for process engines that choreograph the flow of activities between services [14].

2.5. ***Communication and Integration***

The basic principle to a smart factory or a smart production is the integration of the production facilities, both software and hardware, like Information Systems and machines.

Strljic et al. [32] point that the communication and integration of software components are essential to establish a reconfigurable production system or facilitate functionalities in the Industry 4.0 context. To achieve this, communication standards, like OPC UA, are crucial for data exchange. The OPC UA is a platform-neutral standard for data exchange in industrial automation. It establishes a service-oriented architecture to integrate, through web services, machines, equipment, and enterprise systems (e.g., ERP) [33].

The OPC UA research focuses on the shop floor and production facilities configuration and deployment, but not in the production execution, nor into PPC for product customization.

The OPC UA is a key standard of RAMI 4.0, which is a model that augments existing physical facilities with communication technology to make the information available to all the hierarchy levels and lifecycle phases. RAMI 4.0 is not explicitly motivated by the design of new CPS systems or opportunities from exploiting functional requirements of such systems [34]. Nevertheless, since OPC UA is intrinsically compatible with SOA, it can be the technical base to support the SOMA model in practice.

3. Related works

Before the advent of Industry 4.0, the SOA had already been considered a promising approach to achieve higher flexibility in manufacturing [35]. Table 1 lists some critical SOA models, their proposal, and analyzed limitations.

The SOA and its related standards for web services have been proposed for automation control [36], working as the middleware for the integration between the shopfloor and back-end applications, such as Enterprise Resource Planning (ERP) [29]. Although these approaches were a first step towards more adaptive manufacturing systems, they applied the traditional top-down focus of business process integration which, for instance, is too static for highly customized products with small lot sizes [35].

Legat et al. [35] introduce a service-oriented manufacturing architecture, where an intelligent product passes through several production sites and requests the required processing operations as services from the available resources. The product could be manufactured by a priori unknown and changeable manufacturing systems, but the research is based on an abstract model without implementation details. Other similar SOA product-based models have been proposed [37] but validated only the monitoring level.

The Manufacturing Service Bus (MSB), an adaptation of the ESB for manufacturing enterprises, has been presented as a concept of bus communication for the manufacturing systems [38]. The MSB acts as a middleware to distribute work amongst connected components, assuring loose coupling between modules at the shopfloor level. The main role of the MSB implementation is to perform the event dispatch operation allowing shopfloor components to exchange information in an event-driven fashion. The event communication works from shop floor to upper levels but mainly for monitoring purpose and do not enable an adaptive production yet.

The event communication aims to measure the performance of machines and plants in real-time to recognize and correct errors and waste [39] quickly. It complements standard ERP software on the planning level (top floor) using objective performance data coming directly from all factory assets (shopfloor) from one single machine to multiple plants worldwide. A similar approach called Intelligent Enterprise Service-based Bus (iESB) [40] has been proposed to interconnect several factory systems to each other. The architecture is based on intelligent services defined as independent pieces of software that are expected to provide a particular result, either produced by the intelligent service itself or by requesting support from other intelligent services.

Although the ontologies and description languages have also been studied in the manufacturing context, Gamboa Quintanilla et al. [41] explain that they are designed for web applications, which have different use from those found in manufacturing applications. Web applications are mainly focused on interoperability, while in manufacturing, the exploration of process flexibility comes more into play during the stage of process planning.

The IoS or cloud services are presented as an evolution of a networked and service-oriented manufacturing model through which shopfloor items may access a shared pool of computing devices [42]. Manufacturing enterprises have adopted cloud computing mainly on the higher layers of business processes for supply, digital marketing, and ERP [43, 44].

As listed in Table 1, the main SOA models have been tested for event communication from shop floor to upper levels for monitoring purposes. The SOMA model instead addresses the flexibility to adapt to the changes in the production plan.

Moreover, the research of cloud manufacturing services is focused on theoretical frameworks and prototypes. It is missing though the evaluation of such conceptual models in the real industrial environment to assure a readiness level to the industry [47].

Some research explores Plug and Produce's concept to describe how the SOA can be used to design and deploy a flexible factory layout, replacing and integrating machines and systems with well standard protocols. Atmojo et al. [47] present a product-centered and flexible assembly line using OPC UA. Strzelczak et al. [48] propose an open automated manufacturing environment using an ontology that allows the fast commissioning of new plants and the inclusion of new equipment.

Table 1. SOA models

SOA models	Model proposal	Analyzed limitation
SIRENA Service Infrastructure for Realtime Embedded Network Devices (Bohn et al., 2006) [36]	Middleware for the integration between the shopfloor and back-end applications	The top-down focus of business process integration which is too static for highly customized products with small lot sizes
SOCRADES Integration Architecture (de Souza et al., 2008) [29]	Architecture to facilitate the querying and discovery of real-world services from enterprise applications	Focus on integration between the shopfloor and Enterprise Resource Planning with no validation
Abstract Manufacturing Service Model (Legat et al., 2010) [35]	An abstract model combining service orientation to achieve changeability on the shop floor and bottom-up supply chain integration by intelligent products	Focused on mathematical bases to create an abstract level between machine and supervision layers but with no validation on real business
Service-Oriented Operator 2.0 architecture (Nagorny et al., 2012) [37]	A prototype that allows the virtualization of a shop floor, making it feasible to proceed to control and monitoring	Focused on a better monitoring control through the virtualization of the resources
MSB – Manufacturing Service Bus (Morariu et al., 2012) [38]	Middleware to distribute work among connected components, assuring loose coupling between modules at shopfloor level	The event communication works from shop floor to upper levels but mainly for monitoring purpose
Real-time monitoring SOHOMA (Service Oriented, Holonic and Multi-Agent manufacturing Systems (Morariu et al., 2014) [50]	The target system is a manufacturing shop floor, where each component of a system (resource of product) is linked to a monitoring agent. These agents send monitoring data via a monitoring data stream	The solution provides a monitoring portal where system administrators can track key performance indicators in real-time. The paper discusses the strategies for handling the monitoring data in real time
eScop approach based on Plug & Produce (Strzelczak et al., 2015) [48]	Architecture proposed to combine the power of embedded systems with ontologies for a fully opened manufacturing environment	Work to allow the inclusion of new equipment by easy and fast commissioning of new plants, not focusing on production plan
SOIMS Service Oriented Intelligent Manufacturing Services (Giret et al., 2016) [45]	Design of artefacts that facilitate the various manufacturing resources to be intelligently connected to the internet	Focused on notations to support the identification and specification of the system components, pending validation
SoHMS (Service Oriented Holonic Manufacturing Systems (Gamboa Quintanilla et al., 2016) [41]	Modelling framework that creates families of products from their customizable specifications based on manufacturing services.	Focused on computational model for the possible specifications of the products, and let the focus on flexible production plan for future works
Cloud Manufacturing Service Bus (Răileanu et al., 2018) [51]	Solution based on private cloud infrastructure that collects data in real-time from intelligent devices associated to shop-floor resources.	Experimental evaluation of the data collection process from measuring devices embedded on robots and of the data transfer in the cloud
Plug and Produce for Industry 4.0 - 2019 (Madiwalar et al., 2019) [49]	Solution combining Software-defined Networking and OPC UA to add more intelligence to the device discovery	Enables the fast integration of new devices, focusing on fast inclusion of new equipment to the shopfloor but not focusing on production process in the execution time

In the same line of research, Madiwalar et al. [49] propose an OPC UA-based integration model to support flexible and agile production facilities capable of accommodating changes to product specifications, enabling the integration of new devices by Plug and Produce.

The main difference between the Plug and Produce concept and the SOMA model is that SOMA is concerned with the production execution flow, not with the design and deployment of the production facilities.

4. Materials and Methods

The research method is divided in two phases. The first is related to the bibliographic review, presented in sections 2 and 3, to support the concepts related to the SOMA model, its relevance, and differences with other models. The second is related to the case studies evaluating SOMA in the real operational context in two industrial companies.

The bibliographic review is also divided into two parts. The first part was exploratory, looking for the relevance and originality of the subject, and was done to understand better the role of the Internet of Services in the Industry 4.0 manufacturing environment. The second part of the bibliographic review was done to evaluate the SOA application in manufacturing, gathering the foundation concepts of IoS. It was used the string *("service-oriented architecture" OR "service-oriented architecture") AND manufacturing* only in the Web of Science and performed a non-exhaustive inclusion or exclusion selection. This result identified two research lines, and two other searches were explicitly conducted to explore these lines. Table 2 brings the queries, the purpose, and the results.

Table 2. Boolean Strings used for the research

Search query	Purpose	Results
("service-oriented architecture" OR "service-oriented architecture") AND manufacturing	Identify the literature related to SOA and manufacturing.	317 papers were found, 228 of them were proceedings papers. Two lines identified: related with production operation and related with factory deployment and integration ("plug and produce")
("service-oriented architecture" OR "service-oriented architecture") AND "plug and produce"	Characterize the difference between SOMA and the integration or factory deployment models	4 proceedings papers founded
("service-oriented architecture" OR "service-oriented architecture") AND "production planning."	To obtain other models or concepts related to SOMA and their similarities and differences	4 articles and 5 proceedings papers founded

Two case studies were evaluated to answer the research question based on the literature review and a theoretical model representing the SOMA [16]. The case study methodology is often used in the Operation Management area to understand a particular condition better, problem, or solution adopted or occurred in the unit of analysis, like a company. The advantage is the depth of the study but, given the condition, the generalization of the results is not possible. The case study has two research proposes: in the inductive mode, to create theory; in the deductive mode to evaluate in real conditions a theory or model [52]. In this paper, the case study was utilized in the deductive mode to evaluate the SOMA model. The case study used the methodology to evaluate if the theoretical model SOMA can be verified in practice and the concept's implications to production flexibility and product customization at the shop floor.

Two representative cases of Industry 4.0 have been selected to assess the model's adaptability by validating if the manufacturing process in the factory shopfloor would match the SOMA model.

The two case studies were carried out according to a known case research methodology [53], consisting of semi-structured interviews with workers of the organizations and observation carried out *in loco.* It was followed the deductive or theory-testing process explored by the same author in a more recent paper [54]. From the theory or concept, the SOMA model, we addressed the following research question: How could the IoS improve production flexibility and product customization at the shopfloor?

Both cases studies were conducted with interviews and observation *in loco.* In the first moment, we presented the SOMA model to the interviewers and asked if the SOMA model reflects what they have on their production flow. In the affirmative case, we asked how and which services were invoked. In negative case, we asked how the production flow worked then. In a second moment, we visited the factories. The observation was done at the shop floor during the production flow (real-time production observation) because the objective was to understand how IoS has been used in the real-time production flow and how it can provide flexibility. This way we investigated deeply how the production flow worked in both companies. We were able to look for similarities and differences from their productive process against the SOMA model.

The two organizations profile and the reasons why they were selected for this study are explored below:

- ALPHA is a multinational company that develops solutions and products for automation sectors, such as electronic and mechanical sensors, rotary and linear displacement transducers, and identification systems. ALPHA counts with approximately 4000 employees, and it is represented worldwide in more than 60 countries. The plant visited produces inductive, optical, and mechanical sensors, also providing customization for the local market. The organization has been chosen for the case study because it has been gradually inserted into Industry 4.0 scenario, moving from a productive manual process to an automated and robotic plant. Moreover, ALPHA is a partner for industrial automation solutions to make their customer revamp to Industry 4.0. The first semi-structured interview has been done remotely with the product manager, and the engineering supervisor has answered complementary questions during the coordinated visit to the plant.

Being globally inserted in the context of Industry 4.0 has been part of BETA´s strategy since Industry 4.0 emerged, which is why we have chosen it for this case study.- BETA is an automobile manufacturer within a large multinational industrial group that develops industrial and service activities. It currently employs more than 100,000 people in more than 50 countries. The car plant visited produces passenger and utility vehicles. Besides their automated and robotic factories, they have created a compelling, adaptable, and secure workspace by adopting virtual assembly and simulation through Industry 4.0 technologies such as CPS, IoT, and Augmented Reality. The first semi-structured interview has been done remotely with the digital product manager, and complementary questions have been answered by the integrated process operator during the coordinated visit to the plant.

4.1. SOMA conceptual model

In the computer science domain, the service orientation defines the principles for conceiving decentralized control architectures that decompose computational processes into sub-processes, called services. The focus of SOA is to leverage the creation of reusable and interoperable function blocks to reduce the number of reprogramming efforts [41].

A cloud manufacturing system's various manufacturing resources and abilities can be intelligently sensed and connected to the broader Internet utilizing SOA principles [45]. SOA is centered on the notion of service orientation, i.e. the entities provide their functionalities and skills in the form of services that may be searched, requested, and used by other entities [28]. As a metaphor, it is like a shopping mall underground floor in which various services such as barbershop, cell phone repair, tailor´s shop are offered in the same physical location, facilitating customer access [16].

Bhadoria et al. [35] complement that, in SOA, all organizations can offer and consume services in a unique and integrated communication channel, called Enterprise Service Bus, as a simple way to facilitate integration. Since Industry 4.0 brings an increasing number of smart objects interconnected to the manufacturing environment, another challenge is the increasing complexity of managing such networked smart objects. Schel et al. [55] suggest that a *Manufacturing Service Bus* (MSB) could offer a solution.

The model shown in Figure 1 utilizes a Service Bus, where different production workstations or facilities, like robots, machines, manual tasks, and information systems, are available as service providers for the manufacturing processes. The different services can be accessed, matched, and integrated by discovery and composition applications creating the SOMA model, which is an approach to understand how IoS can be used during the production flow in an Industry 4.0 smart manufacturing shopfloor environment [16]. It is related with a flexible and agile PPC, from the inception to the end of the production process (ready products).

In the SOMA model, the products invoke the necessary services shared through the Service Bus following a flexible and modular smart productive chain. Each offered service can be parameterized following the product demand in real-time. By running in the production flow, each product invokes the appropriate service, informing parameters and instructions.

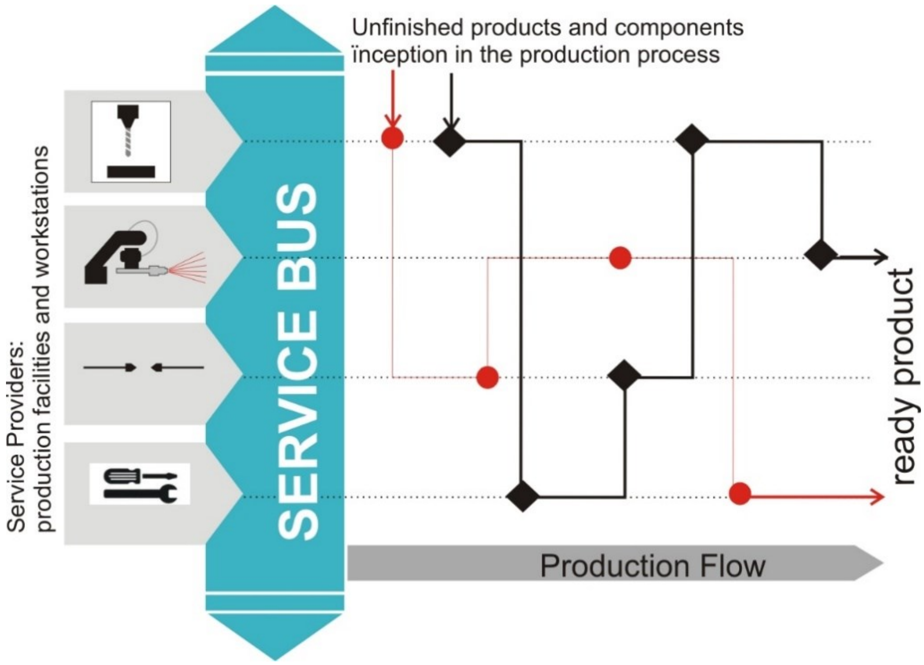

Figure 1. Service-Oriented Manufacturing Architecture (SOMA), adapted [16]

This way, the products batches can attend to different demands from clients and can be reduced until the unitary size or individual product customization. The PPC becomes more agile and flexible, responding quickly to new demands or changes. In this sense, many production features or capabilities related to the Industry 4.0 can be addressed.

The SOMA model is a dynamic model that shows the orchestration of the services and the production flow, where each product (or batch) in the line has its own "music score" to be played.

Although the SOMA is a conceptual model, the service bus can be established at the implementation level based on universal communication and integration protocols, like OPC UA, that are intrinsically SOA-based [33].

4.2. Evaluation of the SOMA model with Case Study

For validating the SOMA model, two representative cases of Industry 4.0 were selected.

Through interviews and observation within the two selected organizations, the model's adaptability has been assessed and validated if the manufacturing process in the factory shopfloor matches the SOMA model.

4.2.1. Validation in the company ALPHA

Although the company ALPHA has been inserted in Industry 4.0 context, most of the manufacturing processes are still manual since ALPHA produces a wide product mix with very customized batches. Digital Poka-yoke is used in almost all the workstations to avoid human errors while workers are assembling the products since all assembling operations are handmade. But there are also automated systems to assure that only the authorized and capable worker can login and operate the machines, thus avoiding production errors. The main products are industrial sensors, but the company also produces many products in the Industry 4.0 context, and, sometimes the shopfloor is used as a showroom.

Through event communication, some machines can trigger alarms of high utilization or operation errors. The Internet is widely used for dashboard publication and remote access to these data so that managers and stakeholders can consult them for decision making.

A specific process that is already automated and matched to the SOMA model is the kiln process, illustrated in Figure 2 and here explained further:

When the components enter the shopfloor, called the baptism step, the tray receives an RFID tag linked to the system that says which sensors (products) are contained therein. Then through the tray number, the system knows all the features of those components. For example, in tray 37, there will be sensors of type M8. They go through the component assembling process (represented by only three assembling workstations in figure 2) and place the resin. In each step, the product in process requests the supervision service by the digital *poka-yoke* (represented in figure 2 by the traced line, since the product has no physical movement, only information flow). The products pass to a control station and go to the drying. The products go to the specific kiln with the required drying time, temperature, and pressure set up in the drying process. There is a total of three kilns, and the selection of which one will be used depends on the type of sensor contained in the tray. The selection process of the kiln is automated as follows: At the reception of the components in the dry kiln room, there is an RFID antenna that reads the RFID tag on the tray. The system looks for the RFID tag number and, since the tag number is already known from the previous baptism step, the system is already able to match the information of sensor type with the kiln that the tray should be sent to and how long the material should remain there, under which temperature and pressure. At the door of each kiln, there is also an antenna, and when the tag passes through it, the counting of the necessary drying time will start. The kiln number, the tray number, and the counting time appear on the monitor for control.

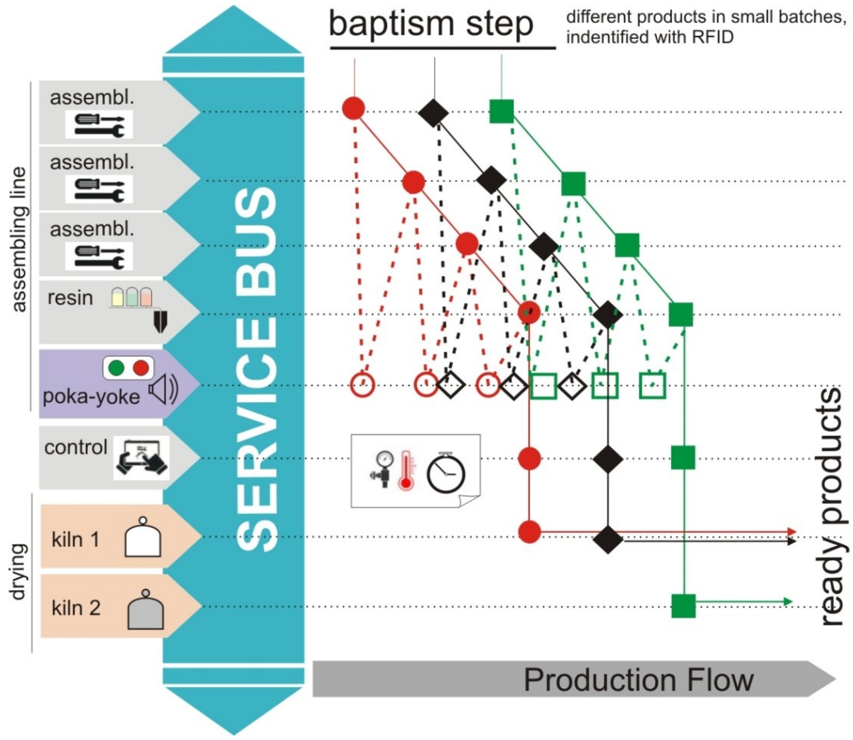

Figure 2. *Company ALPHA production flow*

This way, the company ALPHA can obtain flexibility given the agility to quickly set up the machines and operations, parametrized by the information linked with the product RFID.

It is noticeable that there is a product intelligence being able to invoke the kiln service once the products have made this selection in the process. In addition, internal users and external vendors also have access through the Internet to the operation of the kilns and the traceability of these products. There is also a plan for this to be made available via an App through which salespeople carry out a marketing campaign to show potential customers how the process works.

This kilning process matches the SOMA model because intelligent products arrive at the factory shop floor, request manufacturing services running the necessary tasks and processes. Based on a description of the required task, the production system can determine matching services fulfilling the requested process requirements and available configurations of the manufacturing services.

4.2.2. Validation in the company BETA

The company BETA has been adopting several new technologies of Industry 4.0. The automotive factories are all robotized since the products are more standardized through mass production. Simulation and augmented reality are used for worker training and ergonomic tests.

Through the simulation, for example, the worker can feel if the car is too high and if he would be forcing his arms on the workstation. With this information, the organization takes the right decision on the best layout for the workstations and the best position for the workers to avoid fatigue or absenteeism.

In the plant visited, similar to the SOMA model, a system like a Service Bus manages the production; however, the planning for what will be produced is on the robots, whose programming is previously set by the human operators. The Service Bus system has a menu, and the operators choose the recipe. For example, they need to produce 300 front doors for the model X car and 300 rear doors for the model Y car. The operators start that recipe through the system that triggers the PLC and the robots. Ultimately, at company BETA, the intelligence is not on the products nor in the Service Bus because it does not program the robots. The bus activates the robot that already has an internal program to perform its tasks. The Service Bus has the recipe for what needs to be produced, which means the Service Bus is the orchestrating system. And the way this will be done on the factory floor is already known because the robots already have the program for execution.

All the production plan decisions are taken previously based on existing manufacturing resources and their local states. Already planned activities are considered, and the robots, based on their local policy, will know which and when specific tasks need to be performed. The products themselves do not interfere with production flow decisions.

Suppose it is necessary some changes in the robots' setup. In that case, BETA´s digital product manager explains that it requires extra effort and cost, in addition to the various quality certification processes that need to be followed. Several restrictions must be considered in each process. For example, in painting, each change of paint color has a cost. If the robot is going to paint white instead of red, it is necessary to pass a solvent. In the past, this loss was greater, and the company improved on this matter. Today, the loss is minimal due to the optimal configuration. The system makes the ideal recipe because there is no point in painting only white doors, and when it arrives at the assembly, there is no way to assemble yet due to the unavailability of resources in the next step. So, to better use these resources over time, the system is already programmed, considering the optimal configuration for each product.

The production information regarding the quality condition of the manufacturing equipment and its performance monitoring is distributed throughout many information systems such as Manufacturing Execution Systems (MES) for manufacturing process control and systems for management tasks like ERP, warehouse management, and others depending on the area of application. However, the manufacturing process does not change automatically from a configuration demand of the back-office systems nor from the CPS or products themselves. If any re-programming of the production plan is necessary, this is done manually by the operators.

Comparing the case study with the SOMA model, it was concluded that there is not a scenario of flexible manufacturing at company BETA, with the services being invoked directly and contextually from the shop floor.

5. Results and discussion

Although many papers explore the emerging Industry 4.0, there is still a need to clarify its concepts and how the technologies have been applied in the manufacturing industry [3].

According to the literature review, IoS is an essential pillar for Industry 4.0. It aims to be an Internet that detects and uses contextual information to adapt to an unpredicted scenario, allowing the ad-hoc configuration of new business [23–25].

By exploring the new cloud manufacturing system proposed by Industry 4.0, various manufacturing resources and abilities can be intelligently sensed and connected to the broader Internet through SOA and Service Bus principles [45].

The SOMA conceptual model proposes a conceptual model about how IoS and SOA can provide production flexibility at the PPC level.

Preliminary models of the Manufacturing Service Bus (MSB) have been presented as a concept of bus communication for the manufacturing systems exploring more the event communication through agents in the shopfloor level [38, 39]. It works from the shopfloor to upper levels but mainly for monitoring purposes, for example, to measure the performance of machines and plants in real-time to recognize and correct errors and waste. Such a vertical approach from the shop floor to the cloud systems for events communication is already a reality in some manufacturing systems.

Through the SOMA model, besides the event's communication, it is possible also have a service-oriented solution to create flexible production working on a two-way vertical integration. This way, the CPS participate actively in the production process decision-making when invoking the services themselves.

Although other researchers are proposing theoretical frameworks and prototypes for implementing flexible manufacturing with CPS using SOA, they lack an evaluation and validation of such conceptual models in a real industrial environment to assure a readiness level to the industry [47].

Employing case studies in two organizations that consider themselves already inserted in Industry 4.0 scenario, the SOMA model's adaptability has been assessed and validated if the manufacturing process in the factory shopfloor matches the model.

In the company ALPHA, which presents a more customized production, there is a manufacturing process in the shopfloor that contextualizes the flexible manufacturing scenario of Industry 4.0. For example, when the tray arrives with components in the kiln, a sensor detects the associated RFID tag and sends this information to the system. The system then sends back some information so the tray will follow the line to the best kiln for its components. Consequently, ALPHA has intelligent products arriving at the factory demanding manufacturing services for the necessary tasks and processes. Based on a description of the required task, the production system can determine matching services, fulfilling the requested process requirements as well as available configurations of the manufacturing services. In this sense, it was concluded that the ALPHA company case is following the SOMA model.

In the company BETA, the system delivers a recipe with the information for production steps to the robots. Only previously planned activities are considered since the offering process is based on pre-existing manufacturing resources and their local states. The robot receives the script and performs the specific tasks with no adaptive approach. In parallel, there are a bunch of new technologies of Industry 4.0 in other parts of the plant where human workers are and on training centers. The technologies focus on the operator´s efficiency like an exoskeleton, simulation, and augmented reality. This brings the discussion on what should be analyzed to consider that a factory is already inserted in Industry 4.0. Research regarding Industry 4.0 and mainly regarding the IoS shows that there should be a service-oriented and internet-connected production adaptive to a flexible scenario.

With the case studies in different manufacturing techniques, one more customized and the other a mass production one, it can be said that an automatized and robotized industry, using many concepts of Industry 4.0, is not necessarily inserted in a flexible manufacturing scenario, using IoS for this propose.

In proposed conceptual models close to the SOMA model, the connected smart objects publish events to the Manufacturing Service Bus or receive operation requests from the Service Bus. However, it does not mean that the production is following an adaptive process. This is what the present study aimed to validate to have the research question answered. The research question was: How could the IoS improve the production flexibility and product customization at the shopfloor? The found answer is that the IoS, as a pillar of Industry 4.0, would have the function of enabling, through the SOA and the Service Bus, alternative and parameterized production features (e.g. machine operations, manual assembling, digital poka-yoke support, drying) that can be invoked by the products or the production planning directly at the shopfloor in the real-time production flow, reducing the batches and customizing products.

Nevertheless, our results with the BETA company had shown some difficulty implementing this concept in a mass production manufacturing environment.

6. Conclusions

This paper explores the concepts of Industry 4.0, CPS, IoS, SOA, and Service Bus, giving more emphasis to the service domain of the manufacturing environment, evaluating the conceptual model SOMA in real cases of utilization. The SOMA model proposes a simple model to understand how and why production facilities and workstations provide flexibility and customization along with the production flow.

Besides filling the gap of clarifying IoS role in Industry 4.0 by linking the IoS key foundation concepts on a theoretical model, the paper evaluates and validates the model in a real industrial environment.

In the first organization, it was found that the SOMA model serves to attend the flexible production process. Through the services offered in the ESB, small batches and customizations can be done, and all manual assembling operations are assisted by the *poka-yoke* service, providing quality and assurance that different components are connected, in a non-repetitive task. The services are parameterized by the information associated with the product RFID along the production flow. There is a much more customized production due to the wide product mix and variations in each product with small batches.

In the second organization, it was found that the SOMA model does not apply since the production recipe is ready, with no adaptations throughout the process. Flexibility is much less, and products are more standardized with mass production. The SOMA model becomes more useful when seeking greater flexibility.

The SOMA model is a conceptual model to improve flexibility and adaptability at the shopfloor. It is not a new protocol or model for automation or IT-OT (information technology / operational technology integration) and a future research about how to utilize this concept in the implementation level could be done. The paper is also limited by the two study cases, given the scarcity of cases with the possibility of access to information and personal visits by researchers.

Regarding the social implications of our research, the flexibility proposed with the SOMA model may decrease in waste, resources, and energy consumption, what is understood as a more sustainable production. Moreover, the SOMA model does not exclude the human, but it is well-compatible with a hybrid human-automation process at the shopfloor. As social implication, this brings a discussion about the impact to the workforce in the Industry 4.0. It was observed in the ALPHA company that workers are currently more satisfied to work with the digital poka-yoke and other features of the SOMA than the former condition of manual assembly.

The main contribution of this paper is the conclusion that the implementation of the IoS, the heartwood of Industry 4.0, could suit in one case of Industry 4.0 flexible production process but not in a mass production one. In this same line of reasoning, the SOMA model could as well be useful to a mass production industry; however, this use was not observed in the case. In this sense, a discussion about the application of IoS for non-flexible process and mass production remains open for future studies.

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4.3 Artigo 3

O artigo "*Internet of Services-based business model: A case study in the livestock industry"* foi elaborado pelos autores Jacqueline Zonichenn dos Reis, Rodrigo Franco Gonçalves, Epaminondas de Souza Lage e Irenilza de Alencar Nããs. Foi publicado no periódico *Innovation and Management Review*, em junho de 2021.

Esse artigo atende ao quarto objetivo específico da pesquisa: 4) Propor um framework para criar um modelo de negócio baseado em Internet de Serviços na Agricultura 4.0.

Dos resultados da revisão sistemática realizada no primeiro artigo, verificamos que, apesar de a IoS ser citada como relevante para novos modelos de negócios, é escassa na literatura essa correlação. Falta uma proposta de modelo de negócios baseado em IoS. Além disso, potenciais aplicações são apresentadas na literatura, porém de forma evasiva, sem um esclarecimento da contribuição da IoS para a inovação do modelo de negócios. Na agricultura, por exemplo, sabe-se de inovações envolvendo agricultura de precisão, soluções para monitoramento, rastreamento etc., no entanto, não há uma abordagem de serviços ou da contribuição da IoS para a transformação digital no agronegócio.

Neste artigo, foi proposto um framework para a criação de modelos de negócios baseados em IoS no campo da Agricultura 4.0. O framework foi criado com base na revisão da literatura e avaliado por um estudo de caso único. O estudo de caso foi realizado de acordo com uma metodologia já conhecida (VOSS; TSIKRIKTSIS; FROHLICH, 2002), consistindo em entrevistas semiestruturadas para comparar o framework ao negócio real da empresa.

O artigo apresenta uma contribuição significativa ao avaliar a IoS para apoiar uma empresa brasileira de produção de ovos caipiras durante a inovação do modelo de negócios. Com este artigo, preenche-se a lacuna da literatura sobre a falta de um modelo de negócios baseado em IoS, ao se propor um framewok que indica os atributos de adoção de IoS, descrevendo como a empresa pode criar, entregar e capturar valor. O framework do modelo de negócios baseado em IoS foi elaborado e comparado com um estudo de caso no campo da Agricultura 4.0, mas poderia ser replicado para outros campos de aplicação e inovação, o que fica como proposta de trabalhos futuros.

Internet of services-based business model: a case study in the livestock industry

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Abstract

Purpose – Considering the relevance of innovative business models in the digitally transformed market and the lack of clarity on the internet of services (IoS) contribution for a business model deployment in current literature, this study aims to fill this gap by evaluating a business model that converges to an IoS adoption in a direct sale of free-range eggs from farmers to consumers.

Design/methodology/approach – From the bibliographical research regarding the IoS and business model, the authors developed an IoS-based model framework. The framework has been evaluated in a real business scenario by using a single case study through an interview with the entrepreneur and documental analysis.

Findings – As the main result, a framework with the attributes can be considered a tool for an IoS-based business model deployment. The case study concluded that the business is aligned with the IoS adoption, and the framework presents adherence to it.

Research limitations/implications – The case study was limited to only one company owing to the IoS's novelty and the lack of correlated business models. Although the case study limits to the agriculture field, the proposed framework may be broadly applied.

Originality/value – Considering that the lack of a comprehensive business model causes new businesses to face challenges, it is relevant bringing up the present case study of the IoS-based business model, which correlates these two subjects, still poorly explored in the scientific literature: IoS and business models.

Keywords Business model, Digital transformation, Agriculture 4.0, Internet of services

Paper type Research paper

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1 Introduction

Information and communication technology (ICT) plays a substantial role in catalyzing economic growth, especially in today's age of internet and mobile telecommunication (Pradhan et al., 2018). Nevertheless, enterprise growth's critical challenge relies on integrating digital technologies and their use in new business models (Bouncken et al., 2019).

The digital transformation strategies have four essential dimensions: use of technologies, changes in value creation, structural changes, and financial aspects. Thus, research should seek to identify and concretize elements attributed to these four dimensions (Matt et al., 2015). However, there is still little research on business models intending to create new structures for an innovative market. Furthermore, little is known about how a shift toward service-driven models affects the firm's existing business model and which would be the structure to support the new business model (Schiavi & Behr, 2018). This paper aims to fill this gap by correlating two still poorly explored subjects: business models and the internet of services (IoS).

Although to form the IoS, the services must be described in a way that the business and the technology dimension gather (Wahlster et al., 2014), the scarce literature on IoS focuses on the technological infrastructure and the programming codes to develop applications.

The innovative technologies expanded to rural food production, enabling the digitalization in agricultural production systems (Smith, 2020). In research related to the advances in agriculture and livestock production, the solutions more explored are related to the internet of things (IoT), covering remote sensing and traceability, rarely the IoS domain.

From the bibliographical research regarding the IoS and business models, the present paper brings an IoS-based business model framework. The framework has been evaluated in a real business scenario in the livestock industry by employing a single case study.

Considering that the lack of a comprehensive business model causes new businesses to face crippling challenges (Asadnezhad et al., 2017), it is relevant to bring the study of an IoS-based business model. This article's research agenda presents a framework application empirically by describing how the organization can create, deliver, and capture value through the IoS adoption in a direct sale of free-range eggs from farmers to consumers.

Due to the novelty of the internet of services, the little research available related to a correlated business model, and the absence of studies that investigate Brazilian companies in such an innovative field, this case study presents a significant contribution by evaluating the internet of services to support a Brazilian free-range egg production enterprise during the business model deployment.

2 Conceptual Foundation

2.1 Internet of Services (IoS)

The relevance of the internet of services (IoS) comes from its role as an essential component of the so-called industry 4.0 jointly with the internet of things (IoT) and cyber-physical systems (CPS) (Kagermann et al., 2013; Hofmann & Rüsch, 2017; Satyro et al., 2017; Alcácer & Cruz-Machado, 2019).

While over the IoT, smart objects communicate and cooperate in real-time; via the IoS, both internal and cross-organizational services are offered and used by the value chain participants (Hermann et al., 2016). Traditional value chains are broken up to a large extent and substituted by loose networks of providers and consumers. Every user may publish the content or functionality on the web, becoming a platform operator and consuming resources (or reusing them) to compose new applications and make them publicly available (Hõgg et al., 2006).

As illustrated in Figure 1, the IoT establishes communication between "things," like machines or equipment, through the internet. A "thing" requests data from another "thing" that sends the data, and the unique information needed for this communication is the address as the identification of both parts, given by the internet protocol (IP).

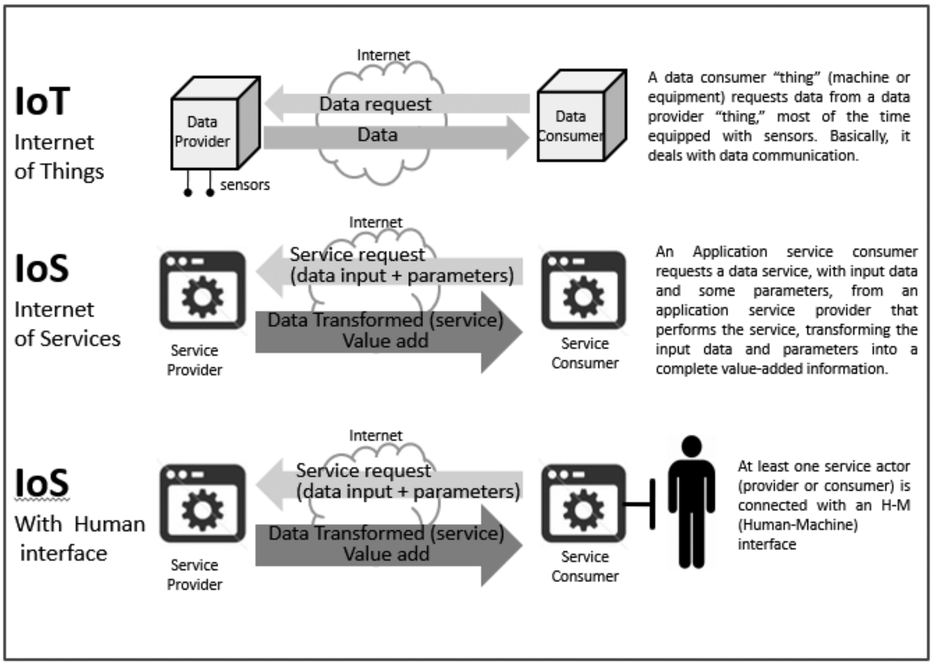

Figure 1. IoT and IoS concepts

Most of the time, the data provider "thing" uses sensors to provide real-time data. On the other hand, the data consumer "thing" can use actuators to act in the physical environment. The IoS concept goes beyond simple data communication because when the service consumer requests a provider's service, the request includes input data and parameters that can modify and personalize the response, returning value-added information. Both provider and consumer services can operate automatically or with human users through a human-machine (H-M) interface, so the final users enter input data and read responses.

Among several definitions offered for the internet of services, the two most common are business related. (1) A collaborative business ecosystem or global market where services from diverse providers (third parties) are offered, discovered, and consumed in shared use (Kritikos & Plexousakis, 2014; Bucchiarone et al., 2017; Givehchi et al., 2017). (2) A future internet that detects and uses contextual information to seamlessly adapt to an unpredicted scenario, allowing the ad-hoc configuration of new ICT business models (Papageorgiou et al., 2014; Camara et al., 2015; Balakrishnan & Sangaiah, 2017). Nevertheless, the scientific literature on IoS focuses on the technological infrastructure and appropriate programming codes to develop applications (Cardoso et al., 2010; Lara et al., 2013; Chmielewski, 2014; Papageorgiou et al., 2014; Bucchiarone et al., 2017). While IoT emerges in the current business model literature (Sun et al., 2012; Dijkman et al., 2015; Ustundag & Cevikcan, 2018), the IoS research is still among the developers' software engineers.

2.2 Business Model

The internet is the primary driver of the surge of interest in business models and the emergence of literature around the topic (Zott et al., 2011). However, there are still important gaps in the research related to business models concerning the new structures for an innovative market.

New business models are likely to provide new opportunities to address customer needs better, generating differentiation from its competitors (Nunes & Russo, 2019). A business model is a conceptual tool containing a set of concepts and relationships to express a specific firm's business logic. It must consider which relationships allow a simplified description and representation of what value is provided to customers, how this is done, and the financial consequences (Osterwalder et al., 2005). An accepted business model approach, both in research and practice, is the business model Canvas (Figure 2A) (Sun et al., 2012; GüNzel & Holm, 2013; Remane et al., 2017) which was introduced by Osterwalder & Pigneur (2010).

Although it is not always clear the reason for the success of a specific business model, it is generally agreed that a well-functioning business model is essential for the success of any enterprise, whether it is a new venture or a well-established company (Magretta, 2002).

The organization of business structures and emerging technologies for the generation of innovation has become a constant concern of managers in recent years (Bouncken et al., 2019). The Business Model Innovation (BMI) literature reveals interesting fields of applications, such as servitization, open innovation, and dynamic capabilities (Foss & Saebi, 2017). Although BMI is predominantly referred to in innovative start-ups, the studies do not shed light on what facilitates entrepreneurial firms' business model innovation.

The literature suggests the main point would be to assess the value-adding of the service-offering and also the value contributed by the partners since partner value and resources play an essential role in service-offering solutions (Weiner & Weisbecker, 2011). The company has to set the service level agreements for delivery and operations among the various stakeholders (Schroth & Janner, 2007), considering the customers play an essential role in the service experience (Berman, 2012; Sun et al., 2012), what is being maximized by the pervasive use of social media tools (Muninger et al., 2019).

The shift from a product-oriented to a service-oriented model leads to new possible revenue opportunities, which brings challenges during the design of new business models (Kastalli & Van Looy, 2013). Enterprises need to focus on getting work with a mix of revenue models (Cristofaro, 2020), such as distribution service charges (pay-per-use), subscriptions, or license renewal for a recurrent revenue (Moreno-Vozmediano et al., 2013).

In the current scientific research, the correlation between the internet of services and the business model is still incipient. One evidence is that the broadly accepted Business Model Canvas (Osterwalder & Pigneur, 2010) is rarely associated with the IoS. Another evidence is that recent research (Grabowska et al., 2020) still brings up challenges related to the adaptation of business models to services scenario, such as the reconfiguration of value chains, the customization and new forms that business models will adopt, and the sharing resources in the network of companies operating under flexible supply chains.

2.3 Agriculture and Livestock 4.0

The current industrial revolution driven by the CPS, IoT, and IoS is expected to have a significant impact on the future of food production as well. The innovative technologies expanded to rural food production, enabling the digitalization in agricultural production systems, value chains, and the decision-making process (Smith, 2020). The need to produce more food with less usable land and reduce environmental impact has led to significant precision agriculture advancements (Lindblom et al., 2017; Bahlo et al., 2019). The robotics and automated systems will improve farm efficiencies and sustainability (Swisher et al., 2018; Smith, 2020).

Several concepts have emerged in the primary food production sector to express different digitalization forms in agricultural production systems. These include smart farming, precision agriculture, precision livestock farming, and agriculture 4.0, to name a few (Dutta et al., 2014; Klerkx et al., 2019).

With the IoT's help, the food supplies can become more transparent than before (Tzounis et al., 2017). The CPS or digital twins (which are sensors and actuators that monitor physical processes and create a virtual copy of the physical world; Jazdi, 2014), will emerge as an essential concept to improve how information about farm industries are coordinated to support decision-making (Dumitrache et al., 2017; Smith, 2020). Therefore, standardization mechanisms at each step of production (from the grower to the consumer- 'farm to fork') need to be adopted to assure food safety and quality. Agriculture 4.0 requires fast, reliable, distributed measurements to give farmers a more detailed overview of the ongoing stage of the production, coordinating the automated processes in such a way that optimizes energy consumption, water use, and the use of pharmaceuticals and chemicals (Tzounis et al., 2017).

Smart Farming includes several areas of interest, for instance, sensor system, traceability, smart logistics, and smart food awareness (Banhazi & Black, 2009; Kutter et al., 2011). The solutions more explored are related to IoT, covering remote sensing and traceability with applications for controlled environment and food supply chain tracking (Banhazi & Black, 2009; Kutter et al., 2011; Liu et al., 2016; Tzounis et al., 2017). An attractive activity could be mapping such platforms with the stakeholders' requirements to establish new valuable services (Lezoche et al., 2020). Such relation with stakeholders is an essential part of the IoS-based business model proposed in the presented case study when evaluating value creation partnerships in a company from the livestock industry.

3 Methodology

Initially, a bibliographic research was carried out to understand the role of the IoS on the business model conception and the gaps in current literature, which were evidenced by the few occurrences of the keywords internet of services with business model. When searching for the string "internet of service*" AND "business model*" in Web of Science, only 14 papers are found. Furthermore, the papers mention the keywords but explore other subjects like IoT solutions or SOA (service-oriented architecture). Due to the novelty, the study became exploratory with searches of relevant papers about the two subjects, internet of services and business model, without a specific inclusion or exclusion criteria for papers selection.

The field research was structured as follows:

1. Definition of a framework to represent an IoS-based business model
2. Case Study describing a free-range egg production enterprise
3. Evaluation of the IoS-based business model using the elements of the case

3.1 *Framework for an IoS-based business model*

The business model concept was used as a tool to conceptualize and illustrate a company's business strategy and objectives (Osterwalder et al., 2005). Before starting to work on the drivers for our IoS-based business model, we used the approach introduced by Gunzel & Holm (2013) for the original business model Canvas (Osterwalder & Pigneur, 2010). The business model describes four essential dimensions: value proposition, value creation, value capture, and value delivery. The analysis of these core elements is crucial for designing the solution based on the key functions (Figure 2B) (GüNzel & Holm, 2013).

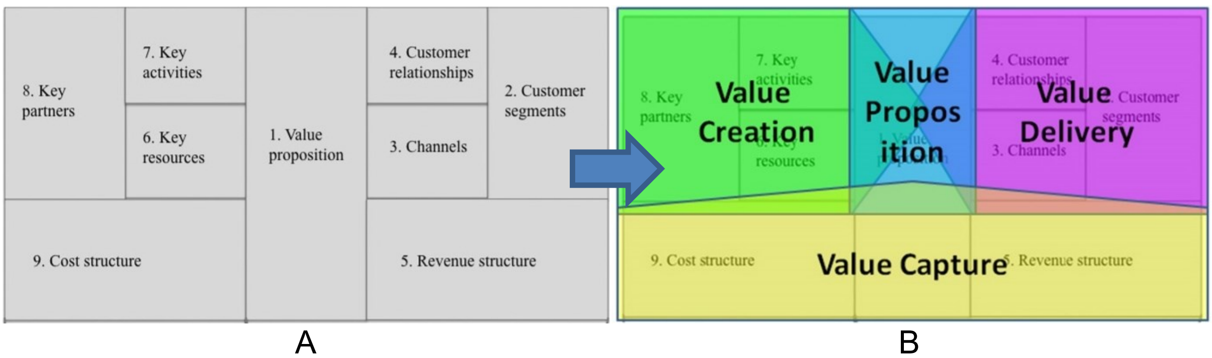

Figure 2. General Business Model Canvas (A), and the Business Model key functions (B).

Those functions are described as (1) Value Proposition, which is the value-adding of service or product; (2) Value Creation, which defines the structure of the value chain to create and distribute the offering; (3) Value Delivery, which covers the segments of clients addressed by the value proposition; the communication and distribution channels used to reach the clients, and (4) Value Capture, which estimates the cost and revenue structures, given the value proposition and the value chain structure chosen. Such mechanisms for creating, delivering, and capturing value reflect the components that are well understood in the Business Model and Business Model Innovation literature (Foss & Saebi, 2017).

By exploring the concepts of IoS and a service-offering view when proposing each business model function's value, we have the framework (Table 1).

Table 1. Framework for the IoS-based business model

Business Model function	Internet of Services-based model outlook
Value Proposition	➢ Describe the value-adding of the service-offering and the advantages compared to an on-premise offering (Weiner & Weisbecker, 2011). ➢ Share the other stakeholders' experiences in the optimization of the supply chain with close respect to production sustainability (Swisher et al., 2018).
Value Creation	1. Use IoS coupled with IoT so that people, machines, and goods are interconnected via the network infrastructure (Hermann et al., 2016). 2. Use predictive analytics to gain insights by exploring patterns in demand and consumer behavior (Lezoche et al., 2020). 3. Assess the value contributed by partners and how critical the value is for their customer and own offering (Weiner & Weisbecker, 2011).
Value Delivery	1. Explore new channels with target customers, mainly by designing apps for smartphones and encouraging social media use (Muninger et al., 2019). 2. Measure the quality and create a feedback loop with customers, since the value is created through collaboration and participation (Berman, 2012; Sun et al., 2012), 3. Set the service level agreements for operations and security rules to protect each stakeholder's services and products (Schroth & Janner, 2007).
Value Capture	1. Work with a mix of revenue models such as pay-per-use charges, subscriptions, or license renewal for a recurrent revenue (Moreno-Vozmediano et al., 2013). 2. Evaluate if worth collaborates with competitors, break into a new business or outsource functions (Berman, 2012). 3. When part of the digital services is offered free, as the mobile app, the value should be captured by In-App purchase or advertising to increase revenues (Cristofaro, 2020).

3.2 Case study

The case study relates to a Brazilian free-range virtual egg business ("Easy Egg," a fictitious name), aiming to develop a virtuous circle through high technology, innovation, and proper animal management practices and welfare. The laying hens (Emprapa 051® genetic strain) are kept in an outdoor 'range' fenced area with access to a house with nests and where they stay overnight. Inside the house, there are feed and fresh water *ad libitum*. The laying hens are free to move inside the house and outside to the pasture area during the daytime. The overall management is done as described by Lay et al. (2011) for free-range laying hens.

The selected company has two main activities, the production of free-range eggs and their commercialization. The production involves free-range egg production farms, which strategy consists of certifying farms for free-range egg farmers, and the commercialization of the eggs is done using an egg cart placed in a common area of housing condominiums. The enterprise developed two mobile apps to perform the online business, one app for the farmers of free-range eggs and another app for the final consumers (Figure 3). Initially, the entrepreneur worked with his single farm, but soon the eggs demand increased, new farms have been homologated, and, thanks to the flexibility and scalability of the business model, the enterprise became a network of egg farmers. Due to the scarcity of business models exploring the internet of services solution, we studied only this real company that started in the digital business proposing a direct sale with a new service offer through the internet. Single-case research typically exploits opportunities to explore a significant phenomenon under rare circumstances scenario (Eisenhardt & Graebner, 2007), which happens to be the case due to the novelty of the internet of services, the scarcity of correlated business models, and the absence of studies that investigate Brazilian companies in such innovative field. The company's selection was also focused on the fact that the business is tightly integrated with emerging technologies. We interviewed the entrepreneur, who is also the Chief Executive Officer (CEO), to assess our IoS-based business model framework and then validate its adherence.

The case study was carried out by adopting a proposed method (Voss et al., 2002), consisting of a semi-structured interview with its manager. We followed the deductive or theory-testing process (Voss et al., 2015). The framework (Table 1), the IoS-based model, has been evaluated in a real business. Besides the interview, we performed documental analysis, visited the social media pages, and installed the tests' apps.

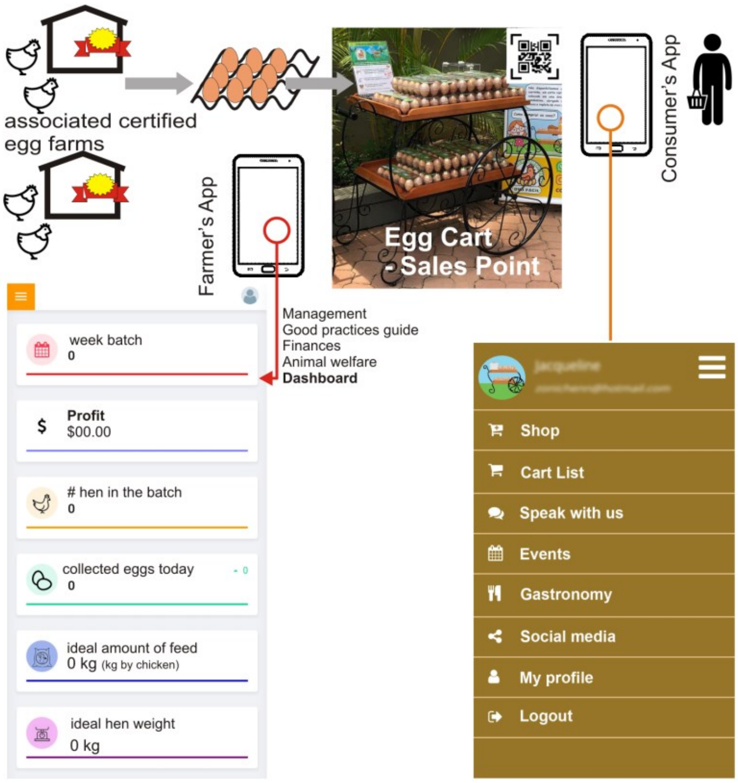

Figure 3. The enterprise business using two mobile applications, the farmers' app and the consumers' app

3.3 *Evaluation of the IoS-based business model with a case study*

The evaluation was carried out according to the method developed by Voss et al. (2015). From our IoS-based model framework, we assessed if the IoS was a driver during the business model conception and if the executives are doing the correct questions on this start-up phase.

There are two apps, one for the farmers and another for the final consumers:

The farmers' app aims to give information concerning the management of the free-range laying hens. The farmers that would like to become partners of the company can easily find all the production lifecycle information before joining the business, such as regulations, lighting plans, and hens' management. Next, the farmers can follow up on their production numbers as well as the financial results through a dashboard.

The consumers' app, also named Egg Cart App, offers egg trays with the final consumers' products. The egg-cart is accessed by scanning the QR-code through the app. The consumers pick up the products physically from the egg-cart and pay online via the app or in cash in a cash box placed on the egg-cart. Also, other services are available like the tracking of the products, virtual visits to the farms, gastronomic recipes with eggs provided by known cuisine chefs. The apps have been developed in the "Apache Cordova" platform software, enabling programmers to build mobile devices web applications. Both Easy Egg apps - the farmers' app and the consumers' app - are free for users to download on the Apple Store and Google Play Store. We installed both apps for tests and ensured they were working properly.

4 Results

The initiatives from the company Easy Egg have matched most of the points addressed in our framework. It has been checked the company's corresponding compliance for each attribute placed in the framework previously presented in Table 1. From the results, it was concluded that the business is aligned with the IoS adoption, and the framework presents adherence to the business. The company could better explore some opportunities, but it depends on the venture's sizing and strategy.

4.1 IoS-based business model aspects in the case

- Value Proposition

The main value proposition of the company Easy Egg is the availability of high-quality free-range eggs directly from the farmer to the consumer in a trust-based sale using the traceability process to increase consumer reliability. The process allows the product path to be tracked from the farm until it reaches the consumer. It matches what enterprises have been doing to reshape their customer value propositions and transform operations using digital technologies for more significant customer interaction and collaboration (Berman, 2012; Parviainen & Tihinen, 2017). In Table 2, there are the results for value proposition evaluation, showing the both attributes from the framework comply with the business.

Table 2. Value proposition evaluation from the framework for the IoS-based business model

Business Model function	IoS-based model outlook	Results: Comply	Results: Does not comply
Value Proposition	1	The main value-adding from Easy Egg is the availability of high-quality free-range eggs directly from the farmers to the consumers in a trust-based sale.	-
	2	With direct selling from farmer to consumer, Easy Egg eliminates intermediaries and creates a more optimized service delivery, closely related to sustainability.	-

➢ Value Creation:

The Easy Egg concept includes egg production in a free-range system (Lay et al., 2011) and delivered from the farm to the consumer. Farmers seek a direct relationship with the consumers, eliminating the intermediaries.

Such internet-based solutions guarantee a positive impact on production and have been implemented using cutting-edge technology developed by a software company. The system has become the Easy Egg farmer app (Figure 3).

The value creation evaluation results are presented in Table 3, showing what complies and what does not comply with the framework.

Table 3. Value creation evaluation from the framework for the IoS-based business model

Business Model function	IoS-based model outlook	Results	
		Comply	Does not comply
Value Creation	1	The Easy Egg farms are connected and monitored with IoT technologies to keep the quality in production and to provide information concerning the management of the free-range laying hens. The farmers feed the App and keep the business running with the latest technological advances.	-
	2	The farmers can follow up their production numbers as well as the financial results through a dashboard in the farmers' app. The dashboard brings the weather forecast for helping the farmers in decision-making.	Easy Egg is a small business still not exploring predictive analytics in all its potential since the managers understand there is no need to apply this yet.
	3	Homologating and certifying farms, keep the service level for free-range egg farmers according to the protocol developed. This way, the eggs have the same quality, and the hens' management meets the agreed conditions.	-

- Value Delivery

Customers who want to request a cart's placement in their condominium might access the website to request the Easy Egg consumers app (Figure 3). All Easy Egg carts consumers, with the mobile application installed and using the previously described QR code, aim to focus the camera on the code that the cart is recognized. It is possible to see the number of free-range eggs available in the cart and the amount needed for replacement on the screen. The management of the Easy Egg cart can be done by both the building manager and the residents.

The application was designed to meet Easy Egg consumers' needs: manage the carts placed in condominiums with 20 dozen free-range eggs. Through the app, the consumers can check when the time has come to replenish the eggs. Usually, they are replenished once a week.

Table 4. Value delivery evaluation from the framework for the IoS-based business model

Business Model function	IoS-based model outlook	Results: Comply	Results: Does not comply
Value Delivery	1	The Egg-cart App offers customers services as tracking the products, virtual visits to the farms, and gastronomic recipes. The egg-carts are replenished once a week. Through the app, the consumers can check when the time has come to replenish the eggs. Easy Egg maintains an active presence in the most popular social media sites.	-
	2	Every new service launched is shared with the customers, and the feedback is followed up on social media. The sites on Facebook and Instagram are regularly updated and used as an open channel for customer complaints and suggestions. If there is some damaged egg, the consumer can report directly through the WhatsApp corporative number that reaches anyone from Easy Egg staff.	-
	3	Regarding security, each farmer or consumer has a login and password for the app, which protects each stakeholder's information.	There is a best effort in returning promptly anything reported by customers, but there is no service level agreement because they are still a small business.

- Value capture

Revenue from the eggs' selling is straightforward from the buyer to the farmer associated with the process. The condominium resident goes to the cart and removes the eggs tray from the egg cart, and closes the purchase doing the payment via the app using a debit or credit card. The online transaction runs without intermediaries or cashier operators, and the service hired, delivered, and paid online matches the IoS-based business model.

Table. 5. Value capture evaluation from the framework for the IoS-based business model

Business Model function	IoS-based model outlook	Results	
		Comply	Does not comply
Value Capture	1	-	Pay-per-use charges or subscriptions would suit better a cloud-based service that demands licenses or subscriptions to run, which is not the Easy Egg business case.
	2	New egg farmers that would like to become partners of the company can easily find all the production lifecycle information before joining the business, such as regulations, lighting plans, and hen's management. The Egg-cart App has offers egg trays with the products to the consumers and offers organic products through partners.	-
	3	The Apps are offered free, and the eggs' selling is the leading business, but some complementary services start to bring some revenue. Virtual visits to the farms live with gastronomic chefs presenting recipes containing eggs and consulting on free-range laying hen's production for new potential farmers.	-

The revenue and production per month are shown in Figure 4. During the period, the price/egg remained unchanged, and a considerable revenue increase has been observed. This is explained by the good response from the market, with more condominiums ordering the egg carts. The convenience of buying online and the good service delivery received a positive return from consumers.

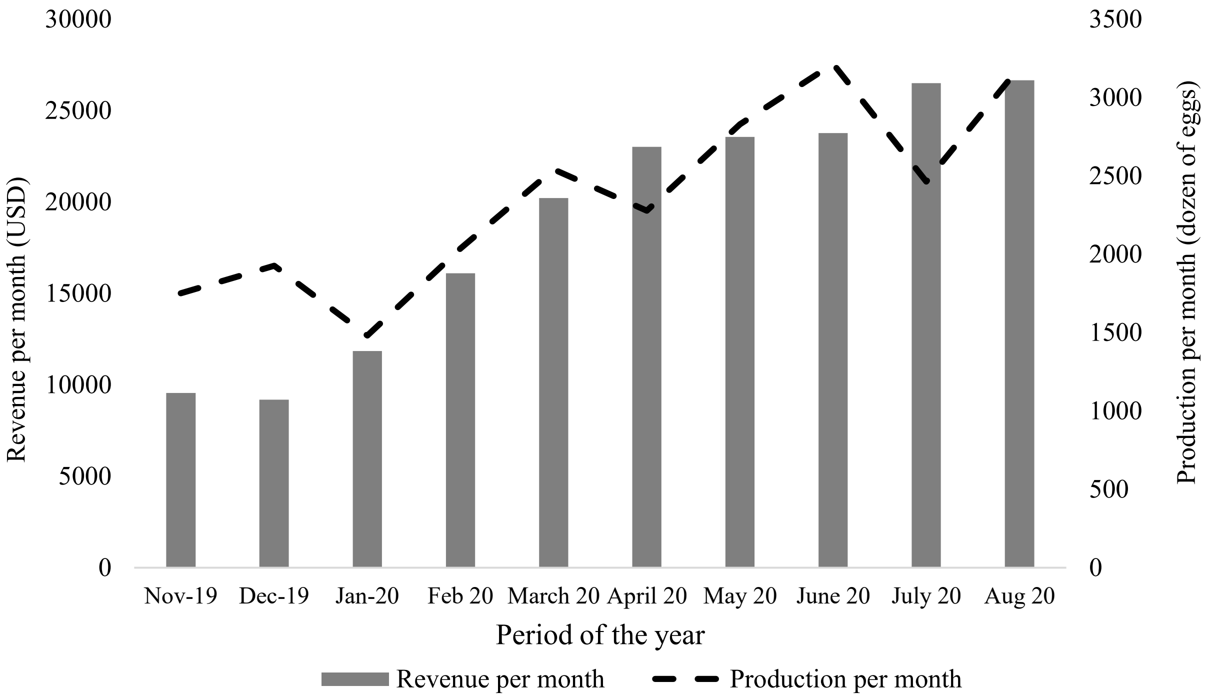

Figure 4. Revenue per month (in USD) and production per month (in dozen of eggs).

As the offer of organic products through other companies, complementary services have also been added in the same mobile app. This way, the revenues may originate from the egg selling and the partnerships by sharing the same applications platform. The IoS application can be easily scalable because a partner network is already established through the Easy Egg farmers app.

5 Discussion

The case study takes its starting point in describing the business model and IoS as central actors. By employing the main dimensions of the business model introduced by Gunzel & Holm (2013) for the original business model Canvas (Osterwalder & Pigneur, 2010), we proposed and evaluated a framework that describes how the enterprise can propose, create, deliver, and capture value through the adoption of the internet of services. The study also fills the gap raised by Matt et al. (2015) that research should seek to identify additional elements attributed to the following dimensions of digital transformation: use of technologies, changes in value creation, structural changes, and financial aspects.

Considering the IoS main target is to present everything as a service on the internet, including software applications and the platform to deliver these mobile applications (Moreno-Vozmediano et al., 2013), the enterprise Easy Egg has succeeded in doing so. When thinking about IoS to build a network of partners to create a cooperative service-offering, it is essential to think about all the contributing roles' potential values. The business model developed by the company Easy Egg explored this idea very well. The mobile app is available on the Apple Store and Google Play Store and is distributed free of charge to free-range egg farmers who want to become partners. The idea was to use the IoS application to connect the egg's production to consumers. A farmer can become a partner using the Easy Egg farmers app. The entrants can start producing and use all the benefits of this cross-enterprise network. The convenience saves time and effort during purchase, and the service receives a positive assessment from consumers. The concept of online collective purchases (Chang et al., 2014) is directly related to social networks, a structure formed by users and their interpersonal relationships.

With the direct selling from farmer to consumer, Easy Egg eliminates intermediaries and creates a more optimized service delivery. The IoS-based business model, evaluated from our case study, shows how adopting a collaborative mobile platform has created revenue opportunities. Although several ideas have been emerging to different digitalization forms in agricultural production systems and value chains (Klerkx et al., 2019), our case study explores the internet of services in depth.

The presented case study brings a framework for a business model construct and the strategies for a revamp of the business in a specific application field, considering the new digital market. IoS adheres to the business model that becomes digital, mainly by using online and social collaboration platforms. This is the primary business value, the viral adoption by users, and the increased customer engagement level, also seen in the Easy Egg enterprise.

While ICT strategies focus on managing the infrastructure with a limited impact on driving innovation and business development (Matt et al., 2015), the IoS covers the ICT aspects but jointly with a business-centric perspective. It has been confirmed from the case study that the IoS-based business model works as a collaborative business ecosystem or global market where services from diverse providers are offered, discovered, and consumed in combined use (Kritikos & Plexousakis, 2014; Bucchiarone et al., 2017; Givehchi et al., 2017).

Chao (2016) shows that the reciprocal is also true when affirming that businesses are no longer only interested in the design of economic models and mechanisms but also have a great interest in information and communication technology. This is a guideline that is shaping the e-business landscape and strategic decisions.

The Easy Egg's business model answered most of the points addressed in our framework, showing that business is aligned with the IoS adoption. The framework has adherence to the business and can be replicated in other fields. Whenever a business is considering the service model through a digital solution, the proposed framework may serve as the initial approach, both for a new venture designing its business model or an established company changing its business model.

The business model improves the integration between the business and IoS domain and leads to mutual reinforcement because it creates a shared understanding by the different stakeholders in the value chain. It has been assessed how the IoS could support the key partners, key activities, and critical resources value through the proposed framework, forming a business model construct.

6 Conclusion

Among the several digital transformation paradigms, the internet of services (IoS) takes a vital role in business through an innovative way of service offering. The presented case study covered an IoS-based business model through a framework that correlates two concepts, internet of services and business models, into a digitally transformed market for service offer.

To keep pace with the swiftly changing digital ecosystem, organizations can not afford to stand still. A company needs to assess its business model continually, and the consequences of not having a comprehensive business model can be severe. Thus, it is essential having tools that support the entrepreneurs and managers during the business model deployment. Due to the internet of services' novelty and the lack of correlated business models in the literature, it is not evident how the IoS and business model interact. The case study aimed to fill this literature gap by defining a framework that indicates the IoS adoption attributes, describing how the enterprise can create, deliver, and capture value.

The digital marketplace does not reward organizations simply for going digital. It rewards them to leverage business practices to enhance the customer's experience and encourage innovation in the organization. The IoS-based business model's contribution is the collaboration among the customers and the enterprises that are inherently competitors. The new platforms and stakeholders' relations establish new valuable services, leading the business to new possible revenue opportunities. By evaluating the framework in a direct sale of free-range eggs direct from farmer to consumers, it is concluded the IoS is adhered in the business model mainly by using online and social collaboration platforms. The IoS-based business model includes mechanisms to attract participants to seek innovative products and spark relevant contributions to enhance the operation. It brings a practical contribution both for a new venture designing the business model or an established company changing its business model.

Due to the scarcity of business models exploring the IoS, a single company has been considered in our case study and analyzed in great depth. Although there is a limitation of taking only the field of agriculture 4.0 for the case study, the proposed framework may contribute broadly to an IoS-based business model deployment. Future studies may explore the IoS-based business model in different business sectors other than the livestock industry.

Declarations

Conflicts of Interest / Competing Interests

The authors declare that they have no conflict of interest.

Appendix

We used the following questions to interview the entrepreneur, who is also the Chief Executive Officer (CEO), to assess our IoS-based business model framework and then validate its adherence.

1. How does the IoS bring advantages to your business when compared to a traditional service offering?
2. Do you have a partner's network using the same application and technology standards?
3. Do customers participate in the service delivery process through the IoS solutions?
4. Do you accept online payment for the service?
5. Do you have complimentary cross-selling offerings through your IoS-based partnership network?

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5 RESULTADOS E DISCUSSÃO

Inicialmente, para um melhor entendimento do estado-da-arte de modelos de negócios em IoS, foi realizada uma revisão sistemática da literatura. Nesta primeira etapa, obteve-se uma maior clareza sobre os conceitos de IoS e modelos de negócios, e sobre a correlação destas duas variáveis. Identificou-se potenciais aplicações, mas também alguns *gaps* importantes, que direcionam o desenvolvimento da tese.

O modelo de negócios tem uma definição clara na literatura. É uma ferramenta para conceituar e ilustrar a estratégia de negócios e os objetivos da empresa, que descreve principalmente como a organização pode criar, fornecer e capturar valor para o seu processo de BMI. Já a IoS alterna definições na literatura, umas com viés mais técnico, e outras com viés para negócios. Entre as diversas definições encontradas para IoS, a mais comumente citada seria "um ecossistema colaborativo ou mercado global onde serviços oferecidos por diversos provedores (terceiros) são oferecidos, descobertos e consumidos em uso combinado (orquestração de serviços)" (BUCCHIARONE *et al.*, 2017; GIVEHCHI *et al.*, 2017; KRITIKOS; PLEXOUSAKIS, 2014).

Dos artigos resultantes da revisão sistemática, é possível identificar aspectos importantes da IoS e sua relação com modelos de negócios. Conforme sugerido por Cardoso, Voigt e Winkler (2009), a IoS consiste em participantes, uma infraestrutura para serviços, modelos de negócios e os próprios serviços. Wahlster *et al.* (2014) complementam que, para formar a IoS, os serviços devem ser descritos de forma que a dimensão do negócio e a dimensão da tecnologia se unam. A partir destas colocações, é possível inferir que, além da infraestrutura para suportar os aspectos de TI, e a operação do serviço que abrange os aspectos operacionais, a IoS precisa de uma aplicação de negócios para existir. Analisando os artigos que trazem potenciais aplicações de IoS, identifica-se, ainda, que a IoS pode ter uma aplicação de negócios ou uma aplicação social, dependendo dos participantes e dos seus objetivos. Uma primeira e importante contribuição da pesquisa, resultante do cruzamento que foi feito destes vários conceitos, é a proposta de uma taxonomia própria que classifica a IoS nas seguintes subáreas: infraestrutura, operação de serviços, aplicações de negócios e aplicações sociais.

A partir da classificação de cada artigo em somente uma das quatro categorias, dependendo da subárea em que o estudo se concentra, tem-se uma distribuição maior de artigos com o foco em infra-estrutura. Esta categoria de infra-estrutura engloba conectividade, hardware, software; ou seja, soluções que viabilizam tecnicamente a IoS. A IoT, inclusive, é considerada um meio para essa conectividade, aumentando a capilaridade e a extensão que os serviços podem alcançar.

Outro aspecto identificado é que mesmo nos artigos categorizados como aplicações de negócios e sociais, embora o enfoque tenha migrado da infraestrutura de TI pura para uma visão de negócios, os autores ainda enfatizam os serviços que podem ser potencializados pela IoT. O resultado se confirma quando Komarov, Konolanov e Kazantsev (2016), ao trazerem aplicações de IoS para casas e cidades inteligentes, mencionam que "os fenômenos da IoS dizem respeito a diferentes esferas, mas o foco na literatura é colocado em sua conexão com a IoT". Por outro lado, verifica-se que IoT e IoS não necessariamente são utilizados em conjunto. Cada um possui seu universo de abrangência, que, no caso da IoS, ainda é pouco explorado. Essa ideia vai de encontro a outro conceito colocado por Hermann, Pentek e Otto (2016) de que "através da IoT, os objetos inteligentes se comunicam e cooperam em tempo real; enquanto que, por meio da IoS, os serviços internos e interorganizacionais são oferecidos e usados pelos participantes da cadeia de valor".

Ainda como resultado da revisão sistemática sobre modelos de negócios baseados em IoS, foram identificados diversos campos para potenciais aplicações da IoS, passando por todos os setores econômicos, como: Manufatura na Indústria 4.0 (COZMIUC; PETRISOR, 2018; GIVEHCHI *et al.*, 2017; KING; GROBBELAAR, 2020), *Smart Environment*, que contempla cidades inteligentes e casas inteligentes (KOMAROV; KHOKHLOVA, 2015; KOMAROV; KONOVALOV; KAZANTSEV, 2016; LOKSHINA; LANTING; DURKIN, 2018), Financeiro (SUSEENDRAN *et al.*, 2020), Agricultura 4.0 ou Fazendas Inteligentes (DUMITRACHE *et al.*, 2017; LEZOCHE *et al.*, 2020), e *Healthcare* (HEPONIEMI *et al.*, 2020; LOKSHINA; LANTING; DURKIN, 2018).

Um dos *gaps* endereçados na agenda de pesquisa proposta no artigo de revisão sistemática, é que, apesar do potencial da IoS para o processo de inovação em modelos de negócios e transformação digital nas empresas, existem lacunas sobre como esta tecnologia é de fato utilizada na prática. Estudos podem promover a expansão da IoS em qualquer área que ainda não tenha sido avaliada em relação aos modelos de negócios, considerando que o domínio do serviço não se restringe aos serviços mais tradicionais, como educação e saúde; mas ele também aparece em indústrias tradicionais orientadas para o produto, como a manufatura e a agricultura. Este *gap* pode ser associado à colocação de Wieland, Hartmann e Vargo (2017) de que, a partir de uma mudança na orientação estratégica, as empresas passam cada vez mais a adotar uma “lógica dominante de serviço”, defendendo a visão que o processo de produção é inteiramente baseado em serviços – a empresa compra serviços dos fornecedores e entrega serviços aos clientes. Faz-se relevante, portanto, entender como essa transformação se dá com a aplicação da IoS nos setores primário e secundário da economia, que seriam a agricultura e indústria, respectivamente.

Nos artigos sobre a Indústria 4.0, citada como um importante campo de aplicação da IoS, praticamente não há exemplos práticos de como ela é utilizada. Enquanto as soluções de IoT e CPS são exaustivamente discutidas, há uma falta de clareza sobre como a IoS atende aos requisitos da Indústria 4.0 em um cenário de produção. Alcácer e Cruz-Machado (2019) ressaltam que ainda falta clareza sobre como estas tecnologias contribuem para o processo de inovação na Indústria 4.0.

A segunda etapa da pesquisa consiste em endereçar este *gap*, e avaliar como a IoS pode ser aplicada na prática, em um chão de fábrica, para promover a flexibilidade no processo de produção na Indústria 4.0. Para tanto, o segundo artigo vincula os conceitos de Indústria 4.0, IoS e SOA, dando mais ênfase ao domínio de serviço do ambiente de manufatura. Um barramento de serviço é ilustrado para propor o modelo SOMA, baseado em SOA, que é um dos fundamentos-base da IoS. O modelo ilustra como IoS e SOA podem fornecer flexibilidade de produção no nível do PPC. A proposta é que máquinas, ferramentas automatizadas e robôs, têm suas funções disponíveis na forma abstrata de serviços, que seriam invocados de forma *ad-hoc* pelos insumos e produtos inacabados até o final da linha de produção, trocando dados e instruções através de um barramento de serviços. O conceito vai de encontro ao que Cozmiuc e Petrisor (2018) vislumbram para o futuro da manufatura: o chão de fábrica se tornará uma rede de agentes de tomada de decisão auto-organizados, transformando todas as máquinas em CPS, que se juntam ao IoT e IoS dentro da Indústria 4.0. O modelo proposto, portanto, corrobora o conceito de IoS como uma futura internet que permite esta configuração *ad-hoc* de serviços.

Ao se verificar a aderência do modelo SOMA em duas empresas de manufatura que já estão engajadas na Indústria 4.0, dois cenários diferentes foram encontrados, e concluiu-se que a IoS se adequou em um processo de produção flexível, mas não em um processo de produção em massa. Com este estudo da IoS na manufatura, foi possível entender com mais clareza a IoS dentro da Indústria 4.0, e exemplificar como ela pode atender às mudanças no plano de produção de um chão de fábrica, contribuindo, assim, para uma produção mais flexível e customizada.

A terceira e última etapa da pesquisa traz o estudo de caso na Agricultura 4.0, correlacionando o modelo de negócios com a adoção da IoS. São empregadas as quatro dimensões do modelo de negócios, consideradas por Günzel e Holm (2013) como os principais meta-componentes do modelo Canvas original de Osterwalder e Pigneur (2010), a saber: proposta de valor, criação de valor, entrega de valor e captura de valor. Um framework é proposto para descrever como a empresa pode endereçar estes quatro atributos por meio de um modelo de negócio baseado em IoS.

O estudo também preenche uma lacuna endereçada na problematização (seção 1.1), ressaltada por Matt, Hess e Benlian (2015), de que pesquisas deveriam buscar identificar e concretizar elementos atribuídos às quatro dimensões da transformação digital. Similarmente aos meta-componentes do modelo de negócios, as estratégias de transformação digital também teriam quatro dimensões essenciais: uso de tecnologias, mudanças na criação de valor, mudanças estruturais e aspectos financeiros. No entanto, ainda são poucas as pesquisas sobre modelos de negócios que pretendem criar novas estruturas para um mercado inovador. Schiavi e Behr (2018) reforçam que pouco se sabe sobre como uma mudança para modelos orientados a serviços afeta o modelo de negócios existente da empresa e qual seria a estrutura para suportar o novo modelo de negócios. A presente pesquisa preenche, portanto, as lacunas deixadas como trabalhos futuros por estes estudos, ao buscar identificar elementos para compor o modelo de negócio baseado em IoS.

A estrutura do modelo proposto foi comparada a um cenário real de negócios da Agricultura 4.0 que realiza a venda direta de ovos caipiras dos agricultores aos consumidores. Ao se constatar que a maioria dos atributos do modelo vai de encontro às iniciativas de inovação da empresa, conclui-se que a IoS se adere ao modelo de negócios, principalmente por meio do uso de plataformas de colaboração. A ideia corresponde ao que Muninger, Hammedi e Mahr (2019) colocam como uma premissa que as empresas devem seguir neste cenário de transformação digital, que seria reformular suas propostas de valor para os clientes e transformar suas operações usando tecnologias digitais para maior interação e colaboração com os clientes, principalmente por meio de aplicativos e mídias sociais. A pesquisa revelou também como as relações da empresa com seus parceiros e a inclusão facilitada de novos fornecedores, por meio dos aplicativos de IoS, estabelecem novos serviços e levam o negócio a novas oportunidades de receita possíveis. Tal resultado responde ao *gap* colocado por Lezoche *et al.* (2020) de que novos serviços poderiam surgir da integração nas cadeias agroalimentares se uma plataforma integrada apoiasse seus vários participantes.

O framework pode auxiliar de forma prática as empresas na construção do modelo de negócios baseado em suas futuras aplicações de IoS, uma vez que ele funciona como um guia para que o empreendedor verifique se as principais questões estão sendo levadas em consideração no processo de BMI. O estudo traz a construção de um modelos de negócios baseado em IoS no campo da Agricultura 4.0, mas que pode ser replicado para outros setores e contextos de aplicação.

6 CONCLUSÃO

A presente tese tem como ponto de partida a internet de serviços (IoS) e o modelo de negócios como atores centrais para o processo de inovação de modelo de negócios (BMI). Embora a IoS desempenhe um papel importante nos negócios por meio de uma forma inovadora de oferta de serviços, identificou-se uma lacuna sobre modelos de negócios baseados em IoS, e é isso que a presente tese explorou.

O objetivo foi avaliar como a IoS é utilizada para inovação em modelos de negócios em diferentes setores econômicos, como Indústria 4.0 e Agricultura 4.0. A pesquisa foi realizada em três etapas, cada uma resultando em um artigo científico, que responde a um ou mais objetivos específicos.

Na primeira etapa, foi realizada uma revisão sistemática em que 23 estudos diferentes são categorizados por uma taxonomia proposta de quatro subáreas da IoS - infraestrutura, operação de serviços, aplicações de negócios e aplicações sociais - e por seus campos de aplicação. Os resultados destacam as oportunidades de aplicações de IoS em diferentes contextos e oferece direções para estudos futuros, atendendo assim aos dois primeiros objetivos específicos que são: organizar uma agenda de pesquisa a partir do estado da arte sobre modelos de negócios baseados em IoS, e caracterizar os campos de aplicação da IoS.

A agenda de pesquisa proposta no artigo de revisão sistemática identificou alguns *gaps* na literatura científica. Um deles é a falta de clareza sobre o papel da IoS na Indústria 4.0. Para endereçar este *gap* e o terceiro objetivo específico, o segundo artigo busca avaliar como a IoS pode ser aplicada na manufatura para promover a flexibilidade dos processos produtivos no chão de fábrica. A partir de um modelo teórico SOMA, propõe-se que máquinas e robôs tenham suas funções disponíveis na forma abstrata de serviços, e conclui-se em estudo de caso que a IoS atende a um processo de produção flexível. Apesar de o segundo artigo atender seu objetivo e trazer mais clareza ao papel da IoS na Indústria 4.0, a pesquisa ainda segue o viés encontrado na literatura, que é o de associar a IoS mais à infra-estrutura do que aos modelos de negócios. Além disso, outras duas lacunas encontradas na revisão sistemática são a falta de um modelo de negócios baseado em IoS e a aplicação desta inovação em outras áreas de atuação, como na agricultura.

O terceiro artigo cobre estas lacunas ao propor um framework para criação de modelo de negócios baseado em IoS, utilizando um estudo de caso no campo da

Agricultura 4.0, atendendo assim ao quarto objetivo específico da tese. O estudo traz uma contribuição significativa ao avaliar a IoS para apoiar uma empresa brasileira de produção de ovos caipiras durante a inovação do modelo de negócios. O framework proposto considera os atributos do modelo de negócios que são: proposta de valor, criação de valor, entrega de valor e captura de valor. Ao avaliar o aspecto financeiro do negócio, o escopo tanto de modelo de negócios como de transformação digital são atendidos de forma mais completa neste último artigo.

Com a presente tese, várias lacunas são endereçadas, esclarecendo e correlacionando estes dois assuntos pouco explorados na literatura: modelos de negócios e IoS. Além desta contribuição teórica, o estudo apresenta uma contribuição prática que é auxiliar as empresas na construção do modelo de negócios baseado em suas futuras aplicações de IoS. O framework proposto funciona como um guia para o empreendedor, o que é também uma importante contribuição social, visto que cada vez mais indivíduos se tornam empreendedores nesta era digital pós-Covid. Através desta conexão entre os campos técnico e de negócios, a IoS se adere não só ao processo de BMI, mas também ao de transformação digital, uma vez que esta também traz na sua concepção o elo entre as TIC e as estratégias de negócios.

Uma limitação da pesquisa é que o objetivo da tese é atendido em sua totalidade apenas no estudo de caso da Agricultura 4.0, quando os atributos do modelo de negócio baseado em IoS são contemplados. De qualquer forma, conclui-se que a IoS ainda não é o estado-da-prática na manufatura, e muito da maturidade do modelo da Indústria 4.0 pode depender também dos avanços na aplicação da IoS.

A pesquisa poderia derivar arquétipos de modelos de negócios baseados em IoS em todas as indústrias, o que é uma oportunidade para trabalhos futuros. O próprio framework do modelo de negócios baseado em IoS, estudado no caso da Agricultura 4.0, poderia ser avaliado em outros setores.

Há ainda bastante a ser estudado sobre o tema, visto que a Internet de Serviços é uma inovação, e por isso se encontra na fronteira do conhecimento, assim como a inovação nos seus vários campos de aplicação. A sustentabilidade é um tema que vem ganhando um vínculo potencial com a tecnologia, possibilitando novas propostas de serviços, indicando que também é um campo ainda a ser explorado junto à IoS.

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