

A Guide for Business Model Innovation through Industry 4.0

João Francisco da Costa Campos
joaofccampos@tecnico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal
January 2021

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

1 RESEARCH APPROACH

“Industrie 4.0” was introduced in 2011 [1], by an eponymous German working group set to address the technological advances of previous years [2]. It was later anglicized abroad to “Industry 4.0” (I4.0) and became synonymous with the 4th Industrial Revolution.

The possibility of business model innovation (BMI) through I4.0 has been identified, yet there are multiple obstacles to its realization, two of which are the basis for the research goals of this work:

1st Goal: Conceptual Overview. One of the commonly reported hurdles for business innovation with Industry 4.0 is a general lack of clarity on the associated concepts [3], often being perceived as something highly complex and unattainable [4]. For that reason, focus is being placed here on building a conceptual overview of I4.0, in chapter 2.

2nd Goal: Tool for Innovation. Beyond struggling with conceptualization, research has also identified that companies lack comprehension of the overall impacts I4.0 could have on their business models, what gains could come through it [4], and, above all, dedicated toolkits to systematically innovate [5] [6]. For that, chapter 3 builds a tool for I4.0 innovation and chapter 4 then applies it.

Chapter 5 sums up the major outputs of this work and suggests some possible future research.

2 CONCEPTUAL OVERVIEW

2.1 Drivers for Innovation

The push for this new revolution comes from the simultaneous occurrence of a set of factors [7]:

Customer Demands Changing. Consumers are increasingly demanding when it comes to

personalized products to satisfy their individual needs and meet quality standards.

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.

Resources Scarcity. The decreasing availability of natural resources, worldwide growth of population and globalization of markets.

New Technologies. The continuous progress of IT enables the emergence of increasingly powerful, interconnected technological systems that can be used in order to grow industries.

2.2 Definition

The existing definitions I4.0 all seem to circle around three key trends:

Changes in manufacturing – “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 planning and management systems” [8].

Reshaping of the value chain – “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” [9].

Interconnectivity of all elements – “internet of things, machines, computers and people, enabling intelligent industrial operations, using advanced

data analytics for transformational business outcomes” [10].

2.3 Implementation Principles

I4.0 implementations are focused on:

Vertical Integration. Integration of various IT systems at different hierarchical levels (e.g. actuators, sensors, control, production management, manufacturing, marketing) [8].

Horizontal Integration. Integration of various IT systems used in the different 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 [8] [11].

End-to-End Integration. IT systems should be deployed in order to provide end-to-end support for a product’s entire life cycle [8] [11].

2.4 Design Principles

These provide a “systemization of knowledge” that supports practitioners [12]:

Interconnection. The popularization of wireless communication technologies is an enabler for increased connection and interaction of machines, devices, sensors, and people.

Information Transparency. Linkage of sensor data with interpretation models can allow the creation of a virtual copy of the physical world, through which organizations can get unique insights into their activities.

Decentralized Decisions. Every element should perform its tasks as autonomous as possible, with external help only being necessary in case of exceptions.

Technical Assistance. The main role of humans is expected to change from an operator of machines towards a strategist and problem solver, assisted by physical and virtual systems.

2.5 Components

These components are the “bricks” used to build the I4.0 “house”. This work expands on the components presented by [12] by adding the latter two of following listing:

Internet of Things (IoT). Drive for interconnection leads to a network that connects uniquely identifiable “Things” to the Internet, with sensing and actuation capabilities [13].

Cyber-Physical Systems (CPS). CPS are a component that links the dynamics of an organization’s processes and infrastructure (buildings, machines or workers, etc.) with its software, by creating digital representations of the physical elements, monitoring their status, as well as acting on them to fulfill goals [2].

Smart Factories. Cyber-physical production systems (CPPS) able to use information to self-optimize in real or near-real time [8].

Smart Products. Smart products are embedded with elements of the IoT, know their production history, current and target state, monitor and relay their usage patterns for additional business insights and performance optimization [2] [12].

Business Ecosystems. Business ecosystems are a coupling of social and economic actors, interacting through institutions and technology, to exchange services and create value in ways beyond any single company’s capacity [14] [15].

2.6 Enabling Technologies

Like previous revolutions, I4.0 is also supported by technological advances. However, since there is not a consensus in the literature as to what those are, it was necessary to conduct a synthesis of seven key technologies, based on reviews of multiple works:

Additive Manufacturing. This process builds products from CAD models, autonomously, by overlapping thin layers of material until a three-dimensional object arises [2] [16].

Sensors. “Smart sensors” (e.g.: RFID, RTLS) can be used to measure data about processes, facilities, equipment and products [16].

Data Analytics. Analytics derive insights for better decision-making from the data collected from several sources [16] [17].

Cloud Computing. The storage of information on external remote servers, which are primarily accessible through the Internet [16].

Integrated Management Software. This work proposes this designation for the new management software that allows connectivity from shop-floor level to business analysis.

Extended Reality. This is an umbrella term that encapsulates the technologies that create real-and-virtual environments [18], whether they are providing additional information about reality (mixed reality/augmented reality) or creating totally simulated worlds (virtual reality) [17].

Autonomous Robots. Unlike traditional automated robots, autonomous robots have the ability to work with low, if any, external control [2]. Their adaptability means that they can be used not only for repetitive low-skilled jobs but also in medium-skilled, routine tasks [16].

2.7 Graphic Overview

Deriving from the previous conceptual overview, this dissertation proposes a simple graphic tool for initial I4.0 comprehension, shown in Figure 1. 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.

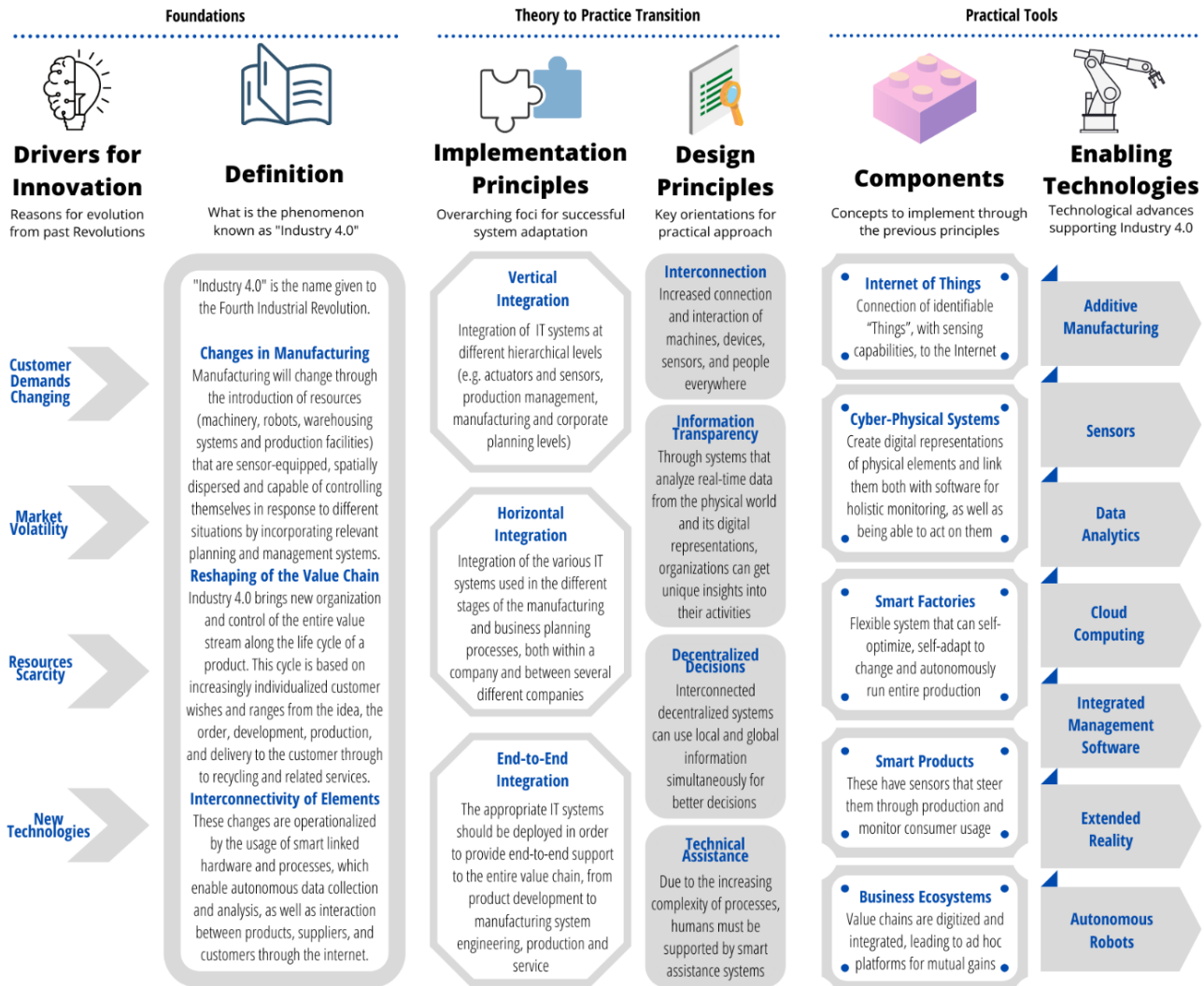


Figure 1. Proposed conceptual overview of Industry 4.0.

3 TOOL FOR INNOVATION

3.1 Development Process

A business model (BM) can be defined as the rationale of how an organization creates, delivers, and captures value [19]. To align the technological developments of I4.0 with economic value creation, companies must undertake business model innovation (BMI) [20].

To develop a guiding tool for BMI through I4.0, it is necessary to research the changes it has brought/is predicted to bring to BMs. These changes are the basis of a set of business opportunities, named "business levers": concrete initiatives that a manager can undertake in order to innovate.

3.1.1 Synthesis of Business Levers

The research focused on economic overviews, works on specific business topics, examples and case studies. Its results serve as the "raw material" for synthesizing the business levers. These are derived from the information gathered through a three-layered strategy:

1st Layer: BMC's Building Blocks. The business model canvas (BMC) is a very popular breakdown of BMs that argues that the main areas of a business can be described through nine "building blocks": Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships and Cost Structure [19]. Here, the impacts of I4.0 on BMs are analyzed according to its effects on each block, which provide a first thematic separation of the information collected.

2nd Layer: BMC's Specifics. Within each block of the BMC, [19] also originally proposed a series of specifics (examples, types, characteristics and examples) that label a company's way of operating in that regard. An updated version of those for I4.0 [21], along with some of the original ones, was used. These specifics serve as a second level of thematic resolution for analysis of I4.0 levers.

3rd Layer: BOS's Four Actions Framework. To help define actionable levers, within each specific, an entrepreneurial layer for innovation is drawn upon: the blue ocean strategy (BOS). The BOS helps construct each lever by assessing its potential

impacts and the interconnections among them [19]; through it, each business opportunity has a set of “associated levers”.

3.1.2 Scope of Applicability

In terms of scope, some of the levers found will not apply to all cases. To assist with that assessment of applicability, each lever presented on the guide has an indication of where it leans on three thematic dichotomies:

Target Audience: B2B vs. B2C. Sales can be business-to-business (B2B), a transaction conducted between one business and another, or business-to-consumer (B2C), the process of businesses selling products/services directly to consumers, with no middleman.

Company Size: SME vs. Big. According to the European Union’s definition, small and medium

enterprises (SMEs) have less than 250 employees, while big companies have more than that.

Value Offering: Service vs. Product. Value propositions can be delivered through products or services. Products are objects that are manufactured, transported and sold, while a service is an intangible item, which arises from the output of one or more individuals.

The classification within these dichotomies is based on the characteristics that separate each end, according to the literature.

3.1.3 Formulation

For the sake of succinctness and practicality, the business levers found are turned into questions, to stimulate the reader’s creativity and make the following guide (Table 1) more interactive than just a sheet of generic “recommendations”.

3.2 Guide for Business Model Innovation

Table 1. 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. <i>Associated levers: L8, L12, L40, L47</i>			
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. <i>Associated levers: L5, L12, L47, L63</i>			
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. <i>Associated levers: L9, L40</i>			
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. <i>Associated levers: L64</i>			
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. <i>Associated levers: L66</i>			
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. <i>Associated levers: L21, L30</i>			
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. <i>Associated levers: L27, L29, L37</i>			
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. <i>Associated levers: L9, L19, L34, L40</i>			
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. <i>Associated levers: L27</i>			
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. <i>Associated levers: L37</i>			
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.			

<i>Associated levers: L31, L62, L64</i>		
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.		
<i>Associated levers: L23, L47</i>		
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.		
<i>Associated levers: L47, L62</i>		
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.		
<i>Associated levers: L1</i>		
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.		
<i>Associated levers: L20, L21, L64</i>		
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.		
<i>Associated levers: L15, L63, L64</i>		
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.		
<i>Associated levers: L40, L61, L63</i>		
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.		
<i>Associated levers: L23, L24, L25, L47</i>		
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.		
<i>Associated levers: L8, L20, L62</i>		
Target Audience: Any	Company Size: Any	Value Offering: Any
L20. How can we have direct online sales channels available and advertised? <i>Associated levers: L13, L17</i>		
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.		
<i>Associated levers: L13, L30, L59</i>		
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).		
<i>Associated levers: L39, L47, L64</i>		
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.		
<i>Associated levers: L34, L47</i>		
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.		
<i>Associated levers: L5</i>		
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.		
<i>Associated levers: L24, L64</i>		
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.		
<i>Associated levers: L37</i>		
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? <i>Associated levers: L45, L47, L66</i>		
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. <i>Associated levers: L58</i>		
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. <i>Associated levers: L37, L40, L41, L43, L44, L45, L55</i>		
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. <i>Associated levers: L58</i>		
Target Audience: Any	Company Size: Any	Value Offering: Any
L48. How can we use rapid prototyping tools for product development? <i>Associated levers: L63</i>		
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. <i>Associated levers: L63, L64</i>		
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. <i>Associated levers: L58</i>		
Target Audience: Any	Company Size: Any	Value Offering: Any
L51. How can we have robots assist the execution of physical tasks? Etalax 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. <i>Associated levers: L63</i>		
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. <i>Associated levers: L63, L64</i>		
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. <i>Associated levers: L55</i>		
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. <i>Associated levers: L43, L44</i>		
Target Audience: Any	Company Size: Any	Value Offering: Any
L55. How can we train our workforce for new relevant skills? <i>Associated levers: L43, L44, L45, L56, L57</i>		
Target Audience: Any	Company Size: Any	Value Offering: Any
L56. How can we keep our software operational and updated? <i>Associated levers: L4, L8, L9, L12, L45</i>		
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. <i>Associated levers: L59</i>		
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. <i>Associated levers: L57</i>		
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 identify a quality defect yet to be noticed in a manufacturer's production run. <i>Associated levers: L40, L42, L44, L45, L62</i>		
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. <i>Associated levers: L47</i>	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? <i>Associated levers: L67</i>	Target Audience: Any	Company Size: Any	Value Offering: Any
L64. How can we use IT outsourcing to simplify internal processes and compensate resource deficits? <i>Associated levers: L67</i>	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. <i>Associated levers: L44, L45</i>	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? <i>Associated levers: L27, L29</i>	Target Audience: Any	Company Size: SME	Value Offering: Any

3.3 Integrated Guide and Canvas

Even though the innovation guide is already a condensation of information, it lacks the simple

visual representation of the BMC. To address that shortcoming, the questions of the guide can be stated on the BMC, as shown in Figure 2.

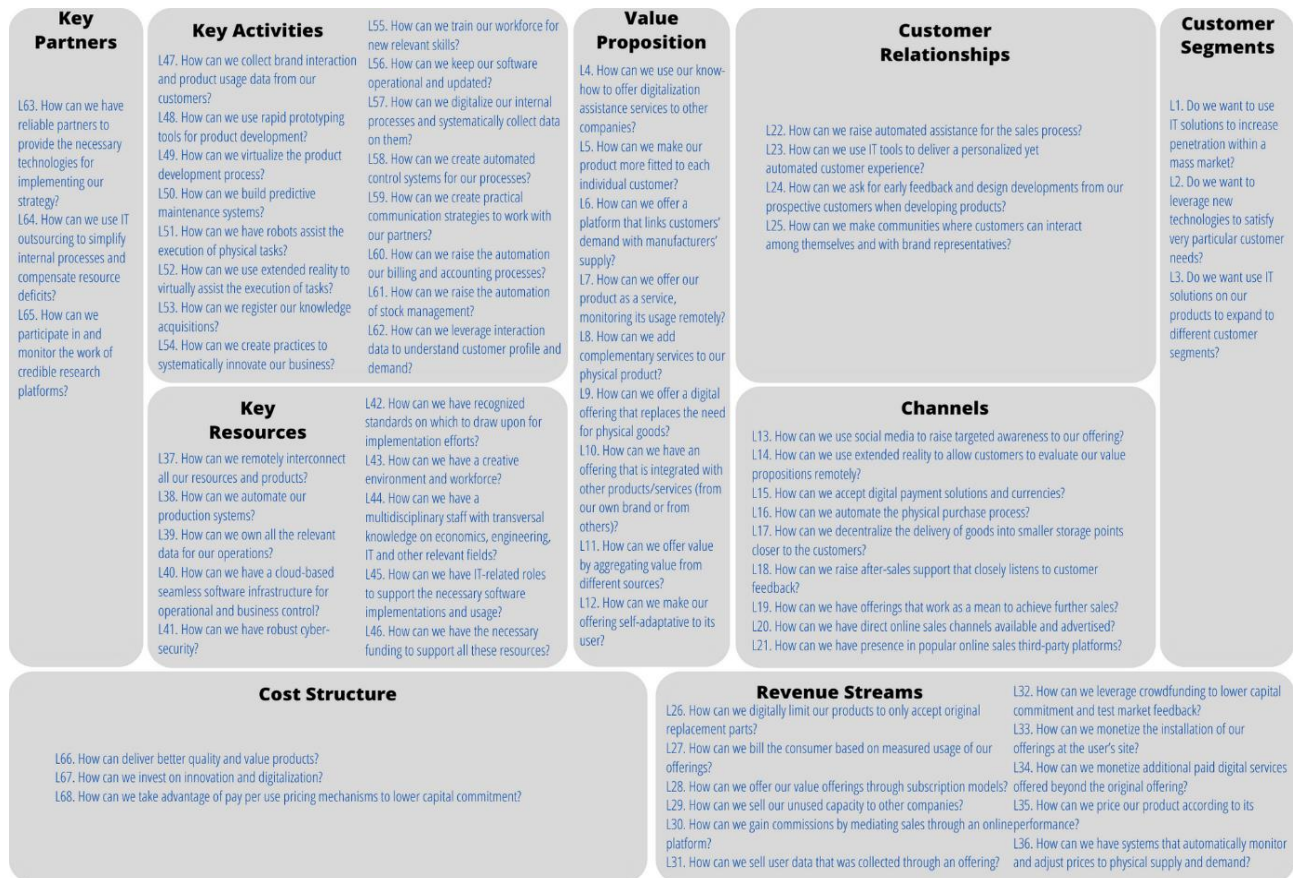


Figure 2. Business Model Canvas with the innovation lever questions distributed by their building block.

3.4 Answering the Questions

The fact that the guide is made up of generic questions may make it hard to be objective when answering them. For that reason, this subsection proposes an approach for organized innovation:

1st Step: Creativity. Product development logic should be applied for this process: the reader 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.

2nd Feasibility. Every idea generated will have some kind of cost that should be quickly estimated to see if the idea is attainable for the context.

3rd Step: Research. If the idea seems feasible, it could be useful to search for similar implementations to the imagined one. Research could reveal unexpected value or problems.

4th Step: Decision. Decide whether the idea proceeds to practice, based on a value-cost relation: is the added value worth the cost?

4 APPLICATION TO A CASE STUDY

4.1 Context

To validate the proposed innovation guide, the next logical step is to apply it to a case study. For it, the innovation guide was applied to a Portuguese enterprise, known here as “Company X” (presented in Figure 3). The author of this document developed the ideas and activities described in this chapter

working in that company between February and December of 2020, with the job of bringing 14.0 BMI.



Figure 3. Presentation of the case study company.

As of February 2020, it was a startup-level enterprise that had developed a pair of complementary physical products but had neither any production planning nor a go-to-market strategy. It had no sales, even though it had secured some minimal funding, and managed to get even more by the end of the year (thus reaching the value shown in Figure 3).

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 electricity or stoves. The intended BM is based on the sale of an initial product and further revenue from recurrent consumables, like what happens with printers and ink cartridges.

4.2 Ideas Generated

Table 2 has a summary of all the ideas generated by applying the innovation guide to Company X, next to the number of the lever that generated them, and their progress status as of late December 2020.

Table 2. 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.
L8	Metallic plate laser marking	Submitting requests for quotation.
	Expand ribbon line	Ribbon models selected.
L12	Build a company app that offers discounts and recipes for good “reheatable” meals	Looking for IT partner app developer.
L13	App suggests reordering heating pads based on usage patterns	To be submitted as design request for IT app developer.
L14	Marketing through Facebook Business	Already extensively done with good return on investment
	Have 360° view of the lunchbox on the sales channel	Approved. Videographer chosen and contract agreed.
L15	Simulation of the rise of temperature of food over time, on the sales channel	Questions over feasibility.
	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.
L19	Head of marketing delivers biweekly compilations of customer feedback	Done ever since.
	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 analyzed 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.
	Conduct crowdfunding campaign	Underway, in pre-campaign stage.
L32	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.
	Use cloud storage Google Drive	Done.
L40	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.
	Establishing minimum complexity criteria for company passwords	Done and enforced.
L41	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 IIEFP 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.
	Use of "Kanban Analytics" add-on on Trello to monitor work productivity and efficiency	Done.
L57	Perform weekly reviews of Kanban Analytics data	Ongoing.
	Add systematic digitalization responsibility to the innovation manager's job	Done.
	Automate Facebook advertising budget control	Done.
L58	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.
	Checking Facebook's demographics data	Periodically done.
L62	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.
	Propose series of virtual I4.0 workshops with incubator and partners	Will be discussed in January 2021.
L65	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 CONCLUSIONS

The main contributes of this work are:

- Synthesis of enabling technologies for I4.0 – section 2.6;
- Conceptual overview and graphic representation – Figure 1.
- A guide for BMI through I4.0 – Table 1;
- A visual integration of the BMC with the questions from the innovation guide – Figure 2;
- An approach for systematically answering the questions of the guide – section 3.4;

REFERENCES

- [1] S. I. Tay, T. C. Lee, A. H. N. Aziati and A. N. A. Ahmad, "An Overview of Industry 4.0: Definition, Components, and Government Initiatives," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10, no. 14, 2018.
- [2] A. G. Özüdođru, E. Ergün and D. Ammari, "How Industry 4.0 Changes Business: A Commercial Perspective," *International Journal of Commerce and Finance*, vol. 4, no. 1, pp. 84-95, 2018.
- [3] N. H. A. Eltrass, "Business Model Innovation in the context of Industry 4.0," Politecnico di Torino, 2019.
- [4] A. Schumacher, S. Erol and W. Sinn, "A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises," *Procedia Manufacturing*, vol. 52, pp. 161-166, 2016.
- [5] K. Girotra and S. Netessine, "Four Paths to Business Model Innovation," *Harvard Business Review*, [Online]. Available: <https://hbr.org/2014/07/four-paths-to-business-model-innovation>.
- [6] C. Burmeister, D. Lüttgens and F. T. Piller, "Business Model Innovation for Industrie 4.0: Why the "Industrial Internet" Mandates a New Perspective on Innovation," *Die Unternehmung*, vol. 70, pp. 124-150, 2016.
- [7] C. J. Bartodziej, *The Concept Industry 4.0 - An Empirical Analysis of Technologies and Applications in Production Logistics*, Wiesbaden: Springer Gabler, 2017.
- [8] H. Kagermann, W. Wahlster and J. Hellbig, "Recommendations for implementing the strategic initiative INDUSTRIE 4.0," Industrie 4.0 Working Group, 2013.
- [9] The Industrie 4.0 Platform, "Implementation Strategy Industrie 4.0 (Translated Version)," 2016.
- [10] Industrial Internet Consortium, "Fact Sheet," September 2015. [Online]. Available: https://www.iiconsortium.org/docs/IIC_FACT_SHEET.pdf.
- [11] S. I. Shafiq, C. Sanin, E. Szczerbicki and C. Toro, "Virtual Engineering Object / Virtual Engineering Process: A specialized form of Cyber Physical System for Industry 4.0," *Procedia Computer Science*, vol. 60, pp. 1146-1155, 2015.
- [12] M. Hermann, T. Pentek and B. Otto, "Design Principles for Industrie 4.0 Scenarios," in *49th Hawaii International Conference on System Sciences*, 2016.
- [13] R. Minerva, A. Biru and D. Rotondi, "Towards a definition of the Internet of Things (IoT)," Institute of Electrical and Electronics Engineers, 2015.
- [14] M. Montanus, "Business Models for Industry 4.0: Developing a Framework to Determine and Assess Impacts on Business Models in the Dutch Oil and Gas Industry," Delft University of Technology, Delft, 2016.
- [15] M. Schroeck, A. Kwan and J. Kawamura, "Ecosystem-driven portfolio strategy," Deloitte, 2020. [Online]. Available: <https://www2.deloitte.com/us/en/insights/focus/industry-4-0/business-ecosystem-strategy.html>.
- [16] L. Bibby and B. Dehe, "Defining and assessing industry 4.0 maturity levels – case of the defence sector," *Production Planning & Control*, vol. 29, no. 12, 2018.
- [17] C. Salkin, M. Oner, A. Usundag and E. Cevcan, "A Conceptual Framework for Industry 4.0," in *Industry 4.0: Managing The Digital Transformation*, Springer, 2018.
- [18] Å. Fast-Berglund, L. Gong and D. Li, "Testing and validating Extended Reality (xR) technologies in manufacturing," *Procedia Manufacturing*, vol. 25, pp. 31-38, 2018.
- [19] A. Osterwalder and Y. Pigneur, *Business Model Generation*, New Jersey: John Wiley & Sons, 2010.
- [20] E. Bucherer and D. Uckelmann, "Business Models for the Internet of Things," in *Architecting the Internet of Things*, D. Uckelmann, M. Harrison and F. Michahelles, Eds., Springer, 2011.
- [21] R. M. Dijkman, B. Sprenkels, T. Peeters and A. Janssen, "Business models for the Internet of Things," *International Journal of Information Management*, vol. 35, no. 6, pp. 672-678, 2015.

- List of ideas generated by the application of the innovation guide to a case study – Table 2.

The present research could be continued by:

- Validation of the outputs in workshops with academics and practitioners;
- Application of the guide to an established company for a different innovation scenario;
- Increasing guide resolution by adding follow-on questions within the existing ones;
- Analysis of environmental/social I4.0 levers.