A DIGITAL INNOVATIONS-DRIVEN REGENERATION MODEL AND CORPORATE SUSTAINABILITY

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A DIGITAL INNOVATIONS-DRIVEN REGENERATION MODEL AND CORPORATE SUSTAINABILITY

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DECLARATION OF ORIGINALITY

I, Abide Coşkun Setirek, certify that

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
- this thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
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ABSTRACT

A Digital Innovations-Driven Regeneration Model
and Corporate Sustainability

The traditional ways of doing business have been changed by digital innovations such as the Internet of things, blockchain and digital currency, data analytics, artificial intelligence, robots, additive manufacturing, etc. Firms can stay competitive using the benefits of digital technologies. The spread of the coronavirus disease in 2019 (COVID-19) all over the world has created a better understanding of the importance of organizations' ability to keep up with digital innovations. In this study, a method for digital innovations-driven business model regeneration is developed and a dynamic business model, which can also be used in the business model regeneration process, to examine the effects of digital innovation strategies on the corporate sustainability is proposed. For this purpose, the existing literature on the business model innovation and system dynamic are examined, and the empirical data are collected from 44 managers using semi-structured interviews to complement gaps in the literature. Moreover, the digital innovations-driven business model regeneration method, which is proposed in this study, is applied to a real case. This study extends the literature on the business model innovation and the dynamic business model. The study can provide strategy analysts and managers with an opportunity to analyze the effects of potential digital innovation strategies on their current business models and to explore the most effective digital innovation strategies in order to regenerate their business model to gain a competitive advantage over their competitors or to sustain their business in light of technological developments.

ÖZET

Dijital İnovasyonlar Odaklı Yenileme Modeli ve Kurumsal Sürdürebilirlik

Geleneksel iş yapma biçimleri, nesnelerin İnterneti, blok zincir ve dijital para birimi, veri analizi, yapay zeka, robotik, eklemeli imalat gibi yeni dijital teknolojilerin ortaya çıkmasıyla önemli ölçüde değişmeye başladı. Firmalar dijital teknolojilerin avantajlarını kullanarak rekabetçi kalmaya devam edebilmektedir. Yeni koronavirus pandemisinin (COVID-19) tüm dünyaya yayılması, dijital inovasyonları mevcut iş modellerine entegre etme yeteneğinin, kuruluşların ayakta kalabilmeleri için hayati önem taşıdığının daha iyi anlaşılmasına neden olmuştur. Bu çalışmada, iş modelinin dijital inovasyon odaklı olacak şekilde yenilenmesine yönelik bir yöntem geliştirilmiş ve dijital inovasyon stratejilerinin kurumsal sürdürebilirlik üzerindeki etkilerini incelemek için iş modelinin yenilenmesi sürecinde de kullanılabilecek dinamik bir iş modeli önerilmiştir. Bu amaç için, mevcut iş modeli inovasyonu ve sistem dinamik literatürü incelenmiş ve bu bilgileri tamamlamak ve doğrulamak için yarı yapılandırılmış görüşmelerle 44 yöneticiden ampirik veriler toplanmıştır. Ayrıca, bu çalışmada önerilen dijital inovasyon odaklı iş modeli yenileme yöntemi gerçek bir vakaya uygulanmıştır. Bu çalışma iş modeli inovasyonu ve sistem dinamik literatürünü genişletmeyi amaçlamaktadır. Çalışma, strateji analistleri ve yöneticilere potansiyel dijital inovasyonların mevcut iş modelleri üzerindeki etkilerini analiz etme, en etkili dijital inovasyon stratejilerini keşfetme ve iş modellerini bu stratejilere göre yenileme imkanı sağlayabilir. Çalışma, kurumların rakiplerine karşı rekabet üstünlüğü elde etmesine ve teknolojik gelişmeler ışığında işlerini sürdürebilmesine yardımcı olabilir.

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ABBREVIATIONS

3D	Three-Dimensional
3DP	Three-Dimensional Printing
A	Activity
AI	Artificial Intelligence
AoP	Accessibility of Product
AoS	Availability of Support
AR	Augmented Reality
AT	Autonomous Things
Awa	Awareness
BMI	Business Model Innovation
C	Capability
CPSs	Cyber-Physical Systems
DA	Data Analytics
DBM	Digital Business Model
DI effect	Digital Innovation Effect
Dmnl	Dimensionless
e-BM	e-Business Model
EC	Edge Computing
ENR	Engineering News-Record’s
HR	Human Resource
ICT	Information and Communication Technology
IE	Immersive Experience Technologies
INTEG	Integration

IoT	Internet of Things
IT	Information Technology
K	Knowledge
LHS	Latin Hypercube Sampling
MR	Mixed Reality
MTs	Mobile Technologies
OECD	Organisation for Economic Co-operation and Development
Q	Quality
R&D	Research and Development
RC	Reality Check
ROE	Return on Equity
ROI	Return on Investment
SC	Supply Chain
VPA	Virtual Personal Assistant
VR	Virtual Reality

CHAPTER 1

INTRODUCTION

The way one works has been revolutionized by digital innovations such as the Internet of things (IoT), wireless networks, artificial intelligence (AI), robotics, augmented reality (AR), cyber-physical systems (CPSs), virtual reality (VR), cloud technology, big data analytics, and simulations are some of these key digital technologies (Ernst & Frische, 2015; Posada et al., 2015; Rüßmann et al., 2015). The ability to adopt these digital innovations has become vital for contemporary organizations. The spread of the coronavirus disease in 2019 (COVID-19) all over the world has created a better understanding of the importance of digital innovations. The closure of schools and offices, the implementation of social distancing, and the long days spent in quarantine have created a greater demand for the use of digital technology. The virus caused a need to move in-person service over to online medical services, online education, online working, and non-contact services in several service sectors became a mandatory need. It is obviously seen that only the companies that can adapt to implementing digital innovations can have a higher probability of success in the digital age.

1.1 Digital innovations

Thanks to CPSs and IoT, all physical devices can connect to the Internet. CPSs incorporate the functions of computing, communications, precision control, coordination, and autonomy (Zhou, Liu, & Zhou, 2015). IoT and CPSs are converging into the Internet of services, which uses cloud technologies (Pisching, Junqueira, Filho, & Miyagi, 2015). On the other hand, cloud technologies can be used to increase data sharing across company boundaries, boost agility and flexibility of system performance, and reduce costs by bringing systems online (Liu & Xu, 2017). Systems are also becoming both flexible and reconfigurable through robotics (Bolmsjo, 2014). Simulation optimization-based tools are used for complex systems and automation technologies. As a result, systems are becoming smarter by using these technologies. Moreover, big data and analytics are used for scaling and evolving information technology (IT). The data with larger volumes and speeds can be analyzed more precisely and faster decisions can be made using these technologies.

Another disruptive technology is the blockchain technology. Blockchain is a type of distributed ledger technology of all transactions across a peer-to-peer network and is the technology behind the large variety of digital currencies transfer. One of the most active areas of the blockchain is in the financial sector, especially in the field of cryptocurrency; however, its scope and field of application are not limited to this. It provides an opportunity to create reliable systems and platforms such as blockchain-based healthcare systems, insurance marketplaces, advertising systems, copyright platforms, voting systems, music platforms, etc. (Chen, Xu, Shi, Zhao, & Zhao, 2018).

Digital technologies are also found in the worlds of production, manufacturing, logistics, etc. Some of the related key technologies are three-dimensional printing (3DP), advanced sensors, robotics, and drones. For example, 3DP can contribute to the sustainability of firms with fewer material resources and rapidly adjusting to new technologies and designs (Bansal & DesJardine, 2014).

1.2 Business model

With the benefits of digital innovations like improvements in productivity and reduction in cost (Hess, Benlian, Matt, & Wiesböck, 2016), firms can stay competitive and foster new growth potentials (Stief, Eidhoff, & Voeth, 2016). The strength of digital technologies stems from how companies are able to integrate them into their existing business strategies (Kane et al., 2015). The business model is described as "an interface or a theoretical layer between the business strategy and the business processes" (Al-Debei, El-Haddadeh, & Avison, 2008). Therefore, the regeneration of business processes and strategies is becoming an increasingly crucial factor for survival in the digital age. Regeneration means "refresh, reassess, or to make new and more relevant" (Mbele, 2010). Regeneration "includes not only the improvement of existing processes but a fundamental revisiting of the direction and portfolio of opportunities a firm is focused" (Muzyka, De Koning, & Churchill, 1995). More studies are required, however, for how a new and more relevant business model can be regenerated by focusing on digital innovations.

1.3 Corporate sustainability

According to the resource-based theory, a firm must continually improve its resources and capabilities for benefiting the advantage of changing conditions (Barney, 1991). On the other hand, the new external environments require new strategies for companies that want to prosper and survive (Gottschalk, 2007). According to business demography indicators in The Organization for Economic Co-operation and Development's (OECD) 2017 statistics (ISIC Rev. 4), the death rate for enterprises is about 8.5% (OECD, 2020). Technological development one of the more important extrinsic factor which can affect business strategies. Making the right strategic choice about which digital innovation strategy to choose is vital for organizations. The approaches of strategic choice theory focus attention on analyzing technologies and incorporating that analysis into the firms' strategic plans (Stacey, 2007). A business model perspective is essential for organizations to attain a sustainable competitive advantage (Geissdoerfer, Vladimirova, & Evans, 2018). Companies that have an innovative business model can better sustain their businesses (Pedersen, Gwozdz, & Hvass, 2018). A sustainable business model is "the activity system of a firm which allocates resources and coordinates activities in a value creation process" (Lüdeke-Freund, 2009). A firm level of analysis explores the resources and capabilities that offer the firm a competitive advantage, and this analysis is focused on the resource-based view (Bansal & DesJardine, 2014).

Corporate sustainability requires "meeting the needs of the firm's direct and indirect stakeholders maintaining and growing its economic, social, and environmental capital" (Dyllick & Hockerts, 2002, p. 131). Economic, social, and environmental sustainability are known as three triple-bottom-line outcomes for corporate sustainability (Elkington, 1998). Since economic corporate sustainability is a prerequisite for a corporation's survival, it is an important one for a corporation (Steurer, Langer, Konrad, & Martinuzzi, 2005).

1.4 System dynamics

Associating the firm's resource-based view with system dynamics can improve the firm's performance (Dierickx & Cool, 1989). Complex dynamic feedback systems have been studied using a system dynamics methodology to develop strategies for management in terms of change (Barlas, 2002; Forrester, 1995; Hajiheydari & Zarei, 2013). System dynamics apply a "system thinking" approach to the entire business system to look at both problematic processes and to provide a policy analysis (Thurlby & Chang, 1995). System dynamic models help managers design and pilot their organizations better (Sterman, 2000). Researchers can study not only the firm's profitability at a certain point in time but also look at its levels of sustainability over time (Bansal & DesJardine, 2014). By constructing causal loop diagrams, a scientific dynamic system model can identify the relationships among business model variables and investigate their evolutionary dynamics (Shao & Shi, 2013).

1.5 Research questions and objectives

Although there have been previous studies on the technology innovation-induced business model change and the impacts of technologies on the business model and corporate sustainability, most have focused on either only one or a few technologies such as the Internet, mobile applications, etc., or one or few industries. In literature, there is a gap that requires studies with the analysis of the impacts of up-to-date disruptive innovations on the business model and digital innovation strategies on corporate sustainability and with digital innovations-driven business model innovation.

Therefore, more studies are required for guiding the following questions, which are the research questions of this study:

- How can a business model be regenerated with a focus on digital innovations?
- How do digital innovation-driven business strategies affect business models and business performance, especially corporate sustainability, over time?

The following objectives are stated for this study in order to answer the research questions:

- to develop a method for digital innovations-driven business model regeneration considering the differences in industries
- to develop a dynamic business model in order to explore the impacts of different digital innovation strategies on the dynamic circulation relationship in terms of the entire business model, and business performance, especially corporate sustainability

1.6 Scientific value of the study

This study brings together the fields of digital innovation and corporate sustainability with the business model perspective and the system science approach. It extends the business model, BMI, corporate sustainability, and system dynamics literature by proposing a method for digital innovations-driven business model regeneration which sheds light on the industry differences and by proposing a digital innovations-driven dynamic business model that can be used for what-if analysis, which investigates the effects of digital innovation strategies on business performance.

From a practitioner perspective, the study allows strategy analysts and managers to analyze the impacts of potential digital innovation strategies on their current business models so that they can experiment as to how the business reacts to these strategies. This will allow them to explore the most effective digital innovation strategies for maintaining sustainability, and hence to helps them to regenerate their business model. This study can help companies to be able to obtain a competitive advantage or sustain their businesses in the light of technological developments.

1.7 Structure of the thesis

The remaining parts of the thesis are structured as follows: the literature review is given in Chapter 2; the methodology of the study is explained in Chapter 3, the findings of the literature review and interviews are used to develop a digital innovation-driven business model regeneration method in Chapter 4; the proposed method is applied to a real case with the case study in Chapter 5; the details on the construction of a digital innovation-oriented dynamic business model, the importance of which has emerged during the case study and which can be used in the business model regeneration process, are given in Chapter 6; the validation tests and analysis of the dynamic business model is made in Chapter 7, the scenario analysis results are given in Chapter 8, and the discussion of all results, the main findings from the analysis are included as well as the implications for both research and practice, a discussion of the limitations of the study, and suggestions for future studies in Chapter 9.

CHAPTER 2

LITERATURE REVIEW

The literature is reviewed comprehensively and presented in this chapter. In order to review the most relevant studies, the following topics are examined: Business model, e-business model (e-BM), BMI, digital business model (DBM)/digital innovations-driven BMI, digital innovations and corporate sustainability, and the system dynamics with a focus of business model, digital innovations and corporate sustainability.

2.1 Business model

In this part, first, the definitions, themes, and objectives for a business model are examined. Then, the elements, components, characteristics, building blocks or pillars of a business model, e-BM, or BMI are identified from reviewing the strategies, architectures, frameworks, and models.

2.1.1 Definition and objectives of business model

In some business model research, researchers have attempted to define the business model. In this study, these definitions are compiled from the literature, and themes of the definitions are specified. Some authors defined the business model, considering the general meaning of the business model (Table 1), whereas others tried to define the business model with its components (Table 2).

Table 1. Definition of Business Model

BM Definition	Theme(s)	Author(s), Year
"The organization's core logic for creating value"	value creation	(Linder & Cantrell, 2000a, pp. 1–2)
"A statement of how a firm will make money and sustain its profit stream over time"	revenue model	(Stewart & Zhao, 2000, p. 290)
"The content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities"	business transactions value creation	(Amit & Zott, 2001)
"A business model describes the logic of a 'business system' for creating value that lies beneath the actual processes"	business processes value creation	(Petrovic, Kittl, & Teksten, 2001)
"A loose conception of how a company does business and generates revenue"	business processes revenue model	(Porter, Michael, & Gibbs, 2001, p. 73)
"A focusing device that mediates between technology development and economic value creation" "The heuristic logic that connects technical potential with the realization of economic value"	technology value creation	(Chesbrough & Rosenbloom, 2002, pp. 532–535)
"Stories that explain how enterprises work"	business processes	(Magretta, 2002, p. 4)
"A model of an existing business or a planned future business. A model is always a simplification of the complex reality"	business plan	(Stähler, 2002, p. 6)
"A detailed conceptualization of an enterprise's strategy at an abstract level, which serves as a base for the implementation of business processes"	business strategy business processes	(Camponovo & Pigneur, 2003, p. 4)
"A term often used to describe the key components of a given business"	business components	(Hedman & Kalling, 2003, p. 49)
"A concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets"	architecture business strategy customers	(Morris, Schindehutte, & Allen, 2005, p. 727)
"A representation of a firm's underlying logic and strategic choices for creating and capturing value within a value network"	business strategy value capturing value creation value network	(Shafer, Smith, & Linder, 2005, p. 202)
"A system manifested in the components and related material and cognitive aspects"	business components business logic resources	(Tikkanen, Lamberg, Parvinen, & Kallunki, 2005, p. 792)
"A blueprint collaborative effort of multiple companies to offer a joint proposition to their consumers"	partners business transactions value proposition	(Haaker, Faber, & Bouwman, 2006, p. 646)
"The core business of an organization and is useful to describe (and even prescribe) the organization from the perspective of its main mission, and the products and services that it provides to its customers"	mission value proposition customers	(Janssen, Kuk, & Wagenaar, 2008, p. 204)
"A configuration of activities and of the organizational units that perform those activities both within and outside the firm designed to create value in the production (and delivery) of a specific product/market set"	business activities customers value creation	(Santos, Spector, & Van der Heyden, 2009, p. 45)
"A reflection of the firm realized strategy"	business strategy	(Casadesus-Masanell & Ricart, 2010, p. 195)
"The description of the rationale of how an organization creates, delivers, and captures value"	value creation value capture value delivery	(Osterwalder & Pigneur, 2010, p. 14)
"A simplified and aggregated representation of the relevant activities of a company"	business activities	(Wirtz, Pistoia, Ullrich, & Göttel, 2016, p. 41)

Table 2. Definition of Business Model with Its Components

BM Definition(s)	Theme(s)	Author(s), Year
"An architecture of the product, service and information flows, including a description of the various business actors and their roles; a description of the potential benefits for the various business actors; a description of the sources of revenues"	revenue model value proposition	(Timmers, 1998, p. 2)
"A strategy that reflects the architecture of a virtual organization along three main vectors: customer interaction, asset configuration, and knowledge leverage"	customer relationship resources	(Venkatraman & Henderson, 1998, pp. 33–34)
"A unique blend of three streams that are critical to the business. These include the value stream for the business partners and the buyers, the revenue stream, and the logistical stream"	customers partners revenue model value proposition	(Balasubramaniam Mahadevan, 2000, p. 59)
"The method by which a firm builds and uses its resources to offer its customers better value than its competitors and to make money doing so"	customers resources revenue model value offer	(Afuah & Tucci, 2001)
"The architecture of a firm and its network of partners for creating, marketing and delivering value and relationship capital to one or several segments of customers in order to generate profitable and sustainable revenue streams"	customers partners revenue model value creation	(Dubosson-Torbay, Osterwalder, & Pigneur, 2001, p. 7)
"A description of roles and relationships of a company, its customers, partners and suppliers, as well as the flows of goods, information and money between these parties and the main benefits for those involved, in particular, but not exclusively the customer"	customers partners value proposition	(Bouwman, 2002, p. 3)
"A set of strategies for corporate establishment and management including a revenue model, high-level business processes, and alliances"	business processes partners revenue model	(Leem, 2002, p. 78)
"A conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value relationship capital, to generate profitable and sustainable revenue streams"	business components business logic customers partners revenue model value offer	(Osterwalder, Pigneur, & Tucci, 2005, pp. 17–18)
"The particular business concept (or way of doing business) as reflected by the business's core value proposition(s) for customers; its configured value network to provide that value, consisting of own strategic capabilities as well as other (e.g. outsourced/allianced) value networks; and its continued sustainability to reinvent itself and satisfy the multiple objectives of its various stakeholders"	capabilities customers value proposition value network business strategy	(Voelpel, Leibold, Tekie, & Von Krogh, 2005, p. 40)
"The means by which a firm is able to create value by coordinating the flow of information, goods and services among the various industry participants it comes in contact with including customers, partners within the value chain, competitors and the government"	customers partners value creation value proposition	(Kallio, Tinnilä, & Tseng, 2006, pp. 282–283)
"The ways of creating value for customers and the way in which a business turns market opportunity into profit through sets of actors, activities, and collaborations"	business activities customers revenue model value creation	(Rajala & Westerlund, 2007, p. 118)
"An abstract representation of an organization, be it conceptual, textual, and/or graphical, of all core interrelated architectural, co-operational, and financial arrangements designed and developed by an organization, as well as all core products and/or services the organization offers based on these arrangements that are needed to achieve its strategic goals and objectives"	business strategy cost structure partners revenue model value offer	(Al-Debei et al., 2008, p. 8)
"A structural template of how a focal firm transacts with customers, partners, and vendors"	customers business transactions partners	(Zott & Amit, 2008, p. 5)
"The logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value"	cost structure customers revenue model value delivery value proposition	(Teece, 2010, p. 179)

In addition to themes, objectives in these definitions are also examined and categorized (Table 3). Most researchers specify value-related and revenue-related objectives as the main business model objectives. Other researchers address objectives that relate to the establishment, management, and continuity of an organization.

Table 3. Business Model Objectives

Objective	Citation(s)
create value	(Amit & Zott, 2001; Chesbrough & Rosenbloom, 2002; Kallio et al., 2006; Linder & Cantrell, 2000b; Petrovic et al., 2001; Rajala & Westerlund, 2007; Santos et al., 2009; Shafer et al., 2005)
offer value	(Afuah & Tucci, 2001; Haaker et al., 2006)
deliver value	(Osterwalder et al., 2005, pp. 17–18; Teece, 2010, p. 179)
support a value proposition	(Teece, 2010, p. 179)
make money	(Afuah & Tucci, 2001)
profit	(Rajala & Westerlund, 2007, p. 118)
generate revenue	(Dubosson-Torbay et al., 2001, p. 7; Osterwalder et al., 2005, pp. 17–18; Porter et al., 2001, p. 73)
satisfy objectives	(Voelpel et al., 2005, p. 40)
achieve strategic goals and objectives	(Al-Debei et al., 2008, p. 8; Casadesus-Masanell & Ricart, 2010, p. 195)
establish and manage the corporate	(Leem, 2002, p. 78)
describe an organization	(Bouwman, 2002, p. 3; Janssen et al., 2008, p. 204; Timmers, 1998, p. 2; Venkatraman & Henderson, 1998, pp. 33–34)
create a market	(Osterwalder et al., 2005, pp. 17–18)
work the business	(Magretta, 2002, p. 4)
implement business processes	(Camponovo & Pigneur, 2003, p. 4)
create competitive advantage	(Morris et al., 2005, p. 727; Osterwalder et al., 2005, pp. 17–18)
exploit business opportunities	(Amit & Zott, 2001)
continue sustainability	(Voelpel et al., 2005, p. 40)

With the analysis of all these themes and objectives which are obtained from the definitions, a definition for the business model is constructed (Figure 1). Therefore, in this study, the business model is defined in the light of the literature as a conceptual, textual, or graphical representation of business system logic or way of doing business including architectural, co-operational, and financial arrangements to achieve revenue and value-related goals and objectives for its customers through sets of business activities using organizational resource and competencies within the value chain for collaboration with value network actors.

- **What** — A conceptual, textual, or graphical representation of business system's logic or way of business including architectural, co-operational, and financial arrangements
- **Why** — in order to achieve revenue and value related goals and objectives
- **to Whom** — to its customers
- **How** — through sets of business activities using organizational resource and competencies
- **Where** — within the value chain
- **with Whom** — with collaboration of value network actors.

Figure 1. Business model definition structure

2.1.2 Business model components

Several researchers have expressed the business model with its parts. The business model is "a system manifested in the components and related material and cognitive aspects" (Tikkanen et al., 2005, p. 792). Various terms have been used in the literature when dealing with the parts of the business model, e-BM, and BMI such as elements, components, characteristics, building blocks, pillars, etc.

The activity systems perspective of Zott and Amit (2010) on value creation has two sets of design parameters: design elements which are content, structure, and governance) and design themes which are novelty, lock-in, complementarities, and efficiency. Amit and Zott (Amit & Zott, 2001) linked their design themes with the value chain analysis (Porter, 1985), Schumpeter's theory of economic development (Schumpeter, 1961), the resource-based view (Amit & Schoemaker, 1993; Penrose, 1959; Peteraf, 1993; Wernerfelt, 1984), in strategic network theory (Gulati, 1999) and transaction cost economics (Willianson, 1975). Teece's (2010) value-centered perspective on the business model depends on value creation, value delivery, and value capture components. The business model canvas, which is the most common and widespread tool to develop and document a business model is developed by Osterwalder and Pigneur (2010, pp. 20–40) and consists of the following nine building blocks:

- Customer segments: “the different groups of people or organizations an enterprise aims to reach and serve”
- Value proposition: “the bundle of products and services that create value for a specific customer segment”
- Channels: “how a company communicates with and reaches its customer segments to deliver a value proposition”
- Customer relationships: “the types of relationships a company establishes with specific customer segments”
- Revenue streams: “the cash a company generates from each customer segment”
- Key resources: “the most important assets required to make a business model work”
- Key activities: “the most important things a company must do to make its business model work”
- Key partnerships: “the network of suppliers and partners that make the business model work”
- Cost structure: “all costs incurred to operate a business model”

In this section, business model components are gathered from the literature, collected under specified titles, and listed according to the number of referenced by authors (Table 4). Some components that are written as italic in Table 4, are generally specified as business model domain or category title of the components in literature. Components which are studied indirectly are signed with the underlined checkmark in the table.

2.2 Business model innovation

Various internal and external factors can force changes in ways of doing business. The idea of applying a new approach leads a company to use BMI (Gambardella & McGahan, 2010). According to Bucherer et al. (2012), it is a process that innovates the way of doing business and its key elements. Indeed, George and Bock (2011, p. 88) defined BMI as a “punctuated phenomena that follow disruptions or enactment of new opportunities”.

Table 4. Business Model Components

Components	e-BM (Timmers, 1998)	BM (Markides, 1999)	BM (Applegate & Collura, 2000)	BM (Linder & Cantrell,	e-BM (Afuah & Tucci, 2001)	e-BM (Gordijn, Akkermans,	BM (Hamel, 2001)	BM (Betz, 2002)	e-BM (Weill & Vitale, 2001)	BM (Chesbrough & Rosenbloom, 2002)	e-BM (Dubosson-Torbay et al., 2001)	e-BM (Osterwalder & Pigneur, 2002)	BM (Hedman & Kalling, 2003)	BMI (B Mahadevan, 2004)	BM (Osterwalder &	BM (Pateli & Giaglis, 2005)	BM (Morris et al., 2005)	BM (Shafer et al., 2005)	BM (Morris, Schindehutte,	BM (Chesbrough, 2007)	BM (Hwang & Christensen, 2007)	BM (Demil & Lecocq,	BMI (Johnson, Christensen,	BM (Osterwalder & Pigneur, 2010)	BM (Nenonen & Storbacka, 2010)	BMI (Teece, 2010)	BM (Yunus, Moingeon, &	e-BM (Magnusson, 2011)	e-BM (X. Zhang, Williams, &	BM (Im & Cho, 2013)	BMI (Gassmann,	BMI (Marolt, Lenart,	BMI (Rayna & Strukova, 2016)	BMI (Spieth & Schneider, 2016)	BMI (Wirtz et al., 2016)	#
Customer/Market			✓		✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓			✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	24
Value Proposition			✓	✓	✓				✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓			23
Revenue	✓			✓	✓			✓	✓		✓	✓			✓	✓		✓	✓	✓		✓		✓	✓		✓	✓		✓	✓			✓		20
Activities				$\underline{✓}$	✓	✓		$\underline{✓}$			✓	✓	✓			✓		✓	✓		✓	$\underline{✓}$	✓	✓				✓				$\underline{✓}$				16
Resources							✓	✓			✓	✓	✓			✓		✓			✓	✓	✓	✓	✓					✓				✓		14
Strategy	$\underline{✓}$						✓		✓	$\underline{✓}$	$\underline{✓}$		$\underline{✓}$				$\underline{✓}$	✓	✓	$\underline{✓}$					✓			✓						$\underline{✓}$	✓	14
Profit/Margin								✓		✓	✓	✓			✓			✓			✓	✓	✓				✓	✓								11
Cost Structure										✓	✓	✓			✓	✓		✓	✓					✓			✓	✓						✓		11
Capabilities			✓		✓						✓	✓			✓		✓	✓	✓						✓				✓							10
Partnerships						✓					✓	✓			✓				✓					✓				✓	✓	✓				✓		10
Channels				✓		✓			✓						✓									✓				$\underline{✓}$		✓			$\underline{✓}$	$\underline{✓}$		9
Value Offering						✓							✓				✓	✓									✓	✓				✓		✓		8
Value Chain										✓			$\underline{✓}$			✓		$\underline{✓}$		✓							✓				✓	✓				8
Value Network	$\underline{✓}$					$\underline{✓}$	✓			✓						✓		✓		✓					✓											8
Infrastructure		✓									✓	✓			✓				✓									✓	✓							7
Customer Relationships		✓									✓	✓			✓			✓						✓												6
Value Creation																		✓	✓							✓							✓	✓	✓	6
Finance		✓									✓	✓					✓	✓											✓							6
Competencies									✓									✓				✓						✓						✓		5
Value Delivery														✓												✓							✓			3
System									$\underline{✓}$																			✓				$\underline{✓}$				3
Value Capture																		✓								✓							✓			3
Value Configuration							✓								✓																					2
Value Architecture																																		✓		1
Sustainability					✓																															1

According to Osterwalder and Pigneur (2010), BMI is realized for meeting missed market needs in the current market so as to offer new technologies, products or services to that market, for improving, disrupting, or transforming the current market with a new business model, or even for creating an entirely new market.

A business model requires innovation because of intrinsic (entrepreneur, social capital) and extrinsic (market demand, technological advancement, and the economic environment's change and intense competition) sources (Casprini, Pucci, & Zanni, 2014). Firms should adapt their business models to such changes (Linder & Cantrell, 2000b). Rapid development in the information and communication technology (ICT) industry is one of the changes that drive BMI (Amit & Zott, 2010).

Researchers studied BMI from different perspectives. Andreini and Bettinelli (Andreini & Bettinelli, 2017) reviewed BMI literature systematically and categorized the findings under seven macro themes: definitions, drivers, outcomes, barriers, enablers, tools, and processes. Foss and Saebi (2017) present a comprehensive systematic review of the articles on BMI published between 2000 and 2015. They collected the findings under the following titles: conceptualization, process, outcome, and consequences of BMI. Mezger (2014) categorized the processes and routines for BMI based on BMI-related capabilities as similar to Teece (2010) who emphasized the importance of dynamic capabilities for BMI. The aspects of BMI in the literature are reviewed and they are listed in Table 5. In this study, the degree of innovation refers the impact level of the change; the domains of BMI are the areas change is needed; the process of BMI address the change process; the reach of BMI implies the scope of the change; the source of BMI are the trigger of the change; the types of BMI are the types of changes in a business model.

Table 5. Business Model Innovation Aspects

Aspect	Items	Citation(s)
Degree	incremental, radical	(Zott & Amit, 2002)
Degree	improvement, catch-up, replacement, actual innovation	(Mitchell & Coles, 2003)
Degree	incremental, radical	(Cavalcante, Kesting, & Ulhøi, 2011)
Degree	adjustment, adoption, improvement, redesign	(Schaltegger, Lüdeke-Freund, & Hansen, 2012)
Degree	changes, incremental, radical	(Witell & Löfgren, 2013)
Degree	incremental, modular, architectural, radical	(Windahl, 2015)
Degree	stabilization model, continuing the evolution adaption model, the extension model, the migration model, finalizing using the radical innovation model	(Wirtz, 2016)
Domain	operational, strategic, economic	(Morris et al., 2005)
Domain	economic, environmental, social, multidimensional, holistic	(Stubbs & Cocklin, 2008)
Domain	technological, social, organizational	(Bocken, Short, Rana, & Evans, 2014; Boons & Lüdeke-Freund, 2013)
Domain	strategic shift, organizational shift, change in the remuneration system	(Ruimin, 2015)
Domain	technology, strategy, organization	(Wirtz, 2016)
Process	understand, identify the Internet's impact, change	(Auer & Follack, 2002)
Process	understand, identify technology's influence, change	(Pateli & Giaglis, 2005)
Process	mobilize, understand, design, implement, manage	(Osterwalder & Pigneur, 2010)
Process	initiation, ideation, integration, implementation	(Gassmann et al., 2014)
Process	baseline determination, rethinking, ideation, prioritization, integration, implementation	(Laukkanen, Huiskonen, & Koivuniemi, 2015)
Process	observing, synthesizing, generating, refining, implementing	(Amit & Zott, 2016)
Process	initial situation, idea generation, feasibility study, prototyping, decision-making, implementation, monitoring and controlling and securing sustainability	(Wirtz, 2016)
Process	initiation, concept, identification, implementation, evaluation	(Schaller, Vatananan-Thesenvitz, & Stefania, 2018)
Reach	company, market, industry, world	(Taran, Boer, & Lindgren, 2015)
Source	technological, market related, commercial	(de Reuver, Bouwman, & MacInnes, 2009)
Source	market forces, industry forces, key trends, macroeconomic factors	(Osterwalder & Pigneur, 2010)
Source	scientific, economic, market, political, social	(Braun, Berlin, & Juni, 2012)
Source	internal opportunity, external opportunity, internal threat, external threat	(Bucherer et al., 2012)
Source	internal, external	(Carayannis, Edgeman, & Sindakis, 2013)
Source	intrinsic (entrepreneur, social capital), extrinsic (market demand, technological advancement, and the economic environment’s change and intense competition)	(Casprini et al., 2014)
Source	changing environment, sustainability, untapped market opportunities, new entrants, changing stakeholder/s	(Mudaly, 2016)
Type	renewal, realization, extension, journey	(Linder & Cantrell, 2000a)
Type	creation, extension, revision, termination	(Cavalcante et al., 2011)
Type	original innovation, induced innovation, imitative innovation	(Y. Zhang & Wen, 2017)

In BMI process literature, the “evolaris methodology”, the process stages of which can be seen in Table 5, based on system theory and action research is proposed to change the business model (Auer & Follack, 2002) and some methodology grounded on this methodology. For example, Pateli and Giaglis (2005) proposed a research methodology for business model evolution basing on the evolaris methodology and iMEDIA methodology and using renewal and extension types of BMI (Linder &

Cantrell, 2000a) and the approach of Kulatilaka and Venkatraman (2001) for defining scenarios.

Moreover, some researchers have focused on a specific industry in their BMI studies. For example, BMI strategies, architectures, frameworks, and models are studied for healthcare (Hwang & Christensen, 2007), beverage (Matzler et al., 2013), digital trade publishing (Shiying, 2013), electric vehicles manufacturing (Bohnsack, Pinkse, & Kolk, 2014), medicine (Ou & Perng, 2014), and banking (Ivens Pitta Ferraz, 2012; Mustafa, 2015), while BMI components are specified for the beverage (Matzler et al., 2013), education (Xiaojun et al., 2013), and health care (Castano, 2014) industries. Pels and Kidd (2015) presented a new conceptualization of BMI using the three dimensions of firm-centric, environment, and customer-centric for the healthcare industry.

2.3 Digital innovations-driven business model

Digital technologies are described as "combinations of information, computing, communication, and connectivity technologies" (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013, p. 471). Digital innovations have unique characteristics that differentiate them from earlier technologies; these are "reprogrammability, the homogenization of data, and the self-referential nature of digital technology" (Yoo, Henfridsson, & Lyytinen, 2010, p. 726).

Large professional service and technology companies have announced the technology trends for the future. Oracle (2015) suggests seven digital technologies as follows: Analytics for improving business performance, big data for identifying new opportunities, cloud technology for saving time and money, social media for contributing to business value, collaboration for workforce engagement, mobile for enabling 7/24 access to customer, and wearable computing for driving efficiency. According to the 2016 PricewaterhouseCoopers report (PWC, 2016), the essential eight technologies which will have the most impact over the next three to seven years are blockchain, drones, IoT, robots, 3DP, VR, AR, and AI. Deloitte (2018) recognizes the 2018 technology trends as reengineering technology, no-collar workforce, enterprise data sovereignty, the new core, digital reality, blockchain to blockchains, application programming interface imperative, exponential technology watch list, and innovation opportunities on the horizon. Gartner (Panetta, 2018) specified top 10 strategic technology trends for 2019 as follows: Autonomous things (AT) like robots, autonomous vehicles, etc., augmented analytics, AI-driven development, digital twins, empowered edge, IE, blockchain, smart spaces like smart cities, digital workplaces, smart homes, connected factories, etc., digital ethics and privacy, and quantum computing. IHS Markit (Markit, 2018) identified the top eight technology trends for 2018 as AI, IoT, cloud technology and virtualization, connectivity, ubiquitous video, computer vision, robots and drones, and blockchain. According to these reports, current digital innovations can be gathered under the titles of CPSs and edge computing (EC), IoT, data analytics (DA) and AI (chatbots, virtual personal assistants (VPA), etc.), cloud technology, and immersive experience technologies (IE) which consists of VR, AR, and mixed reality (MR), and AT which include robots, drones, autonomous vehicles, and so on, blockchain, 3DP, and mobile technologies (MTs) for the current study.

Schumpeter’s (1961) innovation theory emphasizes the importance of technology. According to that theory, innovation is the source of value creation, and it occurs with a new product, the production method market, source of raw material supply, or organization in any industry. Over the last one or two decades, digital innovation-focused business models have started to be studied. Business strategies are an increasingly crucial factor for survival in the digital age. Bharadwaj and his colleagues (2013) identified four key themes as attributes of a digital business strategy: the scope of digital business strategy, the scale of digital business strategy, the speed of digital business strategy, and the sources of business value creation and capture in digital business strategy. Independent of any industry or firm, the four essential dimensions of digital innovation strategies are the use of technologies, changes in value creation, structural changes, and financial aspects (Matt, Hess, & Benlian, 2015). Researchers have studied technology-driven and market-driven disruptive BMI (Habtay, 2012), DBM optimization (Weill & Woerner, 2013), and digital business strategy and digital business success (Vosloo, 2015), and specified their critical business model components. Moreover, de Almeida Pereira et al. (2015) and Vorbach et al. (2017) determined the characteristics of disruptive innovation. The stages of developing DBM/digital innovations-driven BMI are also studied by some researchers. MacInnes (2005) specified four stages: Emphasizing technical issues, considering environmental factors, incorporating traditional business model factors, and focusing on sustainability factors. Amshoff et al. (2015) developed a method to identify nascent business model patterns and combine them to develop new business models. The stages of this method include technology analysis, business model analysis, pattern identification, business model design, and business model assessment. The innovation process stages in digital innovation projects were identified as idea generation, development, and marketization by Antonopoulou et al. (2017).

Digital innovations can affect one or more business model components differently. According to Prem (2015), thanks to CPSs and IoT, data can be generated and collected, and the analysis of these data then provides the basis for the shift from products to services. Besides, DA offers better personalization and individualization of products and services. Therefore, the value proposition component is affected positively. Prem (2015) stated that key activities are affected by robotics with highly automatized processes, while digital interfaces affect the channel component by eliminating any intermediaries. Another example he gives is that the digitization of products leads to service fees, brokerage revenue, and licensing, by detecting the potential anticipation of maintenance needs with sensors, thereby contributing to revenue. According to Baoliang (2015), the IoT business model is a multidimensional construct composed of both efficiency and novelty based on sensing and intelligence. IoT enhances the efficiency of production processes (Laudien & Daxböck, 2016). According to Laudien and Daxböck (2016), it decreases production costs by managing inventory, decreasing the rate of machine downtime, improving the quality control, and leads to time efficiency through communication among machines and tracking systems.

On the other hand, Simonsson and Magnusson (2019) identified some challenges of digital innovations that are related to customer interaction, offer delivery, platform strategies, and organization. Cyber-attacks have become a critical challenge for digital technologies such as CPSs and edge computing, IoT, AI, cloud, AT, blockchain, mobile technologies, etc. The ability to protect or defend the use of these innovations from cyber-attacks like unauthorized access, distributed denial of service attacks, code and SQL injection attacks, man-in-the-middle attacks, DNS tunneling, etc. is critical for organizations. For example, sharing of sensitive information is critical for financial transactions and both effective platform-level and application-level cybersecurity are required. Similarly, a platform without guaranteed latency provisions guaranteed platforms are required for time-critical functions of AT (Greer, Burns, Wollman, & Griffor, 2019). Organizations should consider cybersecurity concepts like system characterization, threat and vulnerability identification, control, and risk determination aspects (Wu et al., 2018). Researchers proposed some risk assessment methods (Wu, Kang, & Li, 2016) and evolutionary computation and other computational intelligence techniques for cybersecurity (He et al., 2016).

Many researchers studied the business model for only one digital technology. Most of these were IoT specific studies. The IoT is a driver for digital BMI (Presser, Zhang, Bechmann, & Beliatis, n.d.). Some researchers studied the IoT specific business model components and frameworks (Baoliang, 2015; Fleisch, Weinberger, & Wortmann, 2015; Fugl, 2015; Gierej, 2017; Kiel, Arnold, & Voigt, 2017; Sun, Yan, Lu, Bie, & Thomas, 2012; Tesch, 2019; Y. Zhang & Wen, 2017). Some researchers examine the IoT technology for a specific industry business model such as the analysis of an IoT-based business model for postal logistics (Fan & Zhou, 2011), e-business (De-li, 2013), and telecommunication (Qin & Yu, 2015). Some of the proposed IoT specific business model for logistic industry (Sun et al., 2012) and e-commerce industry (Y. Zhang & Wen, 2017); evaluated the IoT specific business model in e-recruitment (Sceulovs & Shatrevich, 2015); investigated the effect of IoT on the business models in urban transportation (Flüchter & Wortmann, 2014) and education (Bagheri & Movahed, 2016). On the other hand, Khanagha et al. (2014) analyzed the Cloud-based business model for the ICT technology industry, while DaSilva et al. (2013) proposed a Cloud-specific business model for e-commerce. Labes et al. (2017) specified business model types for companies provide cloud service and determined the success factors for a cloud business model. Faber et al.

(2003) studied the designing of business models for ICT services and developed the STOF model. Their model includes four domains that are service, technology, organizational, and financial domains.

In some studies, DBM/digital innovations-driven BMI has been investigated in specific industries. For example, certain researchers developed strategies, architectures, frameworks, and models for different industries' service (Clark, El Sawy, & Pereira, 2012); airline (Pereira et al., 2015); construction (Leviäkangas, Mok Paik, & Moon, 2017); economy (Watanabe, Naveed, & Neittaanmäki, 2018); medicine (Steinberg, Horwitz, & Zohar, 2015); service (Shirahada, Belal, & Takahashi, 2015); telecommunication (Wiemker, 2015); taxi (Walji & Walji, 2016); music, taxi, e-commerce, airline (Chu, 2017); and healthcare (Pistorio, Locatelli, Cirilli, Gastaldi, & Solvi, 2017; Stanimirovic, 2015). Laudien and Pesch (2018) identified four business model archetypes for digital service firms: the digital beginner service firm business model, customization-focused service firm DBM, distance-bridging service firm DBM, and the full-scale digital service firm business model. They observed that digitalization improves the ways of value creation, value delivery, and value capture, while not bringing any radical change to service firms. Some of the researchers assessed or analyzed the effects of digital innovations on the ICT industry (Sainio, 2005); taxi service (Bashir, Yousaf, & Verma, 2016); enterprise servers, media, hospitality, taxi service (Bala & Hou, 2017); and the media (Jensen & Sund, 2017).

2.4 Corporate sustainability

In recent years, the effects of digital innovations on corporate sustainability have begun to be investigated by researchers. According to the theory of economic development, innovation increases a company's competitive advantage (Kleinknecht, 1990). IT innovation has a superior impact on sustainable performance (Marhraoui & El Manouar, 2018). Digital manufacturing and business processes as well as smart machines and devices may increase manufacturing productivity and resource efficiency while reducing waste (Tortorella & Fettermann, 2018).

On the other hand, one important challenge of disruptive innovation in terms of sustainability is balancing performance among the three dimensions of sustainability, which are economic, environmental, and social (Nasiri, Tura, & Ojanen, 2017). Moreover, there are some researchers who argue that smart technologies have a direct and significant effect on economic sustainability whereas they do not have a direct effect on environmental and social sustainability (Saunila, Nasiri, Ukko, & Rantala, 2019).

The business model is a suitable target for companies that want to strategically improve their sustainability performance (Schaltegger & Müller, 2008). In order to achieve corporate sustainability, organizations' resources and activities should be structured to create value. (Lüdeke-Freund, 2009). Business model innovation requires the application of organizational design and governance competencies that consist of resources, dynamic capabilities, and entrepreneurship to improve organizational sustainability (Carayannis, Sindakis, & Walter, 2015). Business model innovation is more likely to address sustainability, and there is a positive association between the core organizational values and financial performance (Pedersen et al., 2018).

2.5 System dynamics

System thinking is a causality-driven and holistic approach to the problems of complex systems (Behl & Ferreira, 2014), which takes heed of Aristotle's systemic ideas, such as that "the whole is more than the sum of its parts" (Metaphysica 10f-1045a). These systems cannot be understood by merely dividing them into their parts, and there is a need to focus on the whole picture. A change in one part of the system has an impact on others and the whole system. System theory started with Bertalanffy's "general system theory," named after Ludwig von Bertalanffy (1950).

System dynamics methodology is covered by systems theory and quantifies the effects of the interactions between parts and systems. "System dynamics" is a simulation-based methodology that can be used to model and analyze complex and non-linear systems using a feedback perspective. The methodology was developed in the late 1950s by researchers at Massachusetts Institute of Technology under the leadership of Jay W. Forrester (Barlas, 2002; Forrester, 1958; Morecroft, 1985; Sterman, 2000). Dynamic means "changing over time" and the feedback loops, which are dynamic and circular causalities, are the engines of the systems (Barlas, 2002). System dynamics often uses simulations to generate the dynamic behavior of models since finding analytical solutions to most non-linear and complex feedback models is difficult or impossible (Yaşarcan, 2003).

There are some assumptions for system thinking. One of the main assumptions is direct causality. A model consists of causal relations, not mere statistical correlations. The notation X → Y means other things being equal, a change in X causes a change in Y. The causal effect can be positive or negative. Another assumption is circular-feedback causality over time. It means X affects Y, which subsequently affects X again. Moreover, the system's dynamic behavior is caused by the internal structure of it (Barlas, 2002).

There are two types of feedback loops. One is the positive (compounding or reinforcing) feedback loop. Its behavior is divergent, mostly growth, and sometimes collapse. Other is negative (compensating, balancing, contracting) feedback loop. Its behavior is convergent, goal-seeking, or equilibrium seeking.

Stages for system dynamics methodology were proposed by system dynamic scholars. Forrester (1994) proposed four stages for system dynamics methodology, which are conceptualization, formulation, testing, and implementation. Barlas (1996) defined the steps of system dynamics methodology as follows: problem identification, model conceptualization (construction of a conceptual model), model formulation (construction of a formal model), model analysis and validation, policy analysis and design, and implementation. Sterman (2000) proposed five steps that consist of problem articulation, dynamic hypothesis, formulation, testing, and policy formulation and evaluation.

One of the main concepts in the structure of a model in system dynamics methodology is stocks. Stocks are state variables and the accumulations in a system. They represent the values at a point in time. The stocks can change by their inflows and outflows. Another main concept is "flows", which are the rate of change of stocks over time. Inflows fill in stocks while outflows reduce it when they have positive values. Converters or auxiliaries are intermediary parameters or variables while connectors are the arrows that connect objects in a model (Barlas, 2002).

The mathematical relations are defined for the construction of a formal model. In a linear equation, it is assumed that output is proportional to the input. If there is a parameter that is a direct or indirect function of a stock variable, the formulation is non-linear. There is no general form of a nonlinear equation since they are all different. The most general form of model equations (see Eq. 1) is:

$$Stock(t) = Stock(t - dt) + (inflows - outflows)dt \quad (1)$$

2.5.1 Dynamic systems for business strategy

In literature, system dynamics has been successfully applied to many management subfields such as operations, organizational behavior, marketing, behavioral decision making, and strategy (Gary, Kunc, Morecroft, & Rockart, 2008). It has contributed to strategic management in terms of many theoretical perspectives such as strategic planning, organizational learning, stakeholder theory, knowledge elicitation, strategy formulation, knowledge management, resource management, project management, and performance management (Cosenz & Noto, 2016).

Strategic management researchers started to study the system dynamics methodology given that managers need to test strategies on business performance and they also need to be able to make plans and engage in decision making. System dynamics is a proposed methodology for these purposes since it allows one to associate a strategy with an action and to understand the importance of resources on business performance and corporate sustainability (Cosenz, 2017). In the literature, this methodology has been studied to help planning and decision making as well as how to improve performance by testing alternative scenarios in several areas such as academic institutions (Cosenz, 2014), local government (C Bianchi & Rivenbark, 2012), public and government sector (C Bianchi, 2010; Navarra & Bianchi, 2013), and small- and medium-sized enterprises (Carmine Bianchi & Bivona, 2002; Cosenz, 2017; Cosenz & Noto, 2018b).

2.5.2 Dynamic business model

Business models are also involved in complex and dynamic systems (Demil & Lecocq, 2010). When transposing this idea to the level at which businesses operate, researchers have studied dynamic business models. A dynamic business model is developed by taking up representations of conventional business models and modeling them more dynamically in order to provide insights into strategy development by experimenting with the interactions of business model elements over time while also learning how the business reacts to digital innovations (Williams, 2002). Abdelkafi and Täuscher (2016) developed a dynamic business model that consists of three key stocks that represent the three dimensions of the business model: customer value proposition, value creation, and value capture. Shao and Shi (2013) built a dynamic system model to investigate the relationships among the key variables in the business model. Groesser and Jovy (2016) developed a strategy tool for exploring the relationships among strategic initiatives, business models, the business models' elements, and decision-making using an experimental simulation approach. Fayoumi and Loucopoulos (2016) developed a dynamic model combining the business model with system dynamics, demonstrating the effects of this by means of a marketing case study. Cosenz (2017) studied system dynamics modeling in order to support the business model design of start-up business, and the study analyzed the effects of different marketing budget scenarios on the business model variables using a single-case design. Cosenz and Noto (2018b) developed a dynamic start-up business model that aimed to foster entrepreneurial learning processes. They (2018a) also studied new business venture strategies by means of dynamic modeling. In both studies, the business model canvas design was used in modeling.

2.5.3 Dynamic business model for corporate sustainability

Moreover, although there are few studies on this, this methodology has been used to understand the effects of innovation and new technologies on business models and sustainability. Samara et al. (2012) constructed a dynamic model to identify the effects of product and process innovations on the performance of national innovation systems. Yun et al. (2016) developed a causal loop diagram that was based on the dynamic relationships among new technologies, the business model, and the market. According to Hajiheydari and Zarei (2013), dynamic systems provide an operational, quantitative, and flexible approach for the dynamic business model. They built a dynamic business model and applied mobile technology strategies to investigate the impact of these strategies on the business model elements and to see if there were any organizational benefits. Melkonyan et al. (2017) examined the factors that influence the sustainability of corporate businesses from a business model and system dynamics perspective and found that sustainability has a direct relationship with the operational costs and profits.

CHAPTER 3

METHODOLOGY

In this chapter, the research design of the study, data collection techniques, and the data analysis techniques is explained.

3.1 Research design

The research design of this study is based on both qualitative and quantitative methods. Figure 2 shows the research design of the study.

In order to develop a method for digital innovations-driven business model regeneration, first, articles and conference proceedings were reviewed to obtain the existing knowledge about digital innovations and BMI. Then, expert interviews were conducted to complement and validate this knowledge. The results of the literature review and interview analysis were compared and integrated and a method for digital innovations-driven business model regeneration was developed. The proposed method was applied to a real case with a case study. After the case study, a digital innovation-oriented dynamic business model, the importance of which has emerged during the case study and which can be used in the business model regeneration process for analyzing the impact of digital innovations on the business model was developed. System dynamics as a simulation-based methodology was used to develop the digital innovations-driven dynamic business model. The model was built, basing on the literature and interview data. Afterward, various structured and behavioral tests were performed to validate the dynamic business model, and the experiment data were analyzed in terms of various digital innovation scenarios.

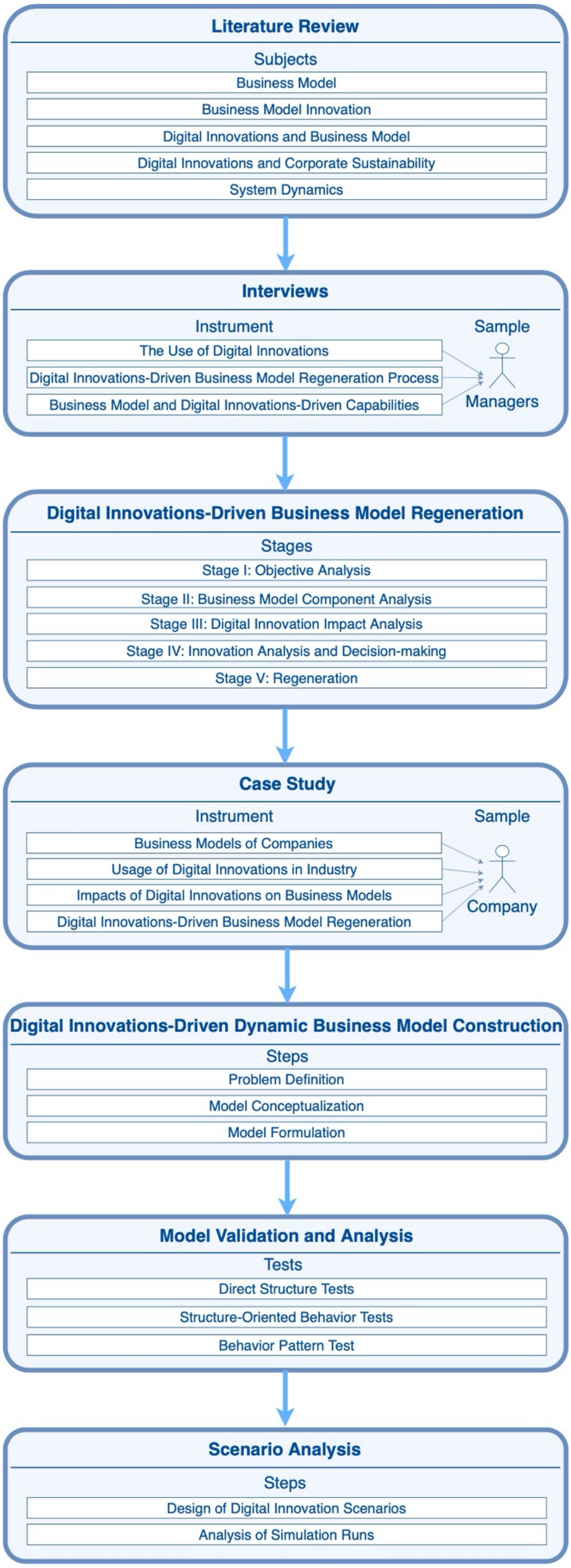


Figure 2. Research design of the study

3.2 Data collection

In this part, the details on the procedure of data collection from the literature review, interviews, case study and simulation experiments, each of which is a separate process but not sequential, is explained under separate subtitles. As can be seen in Figure 2, data from the case study are collected after the stages of the regeneration model are developed by the literature and interview data.

3.2.1 Data from the literature review

Comprehensive databases in the business field were scanned to access the relevant studies. ABI/INFORM Complete, Emerald, ProQuest, Science Direct, and Springer List were selected to reach related studies. For the digital innovations-driven business model regeneration method, BMI and DBM/digital innovations-driven BMI were examined to obtain related BMI aspects. The terms "innovation", "transformation", "extension", and "evolution" are added to the keyword "business model" along with other keywords "digital*", and "disrup* and "technolog*" for the search. On the other hand, these terms were searched with "system" "thinking", and "dynamic" keywords along with the keyword "corporate sustainability" to find those articles related to the digital innovations-driven dynamic business model. All the articles that include these keywords in their titles and abstracts were found. The abstracts of these articles were reviewed, and unrelated articles eliminated. After that was done, the remaining articles were reviewed for the purpose of the data analysis.

3.2.2 Data from the interviews

The actual data for developing a business model regeneration method and dynamic business model in the context of digital innovations were gathered from the interviews. After the related studies and interview questions are examined, the sample of the study was specified, and the instrument of the study was prepared. Semi-structured interviews were conducted with the respondents for a greater amount of flexibility in the discussion of the key issues related to the entire study (Jankowicz, 2005). Respondents included executives, directors, supervisors, leaders, and managers that had business development experience. They were able to give a relevant view of the business model generation and digital technologies were considered for sample selection. Determining the total population size was not possible; however, statistical significance is not required in qualitative studies (Saunders & Lewis, 2012). Therefore, probability-sampling techniques were not considered for this study. A non-probability, the purposive sampling strategy was used to add value to the research objectives (Saunders & Lewis, 2012). Purposive samples are the most commonly used nonprobabilistic sampling technique, and their size generally relies on data saturation (Guest, Bunce, & Johnson, 2006).

Guest et al. (2006) found that saturation occurred within the first twelve interviews. Morse and Field (1995, p. 147) further stated that “saturation is the key to excellent qualitative work”, and recommended at least 12 but ideally 30-50 interviews for ethnographic studies. In this current study, the respondents were purposefully selected with maximum variation (heterogeneity) sampling technique as discussed by Patton (2002), from companies operating in different industries for a diverse set of organizational contexts. Considering the data saturation, a total of 44 interviews were conducted with experts (see Appendix A) in different industries specified by the International Standard Industrial Classification United Statistics (United Nations, 2018).

Semi-structured, in-depth interviews were chosen as the format for interviews. The instrument of data collection was prepared by adapting the related studies in the literature (Amit & Zott, 2001; Giesen, Berman, Bell, & Blitz, 2007; Habtay, 2011; Kiel et al., 2017; Mace, 2016; Morris et al., 2005, 2006; Mudaly, 2016; Osterwalder & Pigneur, 2010; Pereira et al., 2015; Sprenkels, 2014; Weill & Woerner, 2013). The instrument consists of four parts and these parts include the questions about the existing business models of companies, the use of digital innovations in industries, the impacts they have on business models, and digital innovations-driven business model regeneration process (see Appendix B).

A pilot interview was conducted with a single respondent to test the interview schedule, understand the context of the research, and the language used by participants, as well as clarity of the question terminology. After the pilot interviewee stated his view about the interview process and schedule, certain terminology changes were made to increase the clarity of some questions. In total, 44 interviews were conducted with interviews in different industries. Both the face-to-face and virtual interviews were arranged according to the preference of the respondents. Skype was used as the virtual communication platform. Half of the interviews were undertaken in person, while the rest of the participants preferred a virtual interview because of time and location constraints (see Appendix A). In the face-to-face interviews, the consent form sent previously by email was signed after the interview. Virtual interview participants signed and sent their forms within a few days of their interviews. During the interview, notes were taken and then filed after the interview ended. The actual time taken for each interview was about 55 minutes. The minimum interview time was 30 minutes, while the maximum interview time was 90 minutes. The time depended on the participant's willingness to share their ideas.

3.2.3 Data from the case study

The construction industry was selected as the case industry for the application of the proposed regeneration method since the variety of digital innovation usage in that industry is high according to interview analysis. The case company was selected from companies having a considerable market share in the construction industry. The selected company has been listed for years in engineering news-record's (ENR) "top 250 international contractors" list ranking according to construction revenue. The data from the case study were obtained in two meetings with the information systems manager and project management. In the first meeting, the current business model of the company was analyzed. In the second meeting, the steps of the proposed methods are discussed regarding their business model.

3.2.4 Data from the simulation experiments

The system dynamics methodology, which is a simulation-based methodology, was used in order to develop a digital innovations-driven dynamic business model that emphasizes the effects of digital innovation strategies on a firm's economic and corporate sustainability, basing on the steps of system dynamics modeling process (Barlas, 2002; Forrester, 1994; Sterman, 2000). Taking the dynamic nature of the problem of this study and the presence of non-linearity and feedback loops from the model into consideration, system dynamics methodology is compatible with the aims of this study. The data which are required for scenario analysis were obtained from simulation experiments. Vensim PLE Plus simulation software was used for dynamic business model construction, validation, and for the scenario experiments. This tool was selected because of its rich features such as causal loop diagram development, stock-flow diagram development, structural check with tree diagrams and causal tracing, documentation, loop identification, equation edition, built-in function usage, data import with lookup tables, units check, reality check, simulation, graphs and tabular displays, runs comparison, “SyntheSim” function, and on-line help. Since Vensim PLE, which enables a free trial, does not include a sensitivity analysis function, the Vensim PLE Plus configuration was used under a license.

3.3 Data analysis

After a detailed review of the literature and interview data, the business model and BMI concepts were systematically analyzed in the perspective of digital innovations using content analysis as recommended by Gioia et al. (2013). The analysis of data consisted of three steps, namely, immersion, reduction, and interpretation (Forman & Damschroder, 2007). First, the interview data were transcribed. Secondly, the data were reduced to obtain relevancy to the research question. The data were then rearranged with coding to categorize it meaningfully. Both literature and interview transcripts were used for the identification of themes and coding categories. Similar categories were grouped and some of these then split into subcategories. Lastly, the data were synthesized for results. In this study, the objectives, business model components, digital innovations, BMI process steps, dynamic business model elements, and digital innovations-driven capabilities were thematically analyzed and categorized.

In the qualitative data analysis process, Docear, which is an academic literature management software, and Microsoft Excel were used as the tools to support the analysis of the qualitative data. For the analysis of simulation experiment data, Vensim PLE Plus, which provides graphical analysis results, was used.

CHAPTER 4

DIGITAL INNOVATIONS-DRIVEN BUSINESS MODEL REGENERATION

In this chapter, collected data are analyzed and a method for digital innovations-driven business model regeneration is developed.

4.1 Analysis of the use of digital innovations

Given the analysis of literature and interview data, digital innovations were collected under the titles CPSs and EC, IoT, DA and AI (chatbots, VPA, etc.), cloud technology, IE (VR, AR, and MR), AT (robots, drones, autonomous vehicles, etc.), blockchain, 3DP, and MTs in the current study. The uses of digital innovations are analyzed for the industries specified by the International Standard Industrial Classification United Statistics (Statistics, 2018) from the experts' point of view.

Agriculture, forestry, and fishing: In this industry, widely used technologies are IoT, CPSs, robotics, drones, DA and AI, and MTs. Fields and farms are monitored with smart sensors and the realized data are used to provide forecasts and remedies for problems. IoT provides the connectivity of machines in collecting, sharing, and analyzing data; and the Internet of food provides an entire platform connecting the producer and the consumer directly. With the DA and AI technologies, the collected data are processed and converted to useful information. Thanks to the learning capabilities of them, they reduce irregularities and identify problems before they occur. While robotics is used particularly for time-consuming and repetitive tasks in agriculture, drones visit and observe parts of the field and farms for analysis, monitoring, assessment, and to collect information not seen with the human eye, and hence they reduce labor costs. Moreover, MTs improve connectivity and make easier the flow of information among stakeholders with innovative applications. Although not very common, IE, cloud technology, 3DP, and blockchain technologies are also used in this industry. AR provides a visual representation to the farmers for monitoring fields and farms and checking in remotely, lay-outing the options, and demonstrating the impact on the field. VR is used for training employees and workers. 3DP creates a required part for a repair, and thereby potential disruption in production is obviated. Cloud technologies provide possibilities to store valuable information and access instantly everywhere. Blockchain track transactions through the food chain; provide transparent transactions, provide direct connection among actors of the supply chain, ensure to farmers fair payment; and provide security for information thanks to the encryption.

Mining and quarrying: IoT, CPSs, DA and AI, robotics, drones, and AR-VR are commonly used in the mining and quarrying industry. Robotics are used in potentially hazardous mining environments. They reduce the need for human operators and enhance personnel safety. Instead of a human, drones monitor and inspect the environment safely, and survey and map data in real-time. AR-VR help for mine planning, simulate different patterns of processes with different scenarios and show realistic mining conditions to workers in operation training. CPSs collect data in real-time from an operational environment particularly for safety issues and alerts about unexpected operating conditions to predict problems before they happen. While IoT provides real-time monitoring, storing, and sharing data remotely, DA and AI are used to process the data collected, control processes, and predict failures before they occur. Cloud technology is using for storing and sharing information across the organization. Blockchain is using for tracking every transaction and encryption for information security. Moreover, 3DP provides the maintenance parts for equipment failure; reduces lead times and eliminates the transporting process. MTs are using generally in the value chain for the tracking process.

Transportation and storage: CPSs provide feed information between stock tags and signal readers, and thereby provide stock visibility and transparency; monitor driving speed, fuel consumption, brakes, and loading rate of the vehicle; track maintenance time; and controls temperature. CPSs and IoT help to asset and inventory tracking, warehouse management, and fleet management. They are used for tracking transportation goods and inventory movement, enabling to respond to disrupt or hinder the supply chain, sharing speed, position or direction information among trucks, communicating with all stakeholders in real-time, and matching vehicles and nearest empty containers via “uberization”. DA and AI techniques provide advice about shipping orders, stock transfer, and inventory; optimize driving speed for travel time and fuel consumption; anticipate maintenance and predict the risk of malfunctions; optimize the movement of cargo and resources usage; analyze data to identify customer trends and market insights patterns. Robotics are more efficient ways of order picking, inventory location detection, delivery of shipments, and providing information to the entire supply chain. Besides, driverless travel reduces fuel consumption, and accidents due to human error, and adapts its driving behavior according to environmental factors and thereby optimizes of travel times. Drones are used in barcode scanning, cataloging inventory, stacking of stocks, last-mile delivery, traffic monitoring, etc. AR-VR technologies show exactly where items should fit on carts during picking orders and thereby improve the process by making it faster and less prone to error. They make the delivery process safer and more efficient in difficult conditions; control the processes whether are running as planned; reflect important information such as package weight, contents, and navigation instructions; allow identity verification with a picture; support warehouse redesign and planning; and are used intensively on the job training. MTs provide greater transparency and mobility to the operations with real-time tracking of cargo movement and inventory stock. Cloud stores up-to-date information and provide data sharing among stakeholders without inconsistency and time problems. Blockchain ensures that processes are running as planned by providing transparent tracking.

Accommodation: CPSs alert for an unexpected situation. They notify about conditions such as when rooms are ready for cleaning. CPSs prepare the environment for guests such as heating the room before the guests come. Control secure access to rooms and facilities. IoT allows to self-check-in and it provides connection among CPSs. DA and AI techniques are used to provide personalization in service, to make recommendations based on customers' physical location, to answer routine questions in a call center and information desk, to recognize hazardous conditions, and to contribute to predictive maintenance. Robotics are used for some hotel services such as housekeeping service pool service, and product delivery service, and in self-service contact centers. AR-VR route customers can use AR-VR technologies as a personal touristic guide. They also show realistic, virtual representations of hotel activities. MTs are used for many processes such as booking rooms, check-in, payment, and keyless entry. Cloud technology manages the database, client's requirement online from one single place to anywhere in the world.; stores details about door keys on the cloud in which customers can download 3DP files Clients requirement can be managed online from anywhere in the world with cloud technology. Blockchain provides secure tracking points for stakeholders. Drone usage is assessed as an ethical problem in this industry.

Food service activities: CPSs the optimization of food safety measures and monitor temperature, cooking times, and inventory levels to order. Therefore, with the IoT support, they increase efficiency in the use of inventory and equipment, ensure ongoing compliance, and enhance health, safety, and end-customer satisfaction. With the DA and AI, customer waiting time is reduced, the customer ordering experience is enhanced, and the menu is customized based on preferences. Robotics help food preparation and delivery greet of guests and booking and purchasing by providing menu details and menu recommendations. AR-VR technologies make 360-degree tours of the facility for customers. These technologies are used also to monitor employees and test their skills and train them with simulation games. Blockchain brings transparency to supply chains and makes tracking points less expensive and more secure. MTs enable customers to browse the menu, create orders, and pay for orders and reservations. Besides, they provide customers with information about the status of their food during the cooking and delivery process. Some technologies are not commonly used but they are also used in the food service industry. 3DP technology can prepare and serve foods, and thereby more fresh food is served faster than traditional foodservice. Drones take a role in the delivery of food and beverages, while cloud technology provides data consistency and control.

ICT: This industry covers digital innovations. Therefore, all digital technologies serve this industry. It is not possible to mention all the uses of digital technologies in this industry, but some general usage objectives can be given as an example. For example, CPSs are used for location-based communication, face and image recognition, etc. IoT provides machine connectivity for collecting, sharing, and analyzing data. DA and AI provide customer-specific services, complex problem-solving, and decision-making, and support customer via chatbots. Cloud technology is used to store and share data and backup. Robotics support repetitive administrative tasks. Drones are generally used for inspection and control. 3DP meets specific material needs quickly. AR-VR is an efficient way of training, maintenance, audit, and customer engagement. Blockchain improves workflow and collaboration, provide transparency in the supply chain, and provide trustworthy agreement with smart contracts and digital identities. MTs increase the flow of information and improve connectivity.

Financial and insurance activities: CPSs measure risk-sensitive parameters, and provide a smarter alarm, and thereby reduce the cost of insurance. IoT gets real-time and accurate data and ensures immediate support. It tracks the audience, monitors traders' activities, and adjust their policies accordingly. DA and AI analyze customer and service data to provide real-time and customized assistance to customers, offer client-specific insurance, and develop fraud indicators. Virtual agents/brokers who have a high degree of cognitive computing increase efficiency, improve quality, save time, and reduce costs. Cloud technologies are generally used to share data inside. Drones are used in hard-to-reach areas to record and evaluate loss and damages. AR-VR is used generally for customer engagement. They provide a virtual trading experience with VR workstations and virtual branches, and thereby ensure the secure customer experience. They provide navigation to customers for the nearest branch and train employees. Transactions are transparent and identities are secure, and all data is more trustworthy with blockchain technology. It enables transactions with digital currencies including virtual currencies and cryptocurrencies like Bitcoin and Ethereum. MTs are used for payment, digital marketing and sale, experience and interaction, and process application.

Real estate activities: CPSs are used for monitoring variables such as temperature, humidity, climate, and occupancy, and collecting data. They help to identify failures before they happen. IoT allows people to buy, sell, or invest in property online, and to interact with stakeholders with one another. DA and AI are used as an agent that guides the consumer about house prices and availability. They identify trends that will affect occupancy in the building and pricing such as the graduation of a college student, flooding into the area, etc. Cloud technology performs data sharing and data storage, provide mobility, security, cost efficiency, and scalability for the professional, and improve communication and workflow. Drones are used for surveillance and delivery. AR-VR provides a virtual tour of a potential estate and visualizes an empty house as though it has furniture inside. Blockchain ensures the data integrity, make a record for every property, provide smart asset transfer and smart contracts, reduce the security risk, and allow customers to access much more data on individual properties and owners. MTs are used for many activities such as routing and positioning and following deadlines.

Professional, scientific, and technical activities: Companies in this sector give consulting services on the selection of technological devices such as sensors, data analytic techniques, and tools like mobile applications, and data security and privacy. IoT-based and MTs are used for collaboration and expertise sharing in the digital workplace among professionals. DA and AI technologies are generally used as a software agent and to analyze customer data, and thereby offer service based on the analysis. They support trend analysis, risk assessment, scoping, and judgments. AR-VR make faster the processes like exploring and assessing design choices, and remedial work. They minimize on-site changes thanks to virtualization, and thereby save time and money. Blockchain allows stakeholders to interact without a third party. MTs are bridges between vendors and clients. Cloud stores data and shares data with stakeholders. Drones are used for inspection, and 3D printers are used to meet technical needs.

Administrative and support service activities: IoT connects the machines for collecting, sharing, and analyzing data. It provides a platform that connects the producer and the customers and real-time monitoring. DA and AI analyze customers for personalization and offer service and support based on customer data. They are used also as software agents. Cloud technology provides access to the data and allows management of them. These tasks can be performed everywhere. AR-VR technologies enhance customer engagement. They make visualization and organization of large amounts of data easier and faster. MTs are used for payment, digital sales, customer experience, process applications, etc. They create connectivity bridges with clients. Blockchain connects customers with vendors directly by eliminating the third party and ensure data integrity. Stakeholders monitor processes transparently. Usage of some technologies like CPSs, drones, and 3DP technologies are not common in this industry.

Public administration, defense, and compulsory social security: CPSs provide information and manage and control processes. They sense the environment by monitoring cyber and physical indicators and modify the environment with actuators dynamically. For example, the real-time monitor the traffic, and control of traffic lights to prevent traffic congestion; provide better information on waiting times of buses by real-time monitoring of them; send emergency alerts; monitor pollution levels; help to earthquake measurements; and identify an abnormality in infrastructure such as potential sources of fire, leakage in water pipes, etc. IoT has an important role to access information from CPSs and manage and share that information with other devices or users. For example, it updates citizen identity information and citizen's process information, parking and traffic information, etc. DA and AI predict provide greater insight into a problem. They are used in crime prevention and investigations, city planning, pollution and congestion prevention, environmental damage prevention, and waste minimization. Robotics take tasks for dangerous work situations like military operations. Fully automated machines are used for landscaping, garbage collection, park-street cleaning, garden maintenance, and transportation. Drones are used for security inspection. They identify security issues and report them. 3DP technology supports key resource supply. AR-VR technologies are generally used for planning, control, guiding, and training. 360 panoramic tours, simulations for disaster management and employee training, and ground analysis, and city planning tools are some examples of AR-VR applications in this industry. Blockchain provides trustworthy and secure integrated workflows. MTs make information and services available and easily accessible. Many processes like appointments, tax payment, voting, etc. are performed online with this technology. Because of the security and privacy issues, cloud technology is used for storing and sharing data only which does not include personal and private information.

Education: Wearable sensor that detects current behavioral situation like fatigue, and immediately alerts. For example, a pen can check the concentration. Besides, CPSs are used also to keep track of updates and take notifications. IoT based smart boards and pods of smart desks are used to facilitate education. DA and AI can be used as virtual advisors of students. Moreover, data are analyzed to assess the study habits and behaviors, personalized training, and feedback, evaluating the curriculum and content, and facilitating personal tutoring. Cloud-based learning management systems are used to produce and share learning materials and activities for students. Besides, cloud-based tools enable students to engage in research experiences. Robotics can be proxies for teachers, teach students with autism or other disabilities, and even they can attend a class for students who are too sick. They can be used as learning support tools or an educational subject. Drones engage students in more physical activities and outdoor activities and improve their motor skills and hand-eye coordination. 3DP materials can be used as a resource in experiments and physical exercise. AR-VR help to create lessons that are fun and engaging for the student, and to increase visual literacy and technology literacy. Virtual classrooms can be developed, and experiments can be run in AR-VR environments. Blockchain helps to manage and monitor information like student records, transcripts, badges, ridesharing, charity, human resources, governance, libraries, publishing, and public assistance. MTs applications and platforms can be used for many educational purposes such as accessing information, receive instruction, learn, assess learning, etc.

Human health: CPSs track a wide variety of health indicators, including heart rhythm, blood pressure, amount of oxygenated hemoglobin in the blood, brain waves, blood sugar, respiratory rate, and many more. Wearable devices are facilitating the usage of these systems. IoT provides connectivity for CPSs to collect data and for analytic systems to predict potential health issues and monitors the health of patients. DA and AI provide new insights into diseases and epidemics, predict and prevent them, suggest possible causes for symptoms, and personalize the treatment and medicine. Chatbots can answer simple medical questions, and thereby save time and reduce doctor visits. Cloud technology provides access to patient and treatment information. It allows more than one doctor a single access point for in order to view test results or inspect notes about patients. Robots can make guidance as patient assistants for examination, test, and treatment processes. Drones help to deliver healthcare by transporting blood, blood samples, and other supplies to labs or hospitals. 3DP outputs can be designed and produced for treatments such as hearing devices, personalized drugs which have unique dosage, etc. AR-VR technologies are used generally for training and engagement. They allow doctors and doctoral candidates to inspect and interact with patient tissues and organs as if they were real. They provide educational experiences for both patients and doctors to understand current medical conditions. Blockchain allows uniform medical records and provide transparency in workflow, and thereby prevent drug theft and counterfeiting, and resource inefficiency. MTs enable patients to monitor their health and manage their care.

Arts, entertainment, and recreation: There is a wide variety of usage of CPSs in this sector. They monitor gesture control in dancing by motion-tracking technology. They generate digital displays and electronic music; they are used to effective advertising and to measure viewing rates; provide a more immersive gaming experience thanks to wearable gaming, and audit and control production quality. With IoT, machines such as wireless scene resources can connect together, and a variety of data like event information, and services like online gambling and gaming are accessed to persons. DA and AI technologies provide personalization and contextualization in entertainment activities. They offer customer-related products, activities, or events like music, film, etc.; create effective movie plot points by analyzing box office performance, and create trailers based on trailers; make suggestions about product placements in advertising. Cloud technology provides access to information from anywhere and makes flexible information management.

Robotics are used as resources such as transport resource, robotic cameras in sports coverage, smart scene, etc. They are used also as entertainment robots, commercial robots, and art robots. Drones are more efficient and effective ways of capturing breathtaking views and approach scenes. They are used also as flying billboards. 3DP technology is used for decor, costume, special effects, scenic design, wearable makeup, etc. AR-VR technologies can be used in storytelling, shooting and editing film, game development and animation, projection, and environmental analysis. Blockchain prevents digital ad fraud, eliminates middleman, gains information from various sources for filmmakers and creators about customers, and make secure the media files, songs, cover, and workmanship. MTs are used as a channel for accessing customers. They provide share platforms and environments.

Activities of extraterritorial organizations: IoT and CPSs are used for transportation, supply chain, auditing, smart trade, accountants, and smart containers. DA and AI technologies offer customer-related events and activities or products by providing personalization and contextualization. Chatbots provide customer interaction. Cloud stores and shares data provide mobility and flexibility for data access and improve document management. Unmanned vehicles are used in transportation. Drones provide efficiency in monitoring, auditing, and inspection. 3DP technology provides material for those who need it. AR-VR are used generally in planning, auditing, and training. Blockchain brings transparency to network spending, improves workflow and collaboration, and provides information about their stakeholders thanks to digital identity. MTs provide information and service accessibility and improve communication and interaction.

4.2 Digital innovations-driven business model regeneration

As stated in the literature review, there are many researchers who studied the BMI process and proposed a methodology or road-map for BMI (Amit & Zott, 2016; Gassmann et al., 2014; Laukkanen et al., 2015; Osterwalder & Pigneur, 2010; Schaller et al., 2018; Wirtz, 2016). Moreover, Auer and Follack (2002) proposed an internet-specific stepwise BMI methodology grounded system theory or action research while Pateli and Giaglis (2005) proposed a technology-specific stepwise BMI process based on scenario-based methodology. In this study, the proposed methodology for digital innovations-driven business model regeneration is based on all these studies and the interview analysis. The proposed methodology extends existing research with expert views. Managers emphasized the importance of objectives for business model regeneration and industry priorities. While it has similar steps with these studies, it has also distinctive steps that are outlined and described in this section. The proposed methodology consists of 10 steps with five basic stages (Table 6).

Table 6. Digital Innovations-Driven Business Model Regeneration

Stages	Steps
Stage I: Objective analysis	Step 1: Specifying objectives for business model regeneration
Stage II: Business model component analysis	Step 2: Identifying business model components
	Step 3: Determining the importance of business model components
Stage III: Digital innovation impact analysis	Step 4: Specifying potential digital innovations and their uses
	Step 5: Analyzing the impacts of digital innovations on business model components and specifying the impact levels
Stage IV: Innovation analysis and decision-making	Step 6: Identifying the type of innovations
	Step 7: Identifying the degree of innovations
	Step 8: Identifying the speed of innovations
	Step 9: Decision-making
Stage V: Regeneration	Step 10: Renewing the impacted business model components

4.2.1 Stage I: Objective analysis

First, this is the stage that BMI researchers have missed, ignored, or included in another stage. The current study emphasizes that the objectives of a business model regeneration are important for strategic decision-making (Stage IV). This stage has only one-step.

Step 1. Specifying objectives for business model regeneration: Participants emphasized that the objective of regeneration of a company's business model is important for the regeneration process. According to them, the objectives affect the strategic decision-making process. For example, sustaining innovation improves existing products and processes, and it develops the existing market with better values; yet disruptive innovation helps create a new market and value (Bower & Christensen, 1995). Therefore, the company and its process-related objectives can be met by sustaining innovation while customer/market and product/service-related objectives require disruptive innovation or sustaining innovation, depending on whether the aim is a new creation or just improvement of existing.

4.2.2 Stage II: Business model component analysis

This stage includes the design of the current business model and provides a detailed understanding of business model components. The stage corresponds to the understand phase (Auer & Follack, 2002; Pateli & Giaglis, 2005), mobilize and understand (Osterwalder & Pigneur, 2010), observing (Amit & Zott, 2016), initiation (Gassmann et al., 2014), and baseline determination (Laukkanen et al., 2015). Since the components or their significance may vary by industry, and digital innovations may be handled under a separate component in some business model, identifying these business model components, and specifying the importance of those components are two required steps in the stage.

Step 2. Identifying business model components: Both literature and expert views can be used to identify business model components that are their subcategories’ forming the components. The identified components can be categorized for the business model. The outputs of this step are the specific business model components.

Step 3. Determining the importance of business model components: The importance of business model components varies by industry because of the differences between product and service industries or primary, secondary, tertiary, and quaternary industries. The importance of the business model components, as identified in Step 2, should be specified by the industry experts. The outcome of this step is important for component analysis.

4.2.3 Stage III: Digital innovation impact analysis

The goal of this stage is to analyze the impacts of digital innovation on the business model, thereby trying to reach the objectives and integrating these into the business. This stage corresponds to the phase of identifying the Internet's impact (Auer & Follack, 2002), and identifying technology's influence (Pateli & Giaglis, 2005). The following steps should be performed to complete this stage:

Step 4. Specifying potential digital innovations and their uses: First, current and potential digital innovations that could be used in the industry should be identified by reviewing the literature and expert opinions. This step corresponds to the initiation step noted by Schaller and his colleagues (2018). After identifying the potential digital innovations, the use of these technologies is analyzed and their usage level of are specified comparatively.

Step 5. Analyzing the impacts of digital innovations on business model components and specifying the impact levels: Although digital technologies have some common effects on the business model components in different industries, there are also important differences in these effects. Therefore, the business model components that are affected by digital innovations should be identified. The impact level of digital innovations on business model components can be estimated by the uses of digital innovations (Step 4) and examining their affected business model components.

4.2.4 Stage IV: Innovation analysis and decision-making

In this stage, the type, degree, and pace of digital innovations are identified with the outputs of stages II and III, and the findings are used to decide on the digital innovation strategies that will be integrated into the business model. This stage corresponds to phase prioritization (Laukkanen et al., 2015), decision-making (Wirtz, 2016), and identification (Schaller et al., 2018).

Step 6. Identifying the type of innovations: The type of digital innovation can be decided by evaluating the impact of digital technologies on business model components. Most new technologies increase product or process performance. (1997) called these as sustaining technologies. A *sustaining innovation* targets incremental or breakthrough performance increase for existing and high-end customers and it requires improvement of the existing business model. Disruptive innovation, which was defined and first analyzed by Bower and Christensen (1995), brings to the market a very different value proposition, creates a new market and value network, and therefore, requires business model regeneration. Expanding innovations can extend current offerings into new markets, or they can introduce new products and services to existing customers, indeed both of them extending what the company already does (Carpenter, 2015).

Step 7. Identifying the degree of innovations: The degree of innovation is classified in the literature as incremental and radical (Cavalcante et al., 2011; Domínguez Escrig, Mallén Broch, Lapiedra Alcamí, & Chiva Gómez, 2019); improvement, catch-up, replacement, and actual innovation (Mitchell & Coles, 2003); adjustment, adoption, improvement, and redesign (Schaltegger et al., 2012); changes, incremental, and radical (Witell & Löfgren, 2013); incremental, modular, architectural, and radical (Windahl, 2015); and stabilization model, continuing the evolution adaption model, the extension model, the migration model, and finalizing using the radical innovation model (Wirtz et al., 2016). In this study, the most used innovation degree classification (incremental and radical) in literature is determined as the degree of innovation. According to expert response, radical innovations involve a significant impact on business models whereas incremental innovations require minor changes in the business model. Therefore, the innovation degree can be specified by the impact level of digital innovations.

Step 8. Identifying the speed of innovations: The speed can be handled in terms of the rate of improvement that customers can utilize or absorb and the pace of technological development (Christiansen, 1997). Besides, the importance of time affects customer acceptance of business models and is a major issue for market success (Laudien et al., 2018). The pace of digital innovation can be slow, as fast as possible, and rapid based on digital innovation's impact on the business model components and the importance of those components for a company.

Step 9. Decision-making: Prioritization is a decision-making criterion that is utilized to achieve business goals. According to respondents, not each component has equal value for all industries, industries may have different priorities, and not digital innovations have not an equal impact on all industries. Therefore, digital innovation strategies should be decided, basing on the objective of business model regeneration and the type, degree, and speed of innovation.

4.2.5 Stage V: Regeneration

Given the results of these previous steps, decisions on changes to the business model will become clearer. Therefore, this stage includes the changes in business models using the outputs from the previous stages. It corresponds to phase change (Auer & Follack, 2002), design (Osterwalder & Pigneur, 2010), and integration (Gassmann et al., 2014).

Step 10. Renewing the impacted business model components: The identified options are transformed into concrete changes in the business model (Laukkanen et al., 2015). Given an intensive business model inquiry, the transformation of all the knowledge obtained from the analysis into that business model is made (Osterwalder & Pigneur, 2010). The ideas need to be elaborated into business models that describe all the components (Gassmann et al., 2014).

CHAPTER 5

CASE STUDY

The case company is from the construction industry. The company undertakes international infrastructure, substructure, housing, and industrial plant projects as well as energy, oil, and natural gas projects. As a global company, the company has been listed for years in ENR “top 250 international contractors” list ranking according to construction revenue with the projects in Iraq, Qatar, Russia, Saudi Arabia, Turkey, Ukraine, United Arab Emirates, and more. In 2018, the company has 350-million-dollar net revenue, 1.010 million-dollar total assets, and 6643 employees.

5.1 Stage I: Objective analysis

This stage includes only the step “specifying objectives for business model regeneration”. The case study respondents emphasize the importance of the answers to the question “Why does a company regenerate its business model with a focus on digital innovations?”. The answers to this question in literature can be listed as value proposition improvement, product/service differentiation, cost reduction, efficient processes, productivity increase, up-to-dateness, new value proposition, market expansion, new market, and partnership strategy. Almost all industries except public administration and defense and activities of extraterritorial organizations aim to increase in market share and revenue.

On the other hand, there are some differences in industries according to literature. Customer relationship is crucial for service industries such as accommodation and food service; health; transportation and storage; financial and insurance activities; administrative and support service activities; public administration and defense; arts, entertainment and recreation; and professional, scientific and technical activities. In these industries, customer benefit/satisfaction may be the ultimate objective of BMI. However, it is not crucial for wholesale and retail trade companies since they are generally intermediary corporates. The cost structure is important in the construction, and accommodation and foodservice industry because prices may change with respect to customer's economic status. Good partnership is required in the following industries: financial and insurance companies, wholesale and retail trade, manufacturing, hotel and food services, and transportation and storage. On the other hand, manufacturing, ICT, and financial and insurance industries frequently develop a new product or service.

According to the case study, efficient processes, cost reduction, new value proposition, market expansion, and new market are the main objectives for digital innovations-driven business model regeneration. Therefore, these objectives are expected to affect innovation strategies.

5.2 Stage II: Component analysis

In this stage, business model components are identified for the case company and the importance of business model components for the industry of the case company is determined.

5.2.1 Step 2. Identifying business model components

The literature-based component analysis of the business model indicated the following components: customer/market segment, value proposition, revenue, activities/processes, resources/assets, profit/margin, cost structure, partners, capabilities, channels, customer relationships, competencies, and sustainability.

In the case study, the business model and its components were inspected. When the identified components were categorized, the results substantially coincided with the literature with a few exceptions.

First, many researchers indicated profit as their business model component. The case respondents suggest not including profit in the business model components since revenues and costs determined a firm’s profit-or loss-making logic. The difference between revenues of sold value and costs were required to determine the profit of a company (Dubosson-Torbay et al., 2001).

Secondly, the sustainability component is rarely mentioned in the literature. Afuah and Tucci (Afuah & Tucci, 2001) summarized the questions that companies should ask themselves about the sustainability as the following: “What is it about the firm that makes it difficult for other firms to imitate it?”, “How does the firm keep making money?”, and “How does the firm sustain its competitive advantage?”. On the other hand, the respondents in this study saw sustainability as an objective for business model development. Therefore, it was decided not to include this term in the list of business model components.

Lastly, various business models included both capability and competency components in literature. The respondents suggest that “competencies” can be combined with resources and “capabilities” can be combined with activities. Resources, capacities, and competencies are interrelated and thus difficult to handle here. Resources are both tangible and intangible assets, skills, competencies, and knowledge (Wahl & Prause, 2013). Core competency is “a harmonized combination of multiple resources and skills that distinguish a firm in the marketplace” (Hamel, 2001). Since each core competence is a combination of intangible assets (Andriessen & Sandberg, 1999), competencies were combined the resources in this current study. In conclusion, competencies were added to resources components, and a component called “resources and competencies” was then specified. On the other hand, capabilities are “the ability of corporations to exploit their resources” (Wahl & Prause, 2013) and they are functionally based as marketing, production, distribution and logistics, and human resource management capabilities (Javidan, 1998). Therefore, capabilities were combined with activities.

As the output of case study analysis, the business model components of the case company are specified as the customer/market segment, value proposition, revenue model, activities and capabilities, resources and competencies, cost structure, partners, channels, and customer relationships. The component analysis results overlapped the business model canvas items (Osterwalder & Pigneur, 2010).

5.2.2 Step 3. Determining the importance of business model components

The value proposition is important for all industries whether they are a service or product industry and whether they have a qualitative or a quantitative value proposition.

Customer segmentation is another component of the business model. Market type and the type of market segmentation affect the importance a company attaches to this component. In mass-market dominated industries, such as electricity, gas, steam, and water supply industries, market segmentation is not crucial, while in segmented markets, diversified, and multi-sided segment dominated industries, right market segmentation is required for competitiveness. Moreover, more complex decision-making is required for Business-to-Business market dominated industries because of their more rational buyers and smaller target audiences.

The type of customer also affects customer relationships. The industries where their target group is only or mostly individual consumers place more importance on customer relationships than do the industries where their target group is only or mostly other companies. In industries that dominated a monopoly, such as electricity, gas, and steam supply, the customer relationship was not very important. Besides, in an industry where volunteering is essential, such as industry activities of extraterritorial organizations, their customer relationship depended on reliance, but not in the foreground, since the goal here was not to profit.

The importance of channel ranked high in those industries with a dual distribution channel, channel partner, and have a high variety of distribution and a customer support channel. For example, these conditions are quite high in industries related to wholesale and retail trade, accommodation and food service activities, financial and insurance activities, public administration, education, and arts, entertainment, and recreation.

Companies also have a network, partnership, or collaboration to work with other companies in their own or other industries, particularly for sharing resources, information, money, decision-making power, and so on. Supply chain relationships like suppliers, distributors, and retailers are common in most industries. Manufacturing, wholesale and retail trade, transportation and storage, ICT, financial service and insurance, professional, scientific and technical activities, and public administration industries are industries that communicate more. On the other hand, water, electricity, gas and steam supply, and waste management are industries that have fewer relationships with others.

The three types of business activities were production, problem-solving, and platform/network activities (Osterwalder & Pigneur, 2010). The primary sectors were agriculture, forestry and fishing, and mining and quarrying industries, and the secondary and utility sectors were manufacturing, construction, electricity, gas, steam, and water supply. These industries perform production activities, such as product design, production plan and process, quality control, and supply chain and logistics. The tertiary sectors were service industries that perform problem-solving activities like knowledge management, training, and project management. Knowledge management is important for the quaternary sectors or information-based industries. Platform/network activities require quality control, marketing. Moreover, certain activities, such as R&D, project management, sale and marketing, and contact/network can be performed by both product and service industries. R&D activities are important for manufacturing, ICT, and professional, scientific and technical activities, while project management is crucial for mining and quarrying, construction, ICT, and professional, scientific and technical activity industries.

Every enterprise requires physical, intellectual, financial human resources, and competencies, but their intensity varies by industry. Large and skilled employees are particularly prominent in industries like education, health, and public administration, while physical resources like buildings, equipment, vehicles, and tools are required in the construction, agriculture, and waste management industries. On the other hand, intellectual resources are crucial for knowledge-based industries, such as ICT, finance, professional services industries. Financial resources, however, are quite important in almost every industry sector.

The importance of cost structure importance for companies depends on the variety of their variable costs such as human resources, marketing, logistic, and raw material costs, and the variety of their long-term asset costs for vehicles, equipment, and land and buildings. The importance of cost structure is high in agriculture, manufacturing, waste management, construction, public administration, health, and arts and entertainment activities, while it is low in real estate, professional, scientific and technical activities, and administrative and support service industries.

The items that affect revenue importance are a variety of revenue sources, such as asset sale, usage fee, subscription fees, lending/leasing/renting, licensing, brokerage fees, advertising, and others, and pricing strategy like fixed or dynamic (Osterwalder & Pigneur, 2010). Pricing management is more difficult when the pricing strategy is dynamic. The revenue sources for the companies in agriculture and fishing, mining and quarrying, manufacturing, electricity, gas, steam supply, and water supply industries are assets, subscriptions, or both, and their variety of revenue sources are also low. The companies handling hotel and food services, financial and insurance activities, and arts and entertainment activities will have a high variety of revenue sources.

For the construction industry, the importance of the business model components for the industries is specified by analyzing the respondent views and given in Figure 3. In the construction industry, activities and capabilities, cost structure, customer/market segment, resource and competencies, and value proposition have critical importance (Figure 3). On the other hand, customer relationship is stated as not critical since intermediaries have a relation with end-users. Therefore, partnership with the intermediaries is more valuable than the customer relationship.

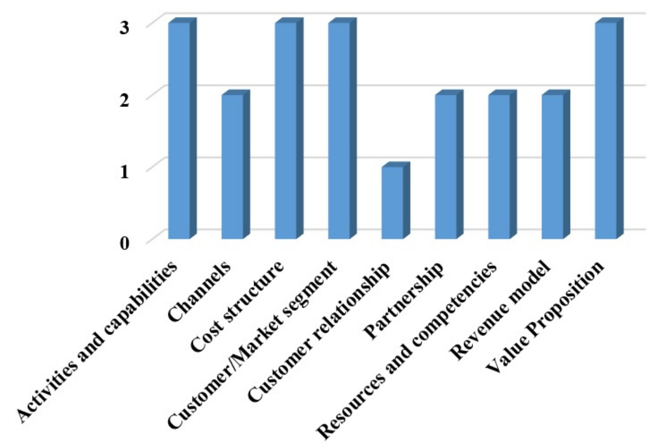


Figure 3. Business model component importance in construction industry

5.3 Stage III: Digital innovation impact analysis

In this stage, potential digital innovations and their uses in the case company are specified and the impact of digital innovations on the business model of the case company is analyzed.

5.3.1 Step 4. Specifying potential digital innovations and their uses

In literature, there are some differences in the usage of digital innovations in industries. From the industry perspective, waste management, sewerage and, remediation activities, construction, ICT, education, and arts, entertainment, and recreation industries all use almost all digital technology for their several strategies and processes. On the other hand, the low-tech sectors' use of digital technologies are administrative and support service activities, agriculture, mining and quarrying, and water supply industries. In these industries, cloud technology, robotics, blockchain, and MTs are more widely used than other digital technologies. According to the literature findings from a digital innovations perspective, CPSs, IoT, DA and AI, robotics, AR & VR, blockchain, and MTs are used in almost every industry. On the other hand, certain technologies are not preferred in some industries.

For example, 3DP technology is not used or is rarely used in the wholesale and retail trade, transportation and storage, finance and insurance, real estate, professional, scientific and technical activities, and administrative and support service industries. Cloud technologies are not seen as secure enough for sensitive data in the finance and insurance industry and the public administration industry. Therefore, these industries cannot use this technology for data sharing. Although AT are used widely in mining and quarrying, electricity, gas, and steam supply, accommodation, and administrative and support service industries, the use of drones that is one of the autonomous technologies, is not common.

The case study respondents collected the digital innovations under the titles CPSs and EC, IoT, DA and AI (chatbots, VPA, etc.), cloud technology, IE (VR, AR, and MR), AT (robots, drones, autonomous vehicles, etc.), blockchain, 3DP, and MTs.

After specifying the potential digital innovations, their uses are analyzed for the industry of the case company:

CPSs technologies provide integration and coordination between virtual models and physical construction. They monitor and obtain information about facilities, processes, and progress, and provide materials, storage environments, and equipment health data. Besides, the materials that have CPSs like smart helmets, smart glasses, and smart vests improve efficiency, labor health, and safety. They control lighting, heating, cooling, and other automation in smart buildings based on real-time external factors. IoT provides communication between the construction site and the remote office to enhance collaboration among the project team and provides communication between devices on the construction site to receive alerts on maintenance, repairs, stock orders, and quality assurance. DA and AI technologies help to build planning with different condition scenarios by analyzing data from similar projects and pre-existing blueprints, and thereby increase construction efficiency, safety, and quality. Cloud safely stores information and allows real-time access, provides a collaborative working environment to stakeholders. Robotics like single-task construction robot is used in some operational tasks such as dismantling, painting, transportation, installation, lay-outing, drilling, and excavation. They improve efficiency and accuracy and reduce mistakes and paperwork, and labor costs. Autonomous or remotely piloted vehicles like drones are used to survey, inspect and monitor building sites, and generate maps or plans. They can reach to extreme and dangerous environments. AR-VR visualizes the status of the construction activities to plan, design, monitor and control, and help to reduce the operation time in hazardous areas. They help to train the employees. Moreover, they extend to marketing by visualizing the different variants of design for customers. They allow customers to give feedback to engineers at an early stage of design and development, therefore, provide personalization before implementation. Customer relations are improved 3DP constructs functional durable structures by printing materials such as concrete, steel, and glass. Blockchain provides smart contracts, transparent and efficient processes in the supply chain, improved integrated workflows and optimized site operations, transparent and secure payments and transactions, and boost collaboration among stakeholders. MTs allow us to make simpler scheduling, to work together in virtual project meetings, to reduce paperwork, to track costs and production in real-time, and to make better collaboration through real-time information.

5.3.2 Step 5. Analyzing the impact of digital innovations on business model components and specifying the impact levels

According to the literature results, although digital technologies have some common effects on business model components in different industries, there are also important differences in those effects.

Commonly, CPSs and EC technologies sense the environment by monitoring cyber and physical indicators, and then they modify the environment with actuators dynamically. Therefore, these technologies have a direct effect on the “activities and capabilities”, and “resources and competencies”, and an indirect effect on the cost structure because of types of resources. Differently, their usage positively affects the revenue sources of companies in construction, accommodations, ICT, education, health, professional services, and the art and entertainment industries. The customer relationship is affected positively by these technologies in public administration, education, and health industries since the technologies provide support channels. On the other hand, their usage is not common in administrative and support services.

IoT provides machine connectivity for collecting, sharing, and analyzing data. It directly affects the “activities and capabilities” of a company. Their usage positively affects the revenue sources of companies in construction, accommodation, ICT, education, health, professional services, and the art and entertainment industries.

With both DA and AI technologies, the collected data are processed, analyzed, and converted into useful information. Thanks to their learning capabilities, they can make predictions. They provide customer-specific products and services, complex problem solving, and planning and decision-making, optimization of processes, and support channel to customers via chatbots. Therefore, channels, customer relations, and activities and capabilities are affected directly by these technologies. Differently, some industries directly make money from the use of these technologies, as they are knowledge-based industries like ICT, finance, real estate, education, health, and professional, scientific, and technical service industries.

Cloud technologies provide flexibility and mobility for storing valuable information, accessing it instantly everywhere, updating information, managing documentation, and sharing consistent information across the entire organization. Its usage directly affects the “activities and capabilities”, and the “resources and competencies” of companies in most industries. However, they are not seen as secure enough for sensitive data in industries like finance and insurance industry and public administration industry. Therefore, these industries do not prefer to use this technology for storing and sharing their private data. Moreover, Cloud technology provides a collaborative working environment for stakeholders of companies in industries where partnership and collaboration are important. Examples are manufacturing, wholesale and retail trade, transportation and storage, ICT, and professional, scientific, and technical services. Therefore, this technology improves the partnership in these sectors. It also provides an environment not only for partners but also for customers in certain industries like education, art and entertainment, transportation and storage, and public administration.

IE technologies such as AR, VR, and MR provide a visual representation for monitoring the environment, checking statuses, planning, layout options, simulating different patterns of processes with different scenarios, demonstrating impacts of new conditions, diagnosing and identifying problems, training employees, improving quality assurance and maintenance, guiding consumers, presenting virtual tours and environments to consumers, allowing consumers to interact with products or services, and getting consumer feedback with 3D prototypes. Therefore, they reduce time and material use, improve efficiency for different processes, and improve customer relations in most industries. They also make money in some industries, such as education, art and entertainment, accommodations, finance, transportation, and others.

In most industries, robotics is used particularly for time-consuming and repetitive tasks, repair and maintenance, delivery services, training, and potentially dangerous or unsuitable working environments. Drones are used generally for data collection by monitoring, inspection, assessment, auditing and identification, and for delivery. Besides, driverless/unmanned vehicles are used in transportation. They improve efficiency and accuracy, and reduce labor costs, and thereby the “activities and capabilities”, and “resources and competencies” of these companies are positively affected by these digital technologies. They are used to make money and used as distribution channels in the transportation, waste management, education, and art and entertainment industries. They are used as a customer support channel in industries like real estate, administrative and support services, and public administration. In some industries, however, drone usage is viewed as an ethical problem, as in, for example, the accommodation industry.

3DP technology provides material, creates a required part for a repair, meets specific material needs, and thereby supports key resource supply as maintenance and operational materials. It reduces lead times and eliminates the transporting process. 3DP materials can be used as resources in experiments and physical exercise and provide possibilities for exploring and testing variations in R&D departments. 3DP products can make money by sales in the manufacturing and construction industries and by recycling in the waste management industry. Moreover, it provides product customization and hence provides better service to customers in the manufacturing and construction industries. On the other hand, its usage is not common in certain industries, such as wholesale and retail, transportation and storage, finance and insurance, real estate, administrative and support services, and professional services industries.

Blockchain provides transparent business transactions and, trusted information sharing and boosted collaboration between stakeholders, security for information thanks to encryption, trustworthy agreement with smart contracts and digital identities, fair payment, data integrity, direct communication with vendors by eliminating the third party, and improved workflow. It improves business customer relations and partnerships and supports business activities and processes in most industries.

MTs make information and services available and easily accessible and improve communication and interaction. They can be used as customer support and sale channel and for many activities and processes, such as booking, ordering, payment, learning, experience, and interaction, etc. Customers can view inventory, give orders, track the process, and access status and delivery information. Moreover, MTs make the flow of information among stakeholders easier, the tracking process in the value chain, and remotely assist collaboration efforts. As a result, they improve customer relationships and partnerships and make both activities and processes easier.

Most of the digital innovations that affect the revenue model either directly affect the customer segment or provide new offers, or both. However, some affect the revenue model and just improve offers. The usages are analyzed for the case company and impact levels of digital innovations on business model components tabulated in Table 7. The scores are determined as no/low-level impact (1), medium level impact (2), and high-level impact (3).

Table 7. Impact Levels of Digital Innovations on Business Model Components

Digital Innovations/ Business Model Components	Activities and Capabilities	Channels	Cost Structure	Customer/ Market Segment	Customer Relationship	Partners	Resources and Competencies	Revenue Model	Value Proposition
CPSs and EC	3	1	2	2	1	2	2	2	3
IoT	3	1	2	2	1	2	2	2	3
DA and AI	2	1	2	1	2	1	2	1	1
Cloud	2	1	2	1	1	2	2	1	1
AT	3	1	3	1	1	1	2	1	2
3DP	3	1	3	2	2	1	3	2	3
IE	3	2	2	1	3	1	2	1	1
Blockchain	2	1	2	1	2	3	2	1	1
MTs	2	3	2	2	2	1	2	1	1

5.4 Stage IV: The decision-making

In this stage, the findings in stages II and III are used to analyze innovations and decide on the digital innovation strategy.

5.4.1 Step 6. Identifying the type of innovations

The type of digital innovation is decided by evaluating the impact of digital technologies on the business model components. According to the construction industry case, CPS's and EC, IoT, and 3DP are disruptive technologies for the construction industry. CPS's and EC, and IoT technologies are used for the construction of a smart home, smart office, smart cities, etc. They bring to the market a very different value proposition and create a new market. The value proposition and customer segment components of the business model are affected. Therefore, these lead to disruptive innovation. Moreover, 3DP technologies introduce new products and services with the construction of functional durable structures by printing materials such as concrete, steel, and glass, and create new markets with customization. They change the way of the business. Other digital innovations are used to increase product or process performance and lead sustaining innovations.

5.4.2 Step 7. Identifying the degree of innovations

In this step, the innovation degree is specified by the impact level of digital innovations. Since radical innovations involve a significant impact on the business model, the level “3” in Table 5 corresponds to radical innovation. Incremental innovations require minor changes in the business model, and therefore the level “2” corresponds to incremental innovation in this step. According to findings, activities and capabilities, cost structure, and resources and competencies are the most impacted components of the business model by digital innovations in the construction industry. Digital innovations lead to radical innovation in these components. CPS’s and EC, IoT, AT, 3DP, and IE technologies have more impact on a business model than others, therefore the degree of innovation for these technologies are radical.

5.4.3 Step 8. Identifying the speed of innovations

The speed of innovation for each digital innovation is handled in this step. The speed of innovation may vary depending on digital innovations' impact on the business model components and the importance of those components for a company. It can be "slow", "as fast as possible", and "rapid". For the construction industry, when the importance of business model components (Figure 2) and the impact level of digital innovations on business model components (Table 5) are examined, it can be seen that CPS’s and EC, IoT, AT, 3DP, and IE technologies have more impact on the components and the components they affect are very important for the industry. For this reason, the speed of these innovations can be assessed as rapid innovation.

5.4.4 Step 9. Decision-making

Digital innovation strategies should be decided, basing on the objective of business model regeneration and the type, degree, and speed of innovation. When the decision is made, first, the objectives for the business model regeneration and the type of innovations are addressed. According to the case study company, improving existing products and processes, developing the existing market, and creating a new market and value is required in the construction industry. Since the objectives for a business model regeneration are process-related, customer/market and product/service-related objectives, all of the digital innovations that have a type sustaining, expanding, and disruptive can be considered. Among these digital innovations, the innovations that have more impact on the business model and that affect the business model components, which are important for the industry, are prioritized. In the previous step, the degree and speed of innovations are identified. The results show that CPS' and EC, IoT, AT, 3DP, and IE technologies should be integrated into the construction business model.

5.5 Stage V: Regeneration

This stage includes only the step "regenerating the business model". In this stage, the identified innovations are transformed into the business model. Since CPSs and EC, and IoT technologies are used as integrated, the changes of them are combined. The changes that stem from the selected digital innovations in business model components are identified and listed in Table 8.

Table 8. Digital Innovations-Driven Changes in Business Model

Business Model Components/ Digital Innovations	CPSs and EC and IoT	AT	3DP	IE
Activities and Capabilities	-Implementation & maintenance -IT management Operation monitoring -Resource and asset management -Partner management -Project management -Risk management -Supply chain management -Training of employees	-Implementation & maintenance -IT management -Operation execution -Operation monitoring -Partner management -Project planning -Risk management -Training of employees	-Implementation & maintenance -IT management -Operation execution -Partner management -Resource and asset management -Training of employees	-Customer relationship management -Implementation & maintenance -IT management -Partner management -Project planning and modelling -Resource and asset management -Risk management -Training of employees
Channels				Fairs Virtual reality module and platform
Cost Structure	-Equipment (IT resource) -Maintenance cost -Marketing cost -Training cost	-Equipment (IT resource) -Long-term assets (Vehicles) -Maintenance cost -Training cost	-Long-term assets (Vehicles) -Maintenance cost -Training cost	-Equipment (IT resource) -Maintenance cost -Marketing cost -R&D cost -Training cost
Customer/ Market Segment	-Smart building market		-3DP construction market	
Customer Relationship			-Personalization	-Customer engagement -Co-creation
Partners	-IT companies (hardware, software, service)	-Construction machine suppliers	-Additive manufacturers	-IT companies (hardware, software, service)
Resources and Competencies	-Human resource with IT skills -Technological resource (IT infrastructure, hardware, software)	-Financial resources -Human resource with IT skills -Technological resource (IT infrastructure, hardware, software)	-Financial resources -Human resource with IT skills -Technological resource (IT infrastructure, hardware, software)	-Human resource with IT skills -Technological resource (IT infrastructure, hardware, software)
Revenue Model	-Performance/value-based pricing model		-Performance/value-based pricing model	
Value Proposition	-Ability to deliver -Aesthetic/image -Comfort -Performance -Usability	-Ability to deliver -Quality	-Ability to deliver -Quality -Mass customization	-Ability to deliver -Quality

CHAPTER 6

CONSTRUCTION OF THE DIGITAL INNOVATIONS-DRIVEN DYNAMIC BUSINESS MODEL

6.1 Problem identification

In this section, the problem identification phase of the system dynamics methodology is applied. The problem identification phase consists of the dynamic problem and the purpose of the study as the solution to the problem (Barlas, 2002).

The way of doing business has been revolutionized the advent of new digital technologies. It is vital to determine the impact of digital innovations on the business model and business performance, and thus to decide on the right digital innovation strategy. The objectives of the study are to develop a dynamic business model in order to examine the dynamic circulation relationship within the entire business model regarding digital innovation strategies and to explore the impacts of different digital innovation strategies on business performance, especially on corporate sustainability. The research question of this study is “How to evaluate the impacts of digital innovations-driven business strategies on business performance, especially on corporate sustainability?”.

6.2 Model conceptualization

In this section, the model conceptualization phase of the system dynamics methodology is described. The model conceptualization phase consists of examining the real problem, listing all of the possible variables, identifying the major causal relations among these variables, identifying the feedback loops, and constructing an initial causal loop diagram (Barlas, 2002). Therefore, based on the literature review and the interviews with the experts on business models and digital innovation, the variables, causal effects, and feedback loops were identified, and a causal loop diagram was constructed.

A business model is “a system manifested in the components and related material and cognitive aspects” (Tikkanen et al., 2005, p. 792). There are several business model frameworks that are examined (Table 4) in this study. The literature-based component analysis of the business model indicated the following business model components: customer/market segment, value proposition, revenue, activities/processes, resources/assets, profit/margin, cost structure, partners, capabilities, channels, customer relationships, competencies, and sustainability. The business model components are rearranged after the case study. As the output of case study analysis, the business model components of the case company are specified as the customer/market segment, value proposition, revenue model, activities and capabilities, resources and competencies, cost structure, partners, channels, and customer relationships. The component analysis results overlapped the business model canvas items (Osterwalder & Pigneur, 2010). Besides, current digital innovations are identified as CPSs, IoT, DA and AI (chatbots, VPA, etc.), cloud, and IE, which consists of VR, AR, MR, and AT, which include robots, drones, autonomous vehicles, blockchain, 3DP, and MTs according to the technology trend reports reviewed for this study. Regarding the specific business model components and digital innovations, the literature on business models and digital innovations related to dynamic systems was reviewed to identify related variables and their causal effects.

The effects of digital innovations on the business model were analyzed, based on the expert views. The affected business model elements were specified as the capability-related variables. Investments, such as those related to digital innovation, can help companies to build their capabilities and allow them to deliver a greater amount of value to their customers (Fayoumi & Loucopoulos, 2016). The causal relationships among these capability variables are formed based on Porter's (1985) value chain. Porter's value chain consists of five primary activities as well as the four secondary activities that support the primary activities. Inbound logistics, operations, outbound logistics, marketing and sales, and service are the primary activities that create value. The secondary activities are procurement, human resource (HR) management, infrastructure, and technological development, and they do not provide a direct value for the company but rather help to improve the primary activities that do create value. In this study, the primary activities are related to supply chain activities, R&D activities, production, marketing activities, shipment, and support service. While these are affected by supportive and managerial capabilities, which are related to the management of IT, HR, risk, strategic partnerships, accounting, and inter-functional processes, they also support these primary activities.

On the other hand, there are other causal effects identified in the literature. Cosenz (2017) combined a business model framework with system dynamics modeling to create a business model. In this study, the proposed dynamic business model structure consists of seven sections and their items, which are the key-partner section (supplier delay and external investors credit line items), the "key-resource" section (workforce, component inventory, assets, and bank account as stock variables), the "cost structure" section (raw material, inventory, salary, and marketing costs), the "revenue stream" section, the "value proposition" section (productivity, delivery delay, return on investments [ROI], profit, and dividends), the "key-activities & channels" section (production and shipment), and the "customer segment & relationships" section (customers). Cosenz and Noto (2018a) studied a dynamic model for analyzing the performance of a single web-based platform using the previous study's structure. This model includes, unlike the previous one, R&D, service quality characteristics, and equity as resources; marketing, R&D activities, and service quality as value proposition; and advertisement, subscription revenues, and the hosting cost. Moreover, Cosenz and Noto (2018b) built a dynamic business model simulator, which has a similar structure to those used in previous studies, to show how a dynamic business model can support entrepreneurial learning processes.

In addition to these dynamic business model studies, there are some system dynamic studies that include items that can be integrated into the dynamic business model structure. Azabadi et al. (2012) used system dynamics to study the interactions among the variables of the organizational knowledge management cycle, which includes knowledge acquisition, knowledge creation, knowledge sharing, and knowledge utilization. The interactions among individual knowledge, shared knowledge, unshared knowledge, and the organizational knowledge stock variables with other activities such as R&D, training, innovation, etc. are also examined in their study. The customer relationship management variables, such as customer satisfaction, are studied along with the variables for product attractiveness, service quality, price, and delivery delay (Afshar Kazemi, Eshlaghy, & Tavasoli, 2011; Bassi & Lorenz, 2005; Crescitelli & Figueiredo, 2009; Octabriyantiningtyas & Suryani, 2019; Yuen & Chan, 2010). The effects of multiple channel strategies and the accessibility of products on customer satisfaction were investigated (Faezipour & Ferreira, 2013; Wallace, Giese, & Johnson, 2004). The interaction between awareness and customer acquisition and sales has been examined in terms of marketing strategies (Fadil, 2015).

After the variables and causal effects were identified, the feedback loops were formed for these variables and causal effects. The digital innovations-driven dynamic business model consists of seven main reinforcing feedback-loops, which are shown with R and four main balancing feedback-loops, which are shown with B. Table 9 outlines these loops and their dynamics.

Table 9. Feedback Loops and Dynamics

Loops	Dynamics
R1: financial resource → budget → R&D budget → R&D activities → product quality → product attractiveness → customer satisfaction → orders → product assembly → shipment → revenue → financial resource	Loop R1 is related to the dynamics that an increase in product quality originated from R&D budget increase leads to increase in revenue
B1: R&D activities → total cost → financial resource → budget → R&D budget → R&D activities	Loop B1 is related to the dynamics of decrease in financial resource stems from R&D activities-based cost increase
R2: financial resource → budget → marketing budget → marketing activities → brand awareness → customer base → orders → product assembly → shipment → revenue → financial resource	Loop R2 is related to the dynamics that an increase in brand awareness originated from marketing budget increase leads to increase in revenue
B2: marketing activities → marketing cost → total cost → financial resource → budget → marketing budget → marketing activities	Loop B2 is related to the dynamics of decrease in financial resources stems from marketing activities-based cost increase
R3: financial resource → budget → HR budget → workforce → total productivity → product assembly → shipment → revenue → financial resource	Loop R3 is related to the dynamics that an increase in total productivity originated from HR budget increase leads to increase in revenue
B3: HR budget → workforce → total cost → financial resource → budget → HR budget	Loop B3 is related to the dynamics of decrease in financial resources stems from salary-based cost increase
B4: workforce → investment → fixed assets → total cost → financial resource → budget → HR budget → workforce	Loop B4 is related to the dynamics of decrease in financial resources stems from workforce equipment-based cost increase
R4: workforce → individual knowledge → knowledge creation → organizational knowledge → product development capability → product quality → product attractiveness → customer satisfaction → orders → product assembly → shipment → revenue → financial resource → budget → HR budget → workforce	Loop R4 is related to the dynamics that an increase in organizational knowledge originated from workforce increase leads to increase in product quality and financial resource
R5: workforce → individual knowledge → knowledge creation → organizational knowledge → marketing & sale management capability → brand awareness → customer base → orders → product assembly → shipment → revenue → financial resource → budget → HR budget → workforce	Loop R5 is related to the dynamics that an increase in organizational knowledge originated from workforce increase leads to increase in brand awareness and financial resource
R6: knowledge sharing → individual knowledge → knowledge creation → organizational knowledge → knowledge acquisition → unshared knowledge → knowledge sharing	Loop R6 is related to the dynamics that an increase in individual knowledge originated from knowledge sharing increase leads to increase in organizational knowledge and knowledge acquisition
R7: delivery delay → product attractiveness → customer satisfaction → orders → delivery delay	Loop R7 is related to the dynamics that an increase in product attractiveness originated from delivery delay decrease leads to increase in customer satisfaction and orders

The causal loop diagram is constructed with the identified main feedback loops using the tool “Vensim PLE Plus” (Figure 4). In Figure 4, the arrows show the causal effects among the business model items. The reinforcing loops are symbolized with

“R” whereas “B” is used for the balancing loops. Digital innovations-driven investment strategies are colored with red. Shadow variables are used for clarity in the appearance of the model. This structure provides a better understanding of how the business model items interact due to the digital innovations-driven investment strategies.

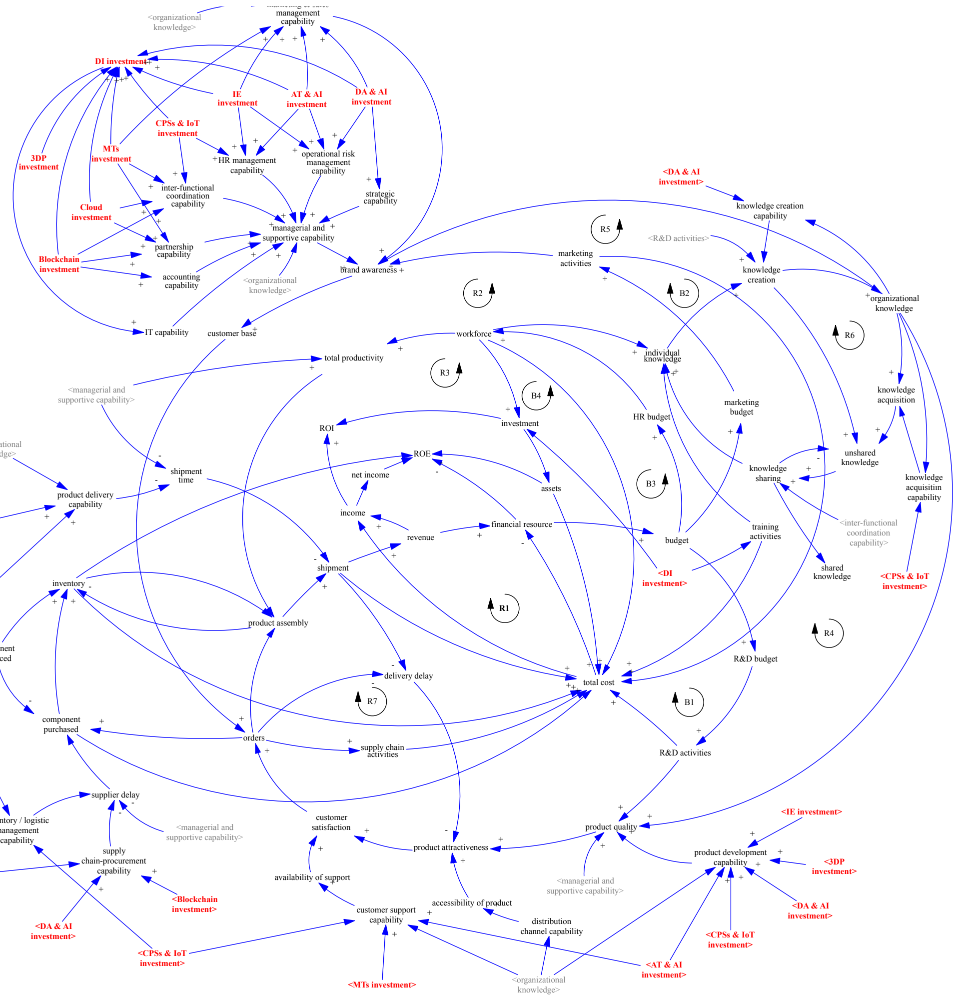


Figure 4. Conceptual model of digital innovations-driven dynamic business model

6.3 Model formulation

In this section, the model formulation phase of the system dynamics methodology is described. The model formulation phase consists of identifying the main stock and flow variables, developing the stock-flow diagram, writing down the mathematical equations for all variables, estimating the initial values of stocks and the values of the parameters, and verification (Barlas, 2002). The stock-flow diagram was constructed (see Appendix C), basing on the business model canvas (Osterwalder & Pigneur, 2010). In addition to the building blocks of the business model canvas, a block is formed for the capabilities, which are affected by digital innovations. Therefore, the model consists of 10 sub-models, which are key partners, key resources, value proposition, capabilities, key activities, customer relationships, channels, customers, revenue streams, and cost structure. Each sub-model is described in this section.

Vensim was used to construct a stock-flow diagram and to write down the mathematical formulas for the variables. All of the equations are given in Appendix D. Synthesim function of the Vensim tool is used to estimating the initial values of stocks and the values of parameters. Moreover, dimensional consistency check proved with the unit check function of the Vensim tool.

6.3.1 Key partners sub-model

The partnership is a cornerstone of a business model and companies create alliances to optimize their business models, reduce risk, or acquire resources (Osterwalder & Pigneur, 2010). In this study, the parameters “external knowledge shares”, which provide knowledge acquisition and “external investors equity shares”, which increase the equity and financial resources are specified for acquiring resources from key partners with strategic alliances (Figure 5). The “suppliers delay” is an important variable, which affects the time of the purchased component to enter inventory. It is affected by inventory/logistics capability, supply chain/procurement capability, and managerial and supportive capability. This sub-model does not contain stock variables.

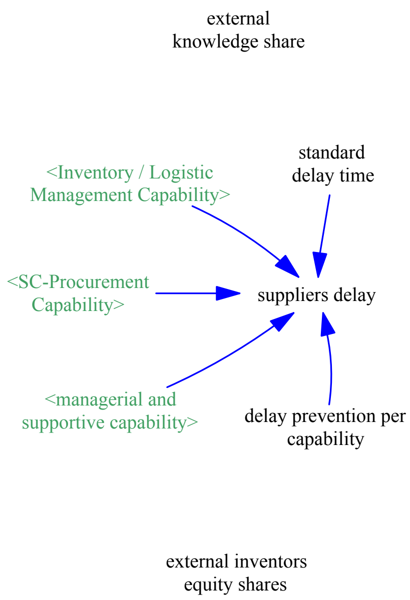


Figure 5. Key partners sub-model

6.3.2 Key resources sub-model

Key resources, which can be physical, financial, intellectual, or human according to the business model canvas, are required to make a business model work. In this study, workforce, individual knowledge, organizational knowledge, inventory, fixed assets, equity, and financial resource are specified as key resources (Figure 6 and Figure 7).

In workforce structure (Figure 6), hires, which can be calculated considering human resource budget and human resource need, increase the workforce while retirements decrease it.

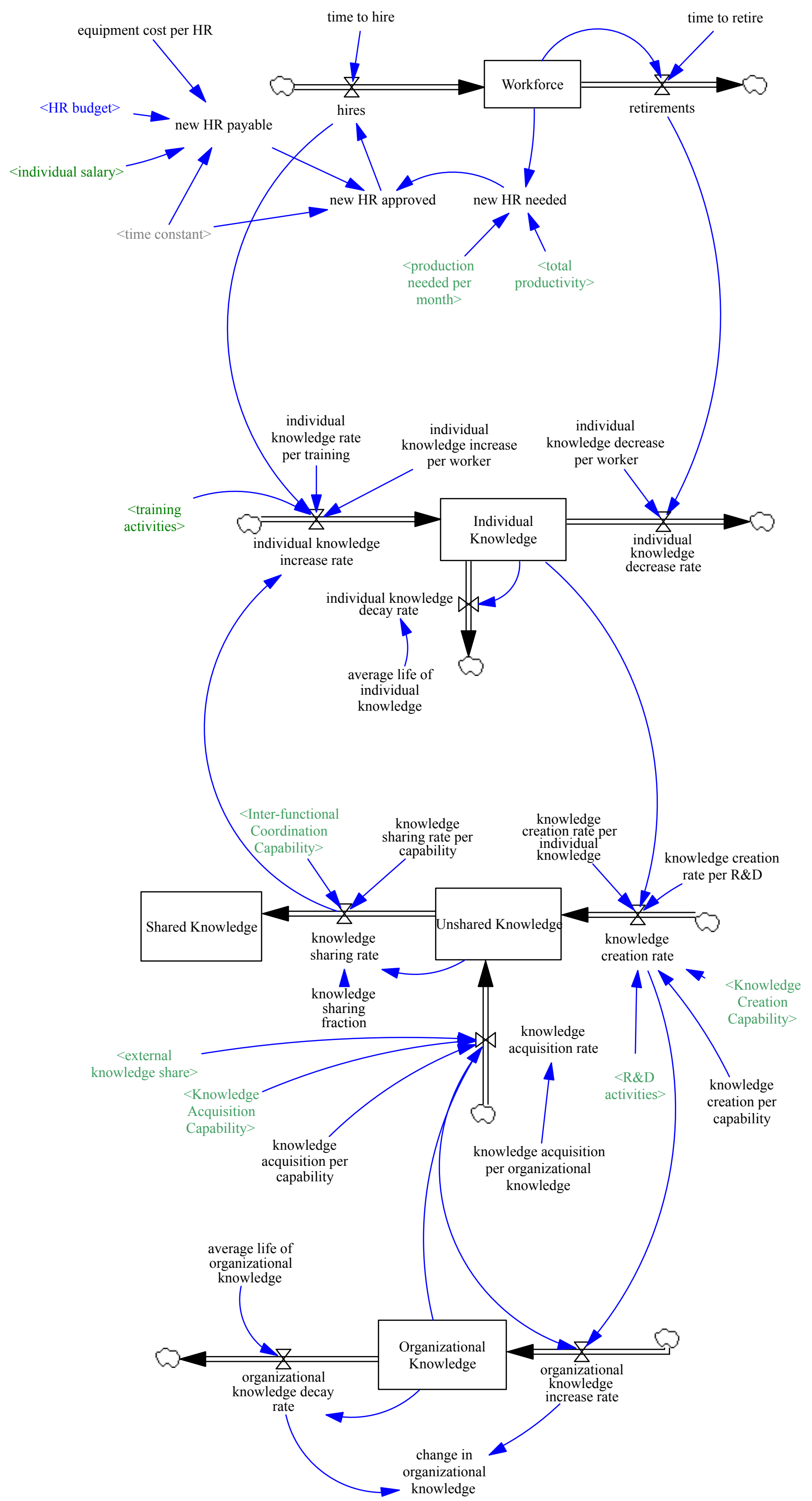


Figure 6. Key resources sub-model I

Individual knowledge increases when hiring occurs while it decreases when a worker retires. It can be increased with training activities. On the other hand, there is an individual knowledge decay rate, which depends on the average life of individual knowledge. Individual knowledge, R&D activities, and knowledge creation capability affect knowledge creation, which increases unshared knowledge and organizational knowledge stocks. Unshared knowledge increases also with knowledge acquisition, which can be provided using organizational knowledge, external knowledge share, and knowledge acquisition capability. Knowledge acquisition means also an increase in organizational knowledge. When unshared knowledge is shared, shared knowledge and individual knowledge increase.

There are other key resources in the key resources sub-model II (Figure 7). Inventory is another key resource, which can be represented as a stock variable. The inventory is managed according to the orders and supplier delay. The purchased component may be decreased with 3DP technology investment. Inventory decreases as production takes place. Fixed assets, one of the strategic resources can be increased with new investments such as new worker equipment and digital innovation investment and they can be decreased with depreciation. Financial resources increase with revenue whereas it decreases with cost and dividends. External investor’s equity shares increase financial resources.

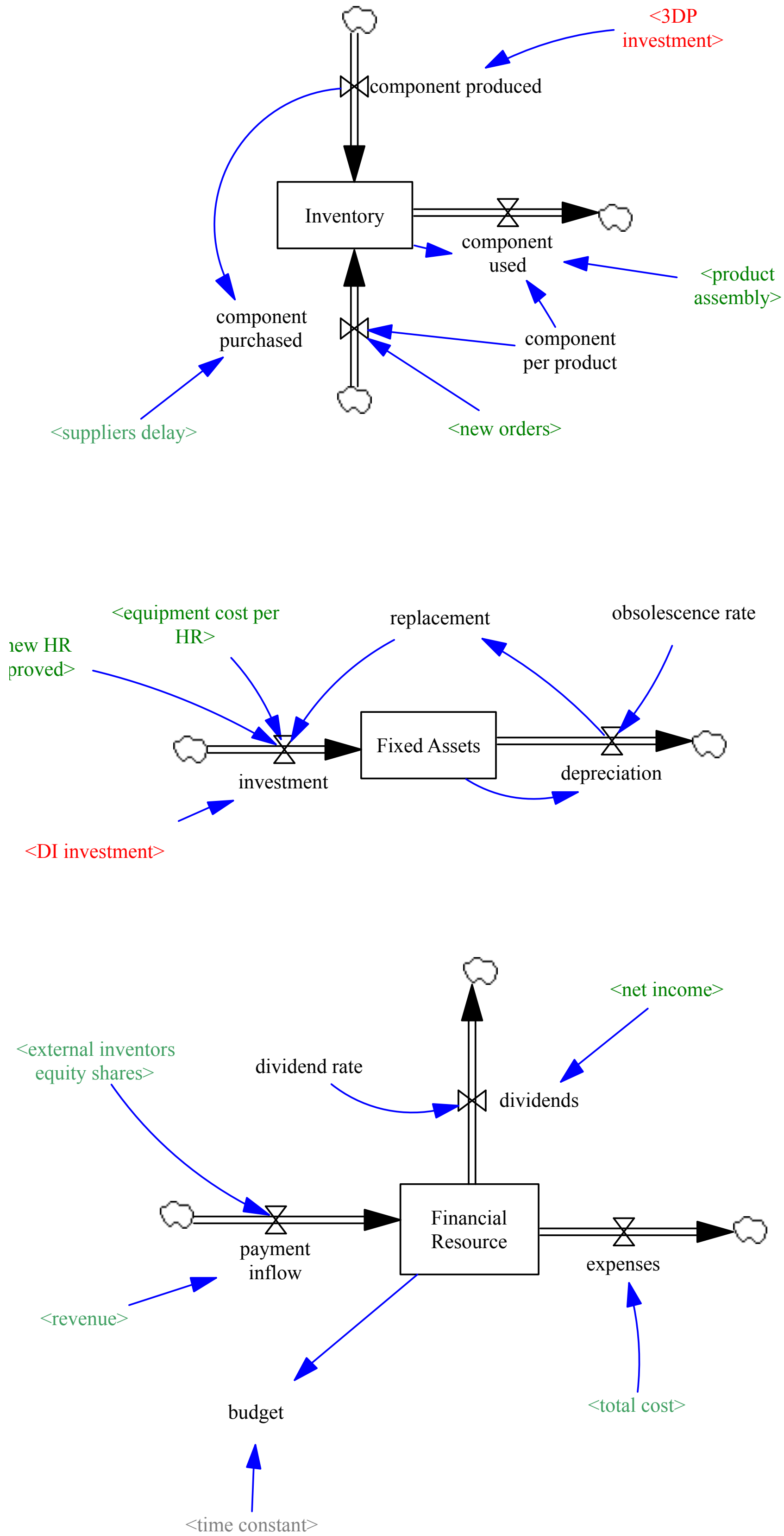


Figure 7. Key resources sub-model II

6.3.3 Capabilities sub-model

Capabilities are "the ability of corporations to exploit their resources" (Wahl & Prause, 2013) and they are functional-based like marketing, production, distribution and logistics, and human resource management capabilities (Javidan, 1998). Therefore, it is expected that they are affected by digital innovations and affect the main activities. Since there are few studies in system dynamic literature about the impact of up-to-date technologies on capabilities, the capabilities sub-model is formed basing on the expert view analysis in this study. Managers (Appendix A) stated their ideas about the effects of digital innovations on the business model. With the analysis of these ideas, six main and seven managerial and supportive capabilities are specified, which will be affected by several digital technologies.

According to main capabilities sub-model (Figure 8), 3DP, DA and AI, AT and AI, CPSs and IoT, and IE investments increase the product development capability; DA and AI, and AT and AI increase the product delivery capability; CPSs and IoT, DA and AI, and 3DP increase the inventory and logistics management capability; CPSs and IoT, AT and AI, and MTs increase the customer support capability; 3DP, MTs, AT and AI, DA and AI, and IE increase the marketing and sale management capability; and blockchain and DA and AI increase the supply chain and procurement capability. Moreover, all these capabilities are affected by "DI effect" and "organizational knowledge effect on capabilities". All these main capabilities are the determinants of important performance indicators like product quality, shipment time, total productivity, brand awareness, accessibility of product, and availability of support.

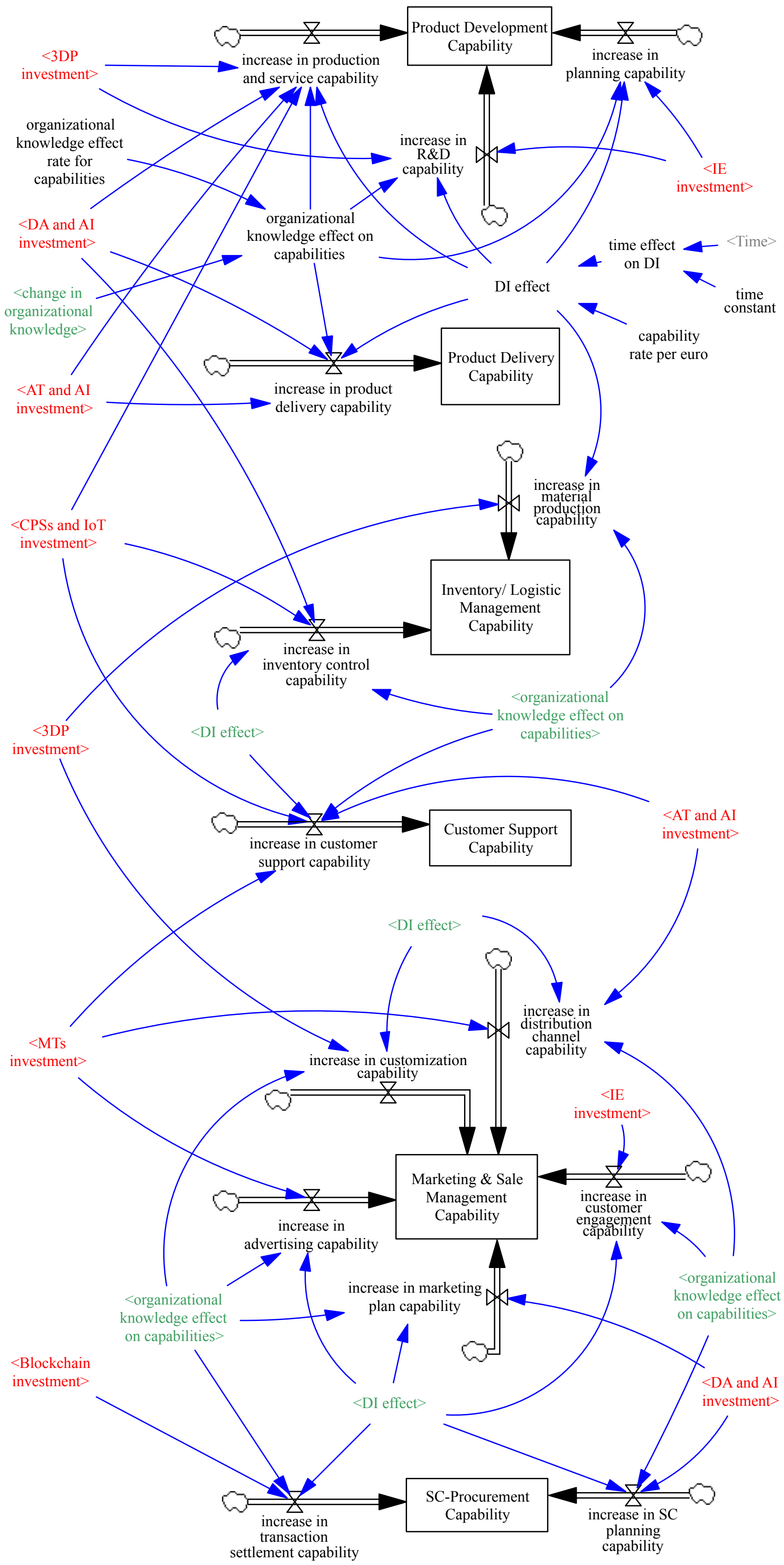


Figure 8. Main capabilities sub-model

Moreover, the capabilities sub-model includes also supportive and managerial capabilities, which are IT capability, human resource management capability, operational risk management capability, strategic capability, partnership capability, accounting capability, and inter-functional coordination capability. These capabilities are affected by digital innovation investments, “DI effect”, and “organizational knowledge effect on capabilities” as can be seen in Figure 9. Managerial and supportive capabilities are important since they affect some critical performance drivers like product quality, shipment time, total productivity, and brand awareness, together with the main activities. Additionally, IT capability is affected by DI investment, which is the sum of all the digital innovation investments.

In the case of digital innovation investment, the increase in the related capability is affected by the DI effect, which provides a change in the capability depending on the time. The increase in capability is based on the diffusion of innovations theory (Rogers, 1995). According to the diffusion of innovations theory, the successful spread of an innovation follows an S-shaped curve. In the early stage of innovation, growth is relatively slow as the new product establishes itself, then the growth increases more rapidly, and towards the end of its lifecycle, growth slows. Therefore, in this study, the DI effect is calculated with the time effect which is set with the lookup (Figure 10).

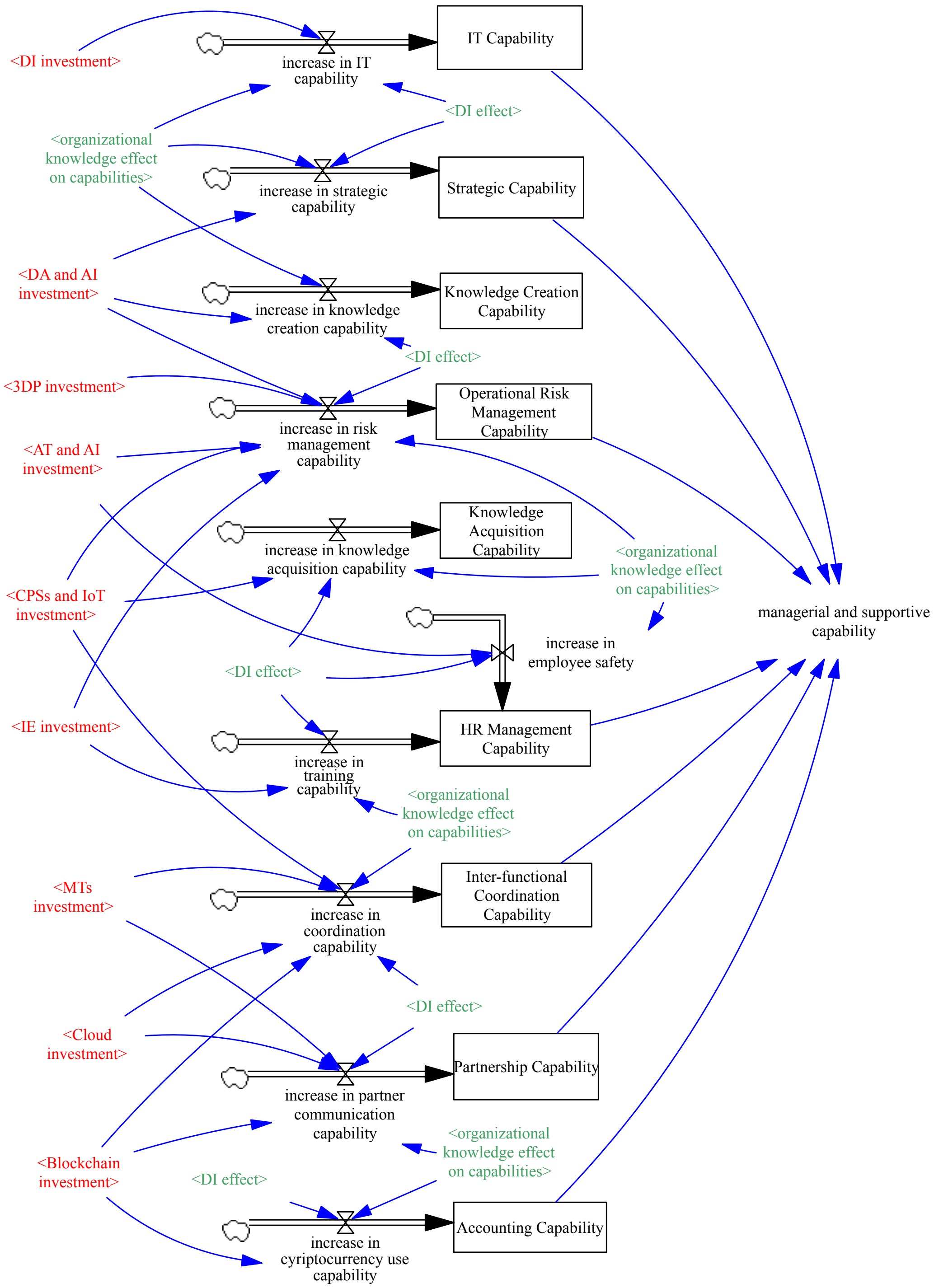


Figure 9. Managerial and supportive capabilities sub-model

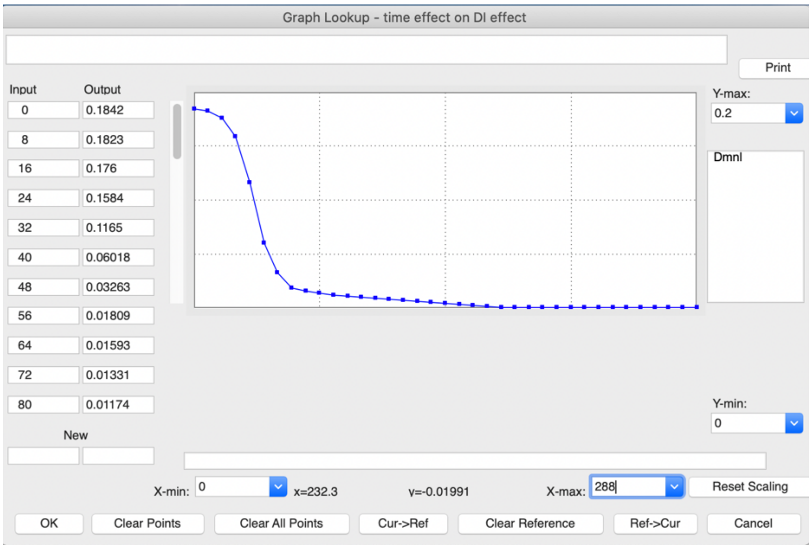


Figure 10. Time effect lookup for DI effect

6.3.4 Key activities sub-model

Key activities are the main actions firms must take. Porter's (1985) value chain includes five primary activities, which are inbound logistics, operations, outbound logistics, marketing and sales, and service. In this study, the key activities sub-model includes product assembly, shipment, supply chain, marketing, R&D, and training activities. According to the key activities sub-model (Figure 11), orders are given by customers at the rate of their satisfaction, and production takes place for orders in the process. Product assembly is equal to the minimum of the following variable: total productivity, inventory, and orders in process. The shipping takes place for the shipment ready products and the shipment time that depends on product delivery capability, managerial capability, and standard shipment time. The production process important since the order time and shipment time measure the delivery delay which affects product attractiveness.

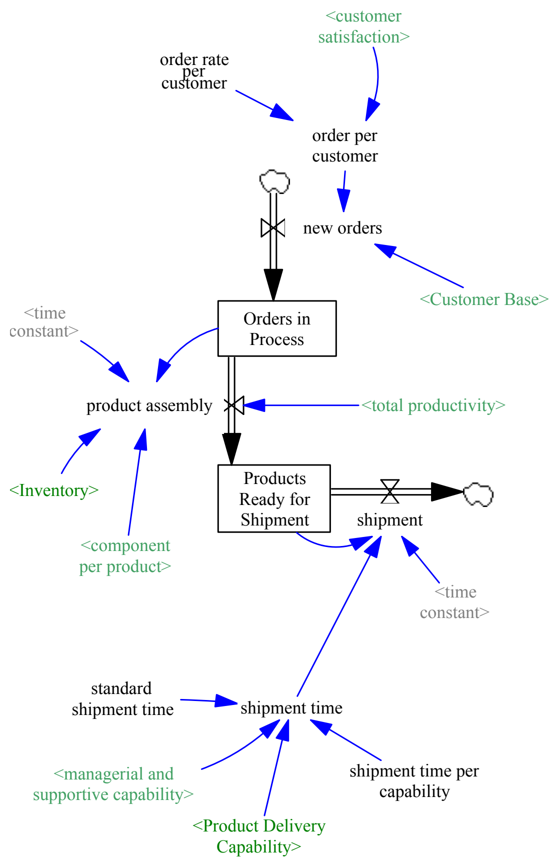


Figure 11. Production and shipment key activities sub-model

The key activities sub-model includes also other activities (Figure 12). R&D and marketing activities depend on specified R&D and marketing budgets. R&D activities affect product quality whereas marketing activities are important for brand awareness. Supply chain activities depend on the number of purchased components for production. Moreover, there is a standard rate for training activities and in case of digital innovation investment, the activities changes depending on the time. For example, more training activities are required at the start of the investments. Therefore, in this study, a time effect on training activities is specified as in Figure 13.

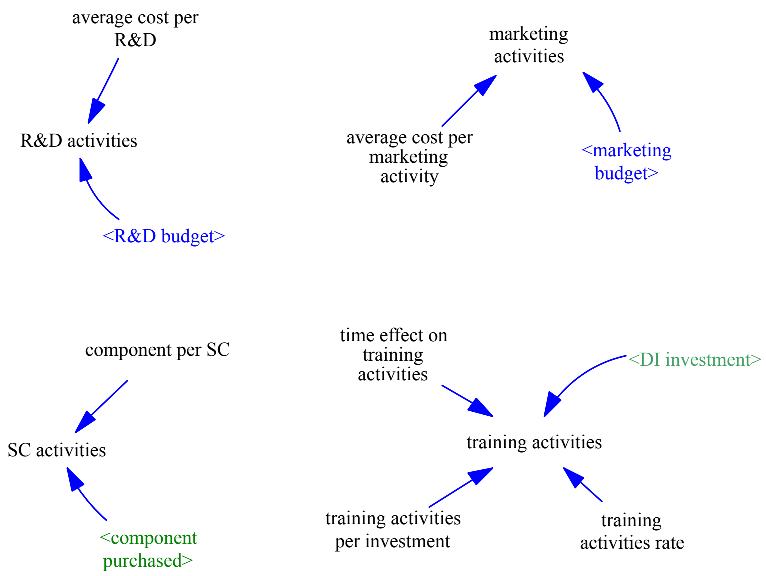


Figure 12. Other key activities sub-model

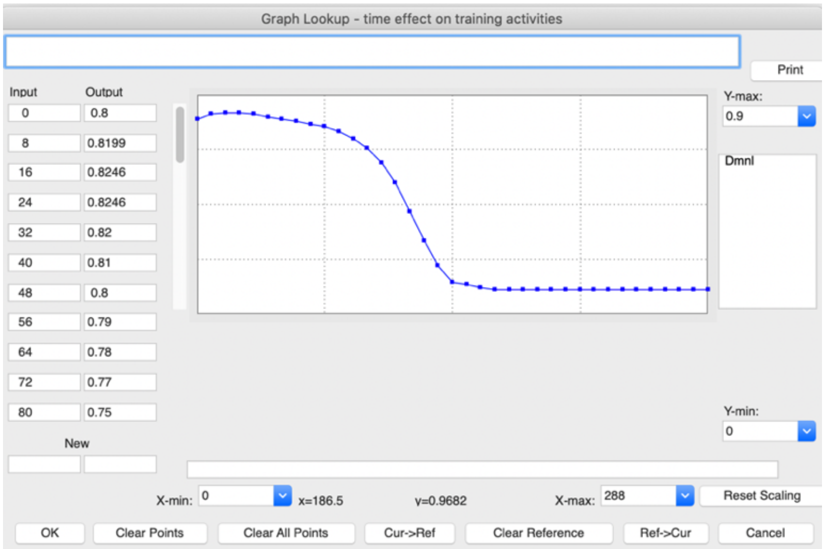


Figure 13. Time effect on training activities

6.3.5 Value propositions and economic measures sub-models

In the value propositions building block of the business model canvas, the bundle of products and services that create value for a customer segment is described. The value proposition may be quantitative like delivery delay and price or qualitative such as quality and accessibility. Financial performance is often used by strategy researchers in order to measure the impacts of a business strategy. According to the

Global Reporting Initiative guidelines, the following main metrics can be used for measuring economic sustainability performance: total/net income, sales/cash flow, production/costs, earnings per share, R&D investments, and subscribed capital. (Marhraoui & El Manouar, 2018). In this study, the value proposition sub-model includes several performance drivers and conventional economic measures (Figure 14).

One of the performance drivers in this study is total productivity. Total productivity affects production. The workforce that affects the total productivity is adapted according to the number of new orders and total productivity. The production process important since the order time and shipment time measure the delivery delay which affects the product attractiveness. Another variable which affects the product attractiveness is product quality. The change in product quality depends on R&D activities, organizational knowledge, product development capability, and managerial and supportive capability. Accessibility of product, which is the distribution and sale channel performance, is another determinant of the product attractiveness. Product attractiveness is important since it affects the number of orders per customer. Moreover, brand awareness is determined by marketing activities, marketing and sale management capability, managerial and supportive capability, and organizational knowledge. It is one of the important performance drivers since it has an impact on the acquisition of new customers.

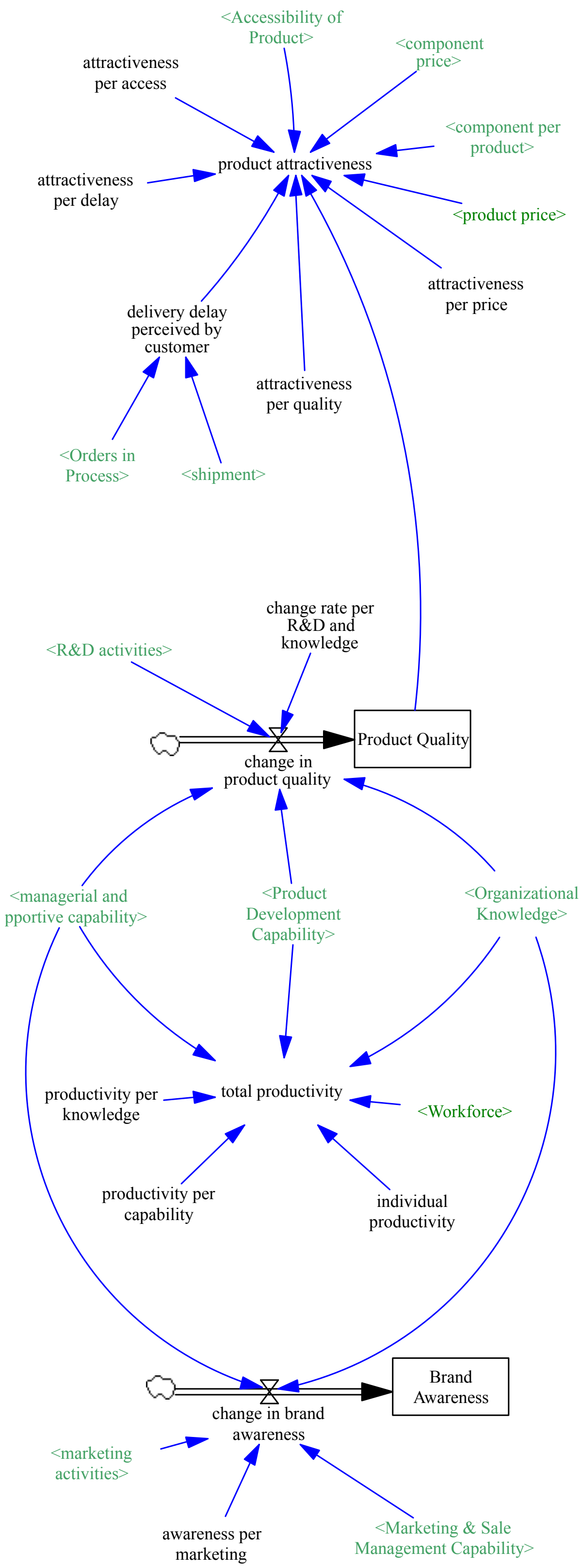


Figure 14. Value propositions sub-model I

There are some conventional economic measures, which are calculated with some of the business model variables (Figure 15). One of them is ROI. ROI is calculated with income and investments. It measures the gain or loss generated on an investment. In this study, it can be calculated for digital innovation investments. Another economic measure of financial performance is the return on equity (ROE). It can be calculated with net income and equity of shareholders, which bases on assets and debts. In this study, the dept is assumed as zero. ROE is used to calculate the sustainable growth rate. The sustainable growth rate is calculated with ROE and business retention rate, which bases on dividend rate.

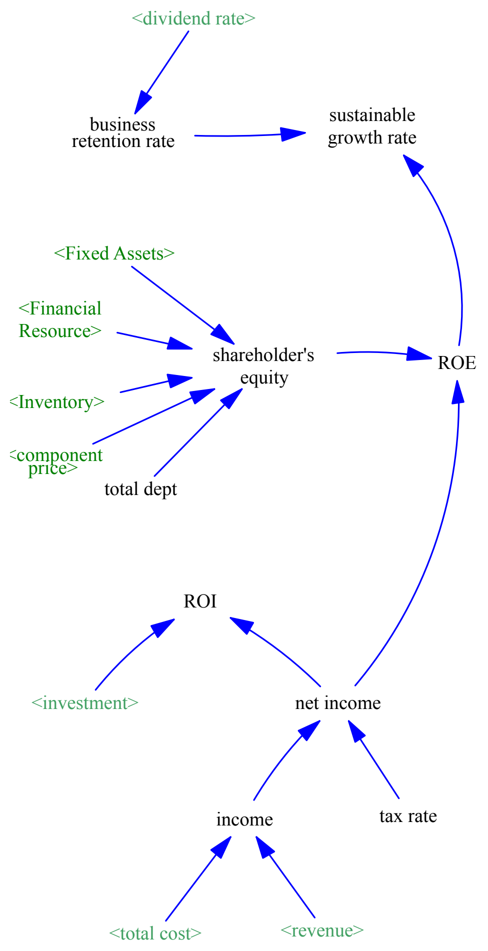


Figure 15. Value propositions sub-model II

6.3.6 Customer relationships sub-model

Companies want to create a relationship with their customers to sustain or grow their market share. In this study, the customer relationship sub-model includes the customer satisfaction variable, which is affected by the product attractiveness and the availability of support (Figure 16). Customer satisfaction is an important variable for sales since it affects the order per customer.

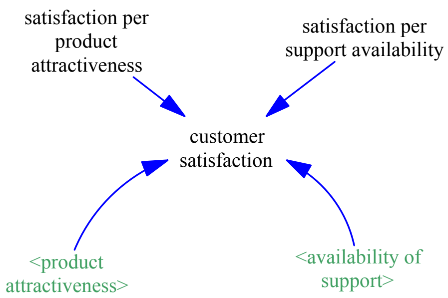


Figure 16. Customer relationships sub-model

6.3.7 Channels sub-model

Companies communicate with and reach their customers through distribution, sale, and communication channels, which serve many functions such as delivering value propositions, raising awareness among customers, and support customers (Osterwalder & Pigneur, 2010). In this study, the channel sub-model includes a stock variable, which is product accessibility that represents the distribution and sale channels and affects the product attractiveness (Figure 17). The accessibility increases with an increase in distribution channel capability. For the communication channel, the availability of support, which affects customer satisfaction is calculated with customer support capability.

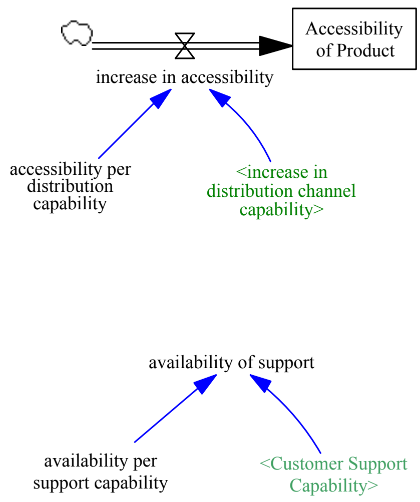


Figure 17. Channels sub-model

6.3.8 Customer segment sub-model

Customers comprise the heart of business models. In this study, the customer segment sub-model includes the stock of customers, which affects the number of new orders (Figure 18). The customer base may increase with new customers, which depends on the change in brand awareness and decrease with customer loss flows. The customer base affects the number of new orders.

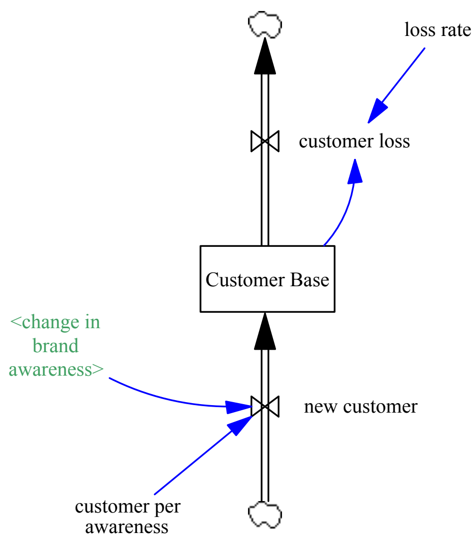


Figure 18. Customer segment sub-model

6.3.9 Cost structure sub-model

The cost structure describes all costs such as fixed and variable costs as defined in the business model canvas, to operate a business model. In this study, the total cost is calculated with marketing cost, R&D cost, HR cost (e.g. salary, training), investment cost, raw material cost, supply chain cost, shipping cost, inventory holding cost, and other costs (Figure 19). The total cost is important for next year's budget planning.

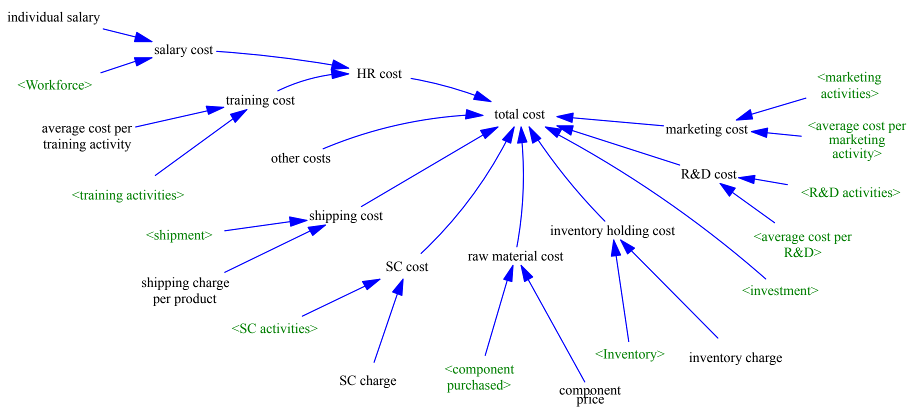


Figure 19. Cost structure sub-model

6.3.10 Revenue stream sub-model

There are several ways a company generates revenue such as sales, advertisement, licensing, lending, renting, etc. (Osterwalder & Pigneur, 2010). In this model, revenue is calculated with the number of products shipped and the product price (Figure 20). It affects the financial resource and the new budget, which will be specified according to financial resources.

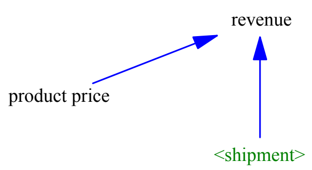


Figure 20. Revenue stream sub-model

CHAPTER 7

MODEL VALIDATION AND ANALYSIS

Validity is a relative concept and absolute proof is not possible for any theory or model (Forrester, 1973). However, models can be judged as valid even though their validity cannot be proved (Barlas & Carpenter, 1990). The aim is to increase the amount of confidence in the model's credibility as is required, rather than trying to fully test the model (Balci, 2007). Model validation is an important step in the system dynamics methodology (Barlas, 1996), which is the case for any model-based methodology (Davis, Eisenhardt, & Bingham, 2007). Structure validity and behavior validity are the two types of validation for a system dynamics model. The structure validity is about whether or not the structure of the model provides a meaningful description of the real relations while the behavior validity concerns whether or not the dynamic patterns of the model are similar to the real dynamic patterns (Barlas, 2002). The structural validity includes the direct structured test and the structure-oriented behavior tests while behavior validity consists of behavior pattern tests (Barlas, 1996).

7.1 Direct structure tests

The validity of a model structure is assessed using direct structure tests, comparing with each relationship in the model with the available knowledge about the real system. Various tests are suggested for direct structure validity by researchers who have studied the validation of system dynamics models. (Balci, 2007; Barlas, 1996; Forrester & Senge, 1980; Richardson & Pugh, 1981). In this study, the structure-confirmation test, boundary adequacy (structure) test, and dimensional consistency test were performed for direct structure validity, and the process was facilitated by means of cause-effect graphing.

7.1.1 Structure-confirmation test

The consistency of a model structure with the real system structure is assessed in this test. It can be theoretical, using generalized knowledge in the literature or empirical, using the relationships that exist in the real system (Barlas, 1996). In this study, the main relationships in the model were justified by means of the existing models in the literature or by the experts' opinions as explained in the model conceptualization section of the previous chapter, thereby the structured validity is demonstrated.

7.1.2 Dimensional consistency test

Dimensional consistency test checks each equation whether it has the same dimensions for its the right-hand side and left-hand side, thereby dimensional consistency among all the equations is checked and internal consistency is performed (Barlas, 1996). In this study, Vensim's "units check" function was used to test dimensional consistency and the model passed (Sterman, 2000).

7.1.3 Boundary adequacy (structure) test

The boundary adequacy test is performed to test whether the model includes all important concepts for addressing the problem (Barlas, 1996). For analyzing the digital innovation strategies on the business model, the key concepts of all building blocks of the business model were endogenous to the model considering the business model canvas.

7.1.4 Cause-effect graphing

Cause-effect graphing supports to show “what causes what in the model representation?” and it assists model correctness assessment by identifying the causes and effects and examining whether they are accurately reflected in the model (Balci, 2007). In this study, Vensim’s “causal tracing” and documentation functions were used to facilitate this process (Barlas, 1996). Causal tracing is useful to discover the relationship among the variables, showing a tree of causes and the uses of each variable (Eberlein & Peterson, 1992).

7.2 Structure-oriented behavior tests

Structure-oriented behavior tests are applied to the whole model and they allow to detect the potential structural flaws when simulating the model (Barlas, 1996). Barlas (1996, p. 184) stated that “since structure-oriented behavior tests combine the strength of structural orientation with the advantage of being quantifiable, they seem to suggest the most promising direction for research on model validation. Some suggested structure-oriented behavior tests include the extreme-condition test, the behavior sensitivity test, and the phase relationship test (Barlas, 1996). For this study, three common structure-oriented behavior tests, which are the integration error test, the extreme-condition test, and the behavior sensitivity tests were performed.

7.2.1 Integration error test

The integration error test checks whether the behaviors are sensitive to the time step (dt) or to the numerical integrating method choice (Sterman, 2000). In this study, for the integration error test, different time step values were used starting from one to 1/128 in combination with different integration methods, which are Euler and fourthorder Runge-Kutta with an automatic adjustment, in Vensim PLE Plus. The results were not sensitive to the time step values starting from 1/4 to 1/128 as well as the choice of numerical integrating method. The 1/4 dt value is small enough. However, according to the rule of thumb, the simulation time step must be smaller than 25% of the smallest time constant of a model. The smallest time constant is one month in this model, so therefore the time step is selected as 1/8 (0.125), which is neither too large to give inaccurate behaviors, nor too small to cause calculation errors. The numerical integrating method is selected as Euler which is the default method in Vensim PLE Plus. As a result, the model passes the integration error test.

7.2.2 Extreme-condition test

In an extreme-condition test, extreme values are assigned to specified parameters and the model behaviors are compared with the anticipated behavior of the real system under the same extreme conditions (Barlas, 1996). According to Barlas (1996), Vensim provides a nice extreme-condition testing environment with its “reality check” facility. Reality Check tests consist of test inputs coupled to expected behaviors and check for the model’s conformance to the expected behaviors with the statements in the following form: “if test input X is imposed on the real system or a valid model of it, then behavior Y will result” (Peterson & Eberlein, 1994). Reality checks can be performed, basing directly from experience and mental models without an equation writing skill (Peterson & Eberlein, 1994). Different reality check functions are used for different purposes. For making sure something goes to zero, a DECAY function; for checking to see that variables make monotone adjustments to a new value, a RAMP function; for making sure variables grow sufficiently fast, a GROW function; for comparing the values of a variable from a different run, a

COMPARE function; and for specifying that an effect takes place after a delay, a STEP function can be used (Eberlein & Peterson, 1992).

In this study, the “reality check” was used as an extreme-condition test. The reality functions “STEP”, “DECAY”, “GROW”, and “RAMP” were used for several constraint statements. Following statements are some examples for the reality check test:

- TI no financial resource: TEST INPUT: Financial Resource=0
- RC no customer base no new order: THE CONDITION: customer base= RC STEP (customer base, 0): IMPLIES: new orders <= RC STEP CHECK (1, new orders, 0)
- RC no product awareness decay in customer base: THE CONDITION: change in brand awareness=RC STEP (change in brand awareness, 0): IMPLIES: Customer Base>=RC DECAY CHECK (0, Customer Base, 95)
- RC increase in knowledge creation rate increase in organizational knowledge: THE CONDITION: knowledge creation rate=RC STEP (knowledge creation rate, 2): IMPLIES: Organizational Knowledge>=RC RAMP CHECK (1, Organizational Knowledge, 1.93, 36)
- RC increase in marketing budget growth in awareness: THE CONDITION: marketing budget=RC RAMP (0, marketing budget, 1.5, 36): IMPLIES: Brand Awareness>=RC GROW CHECK (4, Brand Awareness, 0.006)

In this study, a sub-model for the reality checks of the base model (Figure 21) and another sub-model for the reality checks of digital innovation effects (Figure 22) were developed in order to test the extreme conditions. All the reality check functions used in these sub-models can be seen in Appendix D (the functions 154-

208, 235). The model responded plausibly when extreme values were assigned to the variables and the parameters in the model.

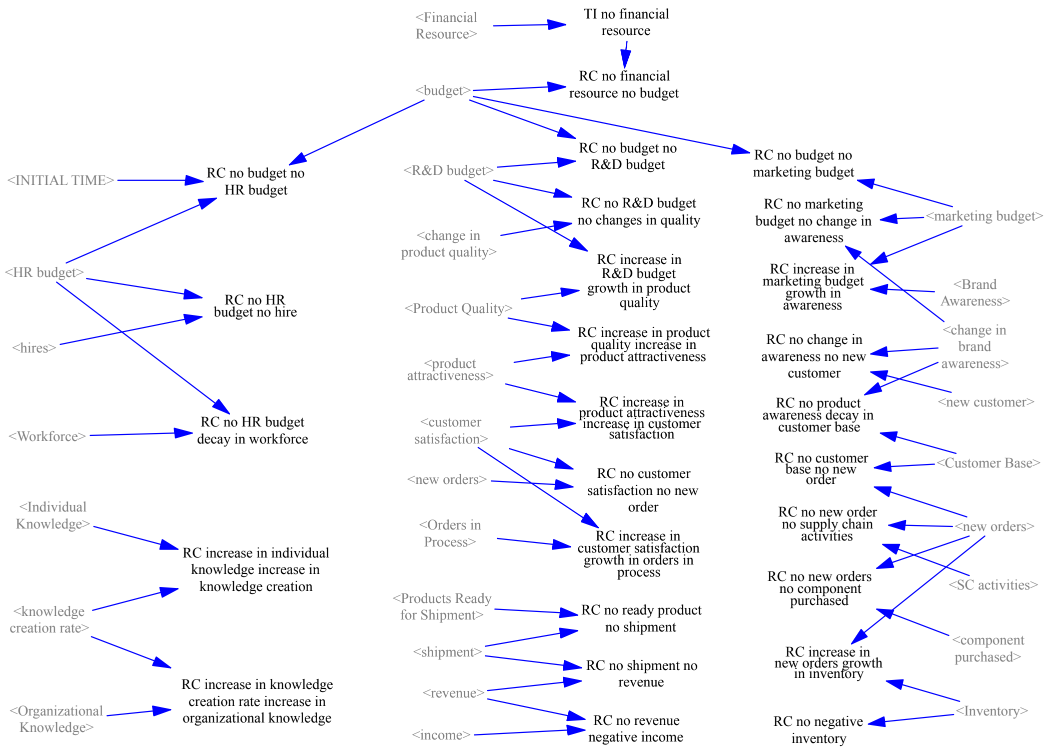


Figure 21. Reality checks for the base model

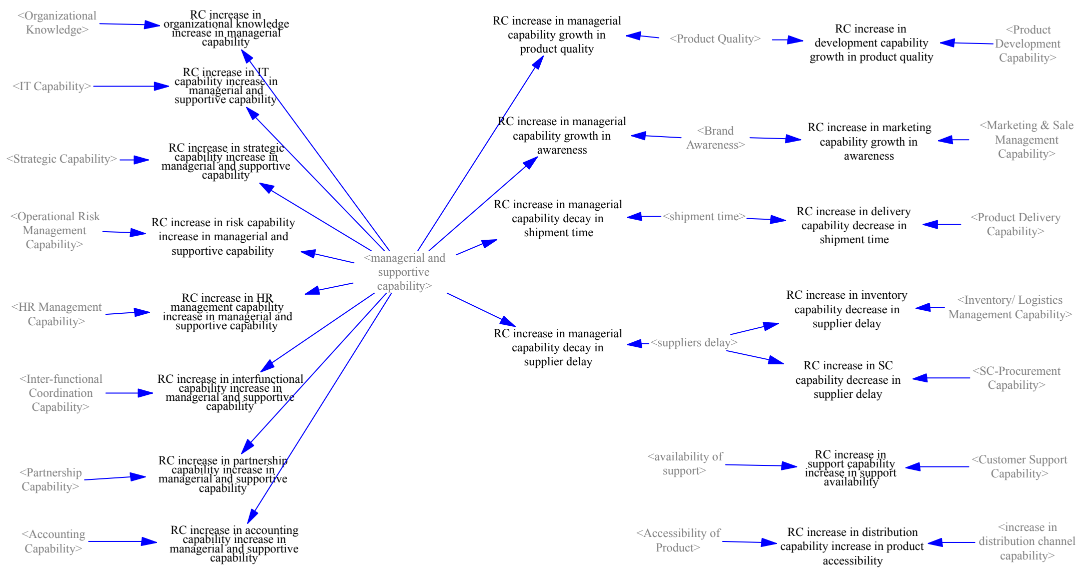


Figure 22. Reality checks for DI effect

7.2.3 Behavior sensitivity test

In the sensitivity test, the parameters to which the model is highly sensitive are determined by assigning the key parameters a set of varying numeric values, and model-generated behavior is tested whether the change in the dynamic behavior consistent with the real system (Barlas, 1996). Thereby, the uncertainties that are often associated with parameters are analyzed.

In this study, sensitivity tests are conducted by observing how model-generated behaviors respond to changes in the values of the key parameters. Vensim's "sensitivity simulation" feature was used for this procedure as explained in full detail in step-by-step instructions by Ford and Flynn (2005).

First, the ranges of the key uncertain parameters were determined. For the parameter values, ± 50% distribution ranges were determined while considering the suggestion for Sterman's (2000) minimum ± 20% distribution ranges. Then, the random uniform distribution was selected as the distribution function for the parameters. The ranges of uncertainty for each parameter are listed in Table 10.

The next step was to decide on the number of simulations and the sampling strategy. Ford and Flynn (2005) recommended 50 runs. Latin Hypercube Sampling (LHS) is the most appropriate sampling strategy for large simulation models among the sampling strategies, which include random sampling, stratified sampling, and LHS (McKay, Beckman, & Conover, 1979). In this study, the number of simulations was specified as 100, and LHS was selected as the sampling strategy.

Table 10. Uncertain Parameter Values

Parameter	Value	Range [min-max values]	Unit
awareness per marketing	0.004	[0.002,0.006]	Awa/A
component price	40	[20,60]	Euro/Component
customer per awareness	1200	[600,1800]	Customer/Awa
individual productivity	50	[25,75]	Product/ (Month*Worker)
individual salary	800	[400,1200]	Euro/ (Month*Worker)
marketing budget rate	0.1	[0.05,0.15]	% (Dimensionless)
order rate per customer	4.5	[2.25,6.75]	Product/ (CS*Customer)
organizational knowledge effect rate for capabilities	0.00002	[0.00001,0.00003]	C/Month
product price	1100	[550,1650]	Euro/Product
quality per R&D	0.004	[0.002,0.006]	Q/A
R&D budget rate	0.1	[0.05,0.15]	% (Dimensionless)
standard shipment time	2	[1,3]	Month

In the next step, the sensitivity simulations were performed, and the tolerance intervals were obtained with the support of the Vensim PLE Plus's sensitivity graph. Appendix E shows the model behaviors for the key performance variables such as financial resource, revenue, total cost, income, product attractiveness, product quality, customer, etc. when the key parameters are set at different numerical values. It can be seen that the behavior of the model is not strongly sensitive to the model parameters. The most sensitive parameters are product price, order rate per customer, marketing budget rate, and the R&D budget rate. However, all of the simulation runs exhibited anticipated behaviors. They displayed the same qualitative behavior and were either slower or faster. This means that the behaviors of the model strongly depend on the structure of the model rather than on some uncertain parameter values. Sensitivity analysis outputs can be seen in Appendix E.

7.3 Behavior pattern test

The behavior pattern test measures whether the model can accurately regenerate the real system behaviors such as growth, decline, and oscillation (Forrester & Senge,

1980) as well as the patterns of behavior like periods, amplitudes, frequencies, trends, phase lags, etc. (Barlas, 1996). This validity test for system dynamics models concerns pattern prediction.

In this study, a set of reference behavior and behavior patterns were identified from the archives, and the model's ability to replicate it was checked. International Data Corporation and Microsoft (2018) studied the impact of digital transformation on Asia Pacific's businesses, economies, and societies. According to the results of their study, digital transformation impacts key performance indicators such as profit margin, productivity, customer advocacy, etc., and the benefits of it will grow by 50% or more between 2017 and 2020. Production efficiency is one of the economic sustainability functions (Ghobakhloo, 2020). According to OECD-Orbis data between 2001 and 2013, firms at the global frontier have about 4.6 times more of an increase in total factor productivity in the manufacturing sector when compared to non-frontier firms (Gal, 2013). The study reported that there is a widening productivity gap between them. When the behavior obtained from these mentioned studies is compared with the behavior of the productivity generated in this study (Figure 23), similar behavior is observed.

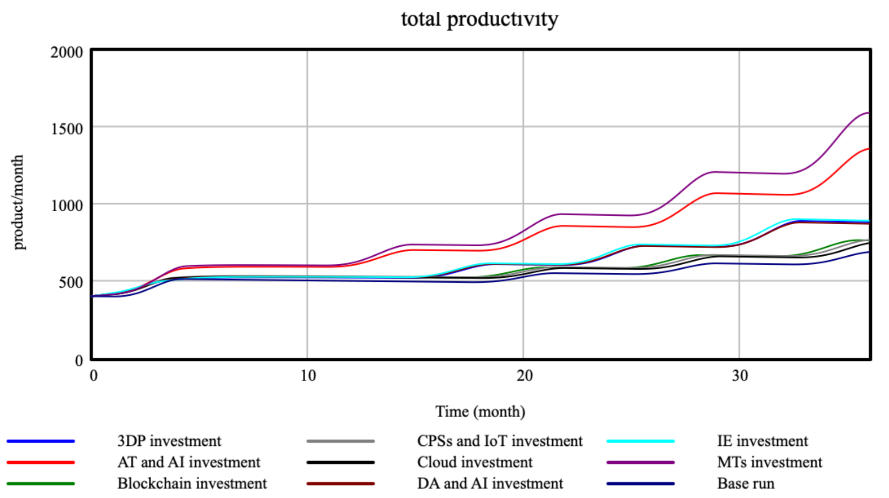


Figure 23 The behaviors of the total productivity variable

The increases in productivity in digital innovation scenarios are more than the increase in the base run, and the gap between them is widening. As a result, the real data and model results are compatible.

CHAPTER 8

SCENARIO ANALYSIS

In the scenario analysis section, the system dynamics simulation model has been built through Vensim, and eight different scenarios were analyzed to address the research question: How do digital innovation-driven business strategies affect business performance, especially corporate sustainability, over time? The topics of the investment scenarios are as follows:

- CPSs and IoT investment
- DA and AI investment
- Cloud investment
- IE investment
- AT and AI investment
- Blockchain investment
- 3DP investment
- MTs investment

Each strategy is applied for the first 12 months. Considering the real data, it is assumed that their impact is completed in the first 24 months. An additional 12 months is run for observing the feedback loops. The simulation interval is specified as 36 months to consider the possible changes in intrinsic factors, such as the entrepreneur, social capital, and price, and extrinsic factors, such as market demand, technological advancement, the economic environment's changes, and intense competition (Casprini et al., 2014). The time unit of the simulation experiments is a month. Using integration error testing, the time step is determined as 1/8 (0.125) and Euler is selected as the numerical integration method.

The results of the eight scenarios were compared with the base run (no digital innovation investment) and with each other to obtain clearer conclusions from the analysis. The behaviors of the key variables from each business model block under the scenarios for different digital investment strategies were examined under separate titles.

8.1 The behaviors of the key partner variables

In the partnership block of the model, external knowledge sharing is defined as constant in terms of knowledge acquisition. Therefore, its behavior is constant for all strategies. The auxiliary variable "external investors equity shares" is defined for the first 12 months as 10,000 Euros and then it is decreased to zero for all strategies.

Suppliers delay, which affects the time for the purchased component to enter inventory, depends on a standard delay time and on some capabilities like inventory/logistics capability, supply chain/procurement capability, and managerial and supportive capability. Its behavior is dynamic since the capabilities change over time. Figure 24 shows the behavioral patterns of supplier delays under different scenarios. Under the base scenario, that is, when there is no digital innovation investment, the delay decreases linearly with a very small rate depending on the capability increase linked to organizational knowledge. All other investment strategies provide a significant delay with a decreasing rate, and the rate gradually arrives at the same decreasing rate as in the base scenario. Among the others, the DA, AI, and blockchain investment strategies show a better performance in terms of a decrease in supplier delay.

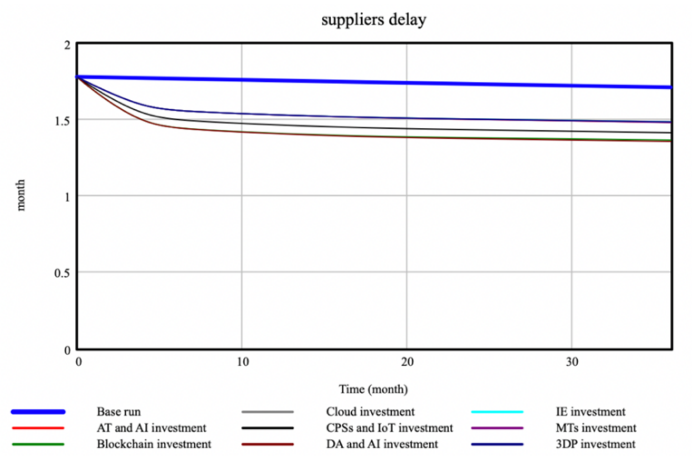


Figure 24. The behaviors of the supplier delay variable

8.2 The behaviors of the key resource variables

These key resources, which are stock variables, were examined under different scenarios: workforce, organizational knowledge, inventory, and financial resource. When the behaviors of the key resources in Figure 25 are compared, one notices that all of the scenarios lead to an increase in resources. However, the rates of increase are significantly different for some resources. Workforce increases with production need per month in all of the scenarios. With MTs investment and AT and AI investment strategies, the increase in the number of workers is higher when compared to other strategies because more production is needed. The increase in organizational knowledge is significant with CPSs and IoT investment, as well as in the DA and AI investment strategies due to the need for knowledge acquisition and knowledge creation. Inventory is another key resource that increases with orders and decreases with production. With 3DP investment strategies, the increase in inventory is slightly higher when compared to other strategies since the 3DP technology can meet a part of the need for inventory. Financial resources increase with revenue and external investors' equity shares while it decreases with cost and dividends. With the

AT, AI, and MTs investments, the behavior of the financial resource linearly increases after the first 12 months when the investment cost is reduced.

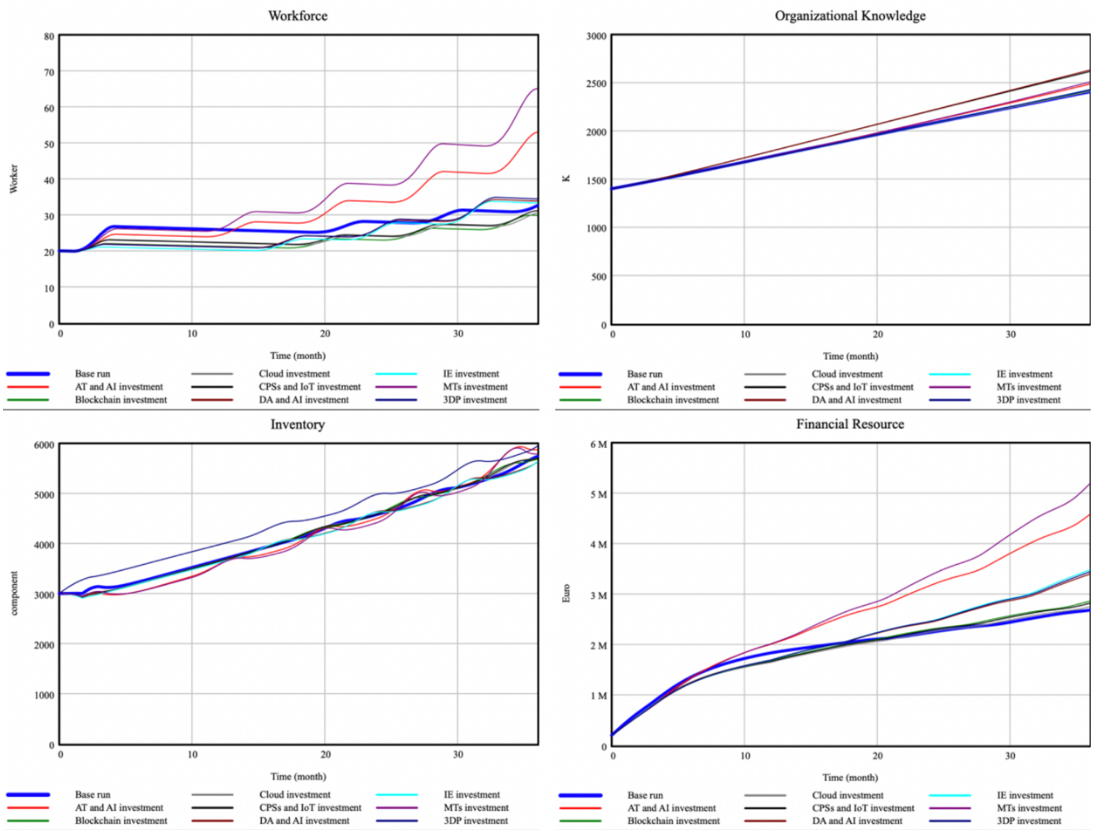


Figure 25. The behaviors of the key resource variables

8.3 The behaviors of the capability variables

The capability variables depend on investments in digital innovation and organizational knowledge. The behavioral patterns of the six main capabilities and the managerial and supportive capabilities utilizing the digital innovation investment strategies are depicted in Figure 26. The capabilities increase linearly with a very small rate depending on the increase in organizational knowledge in the base scenario.

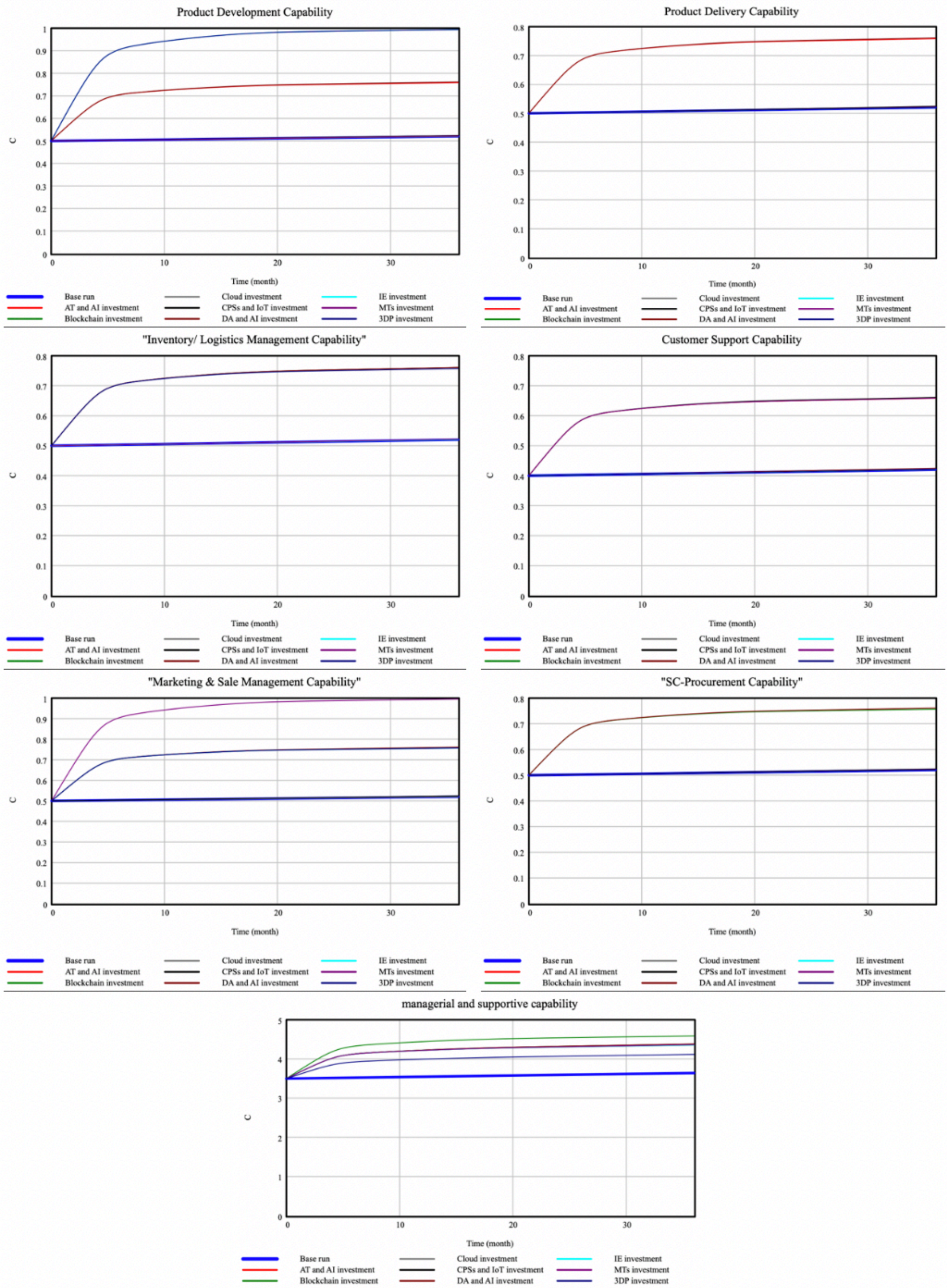


Figure 26. The behaviors of the capability variables

On the other hand, when digital innovation investment strategies are applied, there are significant increases in their behavior with a decreasing rate in the first months, after which the rate of increase gradually arrives at the same rate as the base scenario. The most effective strategies are the 3DP investment and IE investment strategies for product development capability; DA and AI investment and AT and AI investment strategies for product delivery capability; CPSs and IoT, DA, and AI investments and 3DP investment strategies for inventory and logistics management capability; CPSs and IoT investment, AT, AI, and MTs investment strategies for customer support capability; MTs investment strategy for marketing and sale management capability; and blockchain investment and DA and AI investment strategies for supply chain and procurement capability. Besides, all of the scenarios result in an increase in managerial and supportive capabilities. However, the blockchain investment strategy is the most influential in terms of these capabilities. CPSs and IoT investment significantly increases the knowledge acquisition capability while the DA and AI investment strategy is significant for the knowledge creation capability.

8.4 The behaviors of the key activity variables

In the key activities block of the model, these key activities were examined under different digital innovation investment scenarios: product assembly, shipment, supply chain activities, marketing and sale activities, R&D activities, and training activities. It's notable that the behaviors of the key activities significantly changed in terms of the scenarios with respect to the base scenario, as can be seen in Figure 27.

Product assembly and shipment produce similar changes under different scenarios. There is an increase in the rate of increase for these activities, and AT, AI, and MTs investment strategies have more of an impact on them. These strategies result in exponential growth. Since the shipments affect revenue and budget, the budget allocated for R&D and marketing activities increases as the shipments increase.

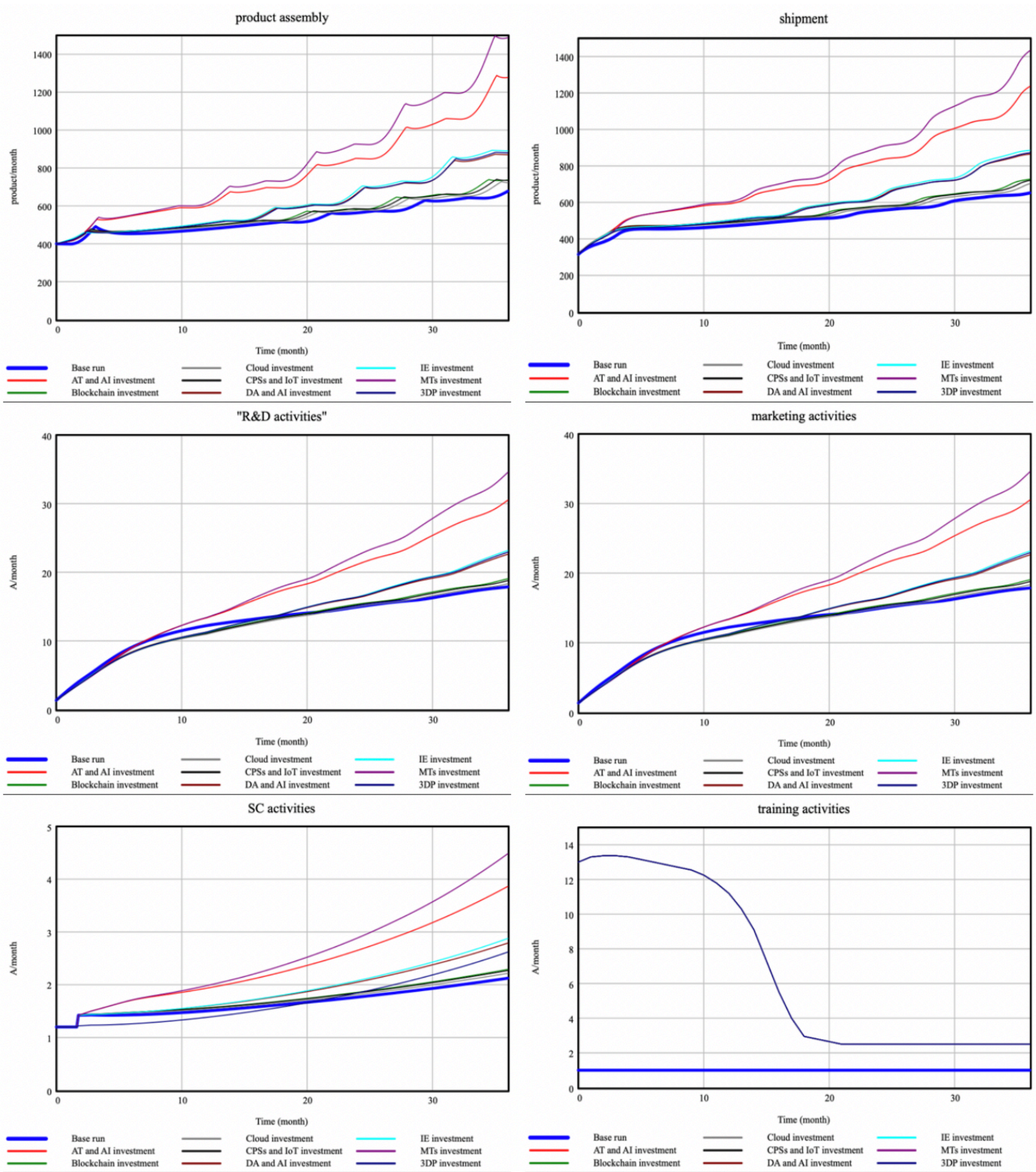


Figure 27. The behaviors of the key activity variables

Similar changes occurred in R&D activities and marketing activities according to different strategies. Supply chain activities depend on the number of purchased components for production. The number of supply chain activities increases as the production increases. For this reason, the behavior of the product assembly and supply chain activity variables are similar. On the other hand, there is a standard rate for training activities in the base scenario. In the case of any digital innovation investment, the number of training activities changes depending on the amount of time. While the number of training activities is high at the beginning of the investments, an exponential collapse is observed in the behavior of these activities. Eventually a state of equilibrium is achieved around the rate of the base scenario.

8.5 The behaviors of the value proposition variables

The behavioral patterns of several performance drivers and conventional economic measures were examined in this block under different scenarios in terms of the digital innovation investment strategies (Figure 28). There are two stock variables in this block, which are product quality and brand awareness, and their behaviors exhibit exponential growth. The change in product quality depends on the R&D activities, product development capability, and the managerial and supportive capabilities. Since the effects of AT and AI, 3DP, and IE technologies on these capabilities are more than the others, they increase product quality significantly. The brand awareness is determined by the marketing activities, the marketing and sale management capabilities, and the managerial and support capabilities. AT, AI, and MTs investment strategies increase with a higher rate of increase compared to the other strategies.

One of the performance drivers, total productivity, increases exponentially with the AT, AI, and MTs investment strategies while it increases linearly under the other strategies. The total productivity effect of production and the production process is important for another performance driver, which is delivery delay, since the order time and shipment time are a measure for it. A delivery delay generates growing oscillations that are caused by productivity shortcomings, and the amplitude of the oscillation is higher in the AT, AI, and MTs investment scenarios than in the other scenarios.

Product attractiveness is an important variable, which affects the number of orders per customer and is measured by the variables for delivery delay, product quality, product price, and accessibility of product. Its behavior shows a negative exponential rate of decay under the AT, AI, and MTs investment scenarios while the behavior exhibits exponential growth with a very small growth rate under the other scenarios.

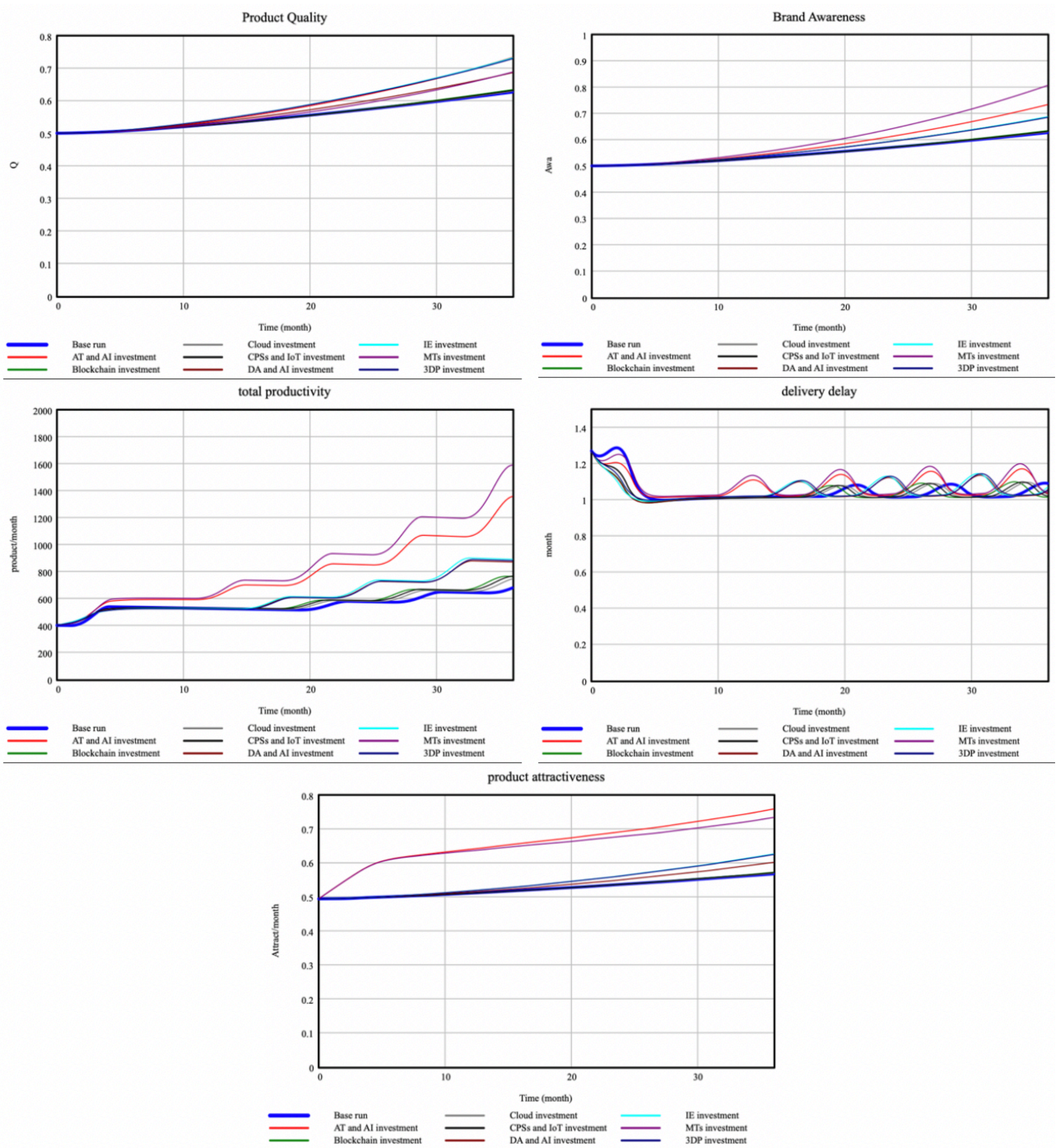


Figure 28. The behaviors of the value proposition variables

When using certain conventional economic measures, there are significant differences between the base strategy and the other digital innovation strategies in terms of income, return on investment (ROI), return on equity (ROE), and sustainable growth rate (Figure 29). They are doubled with DA and AI investments and 3DP investments while they increase at least by a magnitude of four compared to the base scenario with AT, AI, and MTs investment.

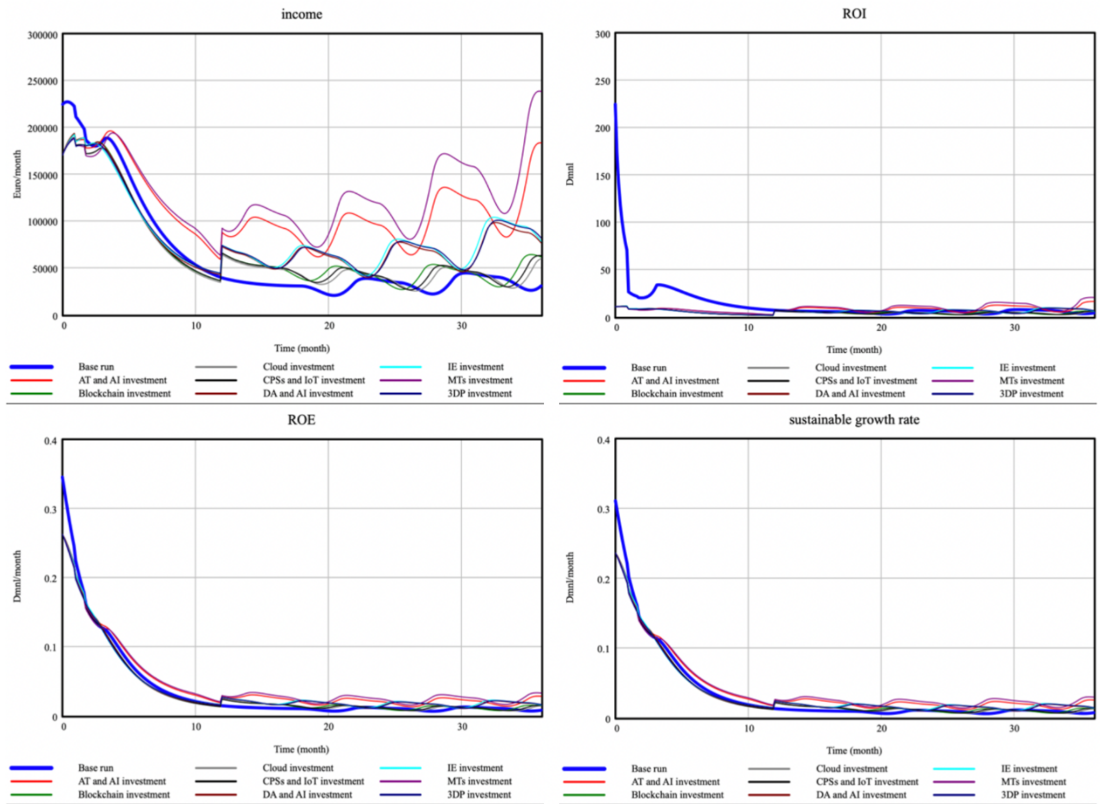


Figure 29. The behaviors of the financial indicators

8.6 The behaviors of the customer relationship variable

The customer satisfaction is affected by product attractiveness and the availability of support. Figure 30 shows the behavior of the customer satisfaction variable under the different scenarios. Negative exponential decay behavior was observed in all of the scenarios except the base scenario. The AT, AI, and MTs investment scenarios show a better performance in terms of customer satisfaction.

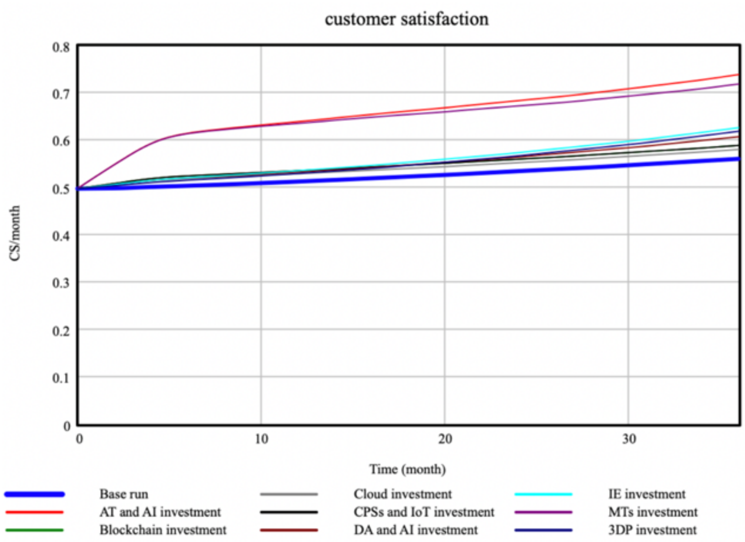


Figure 30. The behaviors of the customer satisfaction variable

8.7 The behaviors of the channel variables

Companies communicate with and reach their customers through their distribution and support channels. The variables accessibility of product, which represents the distribution and sale channels, and availability of support, which represents the support channels, were examined under different scenarios (Figure 31). The accessibility of product increases when there is an increase in the distribution channel capability, which is affected significantly by AT, AI, and MTs investment. For the communication channel, the availability of support increases with customer support capability, which is affected mostly by CPSs and IoT, AT and AI, MTs, and blockchain investments. The behaviors of the channel variables exhibited negative exponential decay for the channel variables under all of the scenarios except for the base scenario.

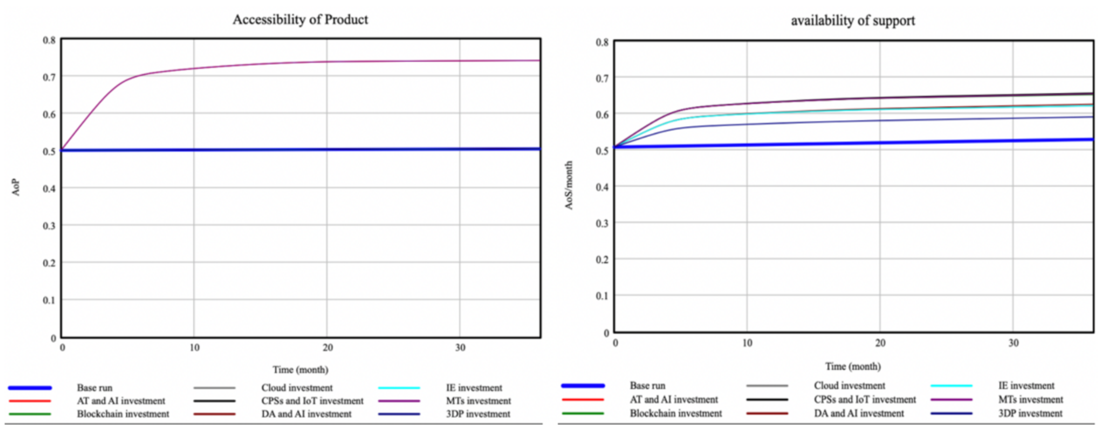


Figure 31. The behaviors of the channel variables

8.8 The behaviors of the customer segment variable

Customer base is one of the most important elements of a business model, and it affects the number of new orders. An increase in production awareness leads to acquiring new customers and then the customer base increases. The customer base affects the number of new orders. Figure 32 shows that the number of customers increases exponentially in the base scenario. However, the rate of increase increases even more with the digital innovation strategies, especially with the AT and AI, MTs, DA and AI, and IE investment strategies.

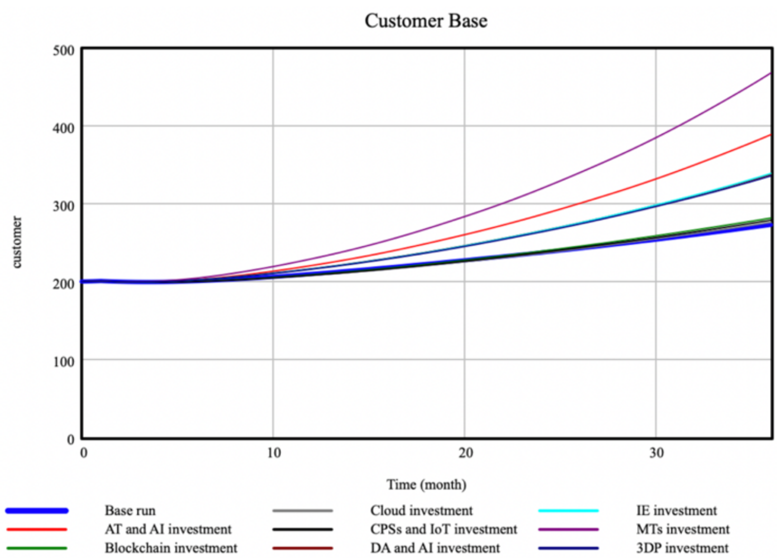


Figure 32. The behaviors of the customer base variable

8.9 The behaviors of the cost structure variable

In this study, the total cost is measured in terms of the costs for marketing, R&D, HR (e.g. salary, training), investment, raw material, supply chain, shipping, inventory holding, and other costs. In the base scenario, the total cost increases with a decreasing rate first, and then it increases linearly (Figure 33). The CPSs and IoT, cloud, and blockchain investment strategies lead to a very similar behavior as the base scenario.

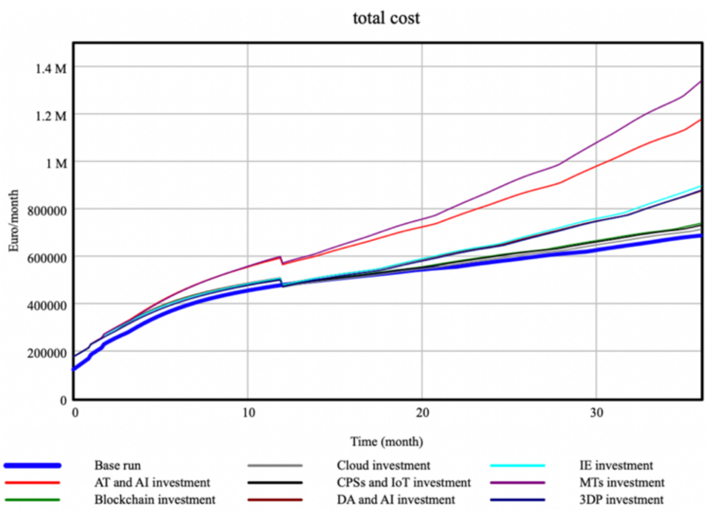


Figure 33. The behaviors of the cost structure variable

On the other hand, the total cost increases with a decreasing rate in the first 12 months due to the costs of investment, and then there is exponential growth in its behavior for the remaining strategies, especially for AT, AI, and MTs investment.

8.10 The behaviors of the revenue stream variable

The revenue is measured in terms of the number of products shipped and the product price. Since the product price is constant, the behavior of the revenue variable is similar to the shipment variable. There are increases in the rate of increase for the revenue variable (Figure 34). AT, AI, and MTs investment strategies have more of an impact on revenue. These strategies result in exponential growth. On the other hand, the difference in the rate of increase between the base scenario and CPSs and IoT, cloud, and blockchain investment scenarios is small.

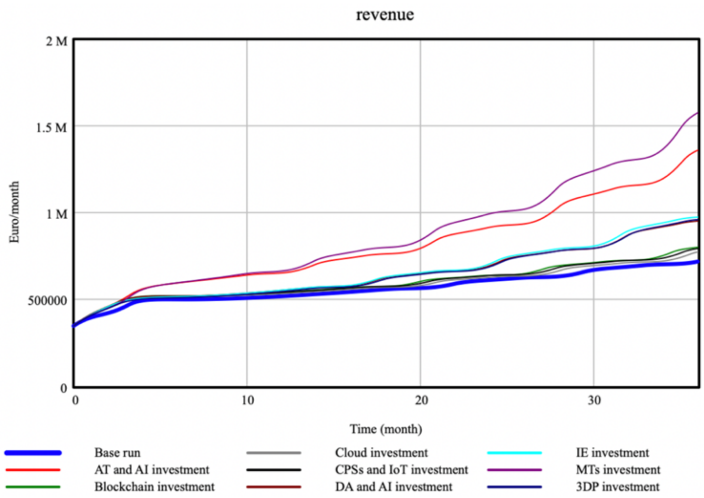


Figure 34. The behaviors of the revenue stream variable

CHAPTER 9

CONCLUSION

In this thesis, the digital innovations-driven business model regeneration process and the impact of digital innovations on the business model and corporate sustainability over time were studied with qualitative and quantitative research approaches.

Firstly, a deeper understanding of BMI in the context of digital innovations was obtained with an integration of the detailed literature review and in-depth interviews that were conducted with 44 managers. As a result, a digital innovations-driven business regeneration method was developed. The proposed method explains the research question for this study which is “How can a business model be regenerated with a focus on digital innovations?”. The proposed process model consists of the following stages: objective analysis, component analysis, digital innovation impact analysis, innovation analysis and decision-making, and regeneration. These stages are described by applying the method to a real case.

The proposed methodology of this study is based on all these studies and the interview analysis. While the methodology is in line with previous research and has similar steps with them, with the expert views, existing research is extended. Managers emphasized the importance of objectives, industry priorities, and innovation analysis for business model regeneration. Therefore, distinctive steps for digital innovations-driven business model regeneration were identified with this study. One of these distinctive steps is objective analysis. Some of the objectives, such as cost reduction, efficient and effective processes, auditability, standardization, etc. are related to improving processes; others focus on creating a market and value. Specifying the objectives for business model regeneration is a key step that helps the decision-making step. Indeed, while improving existing products and processes or existing markets with better value requires sustaining innovation, creating a new market or new value requires disruptive innovation. The component analysis is another important stage for business model regeneration. However, the analysis of the importance of business model components for the industry has missed whereas identification of business model components is studied in the literature. The components and their significance may vary by industry. Indeed, some components are more important for certain industries than for others, and that importance is specified. For example, service industries give more importance to customer relationships while resources are more important for product industries. Other distinctive steps include the analysis of the type, degree, and speed of digital innovations and they play a fundamental role in the decision-making step. The analysis of these aspects of innovation is based on previous steps of the proposed method.

Besides, a few studies focused on digital innovations in literature and they handled only one or at most a few technologies or industries. This study proposes a method for digital innovations-driven business model regeneration by considering the potential digital technologies and the differences of all industries. Therefore, the proposed method does not focus on a specific industry; it can be used by any by placing due emphasis on the importance of the business components of any industry. Industry differences in our analysis results also show the necessity of precise data collection from different industries.

According to the findings from the industry perspective, the waste management activities, construction, ICT, education, and arts, entertainment and recreation industries all use almost all digital technology for their several strategies and processes. On the other hand, the low-tech sectors digital technologies uses are administrative and support service activities, agriculture, mining and quarrying, and water supply industries. In these industries, cloud technology, robotics, blockchain, and MTs are more widely used than other digital technologies. Other industries also use several digital technologies, although some of these technologies are not used intensely.

According to the findings from a digital innovations perspective, CPSs, IoT, DA and AI, robotics, AR & VR, blockchain, and MTs are used in almost every industry. On the other hand, certain technologies are not preferred in some industries. For example, 3DP technology is not used or is rarely used in the wholesale and retail trade, transportation and storage, finance and insurance, real estate, professional, scientific and technical activities, and administrative and support service industries. Cloud technologies are not seen as secure enough for sensitive data in the finance and insurance, and public administration industries. Therefore, these industries cannot use this technology for data sharing. Although AT is used widely in mining and quarrying, electricity, gas, and steam supply, accommodation, and administrative and support service industries, the use of drones which is one of the autonomous technologies, is not common.

Moreover, the importance of a dynamic business model for the business model regeneration process has emerged during the case study. Based on the literature and interview data, a system dynamics simulation model was constructed to examine the interactions among the business model elements and to explore the impacts of different digital innovation strategies on business performance over time. This model was built after reviewing the existing literature on dynamic business models as well as the expert views that specified the capability variables. Seven reinforcing and four balancing loops were specified in the conceptual model. The stock-flow model consists of 10 sub-models which overlap the business model canvas building blocks. Direct structure tests, structure-oriented behavior tests, and a behavior pattern test have been applied to validate the model. Eight different scenarios were analyzed to address the research question and one or two associated digital innovations were invested in each scenario. The results of the eight scenarios were compared with the base run (no digital innovation investment) and the behaviors of key variables were examined for each sub-model.

The results of the scenario experiments with the model clearly show that the objective of an innovation strategy is important for decision-making. An increase in process and resource efficiency, an increase in income, a new value proposition, an improvement in the value proposition, market expansion, and a new market may be the main objectives for utilizing digital innovation strategies.

In the key partners sub-model, the DA and AI investment and blockchain investment strategies provided a greater level of process efficiency. They support supply chain procurement and partnership capabilities, and therefore they decrease the supplier delay. In the key resources sub-model, the MTs, AT, and AI investment strategies increase the amount of the workforce and financial resources because of brand awareness-related and customer satisfaction-related increases in orders. Organizational knowledge increases with CPSs and IoT investment and DA and AI investment strategies while inventory is mostly affected by the 3DP investment strategy. All of these strategies provide for a greater amount of resource efficiency. In the capabilities sub-model, each main capability increases with the related digital innovation strategies, and the managerial and supportive capabilities are mostly affected by the CPSs and IoT investment and DA and AI investment strategies. In the key activities sub-model, the MTs, AT, and AI investment strategies had more of an impact on the key activities such as product assembly, shipment, supply chain activities, marketing and sale activities, and R&D activities. On the other hand, training activities were standard for all digital innovation investment strategies. It was high at the beginning of the investments and decreased as time went on. In the value proposition sub-model, the AT, AI, 3DP, and IE technologies come to the fore for product quality while the AT, AI, and MTs investment strategies are significant for brand awareness. AT, AI, and MTs investment strategies make a difference also in income, ROI, ROE, and the sustainable growth rate. In the customer relationship sub-model, the AT, AI, and MTs investment scenarios show a better performance for customer satisfaction whereas the channel elements availability of support and accessibility of product are mostly affected by CPSs and IoT, AT and AI, MTs, and blockchain investments. When the customer segment sub-model is examined, it can be noticed that the increase rate in customer base increases with AT and AI, MTs, DA and AI, and IE investment strategies. Lastly, compared to other scenarios, the increase in total cost and revenue is more in the AT, AI, and MTs investment scenarios.

9.1 Theoretical and managerial implications of the study

This study brings together the fields of business model, BMI, digital innovation, corporate sustainability, and system dynamics. It contributes to the business model innovation literature and extends the literature by proposing a business model regeneration method with digital innovations-focused and shedding light on the industry differences that emerged from that analysis. Moreover, a digital innovations-driven study allowed us to distinguish digital innovations from technology support when the impacts of technology supports are examined in literature and compared to the impact of digital innovations in this study. Besides, the system dynamics and dynamic business model literature are extended by proposing a digital innovations-driven dynamic business model that can be used for what-if analysis in order to investigate the effects of digital innovation strategies on a business's performance. The capabilities of an organization that are dynamically affected the up-to-date digital innovations were determined and integrated into the current dynamic business model literature.

From a practitioner perspective, this study also has implications for managers. Strategy analysts and managers of companies who are planning to change their business models in the context of digital innovations can utilize the stages of this process model. They can analyze the impacts of potential digital innovations on their current business models and a business's performance, explore the most effective digital innovation strategies so that they can sustain their business when there is technological development, and regenerate their business model. The process for how managers can exploit these stages is described precisely in this study. The study may help companies to be able to gain a competitive advantage over their competitors or sustain their business against technological developments.

9.2 Limitations and future studies

There may certainly be some limitations and recommendations to make for this study. During the thesis study, "cybersecurity" was announced as a future technology trend by major professional service and technology companies (Deloitte, 2019; Oracle, 2019). The digital technologies related to these topics can be studied as a future study. Respondents were selected among experts from companies that have can give a relevant view of their company's business model and the effects of digital innovations; however, the case study was only from the construction industry. Multiple case studies can be made, and the analysis can be compared with real data instead of literature review data. Besides, this qualitative study depends on a researcher's analysis of the collected data. Another researcher might interpret the same data differently. This study is also an initial effort to understand the dynamic impacts of digital innovations. In further studies, some extensions or modifications to the model can be performed to examine the impact of other potential digital innovation strategies by identifying their related capabilities. One limitation is that the simulation interval was specified as 36 months because of the intrinsic factors and extrinsic factors (Casprini et al., 2014). The dynamic nature of the economic variables such as price, salary, etc. may change the story. Moreover, the market is assumed to be big enough for growth. In future studies, it would be useful to focus on competitive markets. Additionally, more real data could be collected for parameter adjustment and behavior validation in future studies.

APPENDIX A

INFORMATION ABOUT THE INTERVIEWEES

Participant	Title	Gender	Channel	Industry	Company	Company Type
P1	Innovation and Project Management Office Manager	Male	Face to face	Manufacturing	International	110000
P2	Business Intelligence Director	Male	Virtual (Skype)	Wholesale and retail trade	National	651
P3	Business Development Director	Male	Face to face	Wholesale and retail trade	National	215
P4	Senior Internal Auditor	Male	Virtual (Skype)	Public administration and defense	National	6445
P5	Head of Presales	Male	Virtual (Skype)	ICT	International	96498
P6	Digital Business Development Director	Male	Virtual (Skype)	Administrative and support service activities	International	11500
P7	Digital Product and Business Development Supervisor	Male	Face to face	Financial and insurance activities	International	18428
P8	Corporate Risk Management and Innovation Leader	Male	Face to face	Professional, scientific and technical activities	International	312000
P9	Corporate Branch Manager	Male	Face to face	Education	International	17500
P10	Manager	Male	Virtual (Skype)	Human health	International	1100
P11	Real Estate Supervisor	Male	Virtual (Skype)	Real estate activities	International	100000
P12	Manager	Female	Virtual (Skype)	Financial and insurance activities	International	5000
P13	Business Owner	Male	Face to face	Accommodation and food service activities	National	200
P14	Strategy & Transformation Manager	Male	Virtual (Skype)	ICT	International	12834
P15	IT Architecture and R&D Manager	Male	Face to face	Financial and insurance activities	National	565
P16	Rooms Division Manager	Male	Face to face	Accommodation and food service activities	International	1300
P17	Travel Trade & Group Sales Manager	Male	Face to face	Accommodation and food service activities	International	4000
P18	Manager	Female	Virtual (Skype)	Administrative and support service activities	National	1500
P19	Management and Finance Consultant	Male	Virtual (Skype)	Agriculture, forestry and fishing	National	1100
P20	Real Estate Appraisal Expert	Male	Face to face	Real estate activities	National	350
P21	Sales and Marketing Manager	Male	Face to face	Manufacturing	National	110
P22	Sales and Marketing Manager	Male	Face to face	Construction	National	400
P23	IT Supervisor	Male	Face to face	Administrative and support service activities	International	9315
P24	Share of Holder	Female	Virtual (Skype)	Transportation and storage	International	1150
P25	Information Systems Director & Project Management Director	Male	Virtual (Zoom)	Construction	International	2594
P26	Communication Network Establishment Team Leader	Male	Virtual (Skype)	ICT	National	1332
P27	Technical Office Chief	Male	Virtual (Skype)	Construction	International	6643

Participant	Title	Gender	Channel	Industry	Company	Company Type
P28	General Manager	Male	Face to face	Professional, scientific and technical activities	International	420
P29	Export Manager/HR Director	Female	Virtual (Skype)	Agriculture, forestry and fishing	National	2500
P30	Sales Manager	Male	Virtual (Skype)	Agriculture, forestry and fishing	National	500
P31	Process Manager	Male	Virtual (Skype)	Mining and quarrying	National	5244
P32	Information Management Associate	Female	Virtual (Skype)	Activities of extraterritorial organizations	International	16765
P33	IT Project Manager; Business Development & Digital Marketing Manager	Male	Face to face	Water supply	International	33500
P34	System Development Manager	Male	Face to face	Water supply	International	31500
P35	Head of Technology, Research and Development	Male	Face to face	Education	International	150000
P36	Innovation Product Portfolio Manager	Female	Face to face	Electricity, gas, and steam supply	National	9622
P37	Business Development Group Director	Male	Face to face	Human health	International	2500
P38	IT Project Manger	Male	Virtual (Skype)	Activities of extraterritorial organizations	International	17000
P39	IT Director – Chief Information Officer	Male	Face to face	Waste management activities	National	500
P40	IT Executive	Male	Virtual (Skype)	Arts, entertainment and recreation	National	200
P41	IT Manager	Male	Face to face	Arts, entertainment and recreation	International	1750
P42	Geographic Information Office Service Manager	Female	Face to face	Public administration and defense	National	323796
P43	System Sub-Configuration Manager & Corporate Communication Executive	Male	Face to face	Electricity, gas, and steam supply	National	916
P44	Management Information Systems Department Head	Male	Virtual (Skype)	Mining and quarrying	National	8398

APPENDIX B

INTERVIEW QUESTIONS

A- Business Model

1. Why should a company develop a business model?
2. For whom should a company create value in your industry? (Customer segments)
3. What bundles of products and services should be the company offering to the focus group in your industry? (Value Propositions)
4. How should a company reach the focus group and deliver the products/services in your industry? (Channels)
5. How should a company interact with the industry's focus group and what kind of relationship should it have? (Customer relationships)
6. Which resources and organizational capabilities are needed to create and offer products/services in your industry? (Key Resources)
7. Which activities are needed to create and offer products/services in your industry? (Key Activities)
8. What kind of partners (other organizations) should be partnered with to deliver the product/service in your industry? (Key partners)
9. Which different revenue streams and payment models should be used in your industry? (Revenue streams)
10. What are the most important cost factors in a business model and what kind of cost structure should this model be based on in your industry? (Cost Structure)
11. What should be the key elements/components of the business model in your industry?

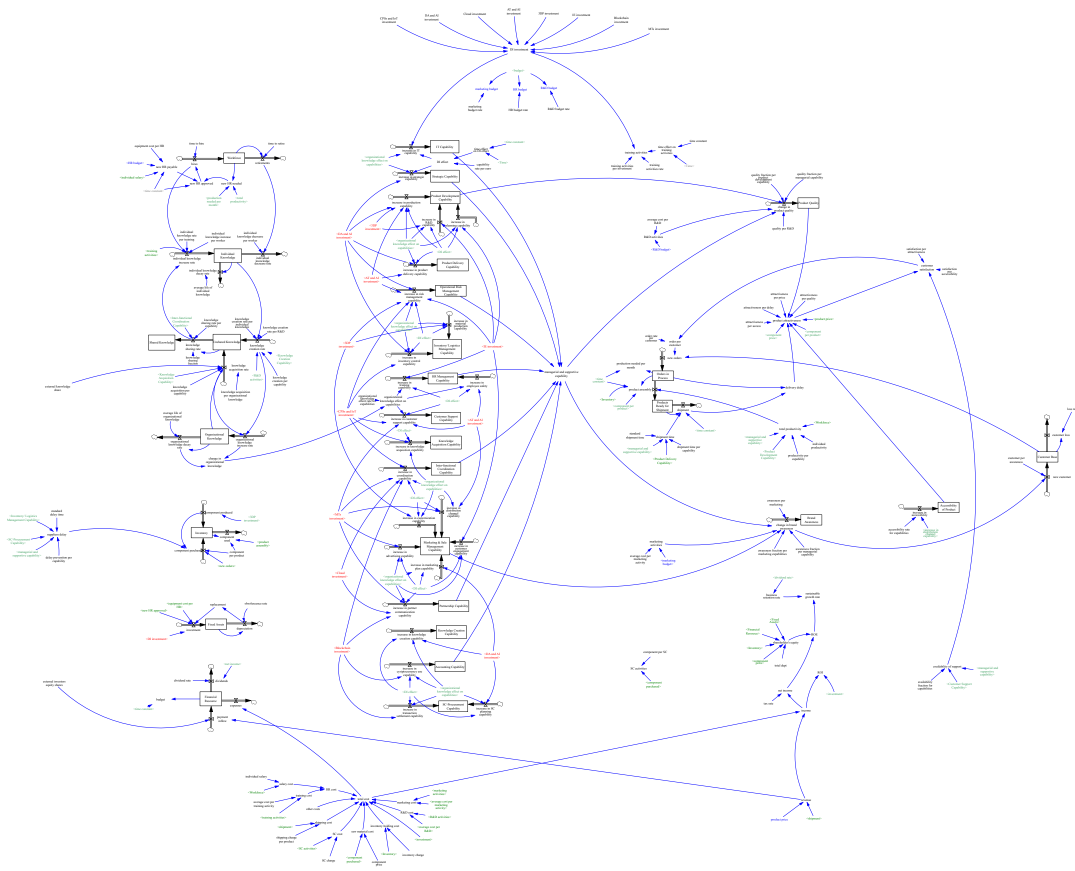
12. What are the additional elements/components of a business model in your industry?
13. What are the most important elements/components that have the biggest impact on your industry?

B- Digital Innovations

14. Which are the digital innovations (opportunities or disruptive threats) do you see emerging in your industry? How important?
15. Which digital innovations do you think will have a substantial influence on the business model of a company in this industry?
16. Which business model components will be affected by these innovations?
17. How are these innovations required changes in the components of the business model in your industry?
18. What is the degree of change and innovation in the business model in your industry?
19. What is the type of change and innovation in the business model in your industry?

APPENDIX C

STOCK-FLOW MODEL



APPENDIX D

MATHEMATICAL FORMULAS FOR THE VARIABLES

(001) "3DP investment" = 0

Units: Euro/month

(002) Accessibility of Product = INTEG (increase in accessibility,0.5)

Units: AoP

(003) accessibility rate for capabilities = 1

Units: AoP/C

(004) Accounting Capability = INTEG (increase in cryptocurrency use capability,0.5)

Units: C

(005) AT and AI investment = 0

Units: Euro/month

(006) attractiveness per access = 1

Units: Attract/(AoP*month)

(007) attractiveness per delay = 0.01

Units: Attract/(month*month)

(008) attractiveness per price = 0.0001

Units: Attract*product/(Euro*month)

(009) attractiveness per quality = 1

Units: Attract/(Q*month)

(010) availability fraction for capabilities = 0.13

Units: AoS/(C*month)

(011) availability of support = availability fraction for capabilities*(Customer Support Capability+managerial and supportive capability)

Units: AoS/month

(012) average cost per marketing activity = 15000

Units: Euro/A

(013) "average cost per R&D" = 15000

Units: Euro/A

(014) average cost per training activity = 2000

Units: Euro/A

(015) average life of individual knowledge = 120

Units: month

(016) average life of organizational knowledge = 100

Units: month

(017) awareness fraction per managerial capability = 0.005

Units: 1/C

(018) awareness fraction per marketing capabilities = 0.1

Units: 1/C

(019) awareness per marketing = 0.004

Units: Awa/A

(020) Blockchain investment = 0

Units: Euro/month

(021) Brand Awareness = INTEG (change in brand awareness, 0.5)

Units: Awa

(022) budget = IF THEN ELSE (Financial Resource/time constant<0,0,Financial Resource/time constant)

Units: Euro/month

(023) business retention rate = 1-dividend rate

Units: Dmnl

(024) capability rate per euro = 1.65e-05

Units: C/Euro

(025) change in brand awareness = (managerial and supportive capability*awareness fraction per managerial capability+"Marketing & Sale Management Capability"*awareness fraction per marketing capabilities)*marketing activities*awareness per marketing

Units: Awa/month

(026) change in organizational knowledge = organizational knowledge increase rate-organizational knowledge decay rate

Units: K/month

(027) change in product quality = "R&D activities"*"quality per R&D"*(Product Development Capability*quality fraction per product development capability+managerial and supportive capability*quality fraction per managerial capability)

Units: Q/month

(028) Cloud investment = 0

Units: Euro/month

(029) component per product = 3

Units: component/product

(030) component per SC = 1000

Units: component/A

(031) component price = 40

Units: Euro/component

(032) component produced = IF THEN ELSE ("3DP investment" = 0,0,200)

Units: component/month

(033) component purchased = DELAY FIXED (1.06*new orders*component per product-component produced,suppliers delay,1200)

Units: component/month

(034) component used = IF THEN ELSE (Inventory<0,0,product assembly*component per product)

Units: component/month

(035) CPSs and IoT investment = 0

Units: Euro/month

(036) Customer Base = INTEG (new customer-customer loss,200)

Units: customer

(037) customer loss = DELAY FIXED (Customer Base*loss rate,1,0)

Units: customer/month

(038) customer per awareness = 1200

Units: customer/Awa

(039) customer satisfaction = 0.2*(satisfaction per accessibility*availability of support)+(satisfaction per attractiveness*product attractiveness)*0.8

Units: CS/month

(040) Customer Support Capability = INTEG (increase in customer support capability, 0.4)

Units: C

(041) DA and AI investment = 0

Units: Euro/month

(042) delay prevention per capability = 0.4

Units: 1/C

(043) delivery delay = IF THEN ELSE (shipment = 0,1,Orders in Process/shipment)

Units: month

(044) depreciation = Fixed Assets/obsolescence rate

Units: Euro/month

(045) DI effect = time effect on DI effect*capability rate per euro

Units: C/Euro

(046) DI investment = "3DP investment"+AT and AI investment+Blockchain investment+Cloud investment+CPSs and IoT investment+DA and AI investment+IE investment+MTs investment

Units: Euro/month

(047) dividend rate = 0.1

Units: Dmnl

(048) dividends = 0+STEP (IF THEN ELSE (net income>0,net income*dividend rate,0),12)

Units: Euro/month

(049) equipment cost per HR = 1000

Units: Euro/Worker

(050) expenses = total cost

Units: Euro/month

(051) external investors equity shares = 10000+STEP (-10000,12)

Units: Euro/month

(052) external knowledge share = 5

Units: K/month

(053) FINAL TIME = 36

Units: month

The final time for the simulation.

(054) Financial Resource = INTEG (dividends+payment inflow-expenses,200000)

Units: Euro

(055) Fixed Assets = INTEG (investment-depreciation,200000)

Units: Euro

(056) hires = DELAY FIXED (new HR approved,time to hire,0)

Units: Worker/month

(057) HR budget = budget*HR budget rate

Units: Euro/month

(058) HR budget rate = 0.1

Units: Dmnl

(059) HR cost = salary cost+training cost

Units: Euro/month

(060) HR Management Capability = INTEG (increase in employee safety+increase in training capability, 0.5)

Units: C

(061) IE investment = 0

Units: Euro/month

(062) income = revenue-total cost

Units: Euro/month

(063) increase in accessibility = increase in distribution channel capability*accessibility rate for capabilities

Units: AoP/month

(064) increase in advertising capability = DI effect*MTs investment+organizational knowledge effect on capabilities*0.2

Units: C/month

(065) increase in coordination capability = DI effect*(Blockchain investment+Cloud investment+CPSs and IoT investment+MTs investment)+organizational knowledge effect on capabilities

Units: C/month

(066) increase in customer engagement capability = DI effect*IE investment+organizational knowledge effect on capabilities*0.2

Units: C/month

(067) increase in customer support capability = DI effect*(AT and AI investment+CPSs and IoT investment+MTs investment)+organizational knowledge effect on capabilities

Units: C/month

(068) increase in customization capability = DI effect*"3DP investment"+organizational knowledge effect on capabilities*0.2

Units: C/month

(069) increase in cryptocurrency use capability = DI effect*Blockchain investment+organizational knowledge effect on capabilities

Units: C/month

(070) increase in distribution channel capability = DI effect*(AT and AI investment+MTs investment)+organizational knowledge effect on capabilities*0.2

Units: C/month

(071) increase in employee safety = DI effect*AT and AI investment+organizational knowledge effect on capabilities/2

Units: C/month

(072) increase in inventory control capability = DI effect*(CPSs and IoT investment+DA and AI investment)+organizational knowledge effect on capabilities/2

Units: C/month

(073) increase in IT capability = DI effect*DI investment+organizational knowledge effect on capabilities

Units: C/month

(074) increase in knowledge acquisition capability = CPSs and IoT investment*DI effect+organizational knowledge effect on capabilities

Units: C/month

(075) increase in knowledge creation capability = DI effect*DA and AI investment+organizational knowledge effect on capabilities

Units: C/month

(076) increase in marketing plan capability = DI effect*DA and AI investment+organizational knowledge effect on capabilities*0.2

Units: C/month

(077) increase in material production capability = DI effect*"3DP investment"+organizational knowledge effect on capabilities/2

Units: C/month

(078) increase in partner communication capability = DI effect*(Blockchain investment+Cloud investment+MTs investment)+organizational knowledge effect on capabilities

Units: C/month

(079) increase in planning capability = DI effect*IE investment+organizational knowledge effect on capabilities/3

Units: C/month

(080) increase in product delivery capability = DI effect*(AT and AI investment+DA and AI investment)+organizational knowledge effect on capabilities

Units: C/month

(081) increase in production capability = DI effect*(AT and AI investment+DA and AI investment+"3DP investment")+organizational knowledge effect on capabilities/3

Units: C/month

(082) "increase in R&D capability" = DI effect*("3DP investment"+IE investment)+organizational knowledge effect on capabilities/3

Units: C/month

(083) increase in risk management capability = DI effect*(AT and AI investment+CPSs and IoT investment+DA and AI investment+IE investment+"3DP investment")+organizational knowledge effect on capabilities

Units: C/month

(084) increase in SC planning capability = DI effect*DA and AI investment+organizational knowledge effect on capabilities/2

Units: C/month

(085) increase in strategic capability = DI effect*DA and AI investment+organizational knowledge effect on capabilities

Units: C/month

(086) increase in training capability = DI effect*IE investment+organizational knowledge effect on capabilities/2

Units: C/month

(087) increase in transaction settlement capability = DI effect*Blockchain investment+organizational knowledge effect on capabilities/2

Units: C/month

(088) Individual Knowledge = INTEG (IF THEN ELSE (Individual Knowledge = 0,0,individual knowledge increase rate-individual knowledge decay rate-individual knowledge decrease rate),70)

Units: K

(089) individual knowledge decay rate = Individual Knowledge/average life of individual knowledge

Units: K/month

(090) individual knowledge decrease per worker = 1

Units: K/Worker

(091) individual knowledge decrease rate = retirements*individual knowledge decrease per worker

Units: K/month

(092) individual knowledge increase per worker = 1

Units: K/Worker

(093) individual knowledge increase rate = knowledge sharing rate+hires*individual knowledge increase per worker+training activities*individual knowledge rate per training

Units: K/month

(094) individual knowledge rate per training = 0.1

Units: K/A

(095) individual productivity = 50

Units: product/(Worker*month)

(096) individual salary = 800

Units: Euro/Worker/month [400,800,200]

(097) INITIAL TIME = 0

Units: month

The initial time for the simulation.

(098) "Inter-functional Coordination Capability" = INTEG (increase in coordination capability,0.5)

Units: C

(099) Inventory = INTEG (component produced+component purchased-component used,3000) Units: component

(100) inventory charge = 0.5

Units: Euro/month/component

(101) inventory holding cost = MAX (inventory charge*Inventory,0)

Units: Euro/month

(102) "Inventory/ Logistics Management Capability" = INTEG (increase in inventory control capability+increase in material production capability,0.5)

Units: C

(103) investment = DI investment+ new HR approved*equipment cost per HR+replacement+ STEP (-(DI investment),12)

Units: Euro/month

(104) IT Capability = INTEG (increase in IT capability, 0.5)

Units: C

(105) Knowledge Acquisition Capability = INTEG (increase in knowledge acquisition capability,0.5)

Units: C

(106) knowledge acquisition per capability = 30

Units: K/(C*month)

(107) knowledge acquisition per organizational knowledge = 0.002

Units: K/(K*month)

(108) knowledge acquisition rate = Knowledge Acquisition Capability*knowledge acquisition per capability+Organizational Knowledge*knowledge acquisition per organizational knowledge+external knowledge share

Units: K/month

(109) Knowledge Creation Capability = INTEG (increase in knowledge creation capability,0.5)

Units: C

(110) knowledge creation per capability = 30

Units: K/(C*month)

(111) knowledge creation rate = ("R&D activities"*"knowledge creation rate per R&D")+(knowledge creation rate per individual knowledge*Individual Knowledge)+(Knowledge Creation Capability*knowledge creation per capability)

Units: K/month

(112) knowledge creation rate per individual knowledge = 0.015

Units: K/(K*month)

(113) "knowledge creation rate per R&D" = 0.5

Units: K/A

(114) knowledge sharing fraction = 0.0001

Units: 1/month

(115) knowledge sharing rate = knowledge sharing rate per capability*"Inter-functional Coordination Capability"*Unshared Knowledge*knowledge sharing fraction

Units: K/month

(116) knowledge sharing rate per capability = 10

Units: 1/C

(117) loss rate = 0.01

Units: 1/month

(118) managerial and supportive capability = Accounting Capability+HR Management Capability+"Inter-functional Coordination Capability"+IT Capability+Operational Risk Management Capability+Partnership Capability+Strategic Capability

Units: C

(119) "Marketing & Sale Management Capability" = INTEG (increase in customer engagement capability+increase in customization capability+increase in distribution channel capability+increase in advertising capability+increase in marketing plan capability,0.5)

Units: C

(120) marketing activities = marketing budget/average cost per marketing activity

Units: A/month

(121) marketing budget = budget*marketing budget rate

Units: Euro/month

(122) marketing budget rate = 0.1

Units: Dmnl

(123) marketing cost = marketing activities*average cost per marketing activity

Units: Euro/month

(124) net income = income-(income*tax rate)

Units: Euro/month

(125) new HR approved = IF THEN ELSE (new HR needed < 0,0,MIN (new HR needed,new HR payable))/time constant

Units: Worker/month

(126) new HR needed = IF THEN ELSE (production needed per month< = 0 :OR: total productivity< = 0,0,Workforce*(production needed per month/total productivity)-Workforce)

Units: Worker

(127) new orders = Customer Base*order per customer

Units: product/month

(128) Operational Risk Management Capability = INTEG (increase in risk management capability,0.5) Units: C

(129) order per customer = customer satisfaction*order rate per customer

Units: product/(customer*month)

(130) Orders in Process = INTEG (new orders-product assembly,400)

Units: product

(131) Organizational Knowledge = INTEG (organizational knowledge increase rate-organizational knowledge decay rate,1400)

Units: K

(132) organizational knowledge decay rate = Organizational Knowledge/average life of organizational knowledge

Units: K/month

(133) organizational knowledge effect on capabilities = change in organizational knowledge*organizational knowledge effect rate for capabilities

Units: C/month

(134) other costs = 5000

Units: Euro/month

(135) payment inflow = revenue+external investors equity shares

Units: Euro/month

(136) product assembly = MIN (MIN (Orders in Process/time constant,Inventory/(component per product*time constant)),total productivity)

Units: product/month

(137) Product Development Capability = INTEG (increase in planning capability+increase in production capability+"increase in R&D capability",0.5)

Units: C

(138) Product Quality = INTEG (change in product quality,0.5)

Units: Q

(139) quality fraction per managerial capability = 0.005

Units: 1/C

(140) "R&D activities" = "R&D budget"/"average cost per R&D"

Units: A/month

(141) "R&D budget" = budget*"R&D budget rate"

Units: Euro/month

(142) RC increase in accounting capability increase in managerial and supportive capability: THE CONDITION:Accounting Capability = RC RAMP (Accounting Capability,1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.105,36)

Units: **undefined**

(143) RC increase in customer satisfaction growth in orders in process:THE CONDITION: customer satisfaction = RC RAMP (customer satisfaction,1.5,36): IMPLIES:Orders in Process> = RC GROW CHECK(6,Orders in Process,0.0265)

Units: **undefined**

(144) RC increase in knowledge creation rate increase in organizational knowledge: THE CONDITION: knowledge creation rate = RC STEP (knowledge creation rate,2):IMPLIES: Organizational Knowledge> = RC RAMP CHECK (1,Organizational Knowledge,1.93,36)

Units: **undefined**

(145) RC increase in organizational knowledge increase in managerial capability:THE CONDITION:Organizational Knowledge = RC RAMP (Organizational Knowledge,1.5,35):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.04,35)

Units: **undefined**

(146) RC no budget no HR budget:THE CONDITION:budget = 0:IMPLIES:HR budget = RC STEP CHECK (HR budget,0,INITIAL TIME)

Units: **undefined**

(147) RC no budget no marketing budget:THE CONDITION:budget = 0:IMPLIES:marketing budget = 0

Units: **undefined**

(148) "RC no budget no R&D budget":THE CONDITION:budget = 0:IMPLIES:"R&D budget" = 0

Units: **undefined**

(149) MTs investment = 0

Units: Euro/month

(150) new customer = change in brand awareness*customer per awareness

Units: customer/month

(151) new HR payable = HR budget/(individual salary+(equipment cost per HR/time constant))

Units: Worker

(152) obsolescence rate = 36

Units: month

(153) order rate per customer = 4.5

Units: product/(customer*CS)

(154) organizational knowledge effect rate for capabilities = 2e-05

Units: C/K

(155) organizational knowledge increase rate = knowledge acquisition rate+knowledge creation rate

Units: K/month

(156) Partnership Capability = INTEG (increase in partner communication capability,0.5)

Units: C

(157) product attractiveness = ((Accessibility of Product*attractiveness per access)+(Product Quality*attractiveness per quality)+(attractiveness per price*((component price*component per product)-product price))-(delivery delay*attractiveness per delay))/1.8

Units: Attract/month

(158) Product Delivery Capability = INTEG (increase in product delivery capability,0.5)

Units: C

(159) product price = 1100

Units: Euro/product

(160) production needed per month = Orders in Process/time constant

Units: product/month

(161) productivity per capability = 0.1

Units: 1/C

(162) Products Ready for Shipment = INTEG (product assembly-shipment,450)

Units: product

(163) quality fraction per product development capability = 0.1

Units: 1/C

(164) "quality per R&D" = 0.004

Units: Q/A

(165) "R&D budget rate" = 0.1

Units: Dmnl

(166) "R&D cost" = "average cost per R&D"*"R&D activities"

Units: Euro/month

(167) raw material cost = component purchased*component price

Units: Euro/month

(168) RC increase in delivery capability decrease in shipment time:THE CONDITION:Product Delivery Capability = RC RAMP (Product Delivery Capability,1.5,36):IMPLIES:shipment time< = RC RAMP CHECK (1,shipment time,0.91,36)

Units: **undefined**

(169) RC increase in development capability growth in product quality:THE CONDITION:Product Development Capability = RC RAMP (Product Development Capability,2,36):IMPLIES:Product Quality> = RC GROW CHECK (4,Product Quality,0.007)

Units: **undefined**

(170) RC increase in distribution capability increase in product accessibility:THE CONDITION:increase in distribution channel capability = RC RAMP (increase in distribution channel capability,2,36):IMPLIES:Accessibility of Product> = RC RAMP CHECK (1,Accessibility of Product,1.001,36)

Units: **undefined**

(171) RC increase in HR management capability increase in managerial and supportive capability:THE CONDITION:HR Management Capability = RC RAMP (HR Management Capability,1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.105,36)

Units: **undefined**

(172) RC increase in individual knowledge increase in knowledge creation:THE CONDITION:Individual Knowledge = RC STEP (Individual Knowledge,2):IMPLIES:knowledge creation rate> = RC RAMP CHECK (12,knowledge creation rate,1.25,36)

Units: **undefined**

(173) RC increase in interfunctional capability increase in managerial and supportive capability:THE CONDITION:"Inter-functional Coordination Capability" = RC RAMP ("Inter-functional Coordination Capability",1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.1065,36)

Units: **undefined**

(174) RC increase in inventory capability decrease in supplier delay:THE CONDITION:"Inventory/ Logistics Management Capability" = RC RAMP ("Inventory/ Logistics Management Capability",1.5,36):IMPLIES:suppliers delay< = RC RAMP CHECK (1,suppliers delay,0.915,36)

Units: **undefined**

(175) RC increase in IT capability increase in managerial and supportive capability:THE CONDITION:IT Capability = RC RAMP (IT Capability,1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.105,36)

Units: **undefined**

(176) RC increase in managerial capability decay in shipment time:THE CONDITION:managerial and supportive capability = RC RAMP (managerial and supportive capability,3,36):IMPLIES:shipment time< = RC DECAY CHECK (1,shipment time,40)

Units: **undefined**

(177) RC increase in managerial capability decay in supplier delay:THE CONDITION:managerial and supportive capability = RC RAMP (managerial and supportive capability,3,36):IMPLIES:suppliers delay< = RC DECAY CHECK (1,suppliers delay,45)

Units: **undefined**

(178) RC increase in managerial capability growth in awareness:THE CONDITION:managerial and supportive capability = RC RAMP (managerial and supportive capability,3,36):IMPLIES:Brand Awareness> = RC GROW CHECK (4,Brand Awareness,0.007)

Units: **undefined**

(179) RC increase in managerial capability growth in product quality:THE CONDITION:managerial and supportive capability = RC RAMP (managerial and supportive capability,3,36):IMPLIES:Product Quality> = RC GROW CHECK (4,Product Quality,0.007)

Units: **undefined**

(180) RC increase in marketing budget growth in awareness:THE CONDITION:marketing budget = RC RAMP (0,marketing budget,1.5,36):IMPLIES:Brand Awareness> = RC GROW CHECK (4,Brand Awareness,0.006)

Units: **undefined**

(181) RC increase in marketing capability growth in awareness:THE CONDITION:"Marketing & Sale Management Capability" = RC RAMP ("Marketing & Sale Management Capability",2,36):IMPLIES:Brand Awareness> = RC GROW CHECK (4,Brand Awareness,0.007)

Units: **undefined**

(182) RC increase in new orders growth in inventory:THE CONDITION:new orders = RC RAMP (new orders,2,36):IMPLIES:Inventory> = RC GROW CHECK (6,Inventory,0.022)

Units: **undefined**

(183) RC increase in partnership capability increase in managerial and supportive capability:THE CONDITION:Partnership Capability = RC RAMP (Partnership Capability,1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.105,36)

Units: **undefined**

(184) RC increase in product attractiveness increase in customer satisfaction:THE CONDITION:product attractiveness = RC RAMP (product attractiveness,2,36):IMPLIES:customer satisfaction> = RC RAMP CHECK (1,customer satisfaction,1.8,36)

Units: **undefined**

(185) RC increase in product quality increase in product attractiveness:THE CONDITION:Product Quality = RC RAMP (Product Quality,2,36):IMPLIES:product attractiveness> = RC RAMP CHECK (1,product attractiveness,1.565,36)

Units: **undefined**

(186) "RC increase in R&D budget growth in product quality":THE CONDITION:"R&D budget" = RC RAMP (0,"R&D budget",1.5,36):IMPLIES:Product Quality> = RC GROW CHECK (4,Product Quality,0.006)

Units: **undefined**

(187) RC increase in risk capability increase in managerial and supportive capability:THE CONDITION:Operational Risk Management Capability = RC RAMP (Operational Risk Management Capability,1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.105,36)

Units: **undefined**

(188) RC increase in SC capability decrease in supplier delay:THE CONDITION:"SC-Procurement Capability" = RC RAMP ("SC-Procurement Capability",1.5,36):IMPLIES:suppliers delay< = RC RAMP CHECK (1,suppliers delay,0.915,36)

Units: **undefined**

(189) RC increase in strategic capability increase in managerial and supportive capability:THE CONDITION:Strategic Capability = RC RAMP (Strategic Capability,1.5,36):IMPLIES:managerial and supportive capability> = RC RAMP CHECK (1,managerial and supportive capability,1.105,36)

Units: **undefined**

(190) RC increase in support capability increase in support availability:THE CONDITION:Customer Support Capability = RC RAMP (Customer Support Capability,2,36):IMPLIES:availability of support> = RC RAMP CHECK (1,availability of support,1.138,36)

Units: **undefined**

(191) RC no change in awareness no new customer:THE CONDITION:change in brand awareness = 0:IMPLIES:new customer = 0

Units: **undefined**

(192) RC no customer base no new order:THE CONDITION:Customer Base = RC STEP (Customer Base,0):IMPLIES:new orders < = RC STEP CHECK (1,new orders,0)

Units: **undefined**

(193) RC no customer satisfaction no new order:THE CONDITION:customer satisfaction = 0:IMPLIES:new orders = 0

Units: **undefined**

(194) RC no financial resource no budget:THE CONDITION:TI no financial resource:IMPLIES:budget = 0

Units: **undefined**

(195) RC no HR budget decay in workforce:THE CONDITION:HR budget = RC STEP (HR budget,0):IMPLIES:Workforce< = RC DECAY CHECK (0,Workforce,300)

Units: **undefined**

(196) RC no HR budget no hire:THE CONDITION:HR budget = 0:IMPLIES:hires = 0

Units: **undefined**

(197) RC no marketing budget no change in awareness:THE CONDITION:marketing budget = 0:IMPLIES:change in brand awareness = 0

Units: **undefined**

(198) RC no negative inventory:THE CONDITION: :IMPLIES:Inventory> = 0

Units: **undefined**

(199) RC no new order no supply chain activities:THE CONDITION:new orders = 0:IMPLIES:SC activities < = RC STEP CHECK (2,SC activities,0)

Units: **undefined**

(200) RC no new orders no component purchased:THE CONDITION:new orders = 0:IMPLIES:component purchased< = RC STEP CHECK (2,component purchased,0)

Units: **undefined**

(201) RC no product awareness decay in customer base:THE CONDITION:change in brand awareness = RC STEP(change in brand awareness,0):IMPLIES:Customer Base> = RC DECAY CHECK (0,Customer Base,95)

Units: **undefined**

(202) "RC no R&D budget no changes in quality":THE CONDITION:"R&D budget" = 0:IMPLIES:change in product quality = 0

Units: **undefined**

(203) RC no ready product no shipment:THE CONDITION:Products Ready for Shipment = 0:IMPLIES:shipment = 0

Units: **undefined**

(204) RC no revenue negative income:THE CONDITION:revenue = 0:IMPLIES:income< = 0

Units: **undefined**

(205) RC no shipment no revenue:THE CONDITION:shipment = 0:IMPLIES:revenue = 0

Units: **undefined**

(206) replacement = DELAY FIXED (depreciation,1,1000)

Units: Euro/month

(207) retirements = Workforce/time to retire

Units: Worker/month

(208) revenue = MAX (product price*shipment,0)

Units: Euro/month

(209) ROE = net income/shareholder's equity

Units: 1/month

(210) ROI = income/investment

Units: Dmnl

(211) salary cost = individual salary*Workforce

Units: Euro/month

(212) satisfaction per accessibility = 1

Units: CS/AoS

(213) satisfaction per attractiveness = 1

Units: CS/Attract

(214) SAVEPER = TIME STEP

Units: month [0,?]

The frequency with which output is stored.

(215) SC activities = component purchased/component per SC

Units: A/month

(216) SC charge = 1000

Units: Euro/A

(217) SC cost = SC activities*SC charge

Units: Euro/month

(218) "SC-Procurement Capability" = INTEG (increase in SC planning capability+increase in transaction settlement capability,0.5)

Units: C

(219) Shared Knowledge = INTEG (knowledge sharing rate,700)

Units: K

(220) shareholder's equity = (Fixed Assets+(Inventory*component price)+Financial Resource-total dept)

Units: Euro

(221) shipment = IF THEN ELSE (shipment time<1,Products Ready for Shipment/time constant,Products Ready for Shipment/shipment time)

Units: product/month

(222) shipment time = IF THEN ELSE (shipment time per capability = 0,standard shipment time,standard shipment time/((managerial and supportive capability+Product Delivery Capability)*shipment time per capability))

Units: month

(223) shipment time per capability = 0.35

Units: 1/C

(224) shipping charge per product = 20

Units: Euro/product

(225) shipping cost = shipment*shipping charge per product

Units: Euro/month

(226) standard delay time = 3.2

Units: month

(227) standard shipment time = 2

Units: month

(228) Strategic Capability = INTEG (increase in strategic capability,0.5)

Units: C

(229) suppliers delay = IF THEN ELSE (delay prevention per capability = 0,standard delay time,standard delay time/(("SC-Procurement Capability"+"Inventory/ Logistics Management Capability"+managerial and supportive capability)*delay prevention per capability))

Units: month

(230) sustainable growth rate = ROE*business retention rate

Units: 1/month

(231) tax rate = 0.2

Units: Dmnl

(232) TI no financial resource:TEST INPUT:Financial Resource = 0

Units: **undefined**

(233) time constant = 1

Units: month

(234) time effect on DI effect = WITH LOOKUP (Time/time constant,([(0,0)-(36,0.2)],(0,0.184211),(1,0.1823),(2,0.176),(3,0.158421),(4,0.11649),(5,0.06018),(6,0.03263),(7,0.01809),(8,0.01593),(9,0.01331),(10,0.01174),(11,0.01057),(12,0.009786),(13,0.008786),(14,0.007786),(15,0.006786),(16,0.005786),(17,0.004786),(18,0.00379147),(19,0.002891),(20,0.001986),(21,0.000986),(22,0.000686),(23,0.000586),(24,0.000486),(25,0.0003),(26,0.0002),(27,0.0001),(28,0.0001),(29,0.0001),(30,0.0001),(31,0.0001),(32,0.0001),(33,0.0001),(34,0.0001),(35,0.0001),(36,0.0001)))

Units: Dmnl

(235) time effect on training activities = WITH LOOKUP (Time/time constant,([(0,0)-(36,0.9)],(0,0.8),(1,0.8199),(2,0.824645),(3,0.824645),(4,0.82),(5,0.81),(6,0.8),(7,0.79),(8,0.78),(9,0.77),(10,0.75),(11,0.72),(12,0.68),(13,0.62),(14,0.54),(15,0.42),(16,0.3),(17,0.2),(18,0.13),(19,0.12),(20,0.11),(21,0.1),(22,0.1),(23,0.1),(24,0.1),(25,0.1),(26,0.1),(27,0.1),(28,0.1),(29,0.1),(30,0.1),(31,0.1),(32,0.1),(33,0.1),(34,0.1),(35,0.1),(36,0.1)))

Units: Dmnl

(236) TIME STEP = 0.125

Units: month [0,?]

The time step for the simulation.

(237) time to hire = 1

Units: month

(238) time to retire = 240

Units: month

(239) total cost = HR cost+inventory holding cost+investment+marketing cost+other costs+"R&D cost"+raw material cost+SC cost+shipping cost+investment

Units: Euro/mont

(240) total dept = 0

Units: Euro

(241) total productivity = individual productivity*Workforce*(Product Development Capability+managerial and supportive capability)*productivity per capability

Units: product/month

(242) training activities = training activities rate+DI investment*time effect on training activities*training activities per investment

Units: A/month

(243) training activities per investment = 0.001

Units: A/Euro

(244) training activities rate = 1

Units: A/month

(245) training cost = average cost per training activity*training activities

Units: Euro/month

(246) Unshared Knowledge = INTEG (knowledge acquisition rate+knowledge creation rate-knowledge sharing rate,700)

Units: K

(247) Workforce = INTEG (hires-retirements,20)

Units: Worker

APPENDIX E

SENSITIVITY ANALYSIS GRAPHS

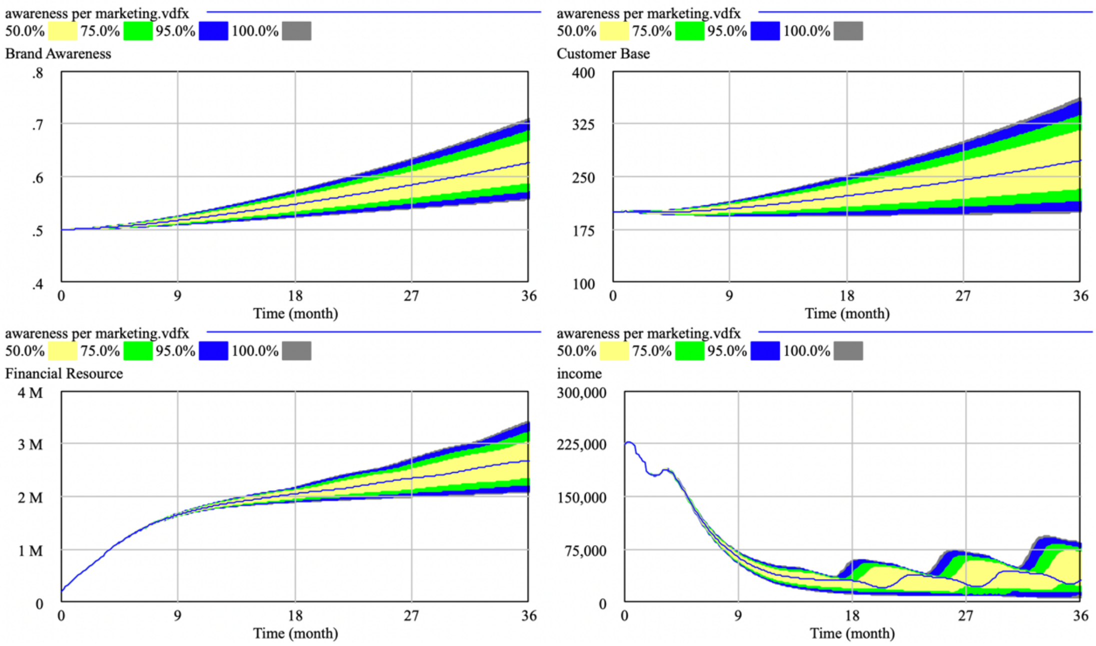


Figure E1. Percentile intervals for the parameter “awareness per marketing”

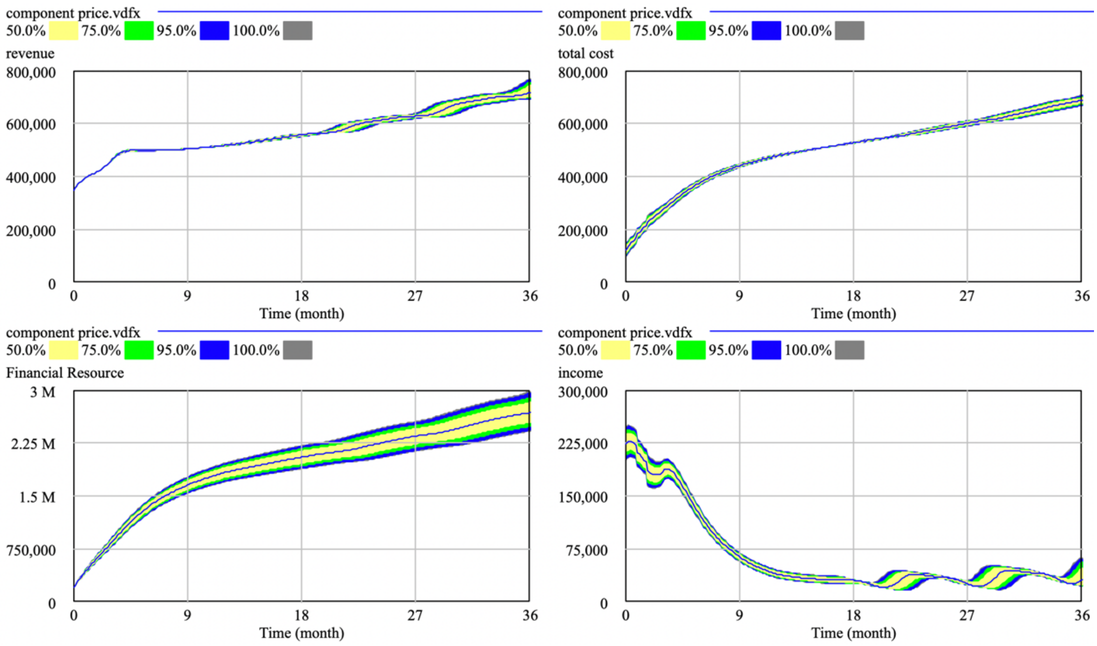


Figure E2. Percentile intervals for the parameter “component price”

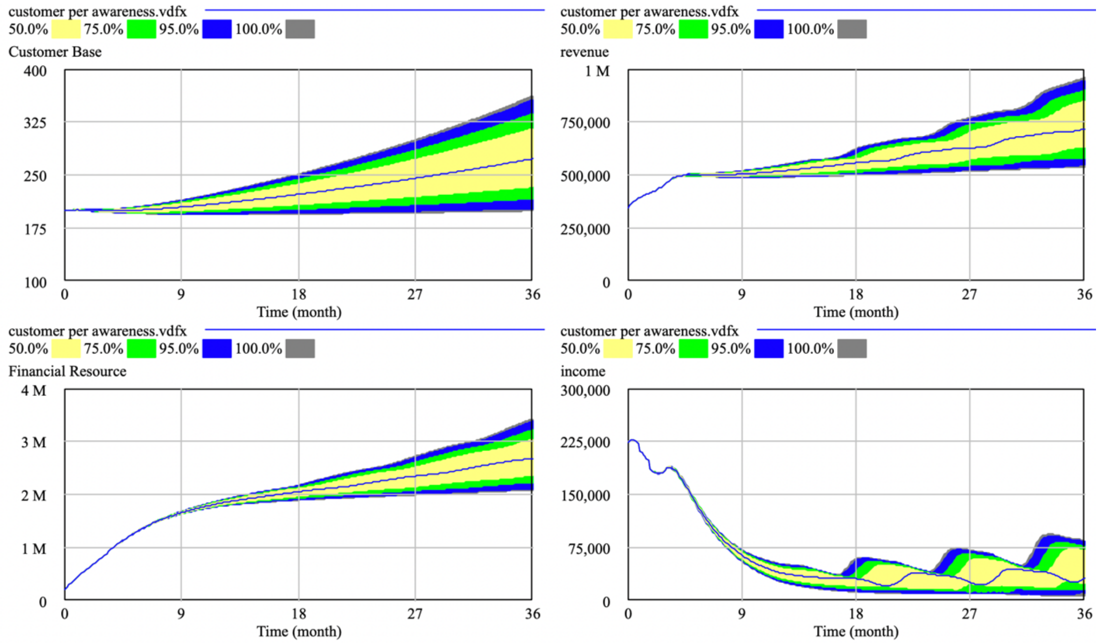


Figure E3. Percentile intervals for the parameter “customer per awareness”

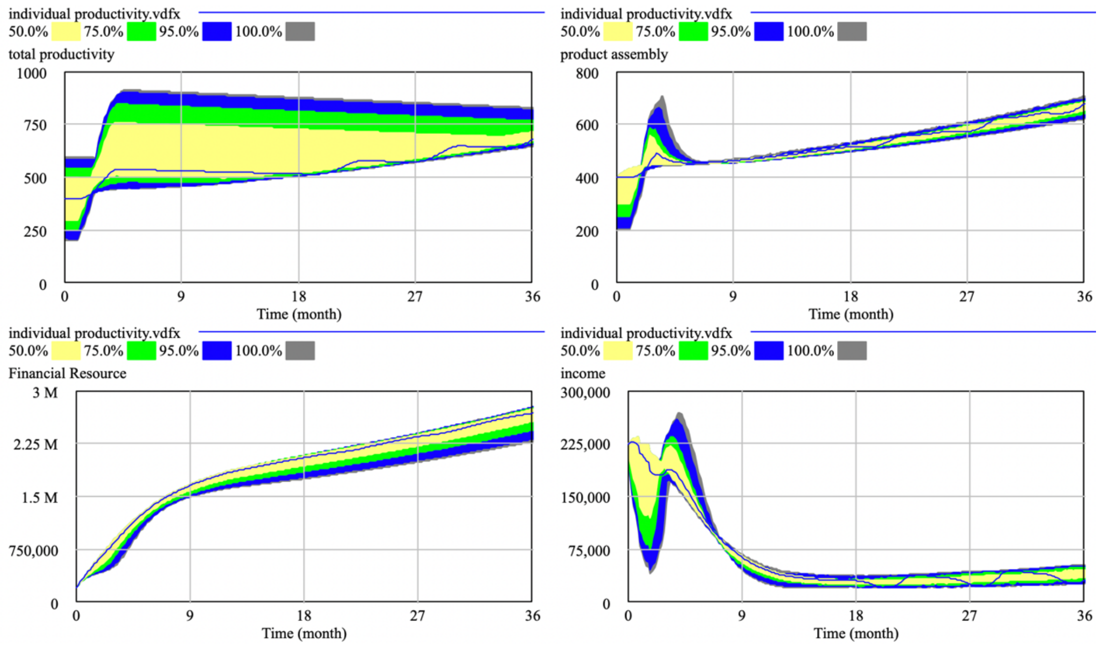


Figure E4. Percentile intervals for the parameter “individual productivity”

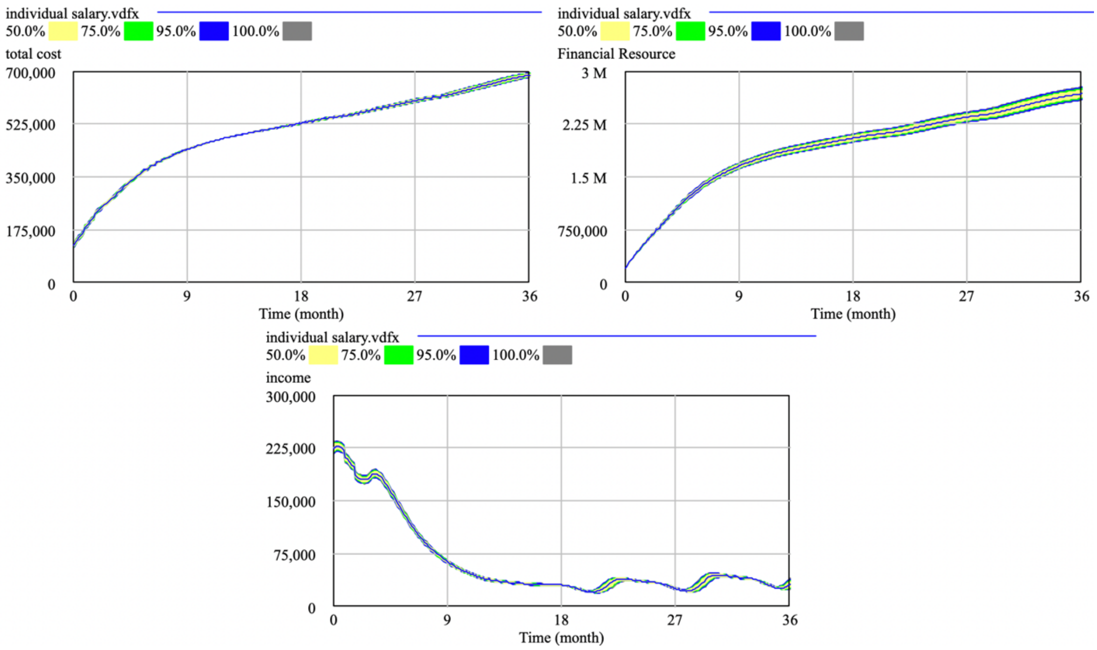


Figure E5. Percentile intervals for the parameter "individual salary"

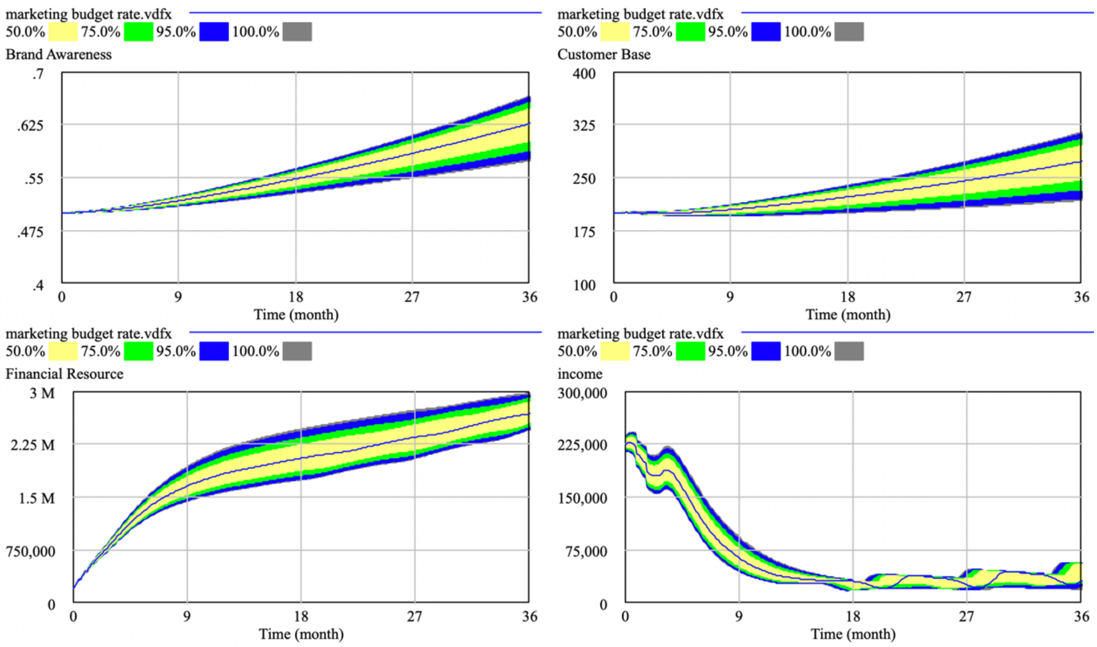


Figure E6. Percentile intervals for the parameter "marketing budget rate"

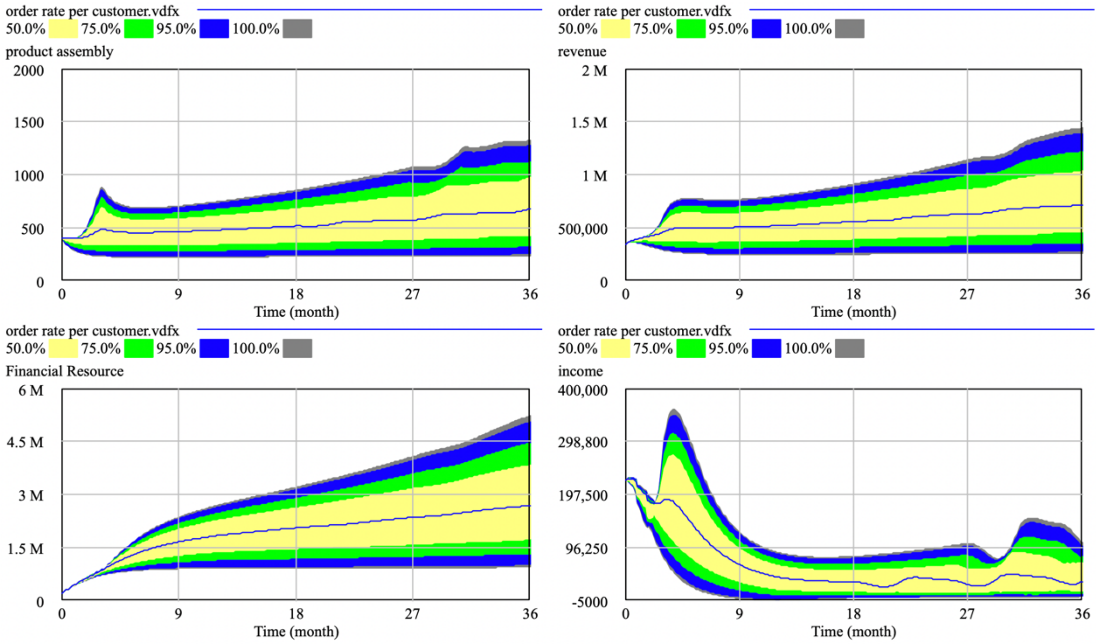


Figure E7. Percentile intervals for the parameter “order rate per customer”

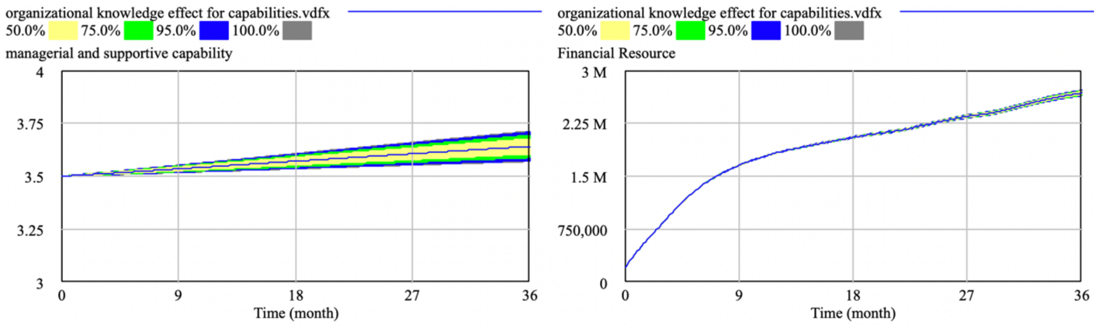


Figure E8. Percentile intervals for the parameter “organizational knowledge effect rate for capabilities”

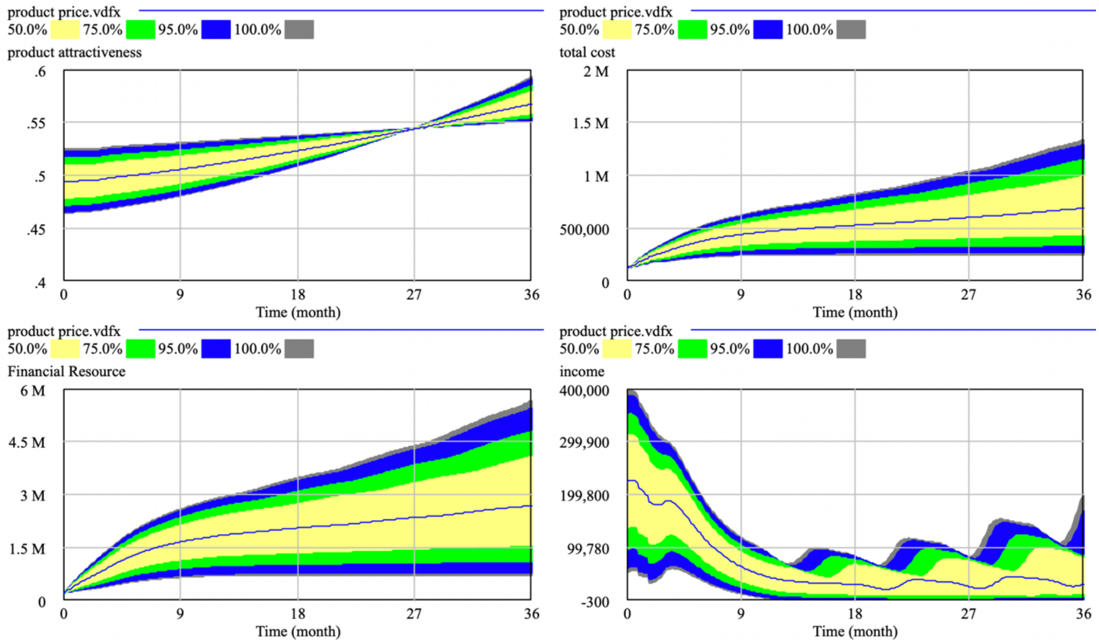


Figure E9. Percentile intervals for the parameter "product price"

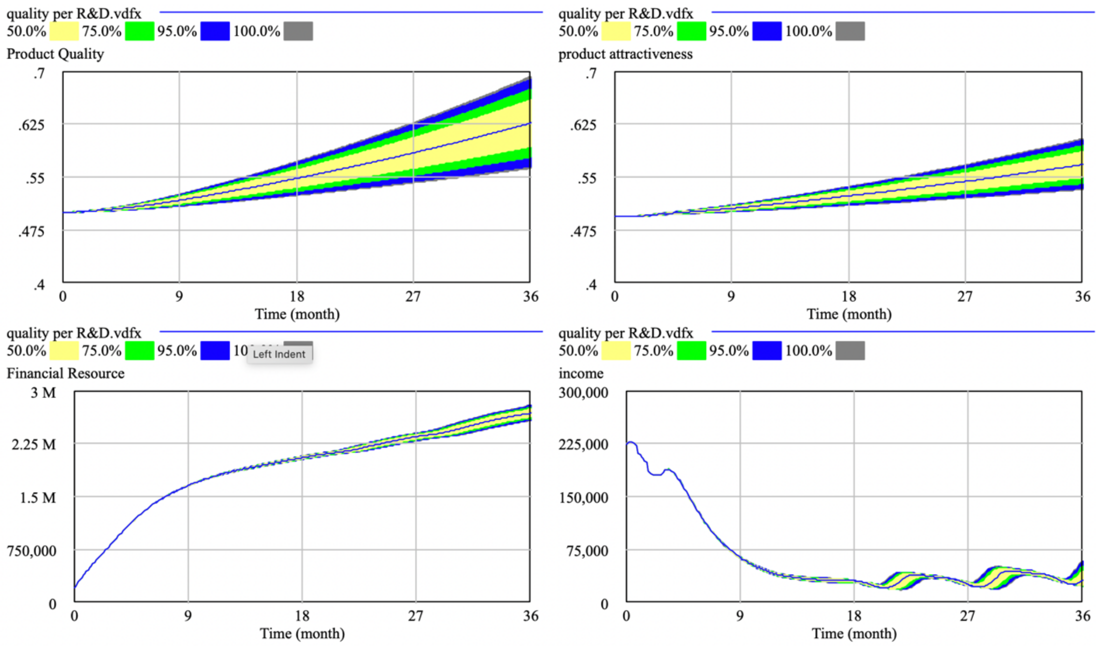


Figure E10. Percentile intervals for the parameter "quality per R&D"

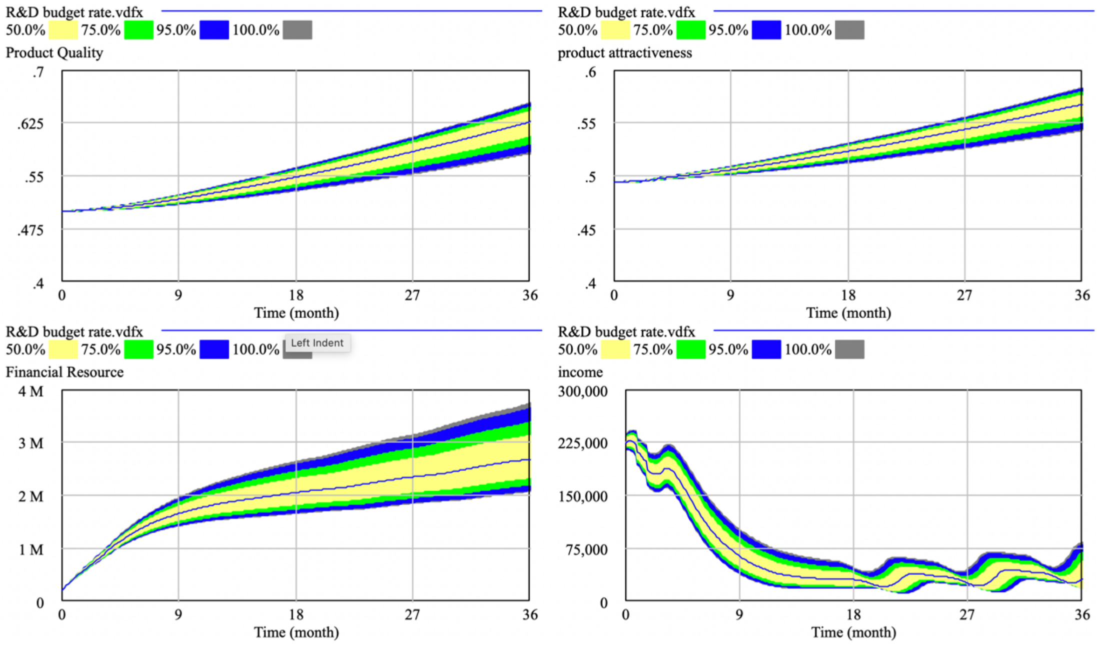


Figure E11. Percentile intervals for the parameter “R&D budget rate”

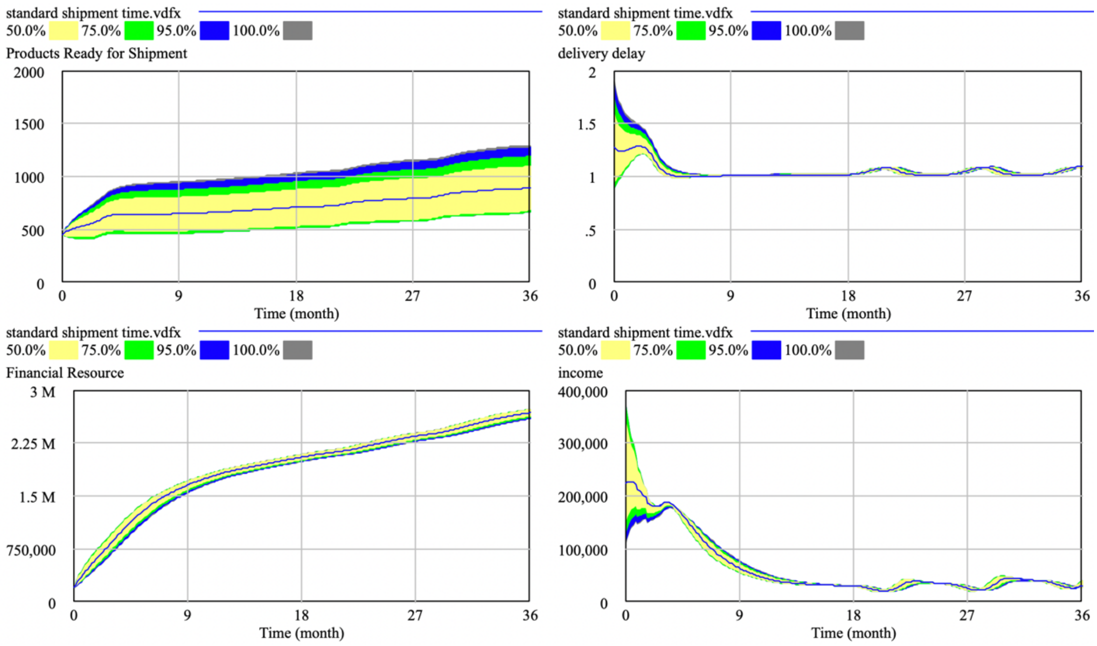


Figure E12. Percentile intervals for the parameter “standard shipment time”

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