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A Guide for Business Model Innovation through Industry 4.0

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RESUMO

Foi previsto que a Indústria 4.0 (I4.0) tem o potencial para trazer oportunidades significativas para a inovação de modelos de negócio (IMN). No entanto, a pesquisa mostrou que não há abordagem sistemáticas para isso.

Uma das causas identificadas para tal é a falta de compreensão por parte da comunidade empresarial do que a I4.0 realmente significa. Para o combater, este trabalho propõe uma simples perspetiva global concetual e visualização gráfica, baseadas em revisões de publicações relevantes.

Depois, dedica-se a uma segunda causa da raridade de IMN pela I4.0: a falta de ferramentas dedicadas. Pela revisão de artigos relevantes no campo da IMN para I4.0, é identificada uma série de "alavancas de negócio", de acordo com a metodologia do *business model canvas* (BMC). Em conjunto com exemplos da vida real, notas sobre interdependências e aplicabilidade, as alavancas são usas para construir uma ferramenta de inovação que guia os leitores à IMN I4.0 através de 68 questões para estimular a sua criatividade. Uma integração visual simplificada do guia com o BMC também é proposta. Finalmente, um curto processo de quatro passos para responder a cada questão é incluído.

Estas ferramentas são então usadas no caso de uma empresa de nível *startup* para gerar ideias de IMN.

Palavras-chave: Indústria 4.0, Tecnologias, *Startups*, Inovação de Modelos de Negócio, *Business Model Canvas*

ABSTRACT

It has been predicted that Industry 4.0 (I4.0) has the potential to bring significant opportunities for business model innovation (BMI). However, research has shown that there are not any systematic approaches to it.

One of the identified causes for that is the lack of comprehension by the entrepreneurial community of what I4.0 actually entails. To address it, this work proposes a simple conceptual overview and graphic visualization, based on a review of relevant publications.

It then tackles a second cause for the rarity of BMI through I4.0: the lack of dedicated tools for it. By reviewing relevant articles on the field of BMI for I4.0, it identifies a series of "business levers", according to the business model canvas (BMC) framework. Along with real-life examples, notes on interdependences and applicability, the levers are used to build an innovation tool that guides readers to I4.0 BMI through 68 questions to stimulate their creativity. A simplified visual integration of the guide with the BMC is also proposed. Finally, a short four step process for answering each question is included.

These tools are then used in the case of a startup-level company to generate BMI ideas.

Keywords: Industry 4.0, Technologies, Startups, Business Model Innovation, Business Model Canvas

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List of Abbreviations

Advanced Process Control	APC
Augmented Reality	AR
Augmented Virtuality	AV
Blue Ocean Strategy	BOS
Business Model	BM
Business Model Innovation	BMI
Business Model Canvas	BMC
Business-to-Business	B2B
Business-to-Customer	B2C
Customer Relationship Management	CRM
Cyber-Physical Systems	CPS
Cyber-Physical Production Systems	CPPS
Enterprise Resource Planning	ERP
Extended Reality	XR
General Data Protection Regulation	GDPR
Industry 4.0	I4.0
Instituto Superior Técnico	IST
Machine-to-Machine Communication	M2M
Manufacturing Execution System	MES
Mixed Reality	MR
Near-Field-Communication	NFC
Partner Relationship Management	PRM
Product as a Service	PaaS
Product-Service System	PSS
Programmable Logic Controller	PLC
Small and Medium Enterprise	SME
Stock Keeping Unit	SKU
Virtual Reality	VR

1 RESEARCH APPROACH

Since 2010, a Fourth Industrial Revolution, popularly known as “Industry 4.0”, has been gaining relevance. It promises the modernization of manufacturing techniques, business practices and end-user participation, with expected gains for both producers and consumers [1].

The possibility of business model innovation through Industry 4.0 has been identified, yet there are multiple obstacles to its realization. If a manager were to think “I want to apply Industry 4.0 to my company”, maybe he would find himself questioning “what can we gain from it?”, “how can we do it?” or “what does Industry 4.0 even mean?”.

One of the commonly reported hurdles for business innovation with Industry 4.0 is a general lack of clarity on the associated concepts [2], often being perceived as something highly complex and unattainable [3]. This is not an unexpected phenomenon, as any research on the topic will reveal dozens of results, each with its own structure and terminology. For that reason, focus is being placed on building an overview of Industry 4.0 [4], which leads to the first research goal of this thesis, defined in Figure 1.

Research Goal: Conceptual Overview of Industry 4.0

For understanding how to innovate business models, it is first necessary to create a conceptual overview than encompasses the main ideas of Industry 4.0 and can be used for managers to understand that concept, its potentials, and pitch it to others within their organization.

Building this overview requires extensive literary review and systematization of knowledge, which is conducted in chapter 2, to finally deliver a graphic summary of the main concepts in section 2.8.

Figure 1. Defining a first research goal of creating an overview of Industry 4.0.

Beyond struggling with conceptualization, research has also identified that companies lack comprehension of the overall impacts Industry 4.0 could have on their business models, what gains could come through it [3], and, above all, dedicated toolkits to systematically innovate [5] [6]. This justifies the second research goal defined in Figure 2.

Research Goal: Guide for Business Model Innovation through Industry 4.0

As managers need guidance tools for business model innovation through Industry 4.0, this dissertation intents on developing a practical tool for that.

For that, chapter 3 reviews reports of impacts it can have and/or has had in company’s business models to derive concrete business levers. From those levers, an “innovation guide” with a series of broad questions for creative business model innovation is built.

Chapter 4 then applies the guide, in order to illustrate how it can be used.

Figure 2. Defining a second research goal of creating a tool for business model innovation through Industry 4.0.

2 CONCEPTUAL OVERVIEW OF INDUSTRY 4.0

2.1 Introduction

2.1.1 Industrial Revolutions

Like Figure 3 illustrates, a Fourth Industrial Revolution, known as "Industry 4.0", is happening just now. It is the first time an industrial revolution has been "predicted" as it happens rather than observed afterwards [7].

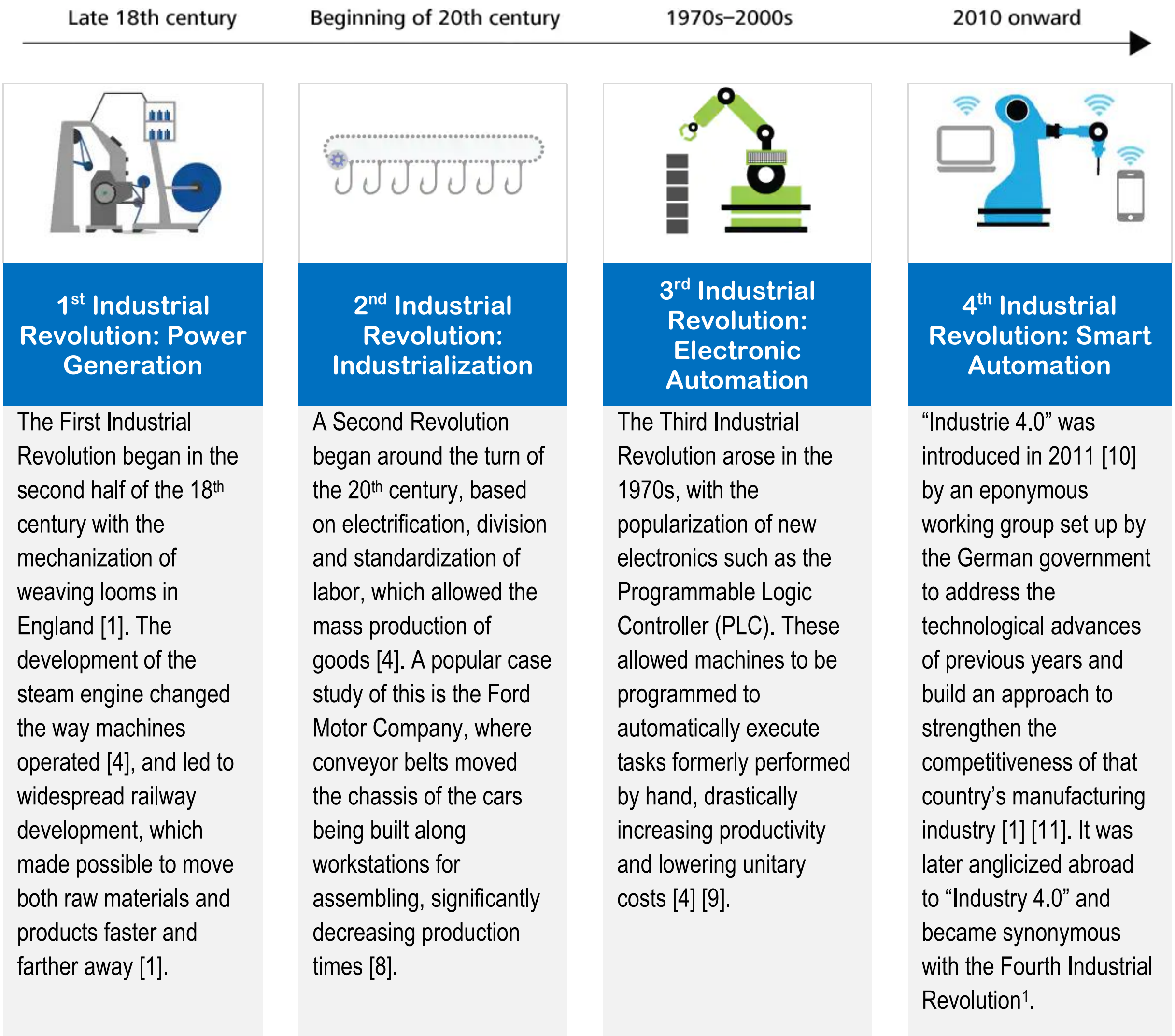


Figure 3. History of industrial revolutions (layout based on [12]).

Before the COVID-19 outbreak, there were promising projections on gains through Industry 4.0: General Electric predicted that it could add \$10 - \$15 trillion to the global GDP in just two decades, while German entities estimated a 23% (roughly 79 billion Euros) national GDP growth until 2025 [4].

[1] Outside of Germany, this Industrial Revolution is also known as "Industrial Internet", "Smart Manufacturing" (both popular in the USA), "Smart Industry", "Manufacturing 4.0", "Internet of Everything" and "Internet of Things for Manufacturing" [1] [12]. Some nations use the name of their governmental initiatives, such as Japan's "Innovation 25" or China's "Internet Plus" [10].

2.1.2 Relevant Knowledge Gap

Even though the potential for business model innovation through Industry 4.0 (I4.0) has been identified, there still are some obstacles to its widespread realization.

The first is a lack of clarity regarding the concepts surrounding this Fourth Industrial Revolution [2] [3], which is why gaining deeper understanding of them has been emphasized as a necessary step towards full entrepreneurial adoption:

> The ongoing developments and elaborations on future technologies in manufacturing are the driving force for research initiatives in this area. […] Nearly every market player (private and public) yields to define, explain, and create a "big picture" of manufacturing future in order to keep the pace with others. […] A deeper understanding of the concepts, ideas, and technologies as well as its relations is needed, especially for the implementation in practice [4, p. 30].

However, in a sea of papers and web publications hailing Industry 4.0, each using different terminology, it can become extenuating to try and understand the meaning of those concepts and their interdependencies, for any kind of business model innovation:

> Even though many academics and practitioners are focusing on the need to rethink the existing business models, the literature on business model innovations for Industry 4.0 is inadequate and seems to be characterized by overlaps with literature on Internet of things, Additive Manufacturing, Big Data and other technologies related to Industry 4.0. [2, p. 3].

Having found the need for conceptual clarification, this chapter deals with addressing it.

2.1.3 Chapter Outline

Given that this is a step towards business model innovation, it is only necessary to build an overview – "a general review or summary of a subject" – instead of an in-depth analysis of every topic related to Industry 4.0. In fact, this business-minded approach means that the conceptual clarification that comes from this chapter must be comprehensive, yet simple and concise.

With this in mind, the steps undertaken to build the overview along this chapter, section by section, are:

- Section 2.2: understand what were the main causes that led to the rise of Industry 4.0, largely by systematizing commonly referred causes presented in the literature;
- Section 2.3: identify the main common threads in popular definitions of Industry 4.0;
- Section 2.4: find the overarching principles of Industry 4.0, based on a benchmark work on the topic, along with further ideas from complementary sources;
- Section 2.5: find what are the main design rules for Industry 4.0 adoption, again based on a benchmark work on the topic;
- Section 2.6: understand what "systems" can be built with Industry 4.0, expanding on popular entries in existing research;

- Section 2.7: derive what are the enabling technologies of Industry 4.0, based on literature review and interpretation;
- Section 2.8: propose a graphic tool that encompasses all the previous concepts.

2.2 Drivers for Innovation

The push for this new age of industrialization and operations comes from the fact society and technology are ever progressing. So, like past revolutions, the paradigm established by the Third Industrial Revolution was also challenged by the simultaneous occurrence of a set of factors, here called “drivers for innovation”, derived mainly by pinpointing loose ideas on [4] and listed in Figure 4.

Drivers for Innovation

- **Customer demands changing**
- **Market volatility**
- **Resources scarcity**
- **New technologies**

Figure 4. Drivers for the innovation of Industry 4.0.

2.2.1 Customer Demands Changing

Nowadays, consumers are increasingly demanding when it comes to personalized products that able to satisfy their specific individual needs and meet quality standards [4] [13]. This means that the focus on achieving economies of scale through traditional industrial mass production needs to be rethought [4].

2.2.2 Market Volatility

Companies are more susceptible to different sources of volatility, particularly in sales, such as short-term company-specific effects, seasonal fluctuations and global competition [4] [14].

The aftermath of the 2008 global economic crisis showed that companies need to be able to deal with short cycled fluctuating markets to survive [4]. To accommodate these challenges, companies will need to reorganize themselves in ways that allow for rapid adaptation, from innovation to production and distribution [13].

2.2.3 Resources Scarcity

Future manufacturing changes will be determined by the decreasing availability of natural resources, worldwide growth of population and globalization of markets [4] [13]. Therefore, resource productivity and efficiency should be included in the strategic goals of manufacturers, as any waste brings economic and social consequences [4].

2.2.4 New Technologies

The continuous progress of information technology (IT) in combination with an exponential growth of computing, transmission, and storage capacity, which enables the emergence of increasingly powerful, interconnected new technological systems that can be used in order to grow industries [4].

More on the enabling technologies of Industry 4.0 will be discussed in section 2.7.

2.3 Definition

Defining Industry 4.0 is a cumbersome task – as of 2017, a study found already more than 100 different proposals [15] – that, luckily, falls beyond the scope of this dissertation. However, it is important to present an idea as of what it may be, since it has been established that a lack of conceptualization complicates the implementation of proposed solutions [9].

A 2013 report by the German platform responsible for planning that country's Industry 4.0 strategy loosely identified that it revolves around:

> […] networks of manufacturing resources (manufacturing machinery, robots, conveyor and warehousing systems and production facilities) that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensor-equipped and spatially dispersed and that also incorporate the relevant planning and management systems [16, p. 20].

This conceptualization emphasizes the changes that Industry 4.0 could bring to the manufacturing process. It is endorsed by other authors, that envision it as a way to achieve full automation [14].

A later 2016 report by the same German entity presented a formal definition that highlighted the structural and commercial changes allowed through Industry 4.0, by proposing that it is something that affects more than just "shop-floor" activities, like past industrial revolutions. For them, Industry 4.0 is:

> […] the next stage in the organization and control of the entire value stream along the life cycle of a product. This cycle is based on increasingly individualized customer wishes and ranges from the idea, the order, development, production, and delivery to the end customer through to recycling and related services [17, p. 8].

Reference [10] presents a definition of Industry 4.0 closely related to this one, built through a brief literary review, that underlines the gains in productivity and flexibility through new levels of control.

On the other hand, others focus more on the "connectivity" component. For instance, the United States' Industrial Internet Consortium defined "Industrial Internet" (the more prevalent terminology in that country) simply as:

> […] an internet of things, machines, computers and people, enabling intelligent industrial operations, using advanced data analytics for transformational business outcomes [18].

This is very much in line with the focus on "internet" that the name suggests by itself, and European researchers give that same emphasis to the Industry 4.0 concept as well:

> Industry 4.0 is operationalized as the usage of intelligent products and processes, which enables autonomous data collection and analysis as well as interaction between products, processes, suppliers, and customers through the internet [15, p. 4].

These definitions of the "Industry 4.0" concept all seem to circle around the points listed in Figure 5.

Key Topics

- **Changes in manufacturing**
- **Reshaping of the value chain**
- **Interconnectivity of all elements**

Figure 5. Key treads common to the definitions of Industry 4.0.

2.4 Implementation Principles

The operationalization of these changes is guided by a set of “implementation principles”, shown in Figure 6, that are the overarching aspects on which this revolution focuses for a successful system adaptation [16] [19].

Implementation Principles

- **Vertical integration**
- **Horizontal integration**
- **End-to-end integration**

Figure 6. Implementation principles for Industry 4.0 [16].

2.4.1 Vertical Integration

Vertical integration refers is the integration of the various IT systems at the different hierarchical levels (e.g. the actuator and sensor, control, production management, manufacturing and execution and corporate planning levels, marketing, etc.) [16], in order to generate agile, reconfigurable and self-organized manufacturing and management systems [20] [21].

It requires that factories have modularization strategies, in order to enable instant automatic reconfigurability of production systems [16], that are able to adapt to changing market demands.

2.4.2 Horizontal Integration

Horizontal integration is the integration of the various IT systems used in the different stages of the manufacturing and business planning processes that involve an exchange of materials, energy and information both within a company (e.g. inbound logistics, production, outbound logistics, marketing) and between different companies [16]. It is a drive to integrate all elements of the value chain [20].

This contributes to real-time data sharing, efficiency in resource allocation, coherent working business units and accurate planning [19].

2.4.3 End-to-End Integration

The appropriate IT systems should be deployed in order to provide end-to-end support to the entire value chain, from product development to manufacturing system engineering, production, the product’s life cycle and different companies [16] [20].

Every step of the physical product lifecycle could have a digital thread that tracks its physical status [22].

2.5 Design Principles

In order to successfully implement a strategic change to any organization, it is necessary to translate the overall idea into design principles [23]. A benchmark work on design principles for Industry 4.0 is that of Hermann et al. [9]. They find that, while it is difficult to define Industry 4.0,

> Design principles explicitly address this issue by providing a "systemization of knowledge" and describing the constituents of a phenomenon. Therefore, design principles support practitioners in developing appropriate solutions [9, p. 1].

After conducting extensive literary review and speaking with industry practitioners, those authors arrived at four main design principles for Industry 4.0[2] [9], listed in Figure 7.

Design Principles

- **Interconnection**
- **Information transparency**
- **Decentralized decisions**
- **Technical assistance**

Figure 7. Design principles for Industry 4.0.

2.5.1 Interconnection

The popularization of wireless communication technologies is an enabler for increased connection and interaction of machines, devices, sensors, and people everywhere [9]. These form the basis of a collaboration for reaching common goals.

To achieve interconnection, common communication standards and cyber-security are required [9].

2.5.2 Information Transparency

Due to the growing number of interconnected objects, the fusion of the physical and virtual world enables a new form of information transparency, where the linkage of sensor data with interpretation models can allow the creation of a virtual copy of the physical world [9].

Through these digital representations ("cyber-twins"), organizations can get unique insights into their activities. In order to create transparency, the results need to be made accessible to key users [9].

2.5.3 Decentralized Decisions

A key idea behind Industry 4.0 is that every element should perform its tasks as autonomous as possible, with external help only being necessary in case of exceptions or interferences [9].

The combination of interconnected and decentralized decision-makers allows to utilize local with global information at the same time for better decision-making and increasing overall productivity [9].

[2] It should be noted that other sources point out additional design principles, such as interoperability, virtualization, real-time capability, service orientation, integrated business processes and modularity [19] [98]. Even though these are valid, the four presented by [9] already contain them; e.g.: decentralized decisions result in real-time capability and modularity, while interconnection implies interoperability and integrated business processes.

2.5.4 Technical Assistance

The main role of humans is expected to change from an operator of machines towards a strategic decision-maker and a flexible problem solver, assisted by systems that aggregate and present information comprehensibly [9].

On a physical level, support of humans by robots is convenient, as they can replace humans in a range of tasks that are too unpleasant, exhausting or unsafe for their human co-workers, as long as the latter are properly trained for this kind of collaboration [9].

Virtual assistance exists as well, through devices such as smart watches, glasses or phones that can help with many tasks [9].

2.6 Components

Beyond the design principles, source [9] also lists "components" of Industry 4.0, drawn from the work of the Industrie 4.0 Working Group [16]. These components are the "bricks" used to build the Industry 4.0 "house". They are a natural consequence of following the implementation and design principles.

The authors from [9] point the Internet of Things, Cyber-Physical Systems and Smart Factories as those components. However, literature review of complementary sources has led to this dissertation expanding on that by adding Smart Products and Business Ecosystems to them, in order to illustrate the impact caused by Industry 4.0 on the whole value chain. Figure 8 shows the proposed components.

Figure 8. Components of Industry 4.0.

Examples of applications of these components are presented in section 3.3, when discussing the business opportunities brought by Industry 4.0.

2.6.1 Internet of Things

The focus on interconnection as a design principle leads to the goal of building an "Internet of Things" (often shortened to "IoT"):

> An IoT is a network that connects uniquely identifiable "Things" to the Internet. The "Things" have sensing/actuation and potential programmability capabilities. Through the exploitation of unique identification and sensing, information about the "Thing" can be collected and the state of the "Thing" can be changed from anywhere, anytime, by anything [24, p. 74].

Alternative/related popular names include "Internet of Everything" (IoE), "Internet of Services" (IoS), "Internet of Things and Services" (IoTS) and "Internet of Processes" (IoP).

2.6.2 Cyber-Physical Systems

Cyber-Physical Systems (CPS) are a component that links the dynamics of an organization's physical processes and infrastructure (buildings, machines or workers, etc.) with its software, by creating digital representations of the physical elements ("cyber-twins"), and monitoring their status through the data collected by sensors and other forms of input, as well as acting on them to fulfill desired goals [1].

CPS are the heart of Industry 4.0. They embody the design principles stated beforehand and are what takes the data collected through the Internet of Things[3], processes it using advanced algorithms, and instructs actuators to change current events [1] [14] [19].

2.6.3 Smart Factories

While past industrial advancements introduced automation as machines performing a discrete set of predefined processes, I4.0 enables "smart factories", where cyber-physical production systems (CPPS) are able to use information to self-optimize in real or near-real time without human input [16] [25]:

> Industry 4.0 advocates that the shop-floor will become a marketplace of capacity (supply) represented by the CPPS and production needs (demand) represented by the CPS. Hence, the manufacturing environment will organize itself based on a multi-agent like system. This decentralized system with competing targets and contradicting constraints will generate a holistically optimized system, ensuring only efficient operations will be conducted [26, p. 2].

Consultancy firm McKinsey predicts that Industry 4.0 is expected to comprise three archetypes of smart factories, depending on which demand segment and needs they target, according to Table 1.

Table 1. The three archetypes of smart factories predicted by [22].

Smart Automated Factory	Customer-Centric Factory	Factory in a Box
Smart automated plants address the need for mass products at low cost and are fully automated, digitized, and highly cost efficient. These plants produce large volumes and commodities.	These are ultra-responsive factories that allow for mass personalization, by producing highly customized products at an affordable cost, with very low lead times.	These small, low-cost and mobile factories can produce a limited range of products at a new location and can be set up quickly to tap into niche and remote unexplored markets.

2.6.4 Smart Products

By embedding their products with elements of the IoT, companies can make their products "smarter".

[3] The Internet of Things and Cyber-Physical Systems are very often named as key technologies of Industry 4.0 [99]. However, this dissertation proposes them as "components", rather than technologies, because they are not something that can be used on its own: IoT and CPS are ideas to be achieved through concrete resources (see section 2.7), such as RFID chips (sensors) and advanced management tools (integrated management software).

Smart products know their production history, their current and target state, and actively steer themselves through the production process by instructing machines to perform the required manufacturing tasks and ordering conveyors for transportation to the next production stage, without human interaction [1] [9].

Beyond factory borders, they monitor and relay their usage patterns for additional business insights and performance optimization [22].

2.6.5 Business Ecosystems

While past Industrial Revolutions predominantly changed the effectiveness of "shop-floor" activities, this Fourth Revolution has a wider bearing on the entire value chain, by presenting integrations of factory-level work with design, engineering, supply chain management, finance and marketing [14]. Following the previously stated horizontal integration principle stated in chapter 2.4.2, smart factories can move beyond their walls and exchange data with suppliers, distributors and customers [14] [25].

The interconnected and digitized value chains are known as "e-value chains" [14], "value networks" [17] or "business ecosystems" [27] (the preferred terminology in this dissertation), which can be defined as:

> […] a spontaneously sensing and responding spatial and temporal structure of largely loosely coupled value proposing social and economic actors, interacting through institutions and technology, to: (1) co-produce service offerings, (2) exchange service offerings, and (3) co-create value [28, p. 5].

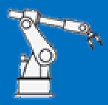
A business ecosystem's value is that it brings together, in real-time, multiple players of different types and sizes in order to create, scale, and serve markets in ways beyond any single organization's capacity [27]. They can be optimized according to a range of criteria such as costs, availability and consumption of resources [17].

Digital integration of partners inside the ecosystem can be performed using enterprise resource planning (ERP) tools and customer relationship management (CRM) software. These help make sure all relevant information in available in real-time through the networking of all entities (from their internal processes, to communication with suppliers and feedback from customers), as well as the ability to derive the best possible value from data at all times [14] [17] [27]. For now, the availability of reliable real-time data between suppliers and customers is often uncertain; however, as time passes, transparency along the ecosystem is expected to become more frequent [14].

2.7 Enabling Technologies

Like previous industrial revolutions, multiple works, such as [19], [29] and [30], have identified that Industry 4.0 is also supported on technological advances.

However, when reviewing those (and more), there is a clear disagreement as to what really are the technologies at stake, with the proposed lists varying widely. In order to build a conceptual overview that aims to precisely address this kind of inconsistency, it was deemed necessary to review several sources, that themselves presented ideas of what the technological cornerstones of Industry 4.0 are. By synthesizing each one and comparing with others, as well as reading additional materials on each topic (annex A cross-references technologies and sources), it was possible to define a set of seven key technologies, shown in Figure 9.



Enabling Technologies

- **Additive manufacturing**
- **Sensors**
- **Data analytics**
- **Cloud computing**
- **Integrated management software**
- **Extended reality**
- **Autonomous robots**

Figure 9. Enabling technologies of Industry 4.0.

To make sure not any field of technology was left out of this synthesis, the set was build based on the idea that it should cover four general areas, as proposed by [22]:

- "Data, computation power and connectivity" – sensors and cloud computing;
- "Analytics and intelligence" – data analytics and integrated management software;
- "Human-machine interaction" – extended reality;
- "Digital-to-physical conversion" – additive manufacturing and autonomous robots.

Similar to what happened with the components presented in section 2.6, real examples of applications of these technologies are saved for the discussion of business opportunities in section 3.3.

2.7.1 Additive Manufacturing

Additive Manufacturing ("3D printing") is a process of using materials (either polymers, ceramics, or metals [19]) to build products from 3D CAD models, autonomously, by overlapping thin layers until a three-dimensional object arises [1] [14].

Even though there are still technical limitations related to material strength, longevity, resistance to heat/moisture and precision, this technology already enables [1] [19]:

- Rapid prototyping for research and development;
- Manufacturing creative pieces with complex geometries otherwise impossible to make;
- Simple tooling manufacture;
- Mass customization through the ability to produce bespoke parts quickly;
- New products to be introduced without purchasing new equipment.

2.7.2 Sensors

A cornerstone of Industry 4.0 is the use of "smart sensors" to measure important and useful data about processes and products, which can then be presented to the decision-makers or users, connecting software, equipment and physical facilities [14]. These newer sensors allow [19]:

- Real-time tracking along the entire production or service systems;
- Enriched system availability, via condition monitoring and possibility for predictive maintenance;
- Continuous documentation and data collection, which are the foundation for data analytics.

Common sensors are the Radio-Frequency Identification (RFID) and Real-Time Location Systems (RTLS), which are used to collect and transmit data back to a common platform [19]. RFID tags have digital data encoded on them that can be captured by a reader via radio waves. Whereas barcodes must be aligned with an optical scanner, RFID can be read outside the line-of-sight [31].

2.7.3 Data Analytics

As technologies (such as sensors) advance and companies focus on collecting information about their processes, machines and products, the amount of data available increases exponentially[4] [14] [19].

Even though the setup process of data analytics structures may prove itself to be complicated, it is fundamental for Industry 4.0 and predicted to bring big advantages, such as the abilities to [14] [21]:

- Effectively plan, control and respond to production processes, systems and networks;
- Manage and leverage information about customers' preferences;
- Derive data-driven decisions, that affect the company's strategy, from complex datasets;
- Improved organization efficiency through better internal monitoring, measuring and managing;
- Evaluate the state of machines, surroundings and other counterpart conditions that can affect the production, which contribute to predictive maintenance and fault prevention and detection;
- Sustain artificial intelligence and self-learning capabilities of machines (machine learning).

2.7.4 Cloud Computing

Cloud computing is the storage of information on external remote servers, which are primarily accessible through the Internet [14]. By connecting computers to the Internet, various jobs are shared over a large network [1]. Some of the best-known systems are Google Drive, Windows Azure and IBM Cloud [21].

"Clouds" act as the foundation on which the Internet of Things is built. Without having to invest a lot for dedicated servers, companies can storage large amounts of data from several members of the value chain on rented cloud space, for later processing (through data analytics, for example) [1] [14]. For further convenience, many of the cloud providers mentioned in the previous paragraph already distribute and serve analytical tools which can process information in enormous quantities [1].

A requirement for cloud computing services is that they have proper cyber-security[5] and mobile access[6].

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[4] Due to the large amounts of data managed by these "data analytics" structures, the names "big data" or "big data analytics" have also become popular for it. In fact, annex A revealed that "big data" is the most common terminology in the literature. However, "data analytics" was preferred here, since it is a more comprehensive term.

[5] As the number of networked elements grows, cyber-attacks will increase and, consequently, foster the need for cyber-security [9]. Therefore, some authors (e.g.: [19]) list it as one of the key technologies of this industrial revolution. However, this dissertation frames it as something transversal to all technologies, mainly cloud computing, since that is the "umbrella" that hosts everything else.

[6] "Mobile technology" – the protocols and means through which devices broadcast large amounts of data to the Internet [19] – is commonly listed as an enabler of Industry 4.0. This is also underlying to cloud computing, since the cloud is were data is aggregated and must be accessible from any authorized device.

2.7.5 Integrated Management Software

Following on from the decentralized decisions design principle and the vertical integration implementation principle, it can be understood that for Industry 4.0 smart factories, the automation pyramid is expected to be integrated to a point it becomes a cyber-physical production system [4], which will bring higher efficiency, allow to accommodate the increased variability of processes and eliminate communication barriers [14] [32] [33].

To implement these cyber-physical production systems (CPPS) within smart factories, integrated management software[7] tools are crucial [33]. Some existing solutions include: Siemens' open cloud platform for industry customers based on SAP HANA technology [34]; GE Digital's "Brilliant Manufacturing Suite", which uses smart analytics to evaluate operational data; M&M Software's industrial cloud service platform, which is based on real time data analytics and consists of a universal core system of individual web portals; Festo's "CPS Gate" operates within the factory's workstations as the "backbone" module for controlling the processes [19]. None of these software can emulate the whole CPPS, but some practical implementations using elements of them already exist.

At a factory level, it has been proposed that a complete operational management system should use ERP and Manufacturing Execution Systems (MES) incorporated with Manufacturing Data Collection (MDC), Production Data Acquisition (PDA), Production Planning System (PPS) and Product Data Management (PDM) systems [35].

Beyond the factory scope of CPPS, there is also room for software solutions that gather information about product usage habits, supplier lead times and more, in order to build horizontally integrated CPS of the whole value chain. With that in mind, an important technological goal is achieving integration of ERP with other software used in the company such as, for example, Product Lifecycle Management (PLM), Customer Relationship Management (CRM), Partner Relationship Management (PRM) and Business Intelligence (BI) tools [33].

2.7.6 Extended Reality

Extended reality (XR) is an umbrella term that encapsulates all the technologies that create real-and-virtual combined environments [36] – defined in Figure 10 –, whether they are providing additional information about reality or create totally simulated worlds for humans to interact with [19] [37].

[7] While the terminology hereby used to identify the other enabling technologies of Industry 4.0 is already popular, "integrated management software" is the only original name. The overarching idea is derived from [35], a work that calls "information technology-based production management" to the new software solutions for the tasks listed on the automation pyramid. This dissertation builds on that and presents a name that highlights the focus on connectivity of components of an enterprise, from shop-floor level to business analysis. The need to create a new name came from the fact that most works present "cyber-physical systems" as synonym of the software that enable them, while this thesis argues that they are separate: CPS are a component built through IT technologies, as well as sensors and actuators.

Reality	Mixed Reality (MR)	Virtual Reality (VR)
No elements of virtuality.	MR is defined as a combination of both the real and virtual world [37]. Microsoft's HoloLens are a promising tool for MR. It comprises both augmented reality (AR), where virtual elements, such as computer-generated audio, graphics or GPS data are integrated into the view of the physical environment [1], usually through tablets, glasses or projectors [36], and augmented virtuality (AV), which is basically AR with more virtual elements [36].	In VR, users are isolated from reality and can look and interact with virtual worlds [36]. It is usually implemented through optical wearable devices, such as Oculus Rift [19].

Figure 10. Definition of Extended Reality concepts along the reality-virtuality continuum (layout based on [38]).

A corollary of XR technologies is the ability to perform enhanced simulations (such as discrete event or 3D motion simulation) inside a virtual world, before undertaking physical actions.

Overall, some of the uses for XR technologies are:

- AR can help assemblies, remote training, product design, plant control and diagnostics [39];
- VR can be used for product development, marketing and visualization of digital factories [36];
- Simulation tools can predict the consequences of an operation in real time and feed them into an AR hardware that superimposes those results to the real images on a visual headset [39];
- Factory's process design can be tested virtually before implementation [36], in order to evaluate autonomous planning rules and system robustness [19].

2.7.7 Autonomous Robots

Unlike traditional automated robots, autonomous robot have "next-level" autonomy – the ability to work with low, if any, external control [1]. With the advance of processing capabilities and methodologies, devices have become "smarter" in terms of having not only the abilities of computing, communication, and control, but also autonomy and the ability to work side-by-side with humans [14] [19].

Alternative names include "adaptive robotics", "collaborative robots" (cobots) or "advanced robotics".

The fact that they are consciously aware of their surroundings and adapt to unexpected scenarios means that they can be used not only for highly repetitive, low-skilled jobs but also in medium skilled, routine tasks [14]. Their use allows to achieve some of the advantages predicted within I4.0, such as:

- Opportunity for easy mass customization [14] (e.g.: custom lettering of products);
- Higher quality and practicality due to faster, stronger and more precise work by robots [14];
- Increased production rates due to further automation, leading to lower unitary costs and equipment downtime [19].

2.8 Graphic Industry 4.0 Conceptual Overview

Deriving from the previous conceptual overview, this dissertation proposes a simple graphic tool for initial Industry 4.0 comprehension, shown in Figure 11. This can be useful for managers looking to understand what I4.0 is all about, as well as present and explain it to their colleagues.

Each of the columns in the figure directly correlates to one of the previous subsections, from 2.2 to 2.7. The image should be read from left to right, starting with the first pair of columns, the “Foundations” of Industry 4.0, which are the drivers for innovation that led to the Revolution that is defined in the adjacent box, in the picture. “Theory to Practice Transition” (second pair of columns) presents the design and implementation principles, which guide the building of real-life systems. The third pair of columns, “Practical Tools”, is all about what are the actual concrete applications one can build with Industry 4.0, having understood where it comes from and what rules guide its practices.

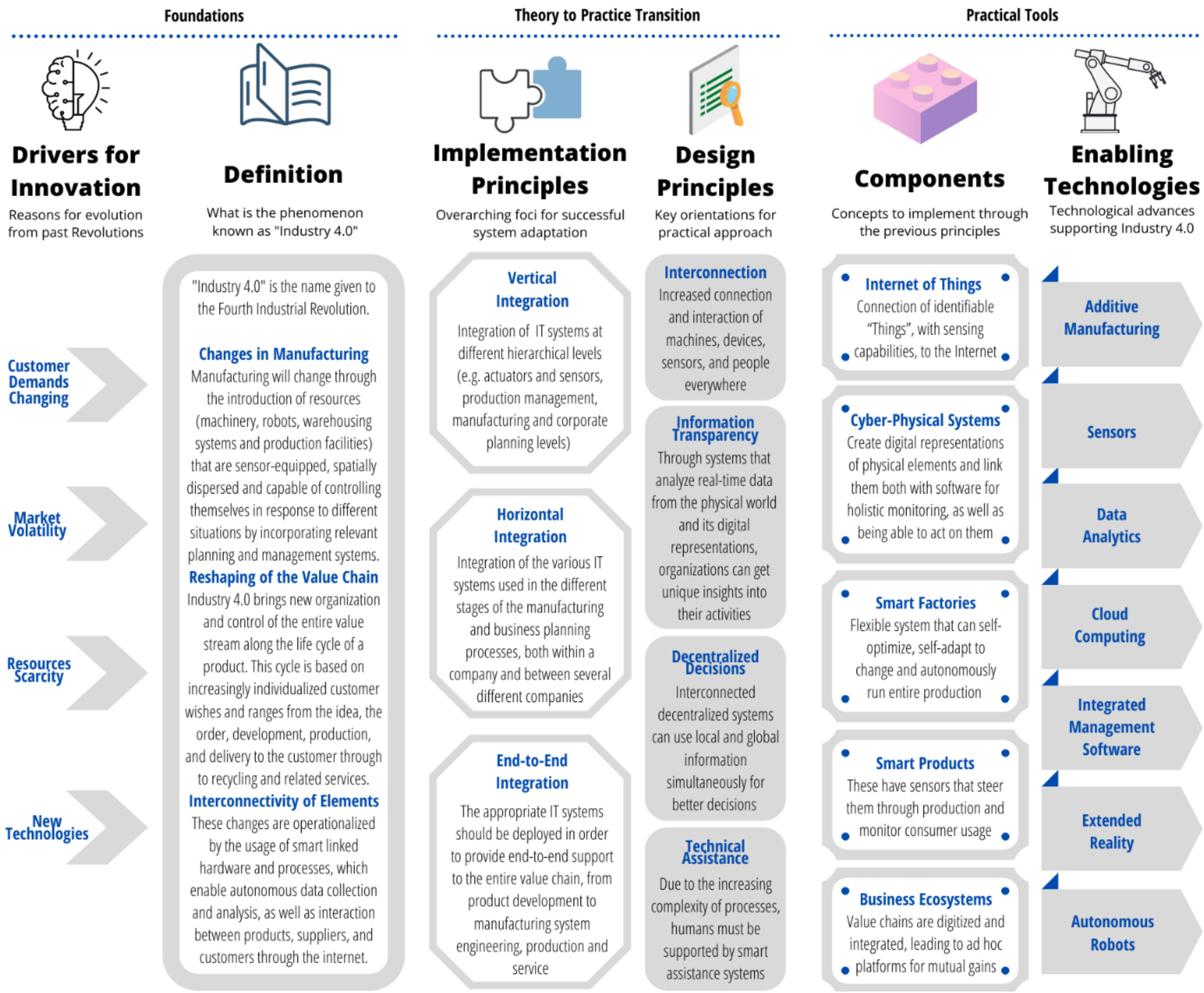

Figure 11. Proposed conceptual overview of Industry 4.0.

3 Business Model Innovation through Industry 4.0

3.1 Introduction

3.1.1 Business Model Innovation

This new industrial paradigm is transforming the current ways of value creation, since it involves changes in the technical and production developments, which in turn have brought extensive organizational consequences and new opportunities. This means that the impact of Industry 4.0 goes beyond technological innovation and integration: it affects the business models (BM) adopted themselves [29].

Many definitions of "business model" exist, but, for this work, it is enough to think of them as:

> […] the rationale of how an organization creates, delivers, and captures value [40, p. 14].

Several studies have shown that businesses struggle to profit from new technologies without applying adequate business models [41], while BM innovators are even more successful than pure product or process innovators [42].

To align the technological developments of Industry 4.0 with economic value creation, companies must undertake business model innovation (BMI) [41], which can be defined as:

> […] the (dynamic) generation process and initial implementation of a (static) BM, which is new from the perspective of the company or target market [6, p. 5].

A benchmark work on business models proposed that they are innovated through a try-and-error approach motivated by changes in the business model environment (BME) surrounding a company, namely driving trends, industry, market and macroeconomic forces [40], as Table 2 shows.

Table 2. Factors within each BME area (adapted from [40, p. 201])

Market Forces	Key Trends	Macroeconomic Forces	Industry Forces
Market Segments Needs and Demands Market Issues Switching Costs Revenue Attractiveness	Technology Regulatory Societal and Cultural Socioeconomic	Global Market Conditions Capital Markets Commodities and Other Resources Economic Infrastructure	Suppliers Stakeholders Competitors New Entrants Substitute Propositions

Industry 4.0 presents changes to many (if not all) of these points, therefore illustrating the need to innovate in terms of business models, as companies look to stay competitive in times of change [41].

Not only new companies need to conduct BMI. Even established businesses are still affected by Industry 4.0 as, even though their business models remain the same, their competitors' are surely changing to incorporate the new ideas and technologies [43], which is why every company needs to ask itself questions concerning the sustainability of its existing business models [44].

3.1.2 Relevant Knowledge Gap

Even though, much like other things, BMI requires dedicated resources and tools, research has found their development and deployment to be scattered between entities [6]. In fact, neither the overall topic of business models for Industry 4.0 nor developing analytical frameworks for their innovation in the context of Industry 4.0 have yet been the focus of many studies [2]. Other authors have argued that without a framework for identifying opportunities, it is hard to be systematic about the process, which is why it is generally done on an *ad hoc* basis [5]. As a result, many companies miss out on ways to improve their profitability and productivity.

In terms of specific tools for innovation within an Industry 4.0 mindset, so far, researchers have only presented two of them with considerable traction among the industrial community, due to their simplicity and practicability of these tools in a workshop setting [6], both "evolutions" of previous tools:

- **Business Model Canvas.** This is an ontology-based framework used for structuring BM ideas, originally proposed by [40]. Later, [45], [46] and [2] proposed Industry 4.0-motivated updates on it – they will be relevant in subsection 3.2.2.
- **List of Business Model Patterns.** A list of 55 business models used for creativity support when looking to innovate, compiled by [47], which has been used by [48], [49] and [42] to derive key opportunities brought on by Industry 4.0 – they will be sparsely cited along section 3.3.

Some criticize them as being too high-level, too restrictive within the parameters they define, and lacking consistency over the entire process [6].

> BMI for I4.0 requires such tools to systematically analyze and understand relationships within the ecosystem and to define compelling value propositions. […] The heterogeneity of tools observed indicates that there is a need for more and better tools. Here, we see great opportunities for future research [6, p. 18].

To address this requirement and the flaws identified within existing solutions, this chapter looks to develop a tool for business model innovation with Industry 4.0, in line with the second research goal. In order to avoid the same limitations of other frameworks, while addressing all the complexity of Industry 4.0, it should respect three design goals:

- Specificity – provide concrete logical actions;
- Fluidity – allow for changes in an iterative, and not necessarily linear, improvement processes;
- Interconnectivity – illustrate the interdependencies between parts of the business model when changes are made.

3.1.3 Chapter Outline

Having understood that there is a need to innovate and to develop tools for that innovation, it is time to build a strategy to do so, as described according to what was done in each of the following sections:

- Section 3.2 – build a methodology to synthesize possible business opportunities from research, according to a modified version of the business model canvas;

- Section 3.3 – list all the business opportunities brought on by Industry 4.0, synthesized according to the methodology from 3.2;
- Section 3.4 – turn the list of opportunities into a succinct and coherent tool, complementing it with auxiliary approaches.

Figure 12 shows a schematic representation of the steps followed along the present chapter.

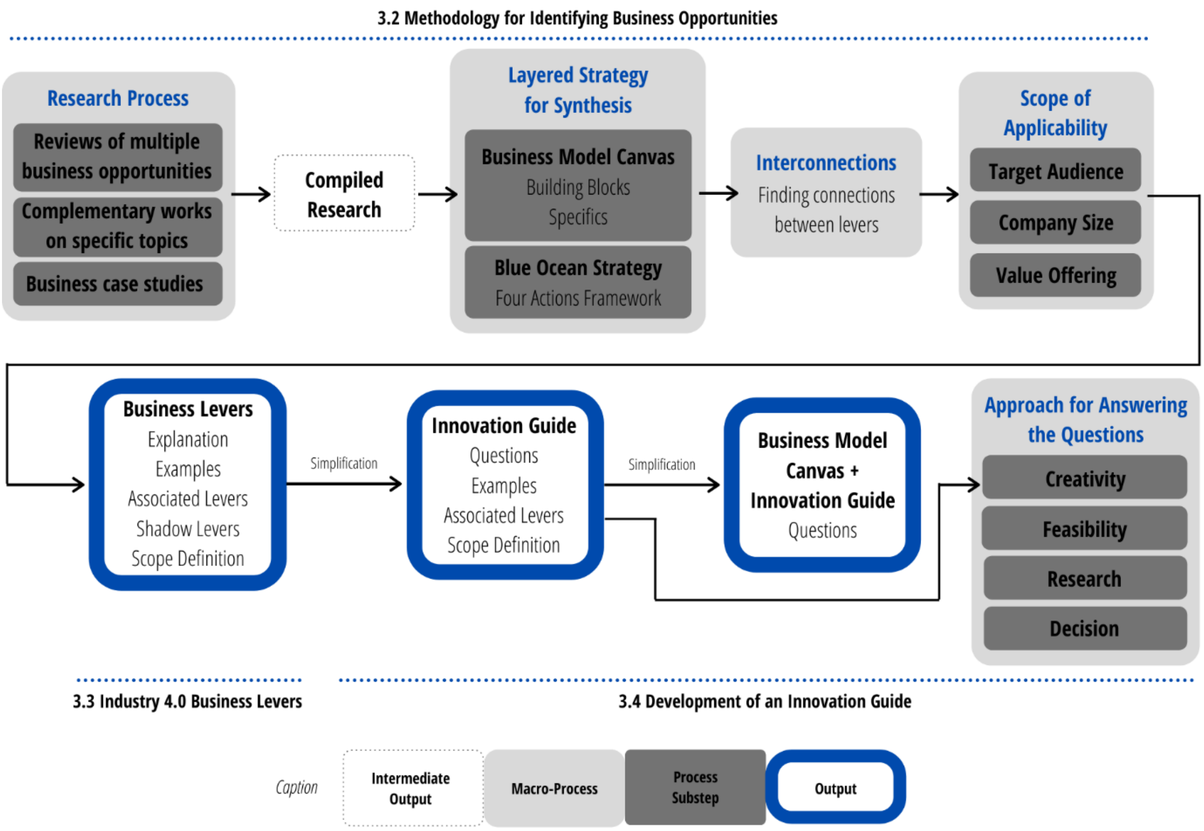

Figure 12. Schematic of the steps undertaken along this chapter.

3.2 Methodology for Identifying Business Opportunities

Even though no one can be certain about what is to come, researching past, present and predicted impacts on business models can give useful insights, that serve as guidelines for designing tomorrow's business models [40]. Therefore, the next step for developing a strategy for BMI through Industry 4.0 is to precisely assess the changes brought on to business models.

To fulfill the need for specificity mentioned in section 3.1, these changes should be listed in a set of business opportunities, named "business levers": concrete initiatives that a manager can undertake in order to drive the desired business model innovation and organizational growth.

3.2.1 Research Process

The first step for this research process is collecting information on impacts Industry 4.0 has had/is predicted to have on business models, that serves as the "raw material" for synthesizing the changes brought on. This was done along multiple threads:

- Review of overviews on possibilities brought on to businesses by Industry 4.0, such as [22], [50] or [51], among others, such as works derivative from the list of 55 business models mentioned in section 3.1 when discussing tools for innovation (e.g.: [48]);
- Complementary works on specific topics (e.g.: [52]), to exploit previously unidentified broad potential business improvement chances;
- Examples and case studies to illustrate ideas, like [53], [54] and more. Some of them are also the base for a generalization into a business lever[8].

Before proceeding, a note on a particular topic that was excluded from further analysis: blockchain[9]. Many sources reference it as a gamechanger of business activity, with the potential to disrupt banking, health care, insurance, and more areas [55] [56]. Indeed, the reviewed research pointed many promising early stage solutions [57], but lacked any live large-scale applications of it, besides cryptocurrencies, which are a type of currency with limited practical application.

3.2.2 Layered Strategy for Synthesis

Collecting information yields only a large tangle of diverse data. The next challenge is to sort through all of this, in a way that produces the desired actionable levers.

The potential levers of Industry 4.0 are derived from the information gathered before through a three-layered strategy, described next.

Business Model Canvas's Building Blocks (First Layer)

The previously mentioned business model canvas (BMC) is a very popular breakdown of business models that argues that the main areas of a business are described through nine basic components or "building blocks" that show the logic of how a company intends to make money: Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships and Cost Structure [40].

This building blocks approach has been regarded as being able to generate a holistic and nuanced view on business models [50]. It has been applied and tested around the world and is already used in organizations such as IBM, Ericsson, Deloitte and many more [40]. For those reasons, the BMC framework is adopted in this dissertation and the overall impacts of Industry 4.0 on business models are analyzed according to the effects it can have on each building block, which provide a first thematic separation of information into the parts of the business model.

[8] Analysis of particular cases can be used to derive useful broader insights, as has been done in the work on design principles mentioned before [9], and a number of rules relating to Lean Management, using induction [103].

[9] A blockchain is a digital chain of blocks which can be used to store and share data in a distributed, transparent and tamper resistant manner. Each block contains data and is linked with other blocks. When new data is added to the chain, a link to the free end is created which extends it by one unit. If one of the blocks is modified in the chain, it breaks cryptographic links, which disrupts the whole blockchain. The blockchain simultaneously stores the data and builds the structural data storage. This ensures safe transactions even without a third-party (like a central bank) to recognize them [56]. These systems would be able monitor, execute and register transactions between consumers through "smart contracts".

Annex B features an analysis of the frequency of changes observed so far in companies, for each component, which is the basis for the comments on that subject made in the following sections.

Business Model Canvas' Specifics (Second Layer)

Within the blocks of the BMC, [40] also originally proposed a series of specifics (examples, types, characteristics and examples) that label a company's way of operating, within that regard.

In 2015, [46] expanded on that, by updating the list of specifics to fit Industry 4.0. This expanded BMC has already been used for analysis of impacts of I4.0 on business models in popular works such as [42], in 2020. Plus, a 2018 dissertation found it to be the business model framework for I4.0 most aligned with descriptions of actual I4.0 business models, among several [58].

However, in their update, [46] ended up omitting some of the original specifics. For example, when discussing the channels block, they did not find any new types, but also omitted the phases, which are an essential part of the value capture stage. On the topic of revenue streams, [46] added two new types to the original ones, but failed to include the accompanying pricing mechanisms originally proposed by [40]. The same thing happened for the key partnerships and cost structure block.

Not reviewing these specifics could result in missing on potential business levers. For that reason, it is necessary to collate information from multiple sources into one coherent and complete business model canvas. That integrated and updated business model canvas is presented below in Figure 13.

Annex C presents definitions for all the specifics contained within the building blocks of the BMC.

Within each block, the specifics serve as a second level of thematic resolution for analysis of potential Industry 4.0 levers. When listing the levers in section 3.3, specifics that do not have any associated levers are omitted.

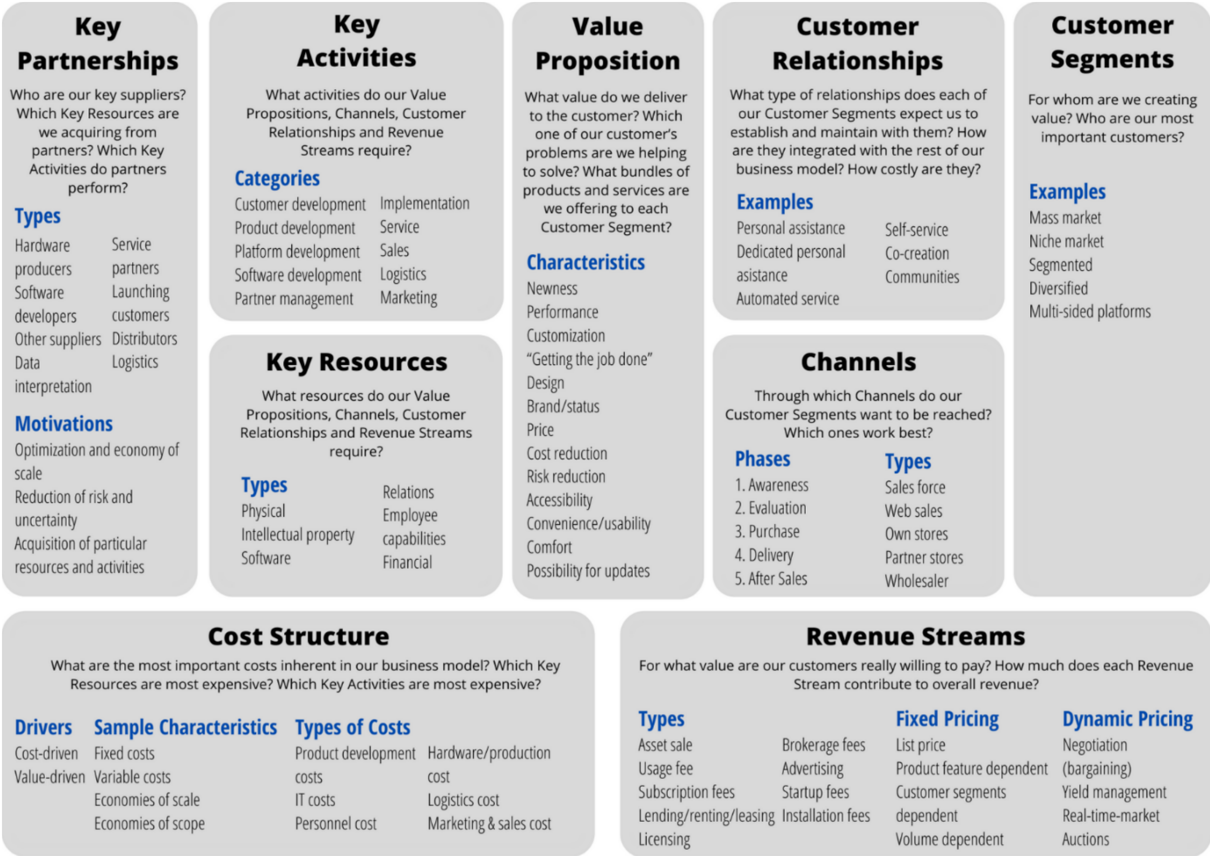

Figure 13. Business Model Canvas for Industry 4.0 (information integrated from [40], [45] and [46]).

Blue Ocean Strategy's Four Actions Framework (Third Layer)

While other works also breakdown changes to each block of the BMC, seldom do they deliver actionable levers, because they mostly present generic "thoughts", rather than actions that can be followed on. To avoid this, within each specific, an entrepreneurial layer (rather than thematic, like the previous two) for innovation is drawn upon, to turn abstract research into concrete business levers: the blue ocean strategy (BOS), which annex D presents some brief background information on. Its use is based on an integration of it with the BMC, proposed along with the latter by [40].

BOS advocated for fundamental differentiation through a "four actions framework": eliminate and/or reduce costs by taking out less valuable features, while raising and/or creating value through interesting and new benefits (Table 3). Application of the BOS to the information sorted in the second layer is what delivers the levers.

Table 3. Blue Ocean Strategy's four actions framework (adapted from [40, p. 227]).

ELIMINATE	REDUCE	RAISE	CREATE
Which factors can you eliminate that your industry has long competed on?	Which factors should be reduced well below the industry's standard?	Which factors should be raised well above the industry's standard?	Which factors should be created that the industry has never offered?

Of course, this framework is relative: what is "the industry's standard" is subjective and, therefore, whether some lever is an "eliminate", "reduce", "raise" or "create", also is. However, that is not detrimental to the process, as the resulting levers do not depend on the BOS action attributed to them; the lever prevails on its own. The BOS action functions as an aide to the reasoning for the lever.

Each business lever topic is presented in **bold blue** and numbered with a "LXX" tag, where XX are sequential numbers.

3.2.3 Interconnections

The integration of the BOS with the BMC also highlights the interconnections that arise between factors on each building block [40].

Industry 4.0 is a "new thing", so all the business levers associated with it will all be raise/create ones. However, in addition to this, for certain levers, there is also a reference to impacts it could have on reducing/eliminating costs (the affected block and specific are identified between square brackets), in **grey bold** and an indented bullet point with the BOS symbol. These are just possible impacts and not "actionable" business opportunities. For that reason, they can be called "shadow levers". Not many were identified, as to not overload the text; only the ones with particular relevance or interesting examples were included.

The proposed business levers are linked among them. In section 3.3, to exploit these interconnections, when the business levers are being described, there are parenthesis with the number of another lever associated with what has just been said, in *italic and blue font*.

3.2.4 Scope of Applicability

In terms of scope, some of the levers found will not apply to all cases and, therefore, should be skipped or *ad hoc* adapted. That assessment is up to the reader's sensitivity.

In an attempt to somewhat curb that uncertainty, there can be identified three main subject dichotomies, as illustrated in Figure 14, that limit the scope of application of each lever:

Figure 14. Three dichotomies identified and corresponding extremes.

To help the readers understand that topic's relevance for their organization, each lever presented in section 3.3 has an assessment of where it lands on these dichotomies; it is either on one of the extremes or in the middle, if the lever is indistinctly appliable to both.

When there are no restrictions to that dichotomy and the proposed classification is "any" – i.e., undifferentiated –, that discussion usually is omitted, for the sake of abbreviation. However, sometimes, additional clarification as to why that dichotomy is undifferentiated may be presented.

Target Audience

In regard to the target audience, there are two types popularly identified: business-to-business (B2B), a transaction conducted between one business and another [59], and business-to-consumer (B2C), the process of businesses selling products/services directly to consumers, with no middleman [60], such as online retailers.

These two types of sales are differentiated by the following characteristics:

J1. B2B markets have a smaller target audience [61], leading to more personalized customer relationships, and are more fragmented [62];
J2. B2B sellers usually have a small number of customers that dominates the sales ledger [61];
J3. Businesses (B2B) value being offered very customized and integrable solutions, while customers (B2C) accept more standardization [61];
J4. B2B transactions are usually of services (outsourcing), a big amount of goods (such as shipments of raw materials) [59], or products of large dimensions and value (e.g.: industrial machinery) [61];
J5. Long-term purchases, either big upfront investments or something that is repeated over a long period of time (e.g.: maintenance), are more common in business-to-business markets [61];
J6. Mass markets and B2C sales are traditionally linked, given that there are many individual customers and many common needs between them (food, household appliances, etc.) [63] [64];
J7. From the previous point, it is derived that B2C sales represent a high number of single transactions, even if each one is of low value;
J8. Individual customers are more susceptible to purchase things they are presented, whereas businesses are more concerned with satisfying concrete needs [61];

These distinctions can be drawn upon for justifications (numbered “JXX”, where “XX” designates its sequential number) for assigning each lever to a side on each dichotomy, in section 3.3.

Company Size

According to the European Union’s definition, small and medium enterprises (SMEs) are businesses that have less than 250 employees [65]. By negation, big companies have more than 250 workers.

This nomenclature is not to be followed to the letter here. The words “SME” and “Big” represent the idea of “smaller”/”bigger” companies, without strict adherence to the number of employees criterium.

For this dichotomy, some justifications for differences in lever applicability can be found as well:

J9. SMEs are part of ecosystems with multiple small participants, including their suppliers and sparse customer segments [66], while big companies often absorb surrounding suppliers or partners through vertical mergers and are more self-sufficient due to their scale [67];
J10. Beyond the definition of company size by number of workers, other sources also list criteria based on revenues [66], which is why, by that logic, big companies are assumed to have a higher volume of transactions;
J11. While SMEs may struggle to fund operations and new projects, big companies have access to quick funding mechanisms such as selling shares of stock or corporate bonds to the public [68];

J12. Small companies often focus on a niche market, while larger companies tend to branch out into new customer segments with more products and services [68].

Value Offering

Value propositions can be delivered either through products or services. Products are objects that are manufactured, stored, transported and sold [69], while, on the other hand, a service is an intangible item, which arises from the output of one or more individuals [69].

Industry 4.0 can be a mean for manufacturing companies to achieve servitization, which has been identified as a trend for the foreseeable future [70]. This explains why "services" are included here in this dissertation concerning Industry 4.0 – companies will move from offering exclusively products to a mix of products-services.

Analyzing the differences between both sides of this dichotomy, the following distinctions are found:

J13. Service businesses have a strong emphasis on the client relationship and widely varying user experiences, while product-based businesses, on the other hand, deliver physical products that are roughly similar, making the customer experience fairly predictable [71];

J14. Even though the digitization of processes and remote conferencing tools have made long distance servicing possible, they are still often limited by geographical proximity to the service provider [71];

J15. Products are tangible and, therefore, require physical equipment for manufacturing and logistics processes for transportation [72].

3.3 Industry 4.0 Business Levers

Figure 15 shows the meaning of all the terminologies adopted when presenting the business levers.

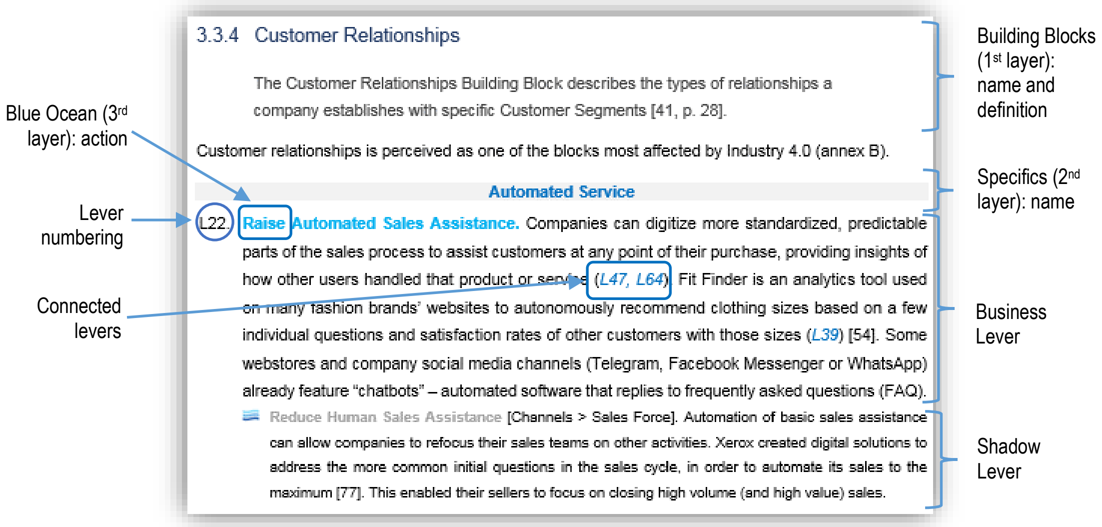

Figure 15. Identification of the layers of synthesis and business levers.

Apart from what is displayed in the figure, the levers may include a related case study highlight box and comments on their applicability, in smaller grey font.

3.3.1 Customer Segments

> The Customer Segments Building Block defines the different groups of people or organizations an enterprise aims to reach and serve [40, p. 20].

The general changes brought on by Industry 4.0 to this building block are mainly related to the type of innovation companies would like to pursue. For being so high-level, they may be the most "abstract" ones identified in the listing of business levers:

Mass Market

L1. **Raise Market Penetration.** The use of IT systems for digitization, data collection and networking (*L8, L12, L40, L47*) will allow companies to better target and serve new customers within their traditional markets [50]. In 2018, Portuguese hypermarket chain Continente launched a mobile application that enabled users to see past purchases and digitized their physical customer loyalty cards and discount coupons [73]. In the United States, retailer Walmart added new features to their "app", including "wish lists", through which friends and family can see what interests and products someone liked on the app. This encouraged them to purchase items in those categories for birthday or Christmas gifts [74].

Target Audience: B2C. Mass markets and B2C sales are traditionally linked (J6).
Company Size: Big. Developing accompanying IT tools to penetrate a mass market is best suited to a company that already has the size to have a team of IT developers parallel to their main business activities or the funds to outsource that task (J11).

Niche Market

L2. **Raise Focus on Niche Needs.** New hypothesis, such as additive manufacturing (*L63*) or data analytics tools that get unique insights into people's necessities (*L12, L47*), provide the ability to satisfy more particular customer needs (*L5*).

Target Audience: Any. While customers are increasingly valuing personalization (as stated in the driver for innovation from section 2.2.1), businesses are also more willing to pay for customized solutions that solve their particular problems (J1).
Company Size: SME. Smaller companies are more suited to take care of niche needs (J12).

Diversified

L3. **Create New Target Audience.** The new data-based products and services (*L9, L40*) will enable companies to tap into new customer segments, unexplored before, by offering new things outside their original business scope [50]. This is illustrated by the Google case in Figure 16.

Company Size: Big. Expansion into multiple customer segments is better suited for a bigger company, with the resources (human or else) to support that growth strategy (J11).

Case Study: Google's Expansion into Hardware

An example of a digital disruptor is Google, who not only dominates the Internet search engine segment, but has also expanded to video streaming (YouTube), cloud services (Google Drive), navigation (Google Maps) and more.

Beyond that, they also are starting to have physical products, such as virtual reality goggles (Google Glass), tablets and computers (Google Pixel) and "smart home" accessories, such as thermostats and smoke detectors, with their Google Nest brand.

Figure 16. Google case study description.

Research shows that this block is one of the least affected by Industry 4.0, so far (annex B); the only field that experienced marked changes is the IT business area [75].

This is to be expected, as it has been pointed out that competition for existing customer segments will increase, due to organizations from the IT industry trying and entering new “hardware”-based markets [50], capitalizing heavily on their core digital capabilities [6]. In 2016, it was predicted that half of 500 leading United States firms would be replaced by 2026 due to new digital disruptors and inability of established firms to reinvent themselves [76]. Due to this competition from IT companies, classical “hardware”-focused businesses will have to extend their focus in the direction of software and system development, in order to stay relevant [6].

3.3.2 Value Propositions

> The Value Propositions Building Block describes the bundle of products and services that create value for a specific Customer Segment [40, p. 22].

The value propositions block is universally recognized as being deeply affected by Industry 4.0, across all industries (annex B).

Performance

L4. **Raise Digitalization Assistance.** Following the growing need for digitalization, a market for business-to-business (B2B) consultancy services will grow [42], as manufacturing companies will need help with machine retrofitting and data analytics services (*L64*) [77], as well as connecting internal departments with each other and supply chain partners through horizontal and vertical integration [28]. These consultants are expected to deliver performance upgrades to companies. For instance, TRUMPF, while continuing to be primarily a machine manufacturer, expanded their business scope to include Industry 4.0 consultancy, software and platform development [78].

Target Audience: B2B. This need for systematic digitalization is mainly for companies.
Company Size: Any. Big companies, such as TRUMPF, can leverage their knowhow to deliver this service, while smaller consultancy firms can dedicate exclusively to digitalization projects.
Value Offering: Service. This assistance is clearly a service.

Customization

L5. **Raise Mass Individualization.** Smart factories’ optimization and new technologies (e.g.: additive manufacturing) allow for more flexible production and services, capable of satisfying the customer’s demand for more individualized products, up to the point of “batch size one” manufacturing, while combining economies of scope and scale to maintain the competitive low costs of standardized production (*L66*) [4] [50] [75]. German company Arburg, that deals with individualized high-volume plastic products, linked a traditional injection molding machine to a 3D printer by means of a seven-axis robot, in order to engrave plastic lettering on their products [19].

- **Reduce Customer Acquisition Costs** [Cost Structure > Marketing & Sales Costs]. As people prefer product individualization and personalized services can lead to increased customer loyalty, which, in turn, leads to savings, as the cost to acquire a customer is greater than the cost of retaining one [76].

Company Size: Any. While it was stated in L2 that smaller companies are more suited to take care of niche needs, it is also true that bigger ones are better equipped to find these compromises between economies of scope and scale.

Value Offering: Product. This lever is built on the idea of customizing a product. Customization or adaptation of services are reserved for other levers.

Accessibility

L6. **Create Platforms that Link Production Services with Customers.** Increased decentralized manufacturers, new markets and technologies have opened up a space for platforms that link entities with a demand for products with the corresponding (manufacturing) services, via predefined communication streams [22]. This is appliable both to a company working around its own production capabilities or a third-party platform provider that adds value to the system by ensuring a certain quality level and ideal distribution of the goods and services offered (*L21, L30*). SLM Solutions, a 3D printer manufacturer, and Atos, a software company, are working together to develop an integrated production network, where machines are connected via the Internet and customer orders are produced with optimal capacity utilization [22].

Value Offering: Service. The value offered here is a mediation service.

L7. **Create Product as a Service (PaaS).** The PaaS proposition removes accessibility barriers by making products temporarily available to customers through renting or use-based fees (*L27, L29*) [42]. Smart sensors enable companies to monitor the use of their physical assets (*L37*). For instance, DriveNow offers shared cars that users can rent by the minute, through apps on their smartphones.

Target Audience: Any. The offering made available can be a product to an individual customer – B2C – or the usage of unoccupied machinery from another company to deal with a spike in demand (L29) – B2B.
Value Offering: Service. This lever concerns precisely the servitization of a physical product.

Convenience/Usability

L8. **Create Product-Service Systems (PSS).** The PSS concept arose to describe the integrated development and offering of incorporated complementary services attached to a physical product [29]. These services add to products more and more, or even become the primary product (*L9*) [43] [44]. A good example of the PSS concept is observed in car manufacturer Tesla, where, if customers pay for software updates (*L19, L34, L40*), they get extra functionalities, making sure the relationship continues beyond the purchase of the vehicle [43].

Target Audience: B2C. Prolonged usage favors the appreciation of the complementary service. Since transactions between companies are often exchanges of services or raw materials (J4), there is not much added value in building PSS.
Value Offering: Product. While this lever concerns a service, it is only a complement to a physical good. Their pairing is what creates a valuable proposition for the client.

L9. **Create Digital Replacements of Physical Products.** With the growing trend towards digitization, the replacement of physical assets by digital services will become an interesting value proposition. While, in the past, people learned how to play chess on wooden boards, nowadays, players use apps such as Chess Time on their smartphones. Companies can mimic this change by transitioning from physical to digital value creation (*L27*).

Value Offering: Service. This lever is precisely the creation of a digital service that replaces a physical product.

L10. **Raise Integrability Between Offerings.** Industry 4.0 introduces the possibility of further integration between several devices or software, making their use more convenient for customers (*L37*). For instance, new Huawei laptops use Near-Field-Communication (NFC) technologies to connect directly with nearby Huawei smartphones and share their files and screens. This allows companies to setup solutions of several interconnected but separated devices; e.g.: industrial machine manufacturers can produce the equipment, set it up and connect it with other machines in the factory, so that everything in the client's factory is integrated [50]. This also allows for modularity through unified sets of individual devices, which can be singularly replaced, instead of relying on more costly entire kits [50].

Target Audience: Any. Even though J3 states that companies value integrability, nowadays, customers have so many available complex systems that will also appreciate the chance to avoid the hassle of compatibility-related problems.
Company Size: Big. Bigger companies will have a diverse product line, which then can be "designed for interconnectivity". An SME with few products and sales will not add much value by connecting them.

L11. **Create Aggregates of Data.** By its nature, the Internet of Things links different sources of information, so, combining it, filtering, pre-processing and customizing can help reduce the information overload and tailor datasets to specific user requirements. For that reason, a business opportunity exists for third-party data aggregator or information service providers to monetize this service (*L31, L62, L64*) [41]. For example, the value of an identification number's electronic component significantly increases, if it is combined with its firmware release number or service history [41].

Target Audience: B2B. This is mostly for companies that need data to understand their B2C customer segments or product history.
Company Size: Big. Bigger companies will have access to a lot more data to mine.

Possibility for Updates

L12. **Create Self-Adaptative Products.** "Smart" connected products can collect a lot of condition data, which, if properly evaluated, allows to satisfy latent user needs significantly better than before (*L23, L47*). These "adaptive" products can be shaped digitally in real-time and adjusted to changing requirements [44] [46], so that companies can deliver value to end users at every opportunity; e.g.: predictive maintenance, self-optimization or energy savings [50] [75] [76]. For example, Amazon launched the "Amazon dash replenishment service", that automatically orders the necessary consumables for household appliances (such as washing machines or printers) when necessary [48].

Target Audience: B2C. B2B transactions usually involve the sale of goods that will either assist or be consumed in making new products (J4), mostly denying the need for adaptability.

3.3.3 Channels

> The Channels Building Block describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition [40, p. 26].

The analysis conducted in annex B hints that managers of manufacturing companies perceive channels as the block least affected by Industry 4.0 transformations. One proposed explanation is that SMEs – a big percentage of the industrial community – and B2B suppliers already have highly individualized and personal channels (face-to-face communication, telephone, and e-mail) as a valuable cornerstone of their operations, so that no major evolutions have happened yet [50] [51].

In line with this perception of irrelevancy, the reviewed literature does not present directly many changes associated with the channels block. However, deeper investigation allows to identify some advances. Most of these advances can be linked with this component by first understanding the five "channel phases", defined in the business model canvas:

Awareness

L13. **Raise Awareness Through Social Media.** Organizations now have new ways to raise awareness to their value proposition, such as social media, in a cost-efficient marketing strategy. Advanced algorithms make product recommendations to potential customers based on a broad sample of data regarding their preferences (*L47, L62*) [76]. For instance, the Facebook Business platform allows companies to hyper-target who sees their ads and repeatedly show them to people who demonstrate interest or visit the enterprise's website.

Target Audience: B2C. Presence on social media is paradigmatic of individuals.
Company Size: SME. While big companies can purchase expensive ad time on television or films, social media allows SMEs to deliver efficient advertising with small starting investments.

Evaluation

L14. **Create Evaluation Systems Using Extended Reality.** New extended reality technologies allow for customers to try out products and narrow down their preferences in an immersive experience, even without viewing the product in person [76]. Furniture seller IKEA launched an app capable of showcasing products through AR. Customers only need to scan the room they are looking to furnish, using their smartphone or tablet, and select the product they are interested in seeing. The app then places a realistically rendered, true-to-scale representation of that product on screen, for the user to see how well it fits in their home, increasing sales conversion (*L1*) [79].

Target Audience: B2C. Application of XR is often for the sale to individual customers. Because they often represent costly investments and/or are made with great thought and economical ponderation, companies privilege face-to-face assessment of goods before purchase.
Value Offering: Product. These systems are easier to use for visualizing products, as illustrated by the IKEA app example.

Purchase

L15. **Raise Acceptance of New Payment Methods.** Sales channels (*L20, L21*) now must adhere to easy digital payment solutions (*L64*), such as Apple Pay, Google Wallet or even cryptocurrencies like Bitcoin. Walmart changed the payments section of their app to accept all forms of payment such as credit, debit and gift cards in one place [74]. By making it easier for their customers to pay, enterprises are eliminating purchasing obstacles.

Target Audience: B2C. Due to their high frequency, B2C transactions (J7) are those that benefit the most from being simplified for further convenience and timesaving.
Company Size: Any. There is not any applicability limit regarding the company's size. Payment service providers are already incorporating these new methods in their payment terminals, available to all companies. In Portugal, most banks already provide terminals that accept debit card Contactless or MB Way QR Code scans.
Value Offering: Product. Like the rationale presented when discussing "Target Audience", this lever is better suited for products.

L16. **Raise Automation of Physical Point of Sales.** Sensors (*L63*) and digital payment services (*L15, L64*) allow for the physical purchasing process to be sped up and simplified. Sports retailer Decathlon created self-checkout kiosks where a customer can place an item into a boxed area so the RFID tag on the product can be read and the item's price and details captured [80]. The customer then removes the item from the boxed area and adds the next one.

Target Audience: B2C. Point of sales automation lends itself more to B2C sales, due to the high volume of products moved through them, like it was mentioned when discussing the target audience in lever L15.
Company Size: Big. The need to invest in sensors for each product is only worth it if there is a high volume of sales (J7).
Value Offering: Product. By nature, this lever is limited to physical products.

Delivery

L17. **Raise Decentralization of Storage and Delivery.** Companies can now have smaller, decentralized warehouses to lower customer waiting times and shipping fees [76]. For instance, delivery service UPS is establishing "access points" across multiple countries: partner retail outlets, such as a grocery store or gas station, that serve as a convenient point for UPS to drop multiple packages and customers to pick them up [81]. This is allowed by the integration of data from stock management software (*L40, L61*), GPS or RFID technology to monitor package status and position (*L63*), so that both UPS and customers can know where the packages are.

Target Audience: B2C. B2B transactions are usually of services, or a big amount of goods (such as shipments of raw materials), or products of large dimensions and value (e.g.: industrial machinery). None of those quite fit this lever, which clearly is B2C.
Company Size: Any. As customers buy more and more online, this kind of delivery solution will be more adopted. Since all companies are betting on e-commerce, there is not a particular distinction between SMEs or big enterprises.
Value Offering: Product. By nature, this lever is limited to physical products.

After Sales

L18. **Raise Customer Support.** After sales customer support will stop being "a necessary evil" to an important part of the company's internal process, as it will allow it to understand the major challenges the users have with the product and for the development of a closer relationship with companies (*L23, L24, L25, L47*) [6]. This support can be through multiple means, such as social media, dedicated forums, email, and more.

Target Audience: Any. Even though a computer network, a new item of machinery or a fleet of vehicles bought in a B2B transaction (J5) usually require far more extensive aftersales service than a house or the single vehicle purchased by a consumer (B2C), the focus on individual customer after sales integration and satisfaction is growing so much in today's competitive market that it matches B2B's importance for this lever.
Value Offering: Product. Products, by their physical nature, are more susceptible to future repair or defective quality.

Additional levers can be found by analyzing channels types:

Web Sales

L19. **Create Products as a Point of Purchase.** Linked to the Product-Service System concept (*L8*) [43], companies can create PSS where the service component allows for products to become platforms for digital sales (*L20*) and marketing services (*L62*) [49]. For instance, a simple version of this already exists today, with Apple iPhones having the App Store, through which the user can buy apps, with Apple gaining a share of each sale; the physical smartphone is just a mean for further sales. The incorporation of Point of Sales on the product itself allows companies to advertise or cross-sell additional things directly.

Target Audience: B2C. Individual customers are more likely to purchase things they are presented (J8).
Value Offering: Any. Customers can be encouraged to buy additional services or complementary products from the same brand.

Own Stores

L20. **Raise Focus on Online Direct Sales.** Research shows that the changing customer relationships and value propositions seem to favor an increasing orientation toward direct sales from manufacturer to customer [51], as companies now are able to reach customers worldwide with online stores and advertising (*L13, L17*). The new products, embedded with IoT hardware, favor intensified close contact with customers [51].

Partner Stores

L21. **Raise Sales Through Online Third-Parties.** While, in the past, manufacturers tried to place their products on the shelves of big supermarket chains, the lockdown imposed by the COVID-19 pandemic has only sped up the transition to digital shopping. Companies can benefit from the exposure of third-party online platforms (*L30, L59*), such as Amazon, who allows them to reach many more customers at once. Following on from a previous topic on social media, it should be noted that Facebook now allows companies to sell their products directly on that social media (*L13*). This growth in sales through online third-party platforms is simultaneous with the focus on direct sales (see previous lever), but on a lesser scale [51].

Company Size: SME. Big companies can sell through their own channels with ease, as they benefit from already being known brands, while SMEs can complement their own stores' sales with additional exposure from third-party platforms, like Amazon.
Value Offering: Any. While Amazon is an example of the sales of physical products, outsourcing platform Fiverr is a popular third-party that mediates the purchase of services.

3.3.4 Customer Relationships

> The Customer Relationships Building Block describes the types of relationships a company establishes with specific Customer Segments [40, p. 28].

Customer relationships is perceived as one of the blocks most affected by Industry 4.0 (annex B).

Automated Service

L22. **Raise Automated Sales Assistance.** Companies can digitize more standardized, predictable parts of the sales process to assist customers at any point of their purchase, providing insights of how other users handled that product or service (*L47, L64*). Fit Finder is an analytics tool used on many fashion brands' websites to autonomously recommend clothing sizes based on a few individual questions and satisfaction rates of other customers with those sizes (*L39*) [53]. Some webstores and company social media channels (Telegram, Facebook Messenger or WhatsApp) already feature "chatbots" – automated software that replies to frequently asked questions (FAQ).

- **Reduce Human Sales Assistance** [Channels > Sales Force]. Automation of basic sales assistance can allow companies to refocus their sales teams on other activities. Xerox created digital solutions to address the more common initial questions in the sales cycle, in order to automate its sales to the maximum [76]. This enabled their sellers to focus on closing high volume (and high value) sales.

L23. **Raise Personalized Automated Feedback.** IT tools allow companies to automate certain parts of the customer-company relationship, while maintaining personalization (*L34, L47*). For instance, even though conventional laundry machines manufacturers only have after-sales customer contact when there is a malfunction, Bundles offers a "smart" washer through which customers get monthly feedback about their washing behavior. This personalized feedback is autonomously generated and sent by connected software without human interaction [46].

- **Reduce Customer Acquisition Costs** [Cost Structure > Marketing & Sales Costs]. Similar to what was said for L5, offering personalized services leads to customer acquisition savings [76].

Target Audience: B2C. B2B have closer relationships with clients, due to their smaller number big singular relevance (J2) and, therefore, will depend less on automating feedback.

Co-Creation

L24. **Raise Integration of Customers as Creative Partners.** New communication technologies enable co-creation between seller and customer, so that users are increasingly and earlier integrated into product/service design, serving as collaborative partners [75] [46]. Plus, individual products can be designed to fulfill individual needs (*L5*) [50] [75], as the LEGO case study presented in Figure 17 shows.

- **Reduce Product Development Efforts Through Co-Creation** [Key Activities > Product Development]. Co-creation strategies are a way to save internal effort. Local Motors is a car manufacturer that was able to reduce its development cycle from the industry average of six to seven years to one year and achieved a massive cost reduction in R&D, with a design crowd sourced from an online community [22].

Target Audience: Any. Co-creation endeavors are a business trend so important it is transversal to both sides of this dichotomy.

Case Study: LEGO's Strategy for Product Line Diversification

Danish toys manufacturer LEGO started experimenting with user-generated content by giving customers the possibility to design, assemble and order their own kits online – people are given the chance to pick buildings, vehicles, themes and characters, choosing from thousands of components and dozens of colors, and even design the box containing the customized kit. In addition to helping users design their own sets, LEGO sells them online. While the success of these varies, what matters for the company is that it can exploit these user-designed sets to expand a product line previously focused on a limited number of best-selling kits [40].

Figure 17. Lego's strategy for diversification.

Communities

L25. **Create Communities with Customers.** For companies, establishing close communities with their customers is a great strategy to gather their feedback directly, provide customer service, and allow for customers to interact and help each other, solving problems without the company's interaction. Apple and Google host customer support forums where people can post their questions about the brands' products and be assisted either by other users (*L24*) or technical assistance staff. Marketing company Salesforce offers a "community cloud" (*L64*) that allows companies to directly interact with their customers and customers to interact with each other [82].

Target Audience: B2C. Individual customers are less prone to have proprietary/confidential information, so building these communities for B2C sales is easier.
Company Size: Big. Larger companies have more clients. That allows them to benefit from a "scale effect" of having many people sharing information with each other.

3.3.5 Revenue Streams

> The Revenue Streams Building Block represents the cash a company generates from each Customer Segment [40, p. 30].

In spite of recognizing potential for new revenue streams, companies still have not experienced significant change in this building block, as the analysis conducted in annex B revealed it is one of the least affected components so far. This can be attributed to a lack of adaptation of their value propositions to the new opportunities [51].

However, literature and practice have identified some changes within the value capture process, as will be listed next.

Asset Sale

L26. **Raise Pay for Parts.** This is an evolution of the well-known Razor and Blade business model, which is based on the sale of an initial product and further revenue from recurrent complementary pieces (e.g.: Gillette with its razors and the related replacement blades). Sensor and actuator technologies (*L37*) will enable new means to limit compatibility of complementary parts with initial products, emphasizing that only original parts are compatible with the system, to avoid counterfeits and to manage guarantees, ensuring future revenue streams [49].

Company Size: Big. Only large companies with known brands will be able to convince customers to purchase "locked-in" products.
Value Offering: Product. "Parts", in this lever, are referring to a physical product. L27 is the "service" version of this lever.

Usage Fee

L27. **Raise Pay for Use.** Remote monitoring technologies allow for equipment to be rented based on actual consumer usage, rather than an initial fixed price [22]. While the client benefits from only paying for what they need, the supplier gets an opportunity to collect additional data during operation of the machine (*L47*) [22]. Integration of elements of the IoT on smart offerings (*L37*), capable of reporting real-time data about their own condition or the environment surrounding them, allows companies to detect errors and potential problems in advance, control for the correct usage of the equipment and offer affordable and efficient maintenance (*L12, L50*) [49]. This can be leveraged to ensure new renting revenue streams, with automated billing (*L60*), as outlined below in greater detail on the Konecranes case study in Figure 18.

Value Offering: Service. This lever is, by nature, the servitization of a product.

Case Study: Konecranes' Smart Rental

In 2015, leading manufacturer and provider of cranes and lifting equipment Konecranes introduced a new business model, allowing customers to rent industrial cranes [48]. Claiming to have launched an industry-first rental solution, the company is targeting to generate new business through offering its customers a novel way of financing the investment. Thus, Konecranes is addressing customers that weren't in their scope earlier.

Offering customers an all-inclusive leasing contract, just charging the actual hours the equipment was used, is not entirely new. Nevertheless, in the case of Konecranes, only new sensor-collected data allowed the company to lease their cranes. This new rental business model for industrial lifting equipment is only possible due to the rich amount of data Konecranes could gather about its customers and their usage behavior of cranes. A broad set of crane usage parameters (runtime, starts, working cycles, overloads etc.) could be used to optimize the maintenance accordingly and improve the safety of operations. The examination and analysis of this data are part of Konecranes' competitive advantage and enable this new business model in the first place.

Figure 18. Konecranes's new rental strategy.

Subscription Fees

L28. **Raise Subscription Models.** Instead of a one-off asset sale, companies can tap into recurring revenue streams through subscription models [51] [77] of software, maintenance and support (*L60*), which is a strategy adopted by ERP provider SAP [22]. Solar panels maintenance companies can sell the physical panels and then bill monthly values in exchange for remote monitoring of equipment (*L8*), through proper sensors and performance indicators.

Value Offering: Service. This lever applies to services such as maintenance and support.

Lending/Renting/Leasing

L29. **Raise Sale of Unused Capacity.** A manufacturer can choose to sell its machine's idle time to another manufacturer that has more demand than it can match [22]. This sale is facilitated through shared platforms between companies (*L6, L36*). This is already common in the service industry, mainly in the digital business, where many companies offer software or infrastructure as a service [22]. As far back as 2006, Amazon decided to leverage its retail sales operations powerful IT infrastructure to host and offer cloud computing services, such as online storage space and on-demand server usage, to third-parties [40].

Target Audience: B2B. Production services are reserved for manufacturing businesses.
Company Size: Any. Both SMEs can sell their machine-hours to other SMEs and larger companies that have excess demand, and big companies such as Amazon can exploit their installed capacity to generate additional revenue.
Value Offering: Service. This lever is, basically, the outsourcing of production services.

Brokerage Fees

L30. **Raise Commission Gains for Mediating Sales.** Decentralization of manufacturers will create opportunities for platforms that link them with the demand, as seen on subsection 3.3.2 when discussing accessibility. The revenue from that usually comes from a percentage of the value sold. This is already done by popular sales websites such as eBay, AliExpress (both B2C), or Alibaba (B2B).

Value Offering: Service. By nature, this lever is a mediation service.

Advertising

L31. **Raise Data as Payment for Later Monetization.** Even if the users have access to a service for free, their usage data can become a pathway to revenue streams [6]. Within the new paradigm of Industry 4.0, the collection and sharing of information between participating stakeholders (*L39, L47, L59*) is made easier and can be monetized through paid access to the provided information (*L27*) [41]. For monetization of data, Google is the most prominent example of this: a search engine as primary product creates the data that is further analyzed and used for targeted advertising (*L62*), which results in a natural revenue stream [22]. There is also SCiO, a low-cost, pocket-sized spectrometer that allows customers to obtain information about the chemical composition of a product using their smartphone by simply scanning the object; every scan automatically contributes to a large database of materials [22]. A monetization strategy would be to identify and target specific customer needs and characteristics based on scans performed.

Target Audience: B2B. This is a lever that has a two-layered targeting: while it collects customer data in exchange for a "free" service ("B2C"), it actually then sells insights generated from that data to other companies (B2B), which is where the actual monetization comes from.
Company Size: Big. The larger the company, more likely it is to have lots of customers and, therefore, lots of data to mine.
Value Offering: Service. This lever is mainly the sale of advertising/customer knowledge services.

Startup Fees

L32. **Raise Crowdfunding.** The widespread use of the internet, along with the integration of customers as partners (*L24*), has led to the rise of a new form of funding mechanism: crowdfunding. Several types of this practice exist, both for and non-profit, all based on funding a project through small contributions from many individuals, using the Internet. For companies, this means that their prospective customers can contribute to their startup capital, bypassing bank loans or venture capital (*L68*). Popular crowdfunding platforms include Kickstarter and Indiegogo. Craft Wallet, a company founded by former mechanical engineering students at IST, got their startup capital through successful crowdfunding campaigns on Indiegogo.

Target Audience: B2C. Crowdfunding is based on a "crowd" of small individual contributors.
Company Size: SME. Established big companies already have the startup capital to launch new products (J11).
Value Offering: Product. Crowdfunding campaigns are very based on the visual appeal of the value offering, which is why they are overwhelmingly used for promoting innovative physical products.

Installation Fees

L33. **Raise Pay for Installation.** Increased use of complex and advanced software, such as SAP's ERP solutions (*L40*), allows them to profit not only by selling licenses to their product, but also on installation consultancy projects on other companies (*L56*, *L64*). Machine manufacturers also adhere to this logic, by monetizing the sale of their "smart" equipment and then its installation on the destination factory (*L37*).

Target Audience: B2B. By default, this lever in inherently B2B, since it related to the profitability of installation fees for complex solutions for companies (J4, J5).

Studying pricing mechanisms, whether fixed or dynamic, further reveals Industry 4.0 levers:

Product Feature Dependent

L34. **Raise Pay for Feature.** There is the possibility of offering various additional digital paid services after the customer adheres to an initial value proposition. Following on from the PSS concept (*L8*), this can be done in the after-sales phase of a physical good, in a model known as "physical freemium": a physical good is sold, along with a digital service that is free at a basic level but has paid-for "premium" features [49]. Besides that, offering these complementary services enhances the value proposition of the product and might allow companies to sell the physical product at a higher price: car manufacturer Tesla offered an autopilot software update digital add-on for $2,500, which enabled the updated vehicles to park automatically [48]. This is a variation on the "digital freemium", where the initial offering is a service itself; music provider Spotify follows this approach. This can be perceived as an extension of the "Product as a Point of Purchase" channel approach (*L19*).

Target Audience: Any. There are no restrictions on this dichotomy, since it extends beyond the limitations of L19 in terms of being suited to B2B sales as well: choosing features for a given offering could be a way for businesses to scale their investments by not spending extra on capabilities they do not need at the moment.
Value Offering: Any. The additional feature can be just another service add-on (e.g.: extra space on a cloud storage system), but it can also be something that totally changes the behavior of a physical product (Tesla autopilot parking update, for instance).

L35. **Create Performance-Based Pricing.** Performance can be assessed in real-time through IoT hardware (*L37, L47*), which enables pricing models based on service level compliance [41]. Rolls-Royce launched an airplane engine maintenance model called "Power by the Hour", where airline carriers only pay a fee in proportion to aircraft flying hours, which in turn are affected by the availability of all major aircraft sub-systems (including engines) [54]. New hardware allows for remote and integrated performance monitoring.

Real-Time-Market

L36. **Create Real-Time Pricing.** IoT hardware (*L37*) and complementary software (*L40*) enables dynamic pricing for an efficient individualization of prices and billing is ensured [51]. Due to improved GPS accuracy and open-sourced algorithms, shared mobility company Uber was able to implement "surge pricing": when there are more riders asking for vehicles in a given area than available drivers, prices automatically increase; this encourages more drivers to serve the busy area and riders to delay their trips until prices fall, restoring supply-demand balance [83].

Target Audience: B2C. The decentralized and real-time nature of this pricing lever indicates it is best suited for individual customers. Businesses expect their expenses to be consistent and cannot depend on volatile prices.

3.3.6 Key Resources

The Key Resources Building Block describes the most important assets required to make a business model work [40, p. 34].

Analysis showed that key resources is perceived to be the second building block most affected by Industry 4.0, after Value Propositions (annex B).

Physical

L37. **Raise Interconnected Devices.** Production facilities equipped with sensors and actuators and supporting equipment such as servers and web-enabled interfaces, will need to be adapted ("retrofitted") or bought new (*L42, L63, L67*), to match the demand for interconnection of Industry 4.0 [50] [51]. Beyond this, the resulting products will tend towards integration with monitoring systems, especially if they are "servitized" – remember the Konecranes case study. In order to monitor product quality along their supply chain, Bosch placed sensors on their transport packaging, connected to the company's cloud system. They continuously record relevant data, such as temperature, shocks or humidity [19].

Value Offering: Any. This lever can be interpreted to mean both the linkage of physical production equipment and resulting products, as well as the monitoring of physical agents (people or equipment) that are performing a service.

L38. **Raise Automated Production Systems.** Autonomous robots (or, broadly speaking, machines) combine precision when executing tasks with the ability to exchange data concerning what and when to perform them among themselves, through machine-to-machine communication (M2M), without human input [50], for full process automation. The main point is to have integration of physical tools (*L37*) with management software (*L40*) and suitable decision algorithms (*L58*). The Kuka KR Quantec is a robot with a humanoid anatomy that supports a camera and image processing systems. On a given factory, it was tasked with distributing screws and other production material by delivering the ordered kanban boxes from the central warehouse rack to the workstations. Its job was facilitated by memory-based activity identification, using independent recognition of the previous positions and characteristics of production parts [19].

- **Reduce Operation Inefficiencies** [Cost Structure > Hardware/Production Cost] Combining advanced IT systems and automation (e.g. self-optimizing production facilities or the completion of routine works through robots) allow lowering material consumption and machine downtime, while increasing process speed and yield, which directly correlate to financial gains [22] [44].

Company Size: Big. Automation may require complex projects, implementation and expensive equipment, which all demand funding, something big companies have more access to than SMEs (J11).
Value Offering: Product. Production systems are for physical products.

Intellectual Property

L39. **Raise Data Ownership.** As more stakeholders across the business ecosystem become connected, questions will arise regarding who owns the data generated and how to ensure appropriate privacy, control, and security (*L41*) [12]. So, for companies to properly explore the potential of data analysis, they will need to control the flow of data and own the information itself [12]. In 2018, the European Union has launched privacy and security law called "General Data Protection Regulation" (GDPR) that forbade companies to collect and process customer information without their explicit consent and gave concrete instructions as to how to handle it (*L42*).

Software

L40. **Create Management Software Infrastructure.** Companies will now need to rely on more complex IT infrastructure (*L45, L64*) to go along with their modernized hardware (*L37, L63*) [51] and manage data [76]. To build the aforementioned cyber-physical systems, companies will need to have advanced, integrated and readily available software solutions (the integrated management software mentioned in subsection 2.7.5). At a factory level, it has been proposed that a complete operational management system should use ERP and MES incorporated with Manufacturing Data Collection (MDC), PDA (Production Data Acquisition), PPS (Production Planning System) and Product Data Management (PDM) systems [35]; an example of this is provided in Figure 19. On a business level, ERPs can be integrated with, Product Lifecycle (PLM), Customer Relationship (CRM) and Partner Relationship Management (PRM), as well as Business Intelligence (BI) tools, for example [33].

Case Study: Implementation of Production Control Software

A complete vertical integration was that of a dual-arm Baxter robot [84].

Researchers developed a graphic user interface on top of a MES DELMIA Apriso software and integrated in the Business Planning and Logistics level of an ERP system to allow submitting production orders to the MES. ERP reads and writes specific data to the database and the logic within Apriso reacts to these triggers. Apriso Machine Integrator reads and writes data to the PLC controlling the shop-floor via an Open Platform Communications (OPC) server. This OPC allows Windows programs to communicate with a variety of PLCs.

Figure 19. Baxter robot vertical integration case study.

L41. **Raise Cyber-Security.** Since data is a crucial part of Industry 4.0, its value and protection against unauthorized access, manipulation and destruction also become more relevant [75]. In order to manage security risks, companies need to use proper protection for their key assets, update defense systems regularly, install backup copies to limit eventual damages (*L56*) and train staff to avoid cyber-risks (*L55*) [12] [22]. Workers should have an antivirus on their work computer, use different (and robust) passwords for each login, avoid connecting to Wi-fi networks of unknown origin and enable two-factor authentication (e.g.: password plus code sent via SMS) [85].

Company Size: Big. While it is also important for SMEs to have security systems against cyber-attacks, big companies are much more targeted by these and have much more data to protect.
Value Offering: Any. Both smart products and services collect data on customers behavior, so no distinction exists.

Relations

L42. **Create Implementation Standards.** Many of the useful Industry 4.0 applications (such as software or advanced robots) can be proprietary (*L40, L63, L64*) and have limited compatibility with other solutions, presenting significant integration challenges [12]. For those reasons, companies will need to rely on industry-wide standards (*L65*) that help guide the implementation. These can be either reference architectures, methodology for building CPS or others.

Company Size: SME. While larger companies can rely on expensive consultants or their own know-how and skilled workforce to conduct implementations, SMEs will depend more heavily on standardized guides.

Employee Capabilities

L43. **Raise Staff Creativity.** As digital solutions take over low to medium-skill everyday tasks, the role of employees will change from operators to controllers and problem-solvers, intervening only when connected elements cause conflicts, dealing with unforeseen events and responsible for systematically innovating (*L54*) [50] [75] [51]. For a creative workplace, Forbes presents a series of simple recommendations for managers, such as that they let workers pitch and develop ideas, even if they do not see their vision and support try-and-error processes without chastising employees for failure [86].

L44. **Create Multidisciplinary Teams.** End-to-end integration and focus on understanding and satisfying customer needs (*L47, L66*) leads to the need of interdisciplinary teams, knowledgeable in economics, engineering, informatics and marketing [75] [51]. Communication within factories will stop focusing being almost always between the industrial manager and the production staff, to involve new contact persons originating in IT (*L45*) and research and development [51].

Company Size: SME. While big companies can have multiple departments, each dedicated to an area of work, SMEs are much less compartmentalized and need personnel capable of adapting and solving a diversity of problems

L45. **Raise IT-Related Roles.** The acquisition and development of increasingly qualified personnel is pointed as key in order to match technological and economic Industry 4.0 requirements [51], with focus on IT skills as software development and data analysis [50] [75]. This may involve the creation of new roles such as developers, data scientists and other digital jobs [76]. These experts should be able to draw insights from the information generated in any department (*L58*) [22].

Financial

L46. **Raise Funding for Adaptation.** For acquiring the resources listed beforehand, considerable starting investments are necessary, whether it is for new advanced machinery or human resources (*L37, L40, L41, L43, L44, L45, L55*) [50]. Companies need to actively search this funding, whether it comes from their own capital or external sources. Portugal has a “Portugal 2020” program that launched an “Industry 4.0 Call”, through which companies could apply to get governmental funding for adapting their manufacturing plants to Industry 4.0.

Company Size: SME. Due to their comparatively smaller budgets, this lever favors SMEs (J11).
Value Offering: Product. Manufacturing facilities for products usually require a lot more funding than services, due to the costs of industrial machinery.

3.3.7 Key Activities

> The Key Activities Building Block describes the most important things a company must do to make its business model work [40, p. 36].

The Key Activities block is also somewhat affected by Industry 4.0 (annex B), more so for big companies than SMEs [50]; this can be due to the latter not being developed in terms of data management, so far, or being more resistant to change.

As manufacturing companies evolve from product-specific companies, competing exclusively on manufacturing costs, time or quality, to include (digital) services in their value propositions, their activities will also change [50].

Customer Development

L47. **Raise User Data Collection.** Companies should establish a focus on understanding customers' problems, requirements, and expectations by taking in a customer's viewpoint [51]. One of the foundations for meeting customers' volatile demands is collecting and using their behavioral data to capture business opportunities [22], improve internal overall operational effectiveness [29] [44], tweak or innovate value propositions in order to preemptively address dissatisfaction within their existing customer base [76], promoting evidence-based decision making (*L58*) and developing integral customer experiences [29], as the case study in Figure 20 illustrates. For instance, "smart products" can gather and share their usage information with the manufacturer and other interconnected products.

Case Study: Bosch's vehicle control

Bosch designed a device for vehicle monitoring that can be connected to the car's internal control network to monitor engine performance and possesses its own sensors, such as a GPS to detect the vehicle's geo-location. The collected data is transmitted via a mobile network to a Bosch backend. There, the transmitted data is coded and documented in databases in order to be analyzed and further processed. In a next step, that data pool is used as the foundation for various digital services such as remote diagnostics, maintenance or fleet control [48].

Figure 20. Bosch's strategy for data collection.

Product Development

L48. **Raise Physical Rapid Prototyping.** To speed up product development, rapid prototyping technologies such as additive manufacturing (*L63*) can be used [19].

Value Offering: Product. By nature, product development is for physical products.

L49. **Raise Virtual Product Development.** The use of extended reality tools allows to simulate what products will look like and function even without physically prototyping them (*L63, L64*). In addition to that, XR tools is also a platform for remote co-creation efforts with customers [22].

- **Reduce Product Development Costs** [Cost Structure > Product Development]. Co-creation with manufacturers and customers, extended reality design assistance tools and rapid prototyping equipment ("3D printing"), allow for shorter product development times, lowering the costs incurred [12]. Machine manufacturer company John Deere estimates that having its engineers use virtual reality simulations to design parts of a cotton harvester equipment reduced the design cycle time by 18 months and design costs by more than $100,000 [12]. They also allowed customers to test and provide feedback on early design concepts, using AR.

Company Size: Big. Setting up advanced XR tools may prove to be too costly for SMEs.
Value Offering: Product. By nature, product development is for physical products.

Implementation

L50. **Create Predictive Maintenance Systems.** Since all physical equipment is turned into "smart things" by featuring sensors to detect equipment wear and tear, data analytics systems can detect patterns and predict failure before it happens (*L58*), increasing operational safety [1] [19]. General Electric offers a predictive maintenance service in which remote sensors collect and report data on the condition of the user's machinery [22]. Based on that sensor data, signs of failure are detected early, allowing for correction at minimal costs, maintenance resources to be better managed, and more machine availability. Predictive maintenance has been found to decrease the machine downtime by 30-50% and increase machine life by 20-40%.

- **Reduce Maintenance Costs** [Cost Structure > Hardware/production cost]. Since the costs of manufacturing are often driven by repair and machine downtimes, using predictive maintenance to decrease them opens up the potential of maintenance cost reductions up to 40% [22].

Value Offering: Any. Production systems are usually for physical products, but, as has been seen before, there is also the possibility of companies offering products as a service. In those situations, they will need to conduct maintenance as well.

L51. **Raise Physical Assistance of Tasks.** Labor productivity can be increased by reducing the strain or complexity of their tasks [22]. For example, Etalex, a Canadian manufacturer of warehouse furniture, retained their employee base while simultaneously introducing autonomous robots (*L63*) to increase labor productivity in their plant, in order to spare workers of the physically straining task of loading large metal parts. For them to work in close proximity to each other without risking injury of the workers, robots had built-in force control, so that they would automatically slow down or stop in case of contact with humans [22].

- **Reduce Labor Unitary Costs** [Cost Structure > Personnel Cost]. Further automation is expected to lower the unitary costs of manufacturing each product.

Company Size: Big. In order to even justify having robots, it is necessary for the company in question to have a sizable number or high value set of situations where it is beneficial to use them.
Value Offering: Product. This assistance solution is best for handling physical goods.

L52. **Raise Virtual Assistance of Tasks.** Extended reality systems can be used to assist human workers in performing manual tasks (*L63, L64*). For instance, with AR glasses linked to simulation software and environment recognition features, the level of a liquid in a tank after a refill can be shown on the tank's surface, the temperature of a chemical reactor after a reagent mixing procedure prompted over the vessel and the stress level of a structure will be highlighted immediately as the load is applied. Figure 21 presents a case study on this.

Company Size: Big. In order to even justify having advanced virtual assistance solutions, it is necessary for the company in question to have a sizable number or high value set of situations where it is beneficial to use them.
Value Offering: Product. As the given examples illustrate, these assistance solutions are best for handling physical goods.

Case Study: Knapp's Warehouse Assistant

Logistics company Knapp AG developed an assistance for warehouse work named KiSoft Vision [22]. It is a headset resembling eyeglasses worn by the worker that shows virtual information on its see-through display. The relevant information for retrieving the products for shipping is superimposed on the user's field of vision. This information helps them locate items more quickly and precisely, guides them, makes suggestions regarding the stacking of fragile items and allows the worker to have his hands free, since it makes redundant the use of paper checklists. Furthermore, the integrated camera with image processing can also capture serial and lot ID numbers, thus enabling real-time stock tracking.

Training time for new and seasonal workers is decreased, the retrieval is sped up, and less errors are made.

Figure 21. Knapp's use of AR for workers' virtual assistance.

Platform Development

The changes brought to the platform used to support the products or services mainly relate to new management practices implemented within companies.

L53. **Create Knowledge Management Strategies.** Not only information should be shared, it should also be recorded and available for workers to read and learn from (*L55*). For instance, consultancy firm McKinsey uses a "knowledge management" software to register knowledge creation within the company, from long detailed reports to practical "information nuggets" on how to connect streaming devices for lectures.

L54. **Create Systematic Innovation Practices.** Industry 4.0 business models must be interested in new forms of differentiation to avoid strategic similarity [44]. In order to systematically innovate, companies can have dedicated "innovation managers" with participation and autonomy in several departments [22] and encourage transversal participation of workers in improving task performance (*L43, L44*). An interesting strategy for fast-tracking innovations, such as breakthrough products or business models, is to create autonomous "startups" within an existing larger company, which can have shorter release cycles and agile business practices that can meet today's quickly changing customer expectations [22].

L55. **Raise Training for New Tasks.** Industry 4.0 requires workers that understand and accept it, are able to operate its tools, with a key focus on IT (*L44, L45, L56, L57*), and make suggestions on improvements, so there is a need for training and requalification of the existing workforce [50]. Furthermore, since the employees' roles will change from operators to problem solvers (*L43*), human resource development activities should be encouraged [75].

Software Development

L56. **Raise Software Setup and Maintenance.** Since CPS, a core component of I4.0, comprise sensors, actuators, central processing units, and respective software, setting up and maintaining them turns out to be crucial (*L45*) [51]. Plus, novel digital value propositions mean that even manufacturers who formerly produced mainly hardware, now have to deal with software implementations (*L4, L8, L9, L12*) [51].

L57. **Raise Internal Digitalization and Data Collection.** Since internal inefficiencies can only be corrected if they are first detected, physical assets and processes need to be digitally mapped, automatically and in real-time by sensors and software [22] [44]. It is necessary to have a set of standards and policies that ensure data quality and traceability, with the goal of creating a holistic (and reliable) view of the entire business ecosystem (*L59*) that can be leveraged bring distinct value to the company [22] [76]. For this, roles such as "chief digital/transformation officers" can be created. For a concrete example of the job associated with this lever, in order to identify and rectify unbalanced usage in a set of automated welding guns, first, it is necessary to understand what are the parameters that assess its wear and then implement sensors to measure them [22].

L58. **Create Automated Process Control.** More reliability for processes can be achieved by creating automated systems capable of self-maintainability and self-optimization of the process efficiency [1]. Low level management can be automated by applying data analytics to internal data (*L57*), in order to extract useful insights into the company's processes [48] [52] [50] [75], and then using the conclusions from that data analysis to take action, such as automatically presenting recommendations for workers or triggering actions of machines [22]. An example of application of this lever is found on the case study in Figure 22.

- **Eliminate Repetitive Quality Defects** [Cost Structure > Hardware/Production Cost]. Using digital performance management tools can mitigate quality inefficiencies caused by deficient packaging, distribution or installation. Improving quality eliminates the costs (machine time, material and labor) of scrap disposal and product rework [22]. Something like this is already implemented in the semiconductor industry, where advanced process control (APC) systems translate anomalies found by statistical analysis of the products into automated adjustments of equipment parameters, that prevent deviations from desired standards, in a negative feedback system [22].
- **Reduce Labor Inefficiencies** [Cost Structure > Personnel Cost]. Real-time optimization of processes will reduce workers' idle time, due to less mistakes, machine stoppages, or other factors [22].

Case Study: ABB's Cement Kiln Process Optimization

An exemplary Industry 4.0 solution to improve process/resource effectiveness is real-time yield optimization as employed in a cement kiln by ABB [22]. At this kiln, a computer-based system for controlling, stabilizing, and optimizing process variables was introduced. It mimics the actions of an "ideal" cement plant operator focused on achieving particular targets. Based on the actual measures, the system calculates the adjustments to the process necessary to achieve that ideal process. The newly calculated values for kiln feed, fuel flow, and fan damper position are then sent automatically to the kiln control system to drive the process towards the optimized kiln targets. Typically, real-time process optimization yields an improvement in throughput up to 5 percent [22].

Figure 22. Real-time cement kiln process optimization.

Partner & Vendor Management

L59. **Create Partner Management Strategies.** Nowadays, innovation is happening so fast that companies cannot do it by themselves [28]. For that reason, they must adopt the culture of openness and collaboration typical of startups, leading to faster innovation and implementation of practices [44]. By investing on standardized digital connection systems such as partner relationship (PRM) or supply chain management (SCM) software (*L40*), companies can quickly exchange “best practices” among them [44] and derive real-time optimized physical flows (routes and schedules), but also integrated information insights and financial flows [28] across participants of the business ecosystem – external consultants, suppliers and customers [1] [76], as long as they have digitized things on their end [46] [28]. For example, a sudden spike in similar repairs on products across multiple dealers can help identity a quality defect yet to be noticed in a production run [76]. Finding compound effects with other enterprises regarding Industry 4.0 could assist in establishing standards (*L42*), gaining access to trained personnel and expertise (*L44, L45*) [50], improving supplier performance [25] and accessing unique platforms for new products’ development, marketing (*L62*), sales and distribution [14] [27].

Company Size: SME. Big companies often absorb surrounding suppliers or partners and are more self-sufficient due to their scale. On the other hand, SMEs are part of ecosystems with multiple small participants.

Sales

L60. **Raise Automation of Billing.** A critical part of any company’s operations is the collection of their revenue streams. On this subject, automated billing and invoicing will streamline payment documentation and increase payment reliability [77]. Automation of billing will allow for less work to be devoted to repetitive chores and ease the implementation of usage-based pricing.

Company Size: Big. Even though, nowadays, billing solutions allow for companies of all sizes to automate this task, it is still something more useful for businesses with many transactions (J10) and more complicated structures.

Logistics

L61. **Raise Stock Management Automation.** The efforts to better understand customer needs will lead to better methods to anticipate demand (*L47*). This, along with increased flexibility and production rate of factories will allow for companies to keep less stock units [77], as systems moves toward “pull production” strategies. In addition to that, stock management software and smarter physical automation and virtual assistance are expected to make warehouse management more efficient. For instance, in Portugal, supermarket chain Auchan has a robot that scans their shelves to detect missing products and incorrect price labels, to then warn the staff of those problems [87].

- **Eliminate Overstocking Costs** [Cost Structure > Logistics Cost]. Industry 4.0 targets causes of excess inventory, such as inaccurate stock numbers, unreliable demand planning necessitating safety stock, or overproduction due to inaccurate perception of customer demand [22]. By eliminating unnecessary stocks, capital is freed, therefore avoiding its costs. Würth’s iBins, for example, uses intelligent camera technologies to capture the actual fill level of a supply box that is wirelessly connected and automatically reorders supply based on accurate fill information [22].

Company Size: Big. Large stocks demand more effort to manage and, therefore, companies who have them benefit more from automating that process and will be open to invest in tools that ease that job.
Value Offering: Product. By nature, stocks are of physical products.

Marketing

L62. **Raise Marketing Analytics.** If, in the past, companies relied on surveys and focus groups, nowadays, they can compile customer interaction, order and web history data to create a demand barometer running from the beginning of the sales cycle (such as initial website visit) to purchase (such as order data), detecting patterns in purchase intent across multiple channels and facilitating more effective product recommendations [76]. For instance, Salesforce offers a Customer Relationship Management (CRM) cloud solution that tracks customer journeys and provides multichannel marketing campaigns [82].

- **Reduce Marketing Inefficiency** [Cost Structure > Marketing & Sales]. Targeting customers based on their digital footprint for online advertising using allows for high return on marketing investment.

3.3.8 Key Partnerships

> The Key Partnerships Building Block describes the network of suppliers and partners that make the business model work [40, p. 38].

Key partnerships is the fourth most affected building block (annex B), with some changes expected.

Hardware Producers

L63. **Raise Enabling Technologies Suppliers.** Companies will need to have trusted partners who can deliver them the enabling technologies for Industry 4.0 (*L67*) and support their use. Consistency and quality are so important that finding the right partner constitutes a lever by itself.

Software Developers

L64. **Raise Suppliers of IT Capabilities.** Studies have found that incorporating Industry 4.0 into industries and product portfolios is a specialization likely to be mainly outsourced (*L67*) [46]. In order to compensate for unavailable resources required for the provision of novel products and services, companies will need strategic partner networks such as need app developers and data analysis partners (related to the "data interpretation" specific listed on the BMC) [75] [46].

Company Size: SME. Due to their (comparatively) smaller workforce, SMEs will depend more on outsourcing IT solutions than big companies, that have the means to build them in-house.

Reviewing the motivations for building partnerships reveals an additional lever:

Acquisition of Particular Resources and Activities

L65. **Raise Integration within Research Platforms.** As complex systems are proposed, the role of research initiatives that push forward technologies and reference architectures for implementation will become key partners for companies, like the Industrie 4.0 working group or the Industrial Internet Consortium (IIC) mentioned in chapter 2. Involvement with these may yield an edge on potential future industry developments, provide a platform for forming strategic partnerships [22], design academic curriculums [51] or capturing skilled workers (*L44, L45*).

Company Size: SME. Big companies will be more capable of doing research and development by themselves, without partners.

3.3.9 Cost Structure

> The Cost Structure describes all costs incurred to operate a business model [40, p. 40].

Research showed that cost structure is one of the least affected building blocks, so far (annex B). In terms of business levers, this also applies, because most of the impacts on this block are consequences of the previous levers; therefore, listing them on its own would be redundant – they would be illustrative topics and not actionable levers.

The BMC predicts cost structures to be somewhere on a spectrum from cost- to value-driven, according to the business focus. Industry 4.0 leans towards value:

Value-Driven

L66. **Raise Focus on Value Offering.** It has been predicted that now cost-centric approaches will lose relevance to value-focused perspectives [41]; in fact, a 2018 market survey found that customer priorities had shifted and the most important product feature in buyers' minds was quality, overtaking price [88]. Without disregarding the potentials of cost reduction, there will be a focus on catering to the growing segment of customers demanding "better" (more innovative, customized and durable) value offerings.

Company Size: SME. Big companies are able to generate their value offerings with minimal costs, due to high negotiating power with suppliers that comes with high volume transactions. For that reason, they are usually unbeatable when it comes to low costs – the hypermarket retail industry is a paradigmatic example of this. SMEs' market space is precisely for creating new and quality offerings that cannot be found on bigger companies.

Moving on to a review of the types of costs brings another lever:

IT Costs

L67. **Raise Investment on Innovation.** To embrace Industry 4.0, it is expected that a larger share of companies' budgets will be devoted to obtain the key resources stated [50], mostly IT infrastructure and production equipment [51]. Despite this need for heavy capital expenditure, managers should not be discouraged from investing in Industry 4.0, as it comes with several added value, revenue, and cost reduction potentials [75]. In addition, prices of "smart" hardware has already fallen significantly [22]. For reference, a proposed assessment model for Industry 4.0 maturity in manufacturing SMEs considered that investing 1-3% of revenues on technology would be for an Industry 4.0 "learner" company, while more than 10% would correspond to a "top performer" [35].

Company Size: Any. Even though, obviously, big companies have more capital for investments, Industry 4.0 adoption is expected to be so important for enterprises to stay competitive that all must some kind of effort. The reference values presented are expressed in percentage of revenue, precisely so that they can be applied to anyone; even if the absolute value is low, it may still contribute for something.

Analysis of cost characteristics reveals one final lever:

Variable Costs

L68. **Raise Variable Payments.** Beyond just individual customers, companies will be able to leverage the "pay for use" contracts (*L27*) or leasing of machinery (*L29*), introduced previously, to turn high initial investments into recurring smaller costs [50].

Company Size: SME. SMEs have less capital for high upfront investments (J11).

3.4 Development of an Innovation Guide

3.4.1 Formulation

While the previous section presented a review on the levers brought to business models by Industry 4.0, reading it would be an extensive and unpractical way for managers to reflect on their company's BM. So, there is a need to turn the levers into a more accessible tool.

When proposing the business model canvas, [40] accompanies the descriptions of each block with a few questions for the reader to ponder on what it would mean to address that theme. Some of those were presented back in Figure 13.

Questions were also used as part of the Toyota Production System, in an iterative interrogative technique that explores cause-and-effect relationships by repeating the question "why?" five times, where each answer forms the basis of the next question. This technique is designed to encourage critical thinking on the causes of things.

The previous two paragraphs illustrate the usage of an interrogative formulation within management practices. In that spirit, the tool developed here is composed by a set of questions to instigate business model innovation, grouped according to the canvas' building blocks. After all, interrogations usually stimulate thought more than statements or recommendations. This falls in line with the design idea of any guide for BMI being fluid (section 3.1): questions work as a thought guidance, rather than a rigid commandment.

Apart from the "Customer Segments" block, where each lever represents a different business path that the manager can opt, every question starts with "how can we…?". This formulation is expected to make the reader critically think about the lever. If, instead, "can we" or "do we" had been used, the reader could be tempted to just answer "no" and move to the next question, which would go against the creative nature intended for the tool. After that initial bit, the rest of the question is the synthesis of the core components identified within the business lever.

For fulfilling the design goal of specificity, neither the examples nor the scope of applicability considerations can be omitted. These can help managers with their creative process so that businesspeople can start seeing concrete and feasible Industry 4.0 applications for their business.

Finally, interconnectivity can be achieved by listing the associated levers identified previously, for each one of them.

Figure 23 illustrates the connections between the parts of the business lever listings and the design goals previously defined.

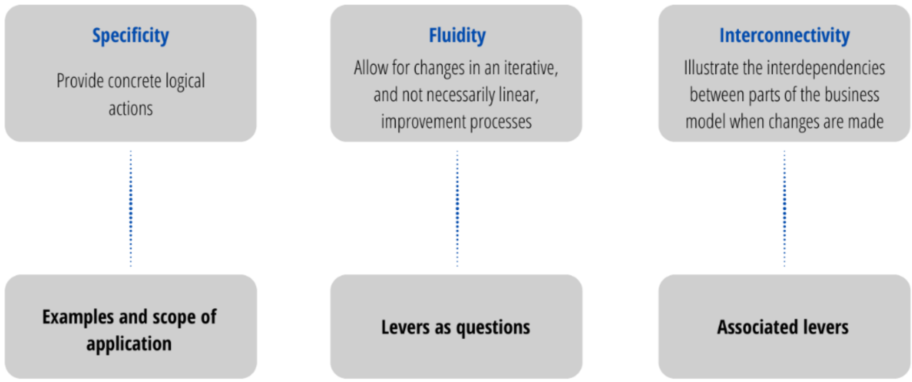

Figure 23. Connection between design goals and contents of the innovation guide.

Having defined the contents, it is only a matter of selecting the information and performing the graphic arrangement, as Figure 24 shows.

Annex E presents the resulting complete guide itself.

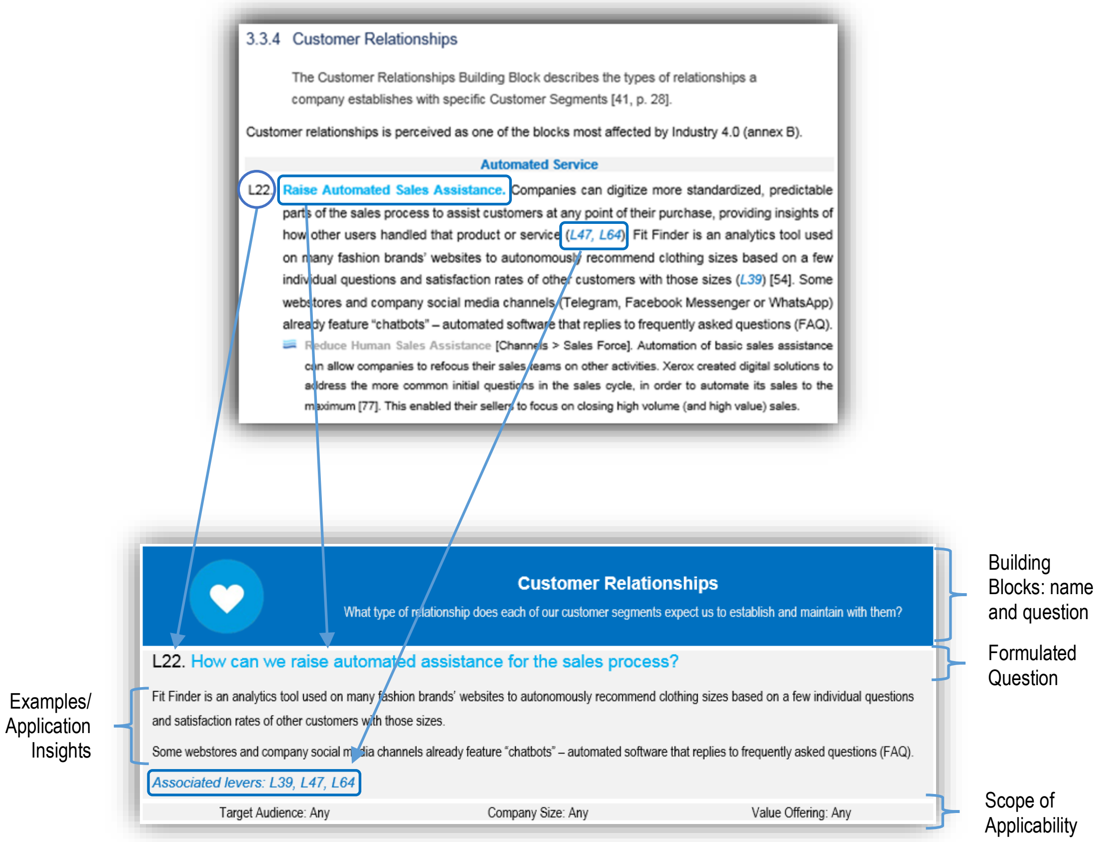

Figure 24. Moving the information from the business lever listing into the innovation guide.

3.4.2 Blending the Guide with the Business Model Canvas

Even though the innovation guide is substantially shorter than the business lever listing from 3.3, it lacks the succinctness, simple visual representation and easiness to use in a workshop setting of the BMC.

To address those shortcomings, further condensation of contents can be performed, by presenting only the questions of the guide on the business model canvas, as done in Figure 25.

Figure 25. Business Model Canvas with the innovation lever questions distributed by their building blocks.

This tool can be used for quicker analysis and broad understanding of potentials brought by Industry 4.0, but lacks the creative boost given by the examples. As Figure 26 graphically illustrates, the level of detail of each of the three tools is inversely proportional to the time required to "digest" it. It is up to the reader to understand what suits its interests best and choose accordingly.

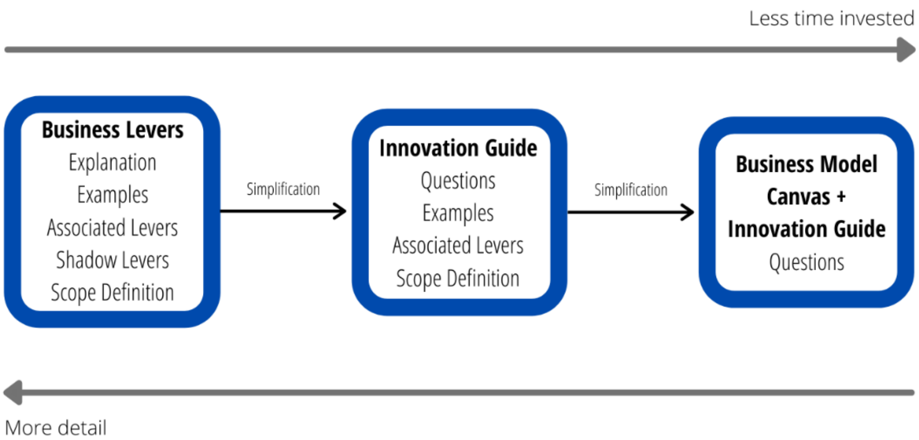

Figure 26. Relationship between time invested for comprehension of each of the outputs and its detail.

3.4.3 Approach for Answering the Questions

The fact that the guide is made up of questions may make it hard to be objective when answering. The complementary information (examples, associated levers, scope of applicability) are there for help, but starting the creative process can be hard.

For that reason, this subsection proposes a "guide for answering the guide": an approach of four sequential steps for organized innovation within each question, each based on one keyword – this is very much stylistically inspired by the BOS's Four Actions Framework, as shown before in Table 3.

Creativity (First Step)

At first, the reader should attempt to imagine how that lever could bring value to its company. This means mentally going through processes, existing resources and ambitions to find suitable applications. Even if those come from a building block different than the one that the question belongs to, that should not stop the creative process.

Product development logic should be applied for this process: the reader, now acting as a "business model developer", must think of ways the lever *can* be implemented, instead of listing all the reasons for which it cannot. The examples provided should be a good starting point, as they ground the reader to a concrete reality. The conclusion from the lever can very well just be the decision to imitate what others have done.

The lever can be abandoned if the reader fails to come up with any possibility for implementation.

Feasibility (Second Step)

Every idea generated will have some kind of "cost", whether it is money (capital expenditure) or time (workhours). Quickly estimating what those could be is the test of feasibility: understanding if the idea is attainable and makes sense for the company's context.

If the related costs and implementation challenges are to be too high, the lever can be abandoned.

Research (Third Step)

If the idea seems feasible, it could be useful to search for similar implementations to the imagined one. Research could reveal tweaks for optimization, unrelated alternatives or serious unforeseen roadblocks. If the idea depends on a software or technology, the research process could also be useful for finding suitable suppliers, customer reviews, etc.

Decision (Fourth Step)

Finally, it is time to decide whether the idea proceeds to practice or not, based on a value-cost relation: is the added value worth the associated cost?

If there are doubts in the reader's mind, he must identify what facts are missing to make that decision, list them, and plan ways to find them.

4 APPLICATION OF THE INNOVATION GUIDE TO A CASE STUDY

4.1 Introduction

Chapter 3 introduced a framework for business model innovation built around the guide presented in annex E. To validate this proposed tool, illustrate its workings and highlight its contribution to the literature, the next logical step is to apply it to a case study.

For the case study, the innovation guide will be applied to a Portuguese enterprise, known here as "Company X". The author of the dissertation developed the ideas and activities described in this chapter working in that company between February and December 2020, within the mindset of bringing Industry 4.0 business model innovation.

4.2 Company Context

Company X's main characteristics are outlined in Figure 27.

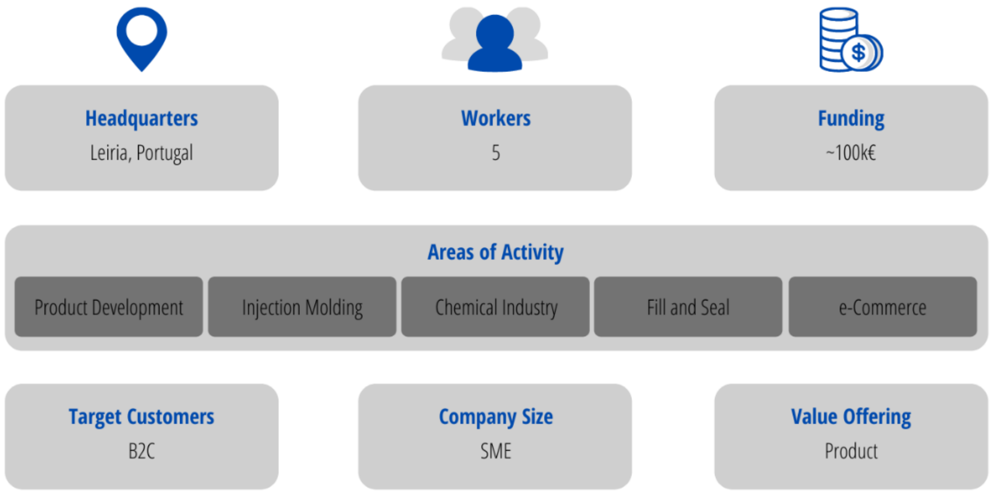

Figure 27. Presentation of the startup used for the case study.

As of February 2020, it was a startup-level enterprise that had developed a pair of complementary physical products, but still had not any production planning done, nor a go-to-market strategy. It still had no sales, even though it had secured some funding, and managed to get even more by the end of the year.

This company aims to start selling two products: a plastic lunchbox and the disposable heating pads that heat food in it through an exothermic reaction, when placed inside the lunchbox and mixed with water. This offering gives the customer the possibility of eating wherever he wants, without depending on electricity or stoves.

The intended business model is based on the sale of an initial product and further revenue from recurrent consumables, similar to what was mentioned in lever L26, in subsection 3.3.5. This can be compared to popular business examples, such as those shown in Table 4.

Table 4. Benchmarking of successful similar business models.

	Coffee	Printers	Razor Blades	Company X
Initial sale	Coffee machine	Printer	Razor	**Lunchbox**
Recurrent sale	Coffee capsules	Ink cartridges	Blades	**Heating pads**
Examples	Nespresso, Delta	EPSON, HP	Gillette	***None... yet***

4.3 Answers to the Innovation Guide

In this chapter, the results of the application of the guide to Company X are presented.

The answers follow the approach proposed in 3.4.3, even without always explicitly mentioning the keywords.

Questions in **blue** indicate that lever was in some way useful.

Along the answers, sometimes “design constraints” are presented. These represent facts that derive from parallel studies and reports conducted by the same author for the company, but whose theme falls outside the scope of this dissertation. However, its results are important to limit and ground the innovation process on the identified technical and strategical constraints.

Customer Segments

L1. **Do we want to use IT solutions to increase penetration within a mass market?**

Not for now. The company is a startup, so it does not have a customer pool that can be mined neither does its value offering target a mass market.

L2. **Do we want to leverage new technologies to satisfy very particular customer needs?**

The company already targets a niche markets of customers that wish to have hot meals without electricity or gas stoves, so, within Customer Segments, this is definitely a lever to follow. For concrete analysis of what to do, special attention should be paid to the associated lever L5.

The example given of using analytics tools to better serve customers is not appliable yet, as the company lacks capabilities for that (feasibility failure).

L3. **Do we want use IT solutions on our products to expand to different customer segments?**

Not for now. The first step is launching a successful product. The brand can then be leveraged for IT expansion into other areas.

Value Propositions

L4. **How can we use our know-how to offer digitalization assistance services to other companies?**

For now, the company is a startup and does not have significant knowhow to offer.

L5. How can we make our product more fitted to each individual customer?

Design constraint: The author made a comparative analysis of costs for manufacturing the lunchbox and the results point that the best solution is to manufacture it by outsourcing an injection molding process. On the other hand, the heating pads are to be manufactured in-house, since the predicted initial investment is relatively low and there are advantages in keeping the trade secret and quality control.

The fact that this company works with a plastic lunchbox makes the Arburg example presented in the guide is particularly relevant. Even though there is not a functional need that can be satisfied using additive manufacturing, adding some aesthetic customization like lettering is an option, such as mentioned in the example on the guide.

Accompanying the lunchbox, there is also a tiny plastic water bottle, with the size of about half a matchbox and rectangular cross-section, which presents an opportunity for an easy customization. An idea for individualization through additive manufacturing is to "3D print" a custom lid cover, with a word of the buyer's choice. Clients could have bottles with their name, or a small message for someone they gift the products. The startup already has a 3D printer, which can handle small volumes.

On the top of that, the lunchbox itself could be customized with similar lettering. However, since it is made through injection molding, it requires a technique other than 3D printing. Research has found that ABS and PC (the two materials planned to be used in the lunchbox) are compatible with laser marking, so that could be an option for engraving words [89]. In terms of cost, even though this could be achieved by buying an equipment for that purpose, the most logical thought for a startup is to outsource it, along with the rest of the lunchbox manufacturing.

This idea of engraving words also applies to an inner metallic plate that comes inside the lunchbox, but this time with metal laser marking.

These ideas have the limitation of depending either on finding a manufacturer that can both perform injection molding and then a secondary customization operation or requiring that Company X establishes its own production line for lettering generic lunchboxes. A final decision will depend on quotations for these processes and assessing their economic viability.

Yet another possibility is the elastic fabric ribbon that holds together the two halves of the lunchbox. That is not something individualizable like the plastic mentioned before, but a wide array of ribbons could be offered, with Christmas based patterns, beach themes, or others. Upon ordering the product, clients could have the option to select their favorite ribbon pattern or color. In terms of feasibility, this is a very easy way to add diversity to the product, since the ribbons are bought made from a supplier.

L6. How can we offer a platform that links customers' demand with manufacturers' supply?

The company is still beginning, so there is no value in this kind of platform. There are no significant supply capabilities nor demanding customers.

L7. **How can we offer our product as a service, monitoring its usage remotely?**

The startup's first product, the lunchbox, is relatively low cost and intended for somewhat regular use, which both go against the logic of "servitization" of the PaaS– it is usually applied to expensive one-off use products.

The other product are the heating pads, which are disposable and, therefore, not "rentable".

L8. **How can we add complementary services to our physical product?**

The lunchbox and heating pads are supposed to be relatively low cost and part of their appeal is precisely the fact that they do not depend on electricity. For that reason, it may be complicated to offer embedded IT services. However, the startup could leverage their users' smartphones to build a company app. This app could allow for sharing discount codes on products, sharing recipes for meals that endure particularly well the reheating process without losing flavor, and more.

The app could be developed in-house through graphical programming services, if it was just for these features, but subsequent levers will demand a more complex work that requires a specialist.

L9. **How can we offer a digital offering that replaces the need for physical goods?**

Not appliable. The value proposition of the products is based on a physical heating process.

L10. **How can we have an offering that is integrated with other products/services (from our own brand or from others)?**

Since it is an original value offering and physical product, there are not many options for integrations.

L11. **How can we offer value by aggregating value from different sources?**

The startup does not have many customers from which to collect data. Plus, the products do not collect usage data directly because they lack sensors, so there would not even be much information to aggregate.

L12. **How can we make our offering self-adaptative to its user?**

In line with the idea of the "Amazon dash replenishment service", Company X could offer the chance for the semi-automated reordering of boxes of heating pads. This could be achieved through the app mentioned previously.

Through analysis of other customer's with similar profiles (gender, age, country of residence), the app could time pop-up recommendations for the user to buy more heating pads before running out of them. Individual order history would then perfect the timing of each user's pop-up reminders. By already having credit card and delivery address information on the customer account, the app would allow for "one-click purchases", triggered by these notifications.

Channels

L13. **How can we use social media to raise targeted awareness to our offering?**

Being a small company with a limited marketing budget, Company X should focus on building a strong online brand and promote its products on Facebook and Instagram, through the Facebook Business platform. This platform allows for detailed segmentation of target audience, has learning capabilities that autonomously improve targeting, and allows to better know who are the people that appreciate and interact with the product.

L14. How can we use extended reality to allow customers to evaluate our value propositions remotely?

Company X's products are straight-forward: a lunchbox and some sachets that function as heating pads. They do not justify investing on complex visualization systems.

However, for complete visual evaluation of the lunchbox, taking advantage of its unique ellipsoid design, the online sales channels could have a 360º view of it.

In addition to that, it would be interesting to have an interactive online map that presented the food's temperature in the point where the customer placed its mouse cursor, as it rises over time after the exothermic reaction begins. This could be used as a proof-of-concept solution, to convince people that the product works as promised. However, it would be quite more complicated to implement than the previous idea.

L15. How can we accept digital payment solutions and currencies?

It comes from the answer to lever L20 that Company X is planning on selling through an online store built on the Shopify platform, to be able to internationalize its sales. Payment processer Stripe has a standardized integration with Shopify and accepts many payment types, such as Apple Pay, Alipay, and more.

L16. How can we automate the physical purchase process?

Not applicable. Sales are made online.

L17. How can we decentralize the delivery of goods into smaller storage points closer to the customers?

For greater flexibility, the best solution is to provide two options for customers:

- Delivery through CTT, which are cheaper but do not have "pickup points" outside of Portugal;
- Shipping with UPS, FedEx or similar, which are more expensive but feature tracking systems and pickup points.

This way, the customer can have greater freedom of choice.

Circling back to this point after passing through L66, another idea for better customer experience was generated: offer free shipping for the heating pads through CTT. Since the box of pads is small, its shipping cost is low, but the customer can perceive a better "treatment" by being offered free shipping.

If the customer desires the most expensive courier, he only has to pay the difference in price. The prices of the packages are tabulated according to the destiny country, so the calculation can be performed automatically on the sales platform.

L18. How can we raise after-sales support that closely listens to customer feedback?

To address this need for closer after-sales service, it is necessary to conduct organizational changes.

First, the startup needs to have a dedicated after-sales representative. Instead of replying to customer feedback on an *ad hoc* basis, the responsibility to systematically monitor customer feedback sent by emails, social media messages, etc., was added to the already existing role of the head of marketing.

To assist that, a “Frequently Asked Questions” (FAQ) document was created. It serves both for customers with questions about the company or product, and for internal standardization of replies to client inquiries.

Finally, the head of marketing started having to deliver biweekly reports on what where the most usual customers complaints and suggestions, grouped by themes such as usability of product, performance problems or logistics.

L19. **How can we have offerings that work as a mean to achieve further sales?**

Besides the obvious reasoning that the lunchbox is a mean to sell heating pads, there is potential for more. L12 already introduced the idea of suggesting purchases of consumables to the customer, through an app.

Additionally, that app could promote further sales by suggesting the acquisition of thematic seasonal elastic ribbons, during Summertime, or even that the customer offers one lunchbox with an engraving saying “Happy Birthday!” to a friend.

L20. **How can we have direct online sales channels available and advertised?**

This lever is a great fit for Company X, that was already leaning towards an e-commerce strategy before this work.

The sales strategy of Company X is then going to be of direct sales through its website, which is advertised on social media.

For building a web store, research revealed that Shopify is a very popular platform, with many integrations with other services available.

L21. **How can we have presence in popular online sales third-party platforms?**

The startup could place their products on big online platforms that allow for further sales and exposure, while, at the same time, still selling on their own website.

Reviewing the existing platforms, the best one for another sales channel has to be Amazon, due to their enormous share of all online shopping. It even has its own logistics service, “Fulfilment by Amazon” (FBA), that stores product units in their warehouses and then ships them to purchasers.

This decentralization of fulfilment efforts could be good for the initial steps of the startup, by generating sales without increasing internal logistics efforts.

Customer Relationships

L22. How can we raise automated assistance for the sales process?

The customer purchase journey can be eased by using a "chatbot" on the startup's website that automatically provides answers to a set of pre-determined questions about the product. The replies can be based on the FAQ document developed in response to L18.

This chatbot can also be present on other company social media channels, namely Facebook Messenger and WhatsApp.

Considering quality and prices, the choice is to implement software "OMQ" on the website and Facebook Messenger. WhatsApp Business provides its own chatbot.

Moving to an exploration of "analytics" tools, a simple idea could be to recommend that the customers purchase a certain number of heating pads boxes upon buying the lunchbox, by presenting a message such as "most shoppers buy X number of heating pads along with their first lunchbox", where X is a number calculated from a dataset of purchasing behavior.

L23. How can we use IT tools to deliver a personalized yet automated customer experience?

Since user data collection is only done through the customer's purchases and their usage of the app, options are limited.

The app can provide basic feedback on the number of meals heated with the products, based on the number of heating pads ordered. Accompanying "fun" statistics, such as a cumulative number of kilojoules released by the heating process, can be included.

L24. **How can we ask for early feedback and design developments from our prospective customers when developing products?**

Not for now. The products were developed before there was any customer base to co-create with.

The launch of the company's first products will allow to build that base. Of those people, some will be contacted to assess their interest in ideas for future offerings and collect their suggestions.

L25. How can we make communities where customers can interact among themselves and with brand representatives?

In an effort to connect with customers, Company X is present on social media platforms Facebook, Instagram and Twitter, through which people can interact "around" brand content and directly with it, either on a public forum or by private messages.

Revenue Streams

L26. **How can we digitally limit our products to only accept original replacement parts?**

Not applicable. A core characteristic of the product is that it is not electricity based. Without electrical components, there is not a way to limit the use of off-brand heating pads, for instance.

L27. **How can we bill the consumer based on measured usage of our offerings?**

Not applicable, for the same reasons as provided in lever L7.

L28. **How can we offer our value offerings through subscription models?**

There could be a model where the customer pays a monthly subscription for a set of heating pads to be home delivered on a specific day.

The subscription price could have a big discount over the regular price, to convince customers to adhere.

L29. **How can we sell our unused capacity to other companies?**

Not for now. The startup does not have enough equipment capacity to sell to others.

L30. **How can we gain commissions by mediating sales through an online platform?**

The company does not develop a mediation service.

L31. **How can we sell user data that was collected through an offering?**

Not for now. As discussed in previous levers, the company is not able to collect much customer data.

L32. **How can we leverage crowdfunding to lower capital commitment and test market feedback?**

This lever is great for any product-based startup.

For collecting the capital for further investments, as well as test market feedback, the company plans to launch a crowdfunding campaign in the first quarter of 2021, through the platform Indiegogo.

Design constraint: Based on the research performed on the topic, the author of the dissertation found that successful execution of crowdfunding requires a pre-campaign phase of several months, where the goal is collecting emails for a mailing list which later will be used to divulge the actual campaign link where people can pre-order. As of December 2020, the startup currently finds itself in this stage.

For this, Company X found that the most cost-effective strategy is running "lead capture ads" on Facebook and Instagram, where the user signs over his/her email in exchange for an exclusive discount when the crowdfunding campaign goes live.

It is also an opportunity for community building, as crowdfunding backers tend to be highly engaged individuals. After the campaign, some could be used for co-creation efforts.

L33. **How can we monetize the installation of our offerings at the user's site?**

By their low cost and simple usage nature, these are products that do not require installation.

L34. **How can we monetize additional paid digital services offered beyond the original offering?**

The digital component of the value offering is contained to the app. Since it does not provide any services that actually affect the product itself, there is no way to justify charging the customer for any digital feature.

L35. **How can we price our product according to its performance?**

The only relevant performance indicators would be food temperature/food temperature distribution over time. In order to measure them, the lunchbox would require sensors and some kind of battery, which goes against the core feature of not being electrically dependent.

L36. How can we have systems that automatically monitor and adjust prices to physical supply and demand?

Typical online shopping conversion rates (units sold per page view) for B2C sales are around 3% [90]. In terms of necessary supply, this means that for every 100 times someone opens the product page, the company, on average, should have three stock units to sell.

Inspired by a case study of dynamic pricing for train tickets [91], a formula for price adjustment can be developed.

Online sales are famous for prominently featuring almost permanent discounts on standard prices, in an effort to encourage customers to buy quickly to take advantage of that opportunity instead of postponing the transaction. By that logic, when working with dynamic pricing, it is best to have the price fluctuate between a reference value (0% discount), when demand is high, and lower discounted values for when demand is low.

The fluctuating discount price is calculated by applying a time-dependent (varies with t) pricing factor to the reference, as Equation 1 dictates:

$$Discount\ Price(t) = Reference\ Price * Pricing\ Factor(t)$$

Equation 1. Formula for calculation of the discount price.

The pricing factor mentioned in Equation 1 is an indicator of the relationship between customer demand and existing stock capabilities. On one side, it is affected by demand parameters, such as the average conversion rate for that product's webpage, measured in units sold per each view, and the online activity around it, quantified by the views in the previous 24 hours (i.e., the full day before instant t); the product of these two variables says "how many units are we going to sell per day". The division of existing units in stock and the supply chain lead time to get more units represents "how many units per day can we stock up". The ratio between demand and supply, presented in Equation 2, gives the pricing factor:

$$Pricing\ Factor(t) \equiv \frac{Demand(t)}{Supply(t)} = \frac{Conversion\ Rate\ \left[\frac{units}{views}\right] * Online\ Activity(t)\left[\frac{views}{day}\right]}{\frac{Units\ in\ Stock(t)\ [units]}{Lead\ Time\ [day]}}$$

Equation 2. Formula for calculation of the pricing factor.

A pricing factor greater than unity means that, at that instant, demand is higher than supply, for which the price should equal the reference price; for a factor lesser than one, the discounted price starts to apply.

This approach has several limitations that should be considered:

- First, Equation 1 needs to have a lower value limit, due to the risk of selling the products almost for free if demand is low. This lower limit will be related to the cost of manufacturing those goods.
- Secondly, conversion rate and lead time were taken as constants, when, in reality, they can vary great according with time of year, for instance. Christmas tends to raise conversion rates and supplier lead times.

- Stock units should be properly accounted for, through reliable and integrated digital stock inventories.
- Finally, there is the problem of knowing at what t intervals the price should be reassessed. Should it be a truly dynamic process, where, for each unit sold, the price rises? Or should it be assessed one day at a time?

Setting safeguards to address these limitations could allow for implementation of this dynamic pricing model. However, as the volume of sales grows, analytics of past transactions should dictate price adjustments.

Key Resources

L37. How can we remotely interconnect all our resources and products?

Since the lunchbox and heating pads do not feature any connectivity capabilities by themselves, it is necessary to search alternative ways of interconnection.

By creating "customer accounts", the client's purchasing history movements can be compiled, whether on the webstore or the app, and the physical goods sold can be matched to that individual through the Stock Keeping Unit (SKU) codes. This can derive useful data, such as "number of heating pads bought since initial lunchbox purchase".

Proper traceability of SKU will also allow to know the production history of the products that reach the customer and monitor quality of batches by assessing the number and reason of complaints regarding each.

Internally, it is all about creating the digital twin of the factory and suppliers. This is a very casuistic and detailed process, which must be analyzed according to the equipment used, its interface and compatible software.

L38. How can we automate our production systems?

Design constraint: The author of this dissertation conducted an analysis of production processes for the heating pads (which are formed by chemical powders plus a layer of permeable film). From there, three sequential "phases", each with several steps, were identified and are presented in Table 5; there, the pads are identified as "sachets", the technical terminology used in the FFS area. The lunchbox is to be outsourced, so that is not a concern for production planning.

Table 5. Production processes for the heating pads.

Mix Preparation	Form Fill and Seal (FFS)	Packaging
1. Storage of raw materials (RM) in low humidity environments 2. Retrieving the RM 3. RM quality control 4. Mixing the RM in the correct proportions 5. Mix quality control 6. Feed the mix into the sachet-filling area of the plant	7. Retrieve the film from storage 8. Feed the film into the sachet forming section 9. Pour the powdered mixture 10. Seal the film to form the container 11. Feed the sachets into the packaging area of the plant	12. Retrieve cardboard packaging 13. Put 10 sachets inside the cardboard box 14. Weight control of batch

When it comes to the mix preparation phase, step 4, the mixing process, is the most important to automate. Research on the topic of industrial mixing, plus considerations regarding volume and powder density indicated that “orbiting screw” mixers would be the best [92].

For FFS, equipment selection is more difficult due to their heterogeneity. Certain FFS machines can perform steps 8-14 all be themselves, at very high production speeds, but at the cost of a steep initial investment. Simpler ones only cover steps 8-10. Research identified at least four types of FFS machines capable of performing some of these tasks. For this reason, the best idea may be to contact a provider of FFS equipment, explain the needs, and get their recommendation.

L39. How can we own all the relevant data for our operations?

In accordance with this lever, the company’s website was created following the European standards for data protection.

To ensure total compliance, one of the criteria for choosing an email marketing service was that it definitely was GDPR compliant; the selected tool for that was Mailchimp.

L40. How can we have a cloud-based seamless software infrastructure for operational and business control?

The investment in a “seamless” IT solution would be too costly for the company. Building such an infrastructure is a gradual process; something to be done as the company grows.

However, in an effort to tentatively approach the desirable levels of integration the following software infrastructure was assembled:

- Google Drive cloud for file storage integrated with project management Kanban-style Trello;
- Mailchimp integrated with Facebook Business for customer email collection and targeted marketing campaigns for crowdfunding;
- Facebook, Instagram and Twitter code embedded in the company’s website on WordPress, to track user visits.

This was a very simple approach that does not make for a “seamless cloud infrastructure”, but it has one important advantage: it did not require spending any money. Further developments will be made as funding becomes available.

L41. **How can we have robust cyber-security?**

Due to the rise of this concern with cyber-security, the startup had to change its practices, following the recommendations presented in the lever:

- All company passwords must be at least eight characters long, have letters and numbers and other symbols;
- Mandating the monthly change of passwords for personal accounts with access to the central cloud system or the social media platforms;
- Installing the Kaspersky Security Cloud Free on all computers, since it was recommended as the best free antivirus by PCMag, in 2020 [85];
- Making a brief compilation of simple practices for a safe navigation on the Internet and pinning it on Trello.

L42. **How can we have recognized standards on which to draw upon for implementation efforts?**

For now, the company does not have any need for standards.

L43. **How can we have a creative environment and workforce?**

Being a startup, the staff is limited. Not much can be changed here, even though the workers seem engaged and often make suggestions.

For concrete (yet small) action, a pin reminding people not to be afraid of trying new things and asking for their suggestions for process improvements was put up on Trello.

The company managers also agreed to foster a nurturing work environment.

L44. **How can we have a multidisciplinary staff with transversal knowledge on economics, engineering, IT and other relevant fields?**

The team is only of five people, with three of them being engineers and the other two having a background in communication studies and marketing, which already offers some diversity. However, knowledge of management, economics and IT is limited. Regarding management, some efforts were made as a consequence of L55. The same is planned for IT (see L45).

L45. **How can we have IT-related roles to support the necessary software implementations and usage?**

The company clearly lacks IT specialists. To address this, a position for a software developer was opened. This position is to be filled through a work experience government-funded paid internship, through the Portuguese state agency *Instituto do Emprego e Formação Profissional* (IEFP).

This developer will work on building the infrastructure mentioned in L40.

L46. How can we have the necessary funding to support all these resources?

As a directive that came from this dissertation, Company X started monitoring possible investment programs for Industry 4.0 adaptation.

In September 2020, a business plan based on the ideas hereby presented for an Industry 4.0-adapted business model allowed the startup to be picked for investment by a venture capital fund, in the context of a call for sustainable technological entrepreneurship.

The company remains vigilant for further opportunities and has in mind applying for support of European cohesion funds (through initiatives as the *Portugal 2020* framework, among similar others) to raise part of the capital necessary to build its production line for the heating pads.

Key Activities

L47. **How can we collect brand interaction and product usage data from our customers?**

As explored previously, user data will be collected through an amalgamation of information about interactions with the brand, whether it was purchases, comments or reviews on social media channels or through the aforementioned app. This answer does not bring any new idea.

L48. How can we use rapid prototyping tools for product development?

Before the start of this work, the startup already had made extensive use of a 3D printer for prototyping the components of the lunchbox.

Following on from that, the plan is to invest in a more advanced device of "3D printing" through selective laser sintering. Pieces made with this will be able to withstand high temperatures without deforming (which was a problem with the previous printer) and have much better superficial quality (almost no visible layers).

L49. **How can we virtualize the product development process?**

Not of interest, for now.

The lunchbox development process is already performed by building CAD models. Those are then 3D printed to get a "real feel" of the product. Given the low costs of this printing process, virtualizing it through VR, for example, would not be a good investment.

The modelling of the chemical part related to the heating pads is more complicated. As of end 2020, there is no software capable of fully predicting what happens when two reactants are mixed. It is something that can only be found by practice. This is another reason why having physical lunchbox prototypes is good: to simulate different heating pad compositions inside them and see the different performances.

Heat distribution finite element analysis is another complicated tale, as the lunchbox's irregular geometry as well as the transient nature of the release of heat has made thermal simulations hard to perform.

L50. **How can we build predictive maintenance systems?**

These cannot be built, for now, and will heavily depend on the equipment acquired.

L51. **How can we have robots assist the execution of physical tasks?**

Steps 2, 6, 7, 11, 12, 14 of Table 5 are simple movement/retrieving of things and, therefore, are prone to robot assistance. However, for the low weight, low complexity and projected low volume of initial sales, investing in assistant robots would be unnecessary.

L52. **How can we use extended reality to virtually assist the execution of tasks?**

It is not worth it. The production activities are so simple that there is no cost-effectiveness in sight for investing on advanced XR systems.

Given that this is a startup, a high volume of orders is not expected at first, so there is no need for virtual assistance for stock management either.

L53. **How can we register our knowledge acquisitions?**

Following the McKinsey example, a standardized "information nugget" form was created using Google Docs, as shown in Figure 28. It asks the user to select the theme among the existing "departments" within the startup, management, product development, marketing, legal & accounting and IT, and describe the information to record. The file is than placed on the Google Drive folder of the corresponding area.

Information Nugget Name

Area	*Management / Product Development / Marketing / Legal & Accounting / IT*
Theme	*E.g.: 3D Printing (if the area was "Product Development")*
Responsible(s)	*Name of author of this record*
Date	*Date of record*
Information	*Describe the relevant information to register, in succinct and sequential form*

Figure 28. Template for registry of information.

The use of web-based Kanban-style list-making application Trello for project management was a step towards further digitalization and information traceability. Trello replaced a "planned activities" spreadsheet, improving the visual layout and separation of tasks into themes.

Within Trello, a list with the "lessons learned" in the previous quarter was created, as illustrated in Figure 29. It consists of a few bullet points warning about potential mistakes to avoid, based on past experiences. At the end of the following quarter, those points are removed, if they are no longer relevant.

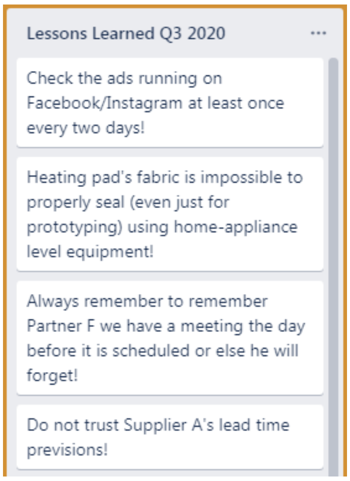

Figure 29. Startup's "lessons learned" from 2020's third quarter, with names anonymized.

L54. **How can we create practices to systematically innovate our business?**

Startups, by nature, are usually already innovative and understaffed. For that reason, it is difficult to allocate a worker to exclusively "innovate", both because everyone is already innovating and also because having someone exclusively dedicated to that task would reduce the capability of the startup to deal with its day-to-day operations.

To arrive at a compromise, the role of "innovation manager" was added to one of the workers' responsibilities. He will look for simple, low cost and attainable innovations the company can pursue, and deliver a quarterly report on them. This report will follow the BOS's four actions framework for innovation. From that report, "innovation actions" will be added to the Trello tasks. The following quarter, he will address the state of implementation of those actions, as well as propose new ones.

This manager's assignment for the first quarter of 2021 is to exploit the company's business model environment for potential value propositions new ideas (whether they are new products or services).

L55. **How can we train our workforce for new relevant skills?**

L44 identified that the workforce lacked management skills. To address it, the managers of the company enrolled in a free "Agile Management" online course provided by IST.

Also, the head of marketing enrolled in a free Google digital marketing course.

The workers lacked time for further training, so no skill-building in the field of IT could be achieved.

L56. **How can we keep our software operational and updated?**

For now, there is no software to maintain. All of the company's digital services are maintained by others (Google Drive, Trello, Facebook Business, Mailchimp, Kaspersky, etc.).

L57. **How can we digitalize our internal processes and systematically collect data on them?**

The introduction of Trello is what allowed for systematic data compilation on the company's processes. Through the Trello add-on "Kanban Analytics", it was possible to start monitoring lead and cycle times, the team's productivity and overall efficiency. It also introduced insightful data visualization tools, such as the dashboard from Figure 30.

Reviews of these analytics reports are conducted weekly, in order to identify process bottlenecks and monitor the work cycle.

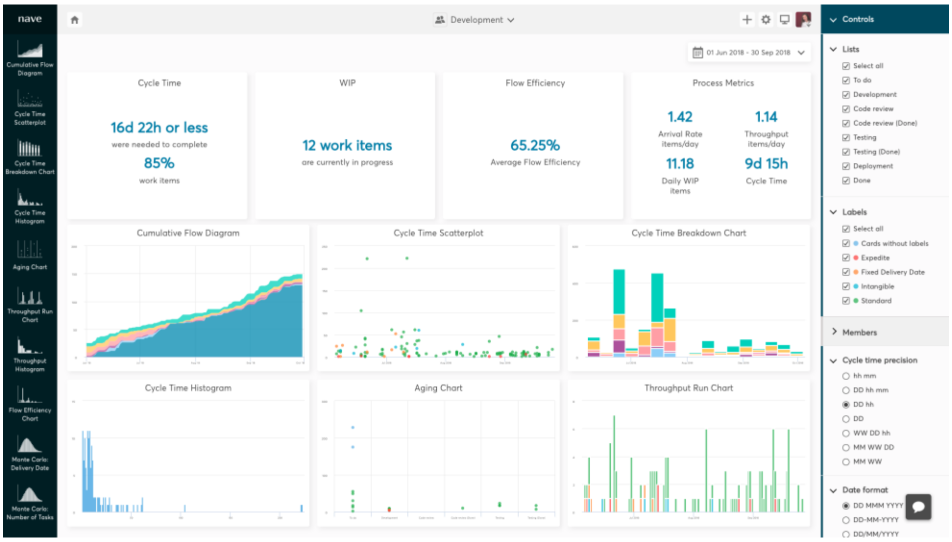

Figure 30. Example of a dashboard obtained with Kanban Analytics.

Finally, following the idea given in the lever text, Company X introduced a job role of a “digitalization manager”. However, for the same reasoning presented in L54, this cannot be a dedicated role. The innovation manager must accumulate this role as leader for digitalization. Ideas for this front will be presented along with other innovations, on the quarterly report introduced in L54.

L58. **How can we create automated control systems for our processes?**

The company already uses Facebook Business for its advertising. That platform self-optimizes its pattern of ad displays. It also features the possibility to introduce “ad budgets” which the advertising campaign will be halted upon reaching.

Trello was configured to automatically send email notifications to the people in charge of certain tasks when the deadline was approaching.

The startup also started used Google Calendar for its appointments. It automatically sent notifications reminding people of meetings, either through an app for smartphones or via email. It was also used to schedule meetings with partners. The need for this was identified as part of one of the “lessons learned”.

The automation of these processes is good for timesaving and efficiency, but pales in comparison to the potential of the examples presented with the lever text. Those applications relate closer to an industrial environment, where production processes are monitored in real time. The startup does not yet have a live setting for these implementations.

L59. **How can we create practical communication strategies to work with our partners?**

To understand who the startup’s partners were, the first step was review who were the entities it most depended on. Next, to somewhat standardize the communication process with them, each partner entity was matched to its contact person and channels, which was done in Table 6, with a **bold** channel indicating the preferential form of reaching them out. That way, communication could be kept consistent over time.

Table 6. Partner contact information.

	Entity	Contact Person	Channel
Operational Support	Incubator	Head of Marketing	**Email** or Department Phone
	Business Consultants	Assigned Consultant	Email or **Phone**
	Venture Capital Fund	Marketing Director	**Email** or Phone
	Law Firm	Assigned Lawyer	**Email** or Phone
	Accounting Office	Assigned Accountant	**Email** or Phone
Manufacturing and Product Development	Raw Material Supplier A	~~Anonymous~~ Salesperson	~~Website~~ **Email** or Company Phone
	Raw Material Supplier B	~~Anonymous~~ Salesperson	~~Website~~ **Email**
	Raw Material Supplier C	~~Anonymous~~ Salesperson	~~Retail Stores~~ **Email**
	Raw Material Supplier D	Administrative Assistant	**Phone**
	Chemical Analysis Lab	Technical Director	Email or **Phone**

Over the course of this process, some of the contact persons (and, therefore, communication channels) changed; the formers are signaled on the previous table with a ~~strikethrough~~. Those cases represent situations where the purchases of raw material were initially done in an anonymous way, through anonymous stores, but moved to a personalized relationship, where the order quantity is not subject to the limitations of the pre-defined products. This also allowed for lowered raw material costs to be negotiated for suppliers B and D. That personalization of relations with suppliers was achieved based on interactions to debate supply chain reliability and logistics questions.

While communication with the "manufacturing and product development" partners is very straightforward (mostly orders and billing), interactions with "operational support" partners are more unpredictable and elongated. For that reason, a responsible for communication with partners was appointed, the same way it was done for innovation and digitalization – the appointed "partner manager" is another person, this time.

For the operational support partners, investing in a PRM is neither necessary nor possible, as the interactions have a bureaucratic and *ad hoc* feeling, rather than a commercial one. For the raw material suppliers, software integration is not possible at all, given that three out of the four do not have the IT infrastructure for integration with a Supply Chain Management (SCM) software, for example, even though their low prices make them the best option.

L60. **How can we raise the automation of our billing and accounting processes?**

Billing is automated through the Stripe service embedded on the Shopify webstore platform, as came from L15.

Accounting is outsourced to an accounting office.

L61. **How can we raise the automation of stock management?**

Difficult to answer since, as of now, stock management activities have not been mapped. To address this, it is necessary to set up a future work task.

L62. How can we leverage interaction data to understand customer profile and demand?

Facebook Business features breakdowns of the characteristics of potential customers.

Mailchimp also provides information about the behavior of recipients of email marketing campaigns.

Company X's website features a survey that asks for interested in the crowdfunding campaign's demographic information (Figure 31) as well as feedback on expectations of pricing for the products (Figure 32).

Figure 31. Customer demographic data.

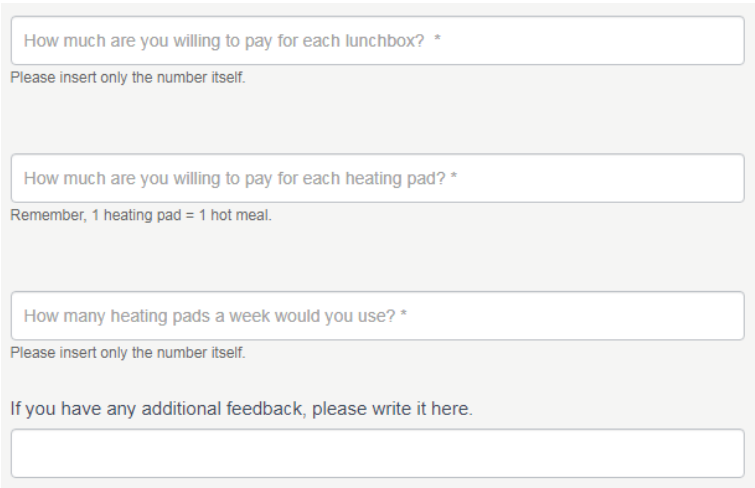

Figure 32. Survey pricing questions.

Key Partnerships

L63. How can we have reliable partners to provide the necessary technologies for implementing our strategy?

For this, experience and knowledge of possible suppliers is key. Through a technological center that is a partner of the incubator where Company X is hosted, it was possible to get a list of trusted companies who deliver quality equipment and implementations, at a reasonable cost.

Other big multinational machine manufacturers have reliable systems, but their price is certainly higher.

L64. How can we use IT outsourcing to simplify internal processes and compensate resource deficits?

As the production ramp-up approaches, it is necessary to start working on a business and production IT infrastructure more advanced than what was described in the answer to L40.

In Portugal, there are consultancy firms with many years of experience in implementing ERP software solutions. A preliminary budget of one of them was asked for and received. Its price is within reach, but the service does not offer any "digital twin" features, i.e., it does not include a full digitalization of the company. However, that may be an acceptable starting point for the company. More budgets have been asked for, but have not been received at the time of writing.

L65. How can we participate in and monitor the work of credible research platforms?

Company X has drafted a proposal for the creation of an Industry 4.0 initiative with its incubator and the technological center mentioned in the answer to L63, which argues for the realization of a series of virtual workshops in 2021, with every incubated company being invited to attend. The proposal is set to be discussed in January 2021.

The workshops would cover the topics of what exactly is Industry 4.0, successful reference case studies, shared stories, etc. It could also serve for B2B smart manufacturing equipment sellers to advertise their products, therefore connecting supply and demand.

On another front, IST has an "IST SPIN-OFF" community for companies that are somehow linked to the university. The accession process to this group has been started by Company X. Integration in it may bring an elevation of reputation and benefits for future partnerships.

IST also has a partnership for Industry 4.0 development with The Navigator Company. Active participation in future workshops could be a good opportunity for new insights and networking.

In this spirit, it could also be interesting to have an Industry 4.0 IST Working Group, involving teachers, students, elements of the "SPIN-OFF" community and partners such as Navigator. This group would pool information and resources for advancement of common research goals, as well as integration of students into companies.

Cost Structure

L66. How can we deliver better quality and value products?

To follow this lever, the chemical composition of the heating pads was changed to a slightly more expensive one, but with a better heating performance. This is likely to improve customer satisfaction with the product.

L67. How can we invest on innovation and digitalization?

At the moment, investment on innovation is difficult to justify, as the company is still launching.

In regard to digitalization, investments are expected to develop IT infrastructure, as mentioned previously, but not in dedicated fashion.

These themes will have to be advanced through simple, low cost, "quick win" solutions.

L68. **How can we take advantage of pay per use pricing mechanisms to lower capital commitment?**

So far, there have not been found any situations where pay per use could be an option.

4.4 Integration of Ideas

The ideas proposed along the previous section are too dispersed for good trackability. In order to ensure they do not get "lost", Table 7 has a summary of all of them, next to the number of the lever that generated them, and their progress status as of late December 2020.

Table 7. Summary of ideas generated from the application guide and current status.

Lever	Ideas	Status
L2	Pursue niche market with new technologies	Pursued.
L5	Customers can have custom lettering on their mini bottles through additive manufacturing	Submitting requests for quotation.
	Lunchbox laser marking with custom lettering	Submitting requests for quotation.
	Metallic plate laser marking	Submitting requests for quotation.
	Expand ribbon line	Ribbon models selected.
L8	Build a company app that offers discounts and recipes for good "reheatable" meals	Looking for IT partner app developer.
L12	App suggests reordering heating pads based on usage patterns	To be submitted as design request for IT app developer.
L13	Marketing through Facebook Business	Already extensively performed, with good return on investment.
L14	Have 360º view of the lunchbox on the sales channel	Approved. Videographer chosen and terms of contract agreed.
	Simulation of the rise of temperature of food over time, on the sales channel	Questions over feasibility.
L15	Use Stripe for payment processing	Will be done when Shopify store is set up.
L17	Offer to the customer the possibility to ship through a cheaper but less flexible courier, or through a more expensive but more decentralized and trackable service	Idea approved. Contract with cheaper courier already negotiated.
	Offer free shipping for the heating pads if sent through the cheaper courier, and the customer only pays the difference if orders through the more expensive one	Idea approved. Necessary to find good partner.
L18	Responsibility of answering customer messages centralized on head of marketing	Done and has been fulfilled.
	Create Frequently Asked Questions document	Done.
	Head of marketing delivers biweekly compilations of customer feedback	Done ever since.

L19	App promotes “special occasion” sales	Added to the list of requirements for the app.
L20	Sales strategy of online direct sales through a webstore built on Shopify	Store will be built after crowdfunding. Shopify architecture study done.
L21	Setting up a secondary sales channel on Amazon	Will be done after crowdfunding.
L22	Having chatbot OMQ auto-reply to customers on digital communication channels	To be implemented in 2021.
	Recommend that the customers purchase a certain number of heating pads boxes upon buying the lunchbox, by presenting a message such as “most shoppers buy X number of heating pads along with their first lunchbox”, where X is calculated from a dataset of purchasing behavior	Lacks feasibility exploration on Shopify’s web store platform, which will be explored after the crowdfunding campaign
L23	Through the app, provide basic feedback statistics on product usage	Added to the list of requirements for the app.
L25	Setting up social media accounts on multiple platforms	Done.
L28	Offer monthly subscription service for a set of heating pads to be home delivered on a specific day	Idea approved by management.
L32	Conduct crowdfunding campaign	Underway, in pre-campaign stage.
	Leverage crowdfunding campaign to build cooperative community	Awaiting the start of the campaign for full ramp-up. Small progresses made during pre-campaign.
L36	Dynamic pricing model drafted, based on relationship between demand and stocks	Requires further study and dry run validation.
L37	Create “customer accounts” for order history aggregation and collecting through SKU codes	Can be done through the Shopify platform.
	Study possibilities of creating “digital twins” of production equipment and suppliers	Future work.
L38	Purchase orbiting screw automated mixer	Submitting requests for quotation.
	Search FFS equipment provider and ask for implementation help and equipment	Portuguese provider found. In conversations.
L39	Website must comply with GDPR	Done.
	Email marketing tool must be GDPR compliant	Done.
L40	Use cloud storage Google Drive	Done.
	Use project management software Trello, integrated with Google Drive	Done.
	Integrate Facebook Business with email marketing tool	Done.
	Integrate social media tracking on website	Done.
L41	Establishing minimum complexity criteria for company passwords	Done and enforced.

	Periodic changes of passwords for accounts with access to the cloud central storage	Done.
	Installing a recommended antivirus on all company computers	Done.
	Pinning a compilation of safe web navigation practices on Trello	Done.
L43	Pinning a message asking for workers to try new things without fear	Done.
	Managers agreeing to foster and nurture creativity	Done.
L45	Job opening for a software developer through an IEFP internship	To be posted in early 2021.
L46	Present an application for venture capital investment with an Industry 4.0-rooted business plan	Successful application.
	Monitoring Portugal 2020 Industry 4.0 related calls	Ongoing.
L48	Invest in a “laser 3D printer” for high quality and speed additive manufacturing	Currently in the process of comparing alternatives.
L53	Create “Information nugget” form for standardized knowledge registry	Done.
	Create listing of recent “lessons learned” and pinning it on Trello	Done.
L54	Nominate innovation manager	Done.
	Propose quarterly innovation report with suggestions	First one expected in the first quarter of 2021.
L55	Enrollment of managerial staff in “Agile Management” IST online course	Done.
	Enrollment of head of marketing in Google “Digital Marketing” course	Done.
L57	Use of “Kanban Analytics” add-on on Trello to monitor work productivity and efficiency	Done.
	Perform weekly reviews of Kanban Analytics data	Ongoing.
	Add systematic digitalization responsibility to the innovation manager’s job	Done.
L58	Automate Facebook advertising budget control	Done.
	Set up Trello “approaching deadline” notifications	Done.
	Connect Google Calendar to remind people of meetings	Done.
L59	Identification of contact persons and respective channels within partner organizations	Done.
	Nominating a “partner manager” (not the same person responsible for innovation and digitalization)	Done.
L60	Set up automated billing	Will be done through an integration of Stripe with Shopify.
L62	Checking Facebook’s demographics data	Periodically done.
	Checking Mailchimp’s demographics data	Periodically done
	Survey of potential customers to understand their profile and pricing expectations for the product on crowdfunding	Done and data was used to define product pricing.
L63	Ask incubator partner for leads on reliable and affordable technology suppliers	Done and received.
L64	Searching business planning software implementation suppliers	Searching for companies.

L65	Propose series of virtual I4.0 workshops with incubator and partners	Will be discussed in January 2021.
	Apply for the IST SPIN-OFF community	Started.
	Propose IST an Industry 4.0 Working Group for shared experiences, projects and student integration	To be presented in 2021.
L66	Change the chemical composition of the heating pads to a slightly more expensive but better performing	Done

5 CLOSING REMARKS

5.1 Conclusions from the Dissertation

Chapter 2 reviews and attempts to integrate all the concepts listed in the literature into one coherent overview. Its major contributes are:

- Finding that the four concrete drivers for the innovation that is Industry 4.0 are the change of customer demands, increased market volatility, scarcity of resources and the rise of new technologies – Figure 4;
- Identifying that formal definitions of Industry 4.0 predict it brings changes in manufacturing processes, a reshaping of the value chain and the interconnectivity of all elements involved – Figure 5;
- Listing the three implementations principles to have in mind for Industry 4.0 adaption: vertical, horizontal and end-to-end integration – Figure 6;
- Presenting the most cited design principles for Industry 4.0: interconnection, information transparency, decentralized decisions and technical assistance – Figure 7;
- Expanding on common components of Industry 4.0 found in the other works, by adding smart products and business ecosystems to the existing internet of things, cyber-physical systems and smart factories – Figure 8;
- Attempting to unify several sources by compiling the seven enabling technologies of Industry 4.0: additive manufacturing, sensors, data analytics, cloud computing, integrated management software (new terminology), extended reality and autonomous robots – Figure 9;
- Providing a graphic overview that encompasses all the previous concepts – Figure 11.

Having clarified the concepts involved with Industry 4.0, chapter 3 proposed:

- A synthesis of business levers for business model innovation through Industry 4.0, grouped thematically according to the building blocks of the business model canvas – section 3.3;
- An innovation guide based on the previous business levers – annex E;
- A visual integration of the business model canvas with the questions from the innovation guide – Figure 25;
- A simple approach for systematically answering the questions of the guide – subsection 3.4.3.

Chapter 4 showed the application of the innovation guide to a startup-level company. It was successful in leading to the presentation of multiple viable ideas for changes to the business model. Many of these changes were successfully implemented.

5.2 Proposed Complementary Future Works

Like every scientific contribution, the present work can be continued or improved by many approaches, four of which are proposed next.

Validation with Academics and Practitioners

In the spirit of what was done by [6] and [9], workshops with academics and practitioners could be organized to discuss, improve and validate both the conceptual overview performed in chapter 2 (and corresponding graphic tool) and the strategy for BMI proposed in chapter 3 (and corresponding guide).

Application of the Guide to an Established Company

The company on which the guide was applied was startup-level. There were many aspects on which to innovate because processes were not clearly defined yet. It was a very "greenfield" scenario.

For further validation, it would be interesting to see the application of the guide to an established company to see what ideas could come from there.

Increasing Guide Resolution

The questions of the innovation guide are "high-level". From reading the question until reaching an idea or action, the reader must undertake a creative thinking process, which can be too abstract or not produce consistent results.

A way to circumvent this would be to have a "branch tree" that, for every lever presented, gave additional more detailed "micro-levers". This would be a subsequent process until reaching a very "micro" but practical level.

For example, on the "mass individualization" lever, the following micro-levers could be: i) manufacturing of unique parts through additive manufacturing, and ii) very customized digital services. Each of these micro-levers would then breakdown into more specific actions, and so on.

Analysis of Environmental and Social Industry 4.0 Levers

The present dissertation was focused on the analysis of Industry 4.0 impacts on the economic component of business models. However, sustainable business model innovation should include and a review of the effects on environmental and social pillars as well.

For instance, Company X, from the case study on chapter 4, has partnerships with reforestation organization TreeSisters for environmental value creation – it will donate enough for the plantation of one tree per lunchbox sold. Similarly, it will feed one child per one day, through a donation to the United Nations, acting on the social plane. However noble, both were *ad hoc* charity gestures, instead of carefully chosen environmental/social investments.

Recent works have proposed adaptations of the BMC to incorporate these factors [93], by finding environmental and social equivalents for the economic building blocks of the original canvas.

The list of economic levers from and corresponding innovation guide from chapter 3 can be expanded to include these new types of levers.

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Annexes

A. Enabling Technologies in the Literature Reviewed

Table 8 presents the sources where each technology was mentioned. The white rows, typed with a smaller font and separated by dotted lines, are terminologies used in the literature that were grouped under the “umbrellas” of the seven enabling technologies proposed in section 2.7 (grey rows).

Table 8. Connections between the technologies listed and their source.

	Reviews of Multiple Technologies							Works on Specific Technologies					
	[1]	[14]	[19]	[21]	[22]	[33]	[10]	[34]	[32]	[84]	[36]	[37]	[39]
Additive Manufacturing	x	x	x	x	x	x	x						
Sensors		x	x		x	x							
RFID & RTLS technologies			x										
Data Analytics			x										
Artificial Intelligence			x		x								
Big Data	x	x		x	x	x	x						
Machine Learning						x							
Cloud Computing	x	x	x	x	x	x	x						
Cyber-Security			x	x		x							
Mobile			x										
Integrated Management Software	*New terminology proposed in this dissertation*												
Internet of Things				x	x	x	x						
Cyber-Physical Systems							x						
Manufacturing Execution Systems		x								x			
Shop-floor IT								x	x				
Extended Reality											x	x	
Augmented Reality	x			x	x		x				x	x	x
Virtual Reality					x	x					x	x	x
Simulation			x	x			x						
Virtualization			x										
Autonomous Robots	x	x		x	x								
Adaptive Robotics			x										

B. Intensity of Business Model Changes to Each Component

In order to assess the most affected building blocks of the business model, a simple analysis is conducted, based on the surveys compiled by sources [75], [50], [46] and [51].

The scores taken from each study are normalized according to Equation 3, where x_i is the value to normalize, $\bar{x}$ is the average of the values from the corresponding study and σ is their standard deviation:

$$Z_i = \frac{x_i - \bar{x}}{\sigma}$$

Equation 3. Formula for normalization of values on different scales.

Table 9 has the aggregated score per block, calculated by adding the normalized values of each study.

Table 9. Original, normalized and aggregated scores for business model component changes, according to the four sources referenced.

	Source [75]		**Source** [50]		**Source** [46]		**Source** [51]		**Aggregated Score**
	x_i	Z_i	x_i	Z_i	x_i	Z_i	x_i	Z_i	
Customer Segments	27	-1,70	41,86	0,04	5,65	0,08	12	-1,48	-3,07 (8th)
Value Propositions	91,2	0,96	53,49	0,97	6,35	2,57	65	1,32	5,83 (1st)
Channels	37,4	-1,27	18,61	-1,82	5,35	-0,99	15	-1,32	-5,41 (9th)
Customer Relationships	86,4	0,76	48,84	0,60	5,55	-0,28	56	0,85	1,93 (3rd)
Revenue Streams	46,2	-0,91	41,86	0,04	5,75	0,43	22	-0,95	-1,38 (7th)
Key Resources	95,8	1,15	58,14	1,34	5,45	-0,63	60	1,06	2,92 (2nd)
Key Activities	89	0,87	23,26	-1,45	5,4	-0,81	53	0,69	-0,70 (6th)
Key Partnerships	65,8	-0,09	48,84	0,60	5,55	-0,28	35	-0,26	-0,03 (4th)
Cost Structure	73,6	0,23	37,21	-0,33	5,6	-0,10	42	0,11	-0,09 (5th)

This analysis concludes that channels and customer segments seem to be the least affected by Industry 4.0, while customer relationships, key resources and value propositions are the most.

Even though their authors tried their best to follow a strict and rigorous sampling project, these studies have two possible sources of data bias:

- They focus on SMEs, which, despite comprehending a significant proportion of enterprises, are not representative of the entire market and may lag behind major players when it comes to I4.0;
- The inquired companies are mostly German, and [22] already showed that organizations from different countries react to I4.0 differently.

C. Definitions of Specifics of the Business Model Canvas

Table 10. Definitions of Specifics of the Business Model Canvas (parts adapted and transcribed from [40] and [45]).

	Specific	Factor Description
	Customer Segments	
Examples	**Mass Market**	Mass markets focus on one large group of customers with broadly similar needs and problems
	Niche Market	Niche markets cater to specific, specialized customer segments
	Segmented	Serving specific market segments with slightly different needs and problems
	Diversified	Serving two or more unrelated customer segments with different needs and problems
	Multi-sided platforms	Serving two or more interdependent customer segments
	Value Propositions	
Characteristics	**Newness**	Satisfy an entirely new set of needs
	Performance	Improving product or service performance
	Customization	Tailoring products and services to the specific needs of customers
	"Getting the job done"	Simply helping a customer get certain jobs done
	Design	A product may stand out because of superior design
	Brand/status	Value due to the simple act of using a specific brand
	Price	Offering similar value at a lower price
	Cost reduction	Helping customers reduce costs
	Risk reduction	Reducing risks customers incur when they purchase products or services
	Accessibility	Making products and services available to customers who previously lacked access to these products and services
	Convenience/usability	Making things more convenient or easier
	Comfort	Making a customer's situation less unpleasant and more comfortable
	Possibility for updates	Offering the possibility to update the product or service
	Channels	
Types	**Sales Force**	One or more persons in the company spend time selling products and services directly to customers
	Web Sales	Selling products and services through a web site
	Own stores	Selling products and services through a self-owned store
	Partner stores	Selling products and services through the store of a partner
	Wholesalers	Selling products and services to customers via wholesalers
Phases	**Awareness**	How do we raise awareness about our company's products and services?
	Evaluation	How do we help customers evaluate our organization's Value Proposition?
	Purchase	How do we allow customers to purchase specific products and services?
	Delivery	How do we deliver a Value Proposition to customers?
	After Sales	How do we provide post-purchase customer support?
	Customer Relationships	
Examples	**Personal assistance**	Offering help during the sales process or after the purchase
	Dedicated personal assistance	Dedicating a customer representative specifically to an individual client
	Self-service	Providing the necessary means for customers to help themselves
	Automated service	Mixes a more sophisticated form of customer self-service with automated processes
	Communities	Utilizing user communities to become more involved with customers and to facilitate connections between community members

	Co-creation	Co-create value together with customers instead of the traditional customer-vendor relationship
	Revenue Streams	
Types	**Asset sale**	Selling ownership rights to a physical product
	Usage fee	Selling the use of a particular service
	Subscription fees	Selling continuous access to a service
	Lending/renting/leasing	Selling the exclusive right to a particular asset for a fixed period
	Licensing	Selling permission to intellectual property
	Brokerage fees	Selling intermediation services performed for two or more parties
	Advertising	Selling advertisement for a particular product, service, or brand
	Startup fees	Selling non-recurring costs associated with the startup of a project
	Installation fees	Selling non-recurring costs associated with the installation of a project
Fixed Pricing	**List price**	Fixed prices for individual products, services, or other Value Propositions
	Product feature dependent	Price depends on the number or quality of Value Proposition features
	Customer segments dependent	Price depends on the type and characteristic of a Customer Segment
	Volume dependent	Price as a function of the quantity purchased
Dynamic Pricing	**Negotiation (bargaining)**	Price negotiated between two or more partners depending on negotiation power and/or negotiation skills
	Yield management	Price depends on inventory and time of purchase (normally used for perishable resources such as hotel rooms or airline seats)
	Real-time-market	Price is established dynamically based on supply and demand
	Auctions	Price determined by outcome of competitive bidding
	Key Resources	
Types	**Physical resources**	Physical assets such as manufacturing facilities, buildings, vehicles, machines, systems, point-of-sales systems, and distribution networks
	Intellectual Property	Intellectual property such as brands, proprietary knowledge, patents and copyrights, partnerships, and customer databases
	Employee Capabilities	The people involved in an organization and their knowledge and skills
	Financial resources	Financial resources and/or financial guarantees, such as cash, lines of credit, or a stock option pool for hiring key employees
	Software	Bought or developed software, applications or platforms
	Relations	Relations acquired or developed over time
	Key Activities	
Categories	**Customer development**	Discovering the right market and researching customer needs
	Product development	The creation and commercialization of ideas into a product or service
	Implementation	Putting the offered solution into place
	Service & support	Offering after sales services and support to customers
	Marketing	Communicating the value of the product or service to potential customers
	Sales	All activities involved in selling products or services
	Platform development	Creation and updating of the platform used to support the products or services
	Software development	Creation and updating of the software used to support the products or services
	Partner & Vendor Management	Coordination of suppliers and other partners
	Logistics	All activities involved in the transportation of the products or services to the customers

Key Partnerships		
Types	**Hardware producers**	Manufacturers and assemblers of hardware
	Software & app developers	Developers and suppliers of any kind of software
	Other suppliers	Suppliers such as designers and consultants
	Data analysis partners	Partners which interpret and analyze generated data
	Launching Customers	Customers which are involved in the development of the products or services
	Distributors	Partners which distribute products and services to customers
	Logistics	Partners involved in the transportation of the products or services to the customers
	Service Partners	Partners involved in offering after sales assistance such as installation, update or maintenance
Motivations	**Optimization and economy of scale**	The most basic form of partnership or buyer-supplier relationship is designed to optimize the allocation of resources and activities. Optimization and economy of scale partnerships are usually formed to reduce costs, and often involve outsourcing or sharing infrastructure.
	Reduction of risk and uncertainty	Partnerships can help reduce risk in a competitive environment characterized by uncertainty. It is not unusual for competitors to form a strategic alliance in one area while competing in another.
	Acquisition of particular resources and activities	Few companies own all the resources or perform all the activities described by their business models. Rather, they extend their own capabilities by relying on other firms to furnish particular resources or perform certain activities. Such partnerships can be motivated by needs to acquire knowledge, licenses, or access to customers.
Cost Structure		
Drivers	**Cost-driven**	Leanest cost structure, low price value proposition, maximum automation, extensive outsourcing.
	Value-driven	Focused on value creation, premium value proposition.
Types	**Product development**	Costs involved in the creation of products or services
	IT costs	Costs accompanied with acquiring or developing of software and IT systems
	Personnel	Costs of compensations of employees
	Hardware/production	Costs accompanied with buying or making products
	Logistics	Costs involved in the transportation of the products or services to the customers
	Marketing & Sales	Costs involved in communicating and selling products and services
Characteristics	**Fixed costs**	Costs that remain the same despite the volume of goods or services produced
	Variable costs	Costs that vary proportionally with the volume of goods or services produced
	Economies of scale	Cost advantages that a business enjoys as its output expands
	Economies of scope	Cost advantages that a business enjoys due to a larger scope of operations

D. Background on the Blue Ocean Strategy

Professors Chan Kim and Renée Mauborgne introduced the Blue Ocean Strategy in their homonymous best-selling book, published in 2005 and updated in 2015 [94].

That strategy is based on the distinction between “red” and “blue oceans”. “Red oceans” are the crowded market space, where profits and growth are reduced. Products become commodities, leading to cutthroat or ‘bloody’ competition; hence the term red oceans [95]. Blue oceans, in contrast, denote the industries not in existence today – the unknown market space, untainted by competition. A blue ocean is an analogy to describe a market that is vast, deep, and powerful in terms of profitable growth [95].

Blue ocean strategy is the simultaneous pursuit of differentiation and low cost to open up a new market space where there is no competition or very less competition, to avoid pricing pressures [96]. It is based on the view that market boundaries and industry structure are not a given and can be reconstructed by the actions and beliefs of industry players [95].

Kim and Mauborgne proposed that value innovation is achieved through an analytical tool they call the Four Actions Framework, which challenge an industry’s established business model [40]:

1. Which of the factors that the industry takes for granted should be eliminated?
2. Which factors should be reduced well below the industry standard?
3. Which factors should be raised well above the industry standard?
4. Which factors should be created that the industry has never offered?

The Cirque du Soleil became a popular example of a “blue ocean”. By focusing on creating an refined experience and cutting animal acts, they were able to charge higher prices to a more sophisticated audience, while lowering costs [97]. Source [40] proposed a blend of the Business Model Canvas with the Blue Ocean Strategy and used it to analyze that case study, as seen in Figure 33.

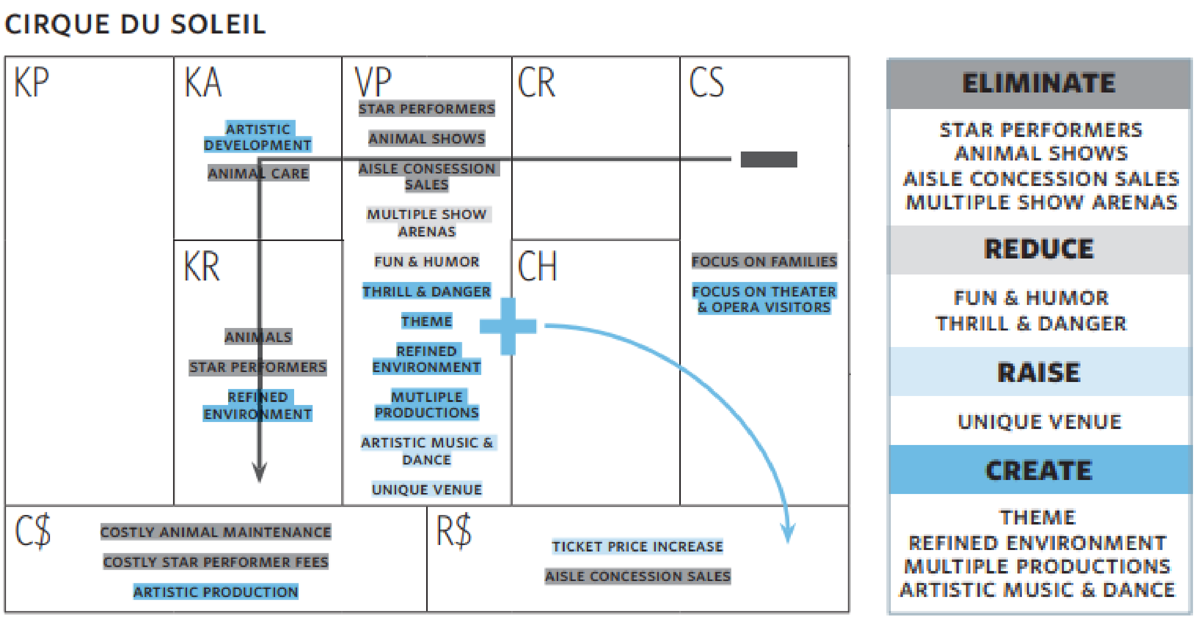

Figure 33. Cirque du Soleil BMC analysis with the Blue Ocean Strategy framework (taken from [40]).

E. Guide for Business Model Innovation

Table 11. Guiding questions for Business Model Innovation through Industry 4.0 application.

Customer Segments

For whom are we creating value?

L1. Do we want to use IT solutions to increase penetration within a mass market?

Retailer Walmart added “wish lists” to their app through which friends and family can see what products someone liked on the app and purchase them for birthday/Christmas gifts. On the same trend, Portuguese hypermarket chain Continente’s app digitized physical customer loyalty cards and coupons.

Associated levers: L8, L12, L40, L47

Target Audience: B2C	Company Size: Big	Value Offering: Any

L2. Do we want to leverage new technologies to satisfy very particular customer needs?

New technologies include additive manufacturing or data analytics tools that get unique insights into people’s necessities.

Associated levers: L5, L12, L47, L63

Target Audience: Any	Company Size: SME	Value Offering: Any

L3. Do we want use IT solutions on our products to expand to different customer segments?

Google is starting to have physical products embedded with their traditional IT prowess, such as virtual reality goggles (Google Glass), tablets and computers (Google Pixel) and “smart home” accessories, such as thermostats and smoke detectors, with their Google Nest brand.

Associated levers: L9, L40

Target Audience: Any	Company Size: Big	Value Offering: Any

Value Propositions

What value do we deliver to the customer segments?

L4. How can we use our know-how to offer digitalization assistance services to other companies?

Machine manufacturer TRUMPF but expanded their business scope to include Industry 4.0 consultancy, software and platform development.

Associated levers: L64

Target Audience: B2B	Company Size: Any	Value Offering: Service

L5. How can we make our product more fitted to each individual customer?

Arburg linked an injection molding machine to a 3D printer by means of a seven-axis robot, in order to engrave lettering on their products.

Associated levers: L66

Target Audience: Any	Company Size: Any	Value Offering: Product

L6. How can we offer a platform that links customers’ demand with manufacturers’ supply?

SLM Solutions, a 3D printer manufacturer, and Atos, a software company, are working together to develop an integrated production network, where machines are connected via the Internet and customer orders are produced directly with optimal capacity utilization.

Associated levers: L21, L30

Target Audience: Any	Company Size: Any	Value Offering: Service

L7. How can we offer our product as a service, monitoring its usage remotely?

DriveNow offers shared cars that users can rent by the minute, through apps on their smartphones.

Associated levers: L27, L29, L37

Target Audience: Any	Company Size: Any	Value Offering: Service

L8. How can we add complementary services to our physical product?

Car manufacturer Tesla sells software updates for their vehicles operating system that adds them extra functionalities, even after the vehicle's acquisition.

Associated levers: L9, L19, L34, L40

Target Audience: B2C | Company Size: Any | Value Offering: Product

L9. How can we offer a digital offering that replaces the need for physical goods?

While, in the past, people learned how to play chess on wooden boards, nowadays, players use apps such as Chess Time on their smartphones. Companies can mimic this change by transitioning from physical to digital value creation.

Associated levers: L27

Target Audience: Any | Company Size: Any | Value Offering: Service

L10. How can we have an offering that is integrated with other products/services (from our own brand or from others)?

New Huawei laptops use NFC technologies to connect directly with nearby Huawei smartphones and share their files and screens.
Industrial machine manufacturers can make an equipment, set it up and connect it with other machines in the customer's factory, for full integration.

Associated levers: L37

Target Audience: Any | Company Size: Big | Value Offering: Any

L11. How can we offer value by aggregating value from different sources?

The value of an identification number's electronic component significantly increases, if it is combined with its firmware release number or service history.

Associated levers: L31, L62, L64

Target Audience: B2B | Company Size: Big | Value Offering: Any

L12. How can we make our offering self-adaptative to its user?

Amazon has a "dash replenishment service", that automatically orders consumables for household appliances (e.g.:washing detergent), when necessary.

Associated levers: L23, L47

Target Audience: B2C | Company Size: Any | Value Offering: Any

Channels

Through which channels can we reach our customer segments?

L13. How can we use social media to raise targeted awareness to our offering?

Facebook Business platform allows companies to target who sees their ads and repeatedly show them to people who demonstrate interest.

Associated levers: L47, L62

Target Audience: B2C | Company Size: SME | Value Offering: Any

L14. How can we use extended reality to allow customers to evaluate our value propositions remotely?

IKEA launched an AR mobile app through which customers can scan the room they are looking to furnish and select the product they are interested in seeing. The app then places a realistically rendered, true-to-scale representation of that product on the screen, for the user to see how well it fits in.

Associated levers: L1

Target Audience: B2C | Company Size: Any | Value Offering: Product

L15. How can we accept digital payment solutions and currencies?

New popular smartphone-based payment solutions include Apple Pay or Google Wallet. In Portugal, there is also MB Way.

Associated levers: L20, L21, L64

Target Audience: B2C | Company Size: Any | Value Offering: Product

L16. How can we automate the physical purchase process?

Sports retailer Decathlon created self-checkout kiosks where a customer can place an item into a boxed area so the RFID tag on the product can be read and the item's price and details captured. The customer then removes the item from the boxed area and adds the next one.

Associated levers: L15, L63, L64

Target Audience: B2C	Company Size: Big	Value Offering: Product

L17. How can we decentralize the delivery of goods into smaller storage points closer to the customers?

Delivery service UPS is establishing "access points" across multiple countries: partner retail outlets, such as a grocery store or gas station, that serve as a convenient point for UPS to drop multiple packages and customers to pick them up.

Associated levers: L40, L61, L63

Target Audience: B2C	Company Size: Any	Value Offering: Product

L18. How can we raise after-sales support that closely listens to customer feedback?

After sales support can be through multiple means, such as social media, dedicated forums, email, and more.

Associated levers: L23, L24, L25, L47

Target Audience: Any	Company Size: Any	Value Offering: Product

L19. How can we have offerings that work as a mean to achieve further sales?

iPhones have the App Store, through which the user can buy apps, with Apple gaining a share of each sale; the phone is just a mean for further sales.

Associated levers: L8, L20, L62

Target Audience: Any	Company Size: Any	Value Offering: Any

L20. How can we have direct online sales channels available and advertised?

Associated levers: L13, L17

Target Audience: Any	Company Size: Any	Value Offering: Any

L21. How can we have presence in popular online sales third-party platforms?

Companies can benefit from the exposure of third-party online platforms, such as Amazon, who allows them to reach many more customers at once. Facebook now allows companies to sell their products directly on that social media. For services, there is popular outsourcing platform Fiverr.

Associated levers: L13, L30, L59

Target Audience: Any	Company Size: SME	Value Offering: Any

Customer Relationships

What type of relationship does each of our customer segments expect us to establish and maintain with them?

L22. How can we raise automated assistance for the sales process?

Fit Finder is an analytics tool used on many fashion brands' websites to autonomously recommend clothing sizes based on a few individual questions and satisfaction rates of other customers with those sizes.

Some webstores and company social media channels already feature "chatbots" – automated software that replies to frequently asked questions (FAQ).

Associated levers: L39, L47, L64

Target Audience: Any	Company Size: Any	Value Offering: Any

L23. How can we use IT tools to deliver a personalized yet automated customer experience?

Laundry machine company Bundles offers a "smart" washer through which customers get monthly feedback about their washing behavior. This personalized feedback is autonomously generated and sent by connected software without human interaction.

Associated levers: L34, L47

Target Audience: B2C	Company Size: Any	Value Offering: Any

L24. How can we ask for early feedback and design developments from our prospective customers when developing products?

LEGO gave customers the possibility to design, assemble and order their own kits online – people are given the chance to pick buildings, vehicles, themes and characters, choosing from thousands of components and dozens of colors, and even design the box containing the customized kit. In addition to helping users design their own sets, LEGO sells them online, expanding a product line previously focused on a limited number of best-selling kits.

Associated levers: L5

Target Audience: Any	Company Size: Any	Value Offering: Any

L25. How can we make communities where customers can interact among themselves and with brand representatives?

Apple and Google host customer support forums where people can post their questions and be assisted either by other users or technical staff.

Marketing company Salesforce offers a "community cloud" where customers can interact with each other and with the company.

Associated levers: L24, L64

Target Audience: B2C	Company Size: Big	Value Offering: Any

Revenue Streams

For what value and how are our customers paying?

L26. How can we digitally limit our products to only accept original replacement parts?

Sensor and actuator technologies will enable new means to limit compatibility of complementary parts with initial products, emphasizing that only original parts are compatible with the system.

Associated levers: L37

Target Audience: Any	Company Size: Big	Value Offering: Product

L27. How can we bill the consumer based on measured usage of our offerings?

Konecranes allowed customers to rent industrial cranes, where they would just pay the actual hours the equipment was used. This new rental business model was only possible due to the data they could gather about its customers and their usage behavior through sensors installed on the equipment.

Associated levers: L12, L37, L47, L50, L60

Target Audience: Any	Company Size: Any	Value Offering: Service

L28. How can we offer our value offerings through subscription models?

ERP provider SAP profits of selling annual licenses and maintenance services for their software.

Solar panels maintenance companies sell the panels and then bill monthly values for remote monitoring, through sensors and performance indicators.

Associated levers: L8, L60

Target Audience: Any	Company Size: Any	Value Offering: Service

L29. How can we sell our unused capacity to other companies?

Amazon decided to leverage its retail sales operations powerful IT infrastructure to host and offer cloud computing services, such as online storage space and on-demand server usage, to third-parties.

Associated levers: L6, L36

Target Audience: B2B | Company Size: Any | Value Offering: Service

L30. How can we gain commissions by mediating sales through an online platform?

This is already done by popular sales websites such as eBay, AliExpress (both B2C), or Alibaba (B2B).

Target Audience: Any | Company Size: Any | Value Offering: Service

L31. How can we sell user data that was collected through an offering?

Google provides a free search engine that creates user data that is sold for targeted advertising.

SCiO is a low-cost, pocket-sized spectrometer that allows customers to obtain information about the chemical composition of a product using their smartphone by simply scanning the object. Based on scans performed, customer needs and characteristics can be identified for advertising purposes.

Associated levers: L27, L39, L47, L59, L62

Target Audience: B2B | Company Size: Big | Value Offering: Service

L32. How can we leverage crowdfunding to lower capital commitment and test market feedback?

Popular crowdfunding platforms include Kickstarter and Indiegogo.

Associated levers: L24, L68

Target Audience: B2C | Company Size: SME | Value Offering: Product

L33. How can we monetize the installation of our offerings at the user's site?

SAP profits not only by selling licenses to their ERP software, but also on installation consultancy projects on other companies.

Machine manufacturers also adhere to this logic, by monetizing the sale of their "smart" equipment and then its installation on the destination factory.

Associated levers: L37, L40, L56, L64

Target Audience: B2B | Company Size: Any | Value Offering: Any

L34. How can we monetize additional paid digital services offered beyond the original offering?

Car manufacturer Tesla offered an autopilot software update digital add-on for $2,500, which enabled the updated vehicles to park automatically.

Associated levers: L8, L19

Target Audience: Any | Company Size: Any | Value Offering: Any

L35. How can we price our product according to its performance?

Rolls-Royce has an airplane engine maintenance model where airline carriers only pay them a fee in proportion to aircraft flying hours, which in turn are affected by the availability of all major aircraft sub-systems, including engines.

Associated levers: L37, L47

Target Audience: Any | Company Size: Any | Value Offering: Any

L36. How can we have systems that automatically monitor and adjust prices to physical supply and demand?

Due to improved GPS and open-sourced algorithms, Uber was able to implement "surge pricing": when there are more riders asking for vehicles than drivers in a given area, prices automatically increase. This makes more drivers serve the busy area and riders to delay their trips, restoring balance.

Associated levers: L37, L40

Target Audience: B2C | Company Size: Any | Value Offering: Any

Key Resources

What resources do our value propositions, distribution channels, customer relationships and revenue streams require?

L37. How can we remotely interconnect all our resources and products?

In order to monitor product quality along their supply chain, Bosch placed sensors on their transport packaging, connected to the company's cloud system. They continuously record relevant data, such as temperature, shocks or humidity.

Associated levers: L42, L63, L67

Target Audience: Any	Company Size: Any	Value Offering: Big

L38. How can we automate our production systems?

On a given factory, the Kuka KR Quantec humanoid robot was tasked with distributing screws and other material by delivering the ordered kanban boxes from the central warehouse to the workstations, using its memory-based activity identification and recognition of characteristics of parts.

Associated levers: L37, L40, L58

Target Audience: Any	Company Size: Big	Value Offering: Product

L39. How can we own all the relevant data for our operations?

The European Union has launched the "General Data Protection Regulation" that gives concrete instructions for handling customer information.

Associated levers: L41, L42

Target Audience: Any	Company Size: Any	Value Offering: Any

L40. How can we have a cloud-based seamless software infrastructure for operational and business control?

At a factory level, it has been proposed that a top operational management system should use ERP and MES incorporated with Manufacturing Data Collection, Production Data Acquisition, Production Planning System and Product Data Management systems. On a business level, ERPs can be integrated with Product Lifecycle, Customer Relationship and Partner Relationship Management, as well as Business Intelligence tools.

Associated levers: L37, L45, L63, L64

Target Audience: Any	Company Size: Any	Value Offering: Any

L41. How can we have robust cyber-security?

Companies need to update defense systems regularly, install backup copies to limit eventual damages and train staff to avoid cyber-risks. Workers should have an antivirus on their computer, use robust passwords, avoid connecting to unknown Wi-fi networks and enable two-factor authentication.

Associated levers: L55, L56

Target Audience: Any	Company Size: Big	Value Offering: Any

L42. How can we have recognized standards on which to draw upon for implementation efforts?

These can be either reference architectures, methodology for building CPS or others.

Associated levers: L59, L63, L64, L65

Target Audience: SME	Company Size: Any	Value Offering: Any

L43. How can we have a creative environment and workforce?

Managers should let workers pitch and develop ideas and support try-and-error processes without chastising employees for failure.

Associated levers: L54

Target Audience: Any	Company Size: Any	Value Offering: Any

L44. How can we have a multidisciplinary staff with transversal knowledge on economics, engineering, IT and other relevant fields?

Associated levers: L45, L47, L66

Target Audience: SME	Company Size: Any	Value Offering: Any

L45. How can we have IT-related roles to support the necessary software implementations and usage?

This may involve the hiring of as developers, data scientists and other digital experts, across all departments.

Associated levers: L58

Target Audience: Any | Company Size: Any | Value Offering: Any

L46. How can we have the necessary funding to support all these resources?

The “Portugal 2020” program launched an “Industry 4.0 Call”, through which companies could apply to get governmental funding for I4.0 plant adaptation.

Associated levers: L37, L40, L41, L43, L44, L45, L55

Target Audience: Any | Company Size: SME | Value Offering: Product

Key Activities

What activities do our value propositions, distribution channels, customer relationships and revenue streams require?

L47. How can we collect brand interaction and product usage data from our customers?

Bosch designed a device that can be connected to a car’s internal control network to monitor engine performance and geo-location. The collected data is transmitted to a Bosch backend, where it is stored. That data pool is used as for digital services like remote diagnostics, maintenance or fleet control.

Associated levers: L58

Target Audience: Any | Company Size: Any | Value Offering: Any

L48. How can we use rapid prototyping tools for product development?

Associated levers: L63

Target Audience: Any | Company Size: Any | Value Offering: Product

L49. How can we virtualize the product development process?

Machine manufacturer company John Deere estimates that using VR simulations to design parts of a cotton harvester equipment reduced the design time by 18 months and design costs by more than $100,000. They also allowed customers to test and provide feedback on early concepts, using AR.

Associated levers: L63, L64

Target Audience: Any | Company Size: Big | Value Offering: Product

L50. How can we build predictive maintenance systems?

GE offers a predictive maintenance service in which remote sensors collect and report data on the condition of the user’s machinery. Based on that data, signs of failure are detected early, allowing for correction at minimal costs, maintenance resources to be better managed, and availability.

Associated levers: L58

Target Audience: Any | Company Size: Any | Value Offering: Any

L51. How can we have robots assist the execution of physical tasks?

Etalex introduced autonomous robots capable of lifting large metal parts in their plant. For them to work in close proximity to each other without risking injury of the workers, robots had built-in force control, so that they would automatically slow down or stop in case of contact with humans.

Associated levers: L63

Target Audience: Any | Company Size: Big | Value Offering: Product

L52. How can we use extended reality to virtually assist the execution of tasks?

KiSoft Vision is a wearable optical headset assistant for warehouse tasks. It shows the workers the relevant information for retrieving products superimposed on its see-through display, guides them, makes suggestions regarding the stacking of fragile items and allows them to have their hands free, by making paper checklists redundant. Its camera image processing also captures serial and lot ID numbers, enabling real-time stock tracking.

Associated levers: L63, L64

Target Audience: Any | Company Size: Big | Value Offering: Product

L53. How can we register our knowledge acquisitions?

McKinsey uses a dedicated software to register long detailed reports to practical “information nuggets” on how to connect streaming devices for lectures.

Associated levers: L55

Target Audience: Any | Company Size: Any | Value Offering: Any

L54. How can we create practices to systematically innovate our business?

Companies can have “innovation managers” with participation in several departments and encourage transversal participation of workers.

Autonomous “startups” within an existing larger company can be created for fast-tracking innovations such as breakthrough products or business models.

Associated levers: L43, L44

Target Audience: Any | Company Size: Any | Value Offering: Any

L55. How can we train our workforce for new relevant skills?

Associated levers: L43, L44, L45, L56, L57

Target Audience: Any | Company Size: Any | Value Offering: Any

L56. How can we keep our software operational and updated?

Associated levers: L4, L8, L9, L12, L45

L57. How can we digitalize our internal processes and systematically collect data on them?

In order to identify and rectify unbalanced usage in a set of automated welding guns, first, it is necessary to understand what are the parameters that assess its wear and then implement sensors to measure them.

For this kind of systematic digitalization, roles such as “chief digital/transformation officers” can be created.

Associated levers: L59

Target Audience: Any | Company Size: Any | Value Offering: Any

L58. How can we create automated control systems for our processes?

In the semiconductor industry, advanced process control (APC) systems translate anomalies found by statistical analysis of the products into automated adjustments of equipment parameters, that prevent deviations from desired standards, in a negative feedback system.

At an ABB cement kiln, it was introduced a system that simulates an “ideal” cement plant and then calculates the necessary adjustments to the real process to achieve that ideal state. The new values for kiln feed, fuel flow, and fan damper position are then sent automatically to the kiln control system.

Associated levers: L57

Target Audience: Any | Company Size: Any | Value Offering: Any

L59. How can we create practical communication strategies to work with our partners?

Standardized digital connection channels such as PRM or SCM software, involving a company, external consultants, suppliers and customers, allow companies to exchange “best practices” among them and derive real-time optimized physical (routes and schedules) and financial flows. For instance, a spike in similar repairs on products across multiple dealers can help identity a quality defect yet to be noticed in a manufacturer’s production run.

Associated levers: L40, L42, L44, L45, L62

Target Audience: Any | Company Size: SME | Value Offering: Any

L60. How can we raise the automation of our billing and accounting processes?

Target Audience: Any | Company Size: Big | Value Offering: Any

L61. How can we raise the automation of stock management?

In Portugal, supermarket chain Auchan has an autonomous robot that scans their shelves to detect missing products and incorrect price labels.

Würth’s iBins uses intelligent camera technologies to capture the actual fill level of a supply box and automatically reorders more if the level is low.

Associated levers: L47

Target Audience: Any | Company Size: Big | Value Offering: Product

L62. How can we leverage interaction data to understand customer profile and demand?

Salesforce offers a CRM cloud solution that tracks customer journeys and provides multichannel marketing campaigns.

Target Audience: Any	Company Size: Any	Value Offering: Any

Key Partnerships

Who do we depend on to supply key resources and perform key activities?

L63. How can we have reliable partners to provide the necessary technologies for implementing our strategy?

Associated levers: L67

Target Audience: Any	Company Size: Any	Value Offering: Any

L64. How can we use IT outsourcing to simplify internal processes and compensate resource deficits?

Associated levers: L67

Target Audience: Any	Company Size: SME	Value Offering: Any

L65. How can we participate in and monitor the work of credible research platforms?

Involvement with associations such as the Industrial Internet Consortium (IIC) or the Industrie 4.0 Working Group may yield a future edge.

Associated levers: L44, L45

Target Audience: Any	Company Size: SME	Value Offering: Any

Cost Structure

What are the most important costs inherent in our business model?

L66. How can we deliver better quality and value products?

Target Audience: Any	Company Size: SME	Value Offering: Any

L67. How can we invest on innovation and digitalization?

For reference, a proposed assessment model for Industry 4.0 maturity in manufacturing SMEs considered that investing 1-3% of revenues on technology would be for an Industry 4.0 “learner” company, while more than 10% would correspond to a “top performer”.

Target Audience: Any	Company Size: Any	Value Offering: Any

L68. How can we take advantage of pay per use pricing mechanisms to lower capital commitment?

Associated levers: L27, L29

Target Audience: Any	Company Size: SME	Value Offering: Any