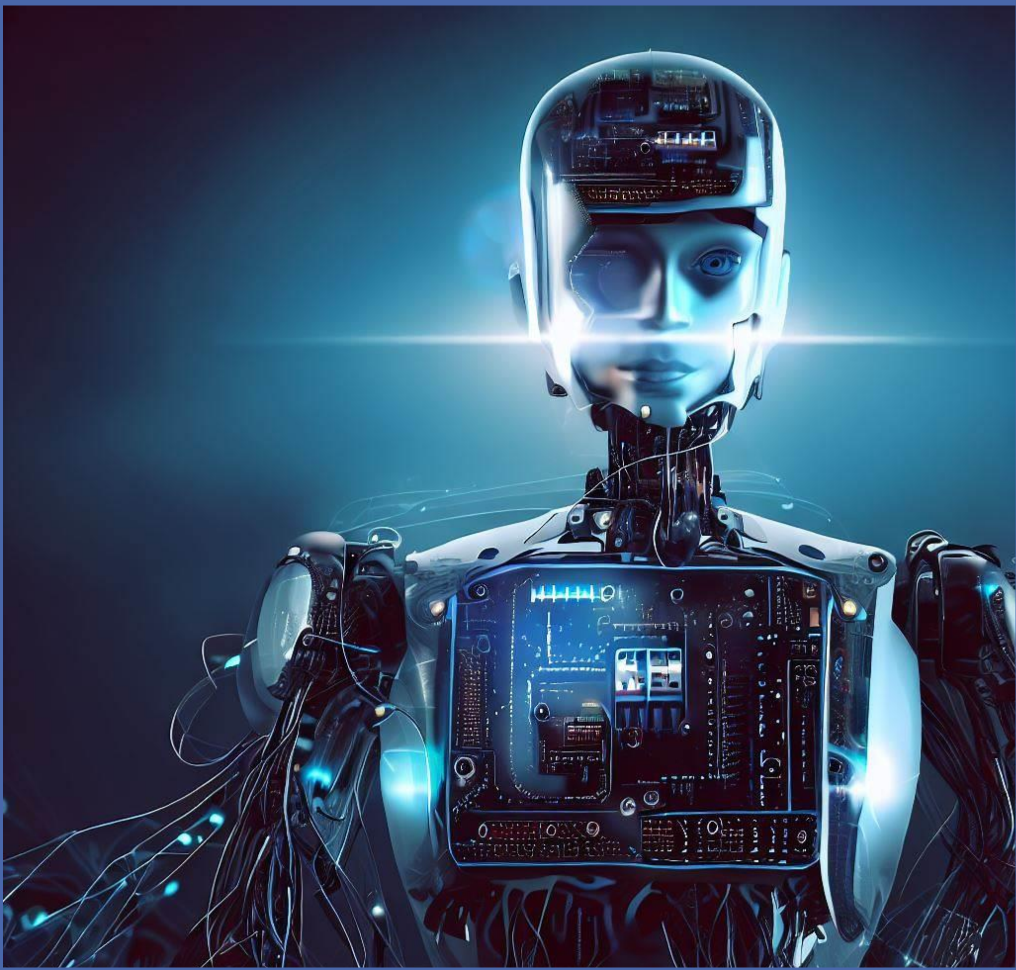

BUSINESS MODELS FOR AIOT

Deliverable I:
An overview of the current business models, definitions, maturity model and value propositions

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EXECUTIVE SUMMARY

An overview of the main points of the report: concepts, maturity model, current BMs

The current report is the first deliverable from a three-part deliverable from CBS in the DIREC project “Embedded AI”. This project is organized into 6 work packages (WP1 to 6) covering several angles related to the artificial intelligence of things and embedded AI, including hardware, software, and business aspects. WP6 focuses on business models for embedded AI. This work package will develop scenarios for different types of business models in a business ecosystem of AIoT companies. In this section, an executive summary of the report is provided. As part of the DIREC Embedded AI project, this study aims to provide a common understanding of AIoT and embedded AI and the relevant business models. This research emphasizes the importance of clear definitions and concepts that are central to the embedded AI project. By establishing a robust theoretical foundation, it is possible to enhance the understanding of the stakeholders as well as have a deeper analysis perspective and effective communication with the audience. Such clear definitions enable the establishment of a common language that bridges the gap between academics and practitioners and facilitates the transfer of knowledge and insights between the parties. The IoT ecosystem comprises a wide range of technologies and domains that disrupts our activities and lives.

With the evolution of IoT, the concept of Intelligent IoT and Intelligent Edge has emerged, referring to devices with sophisticated intelligent capabilities. This shift towards intelligent edge computing brings decision-making closer to end-users and data sources and leverages AI and machine learning to enable real-time decision-making. The integration of AI and ML within the IoT systems can allow data analysis, pattern identification, prediction, and informed decision-making using the collected data. The symbiotic relationship between AI and IoT can result in the generation of massive sets of data. And with this, AI can play a crucial role in deriving valuable insights from this data. AI acts as the cognitive element in the IoT structure, while IoT functions as a digital nervous system. The combination of AI, ML, and IoT represents a powerful technological force with huge potential for agile solutions and automated processes. The emergence of these novel technologies and the innovative integration of them in new applications and formats necessitates clear descriptions and definitions, specifically in projects where stakeholders come from various backgrounds.

On the business model side, the challenge is still there. The multitude of definitions and interpretations in this area has led to confusion in both academia and industry. While various researchers have studied business models, there is still a lack of unified definitions and descriptions. In addition to this, the lack of robust theories specific to these concepts makes it difficult to conduct research and contribute to the literature. Current literature provides frameworks and tools to examine business models, with value being the core element. Fundamentally, a business model represents the mechanism through which a firm proposes, creates, delivers, and captures value. It encompasses value proposition, value creation, value capture, and value delivery as the main elements. The proposed definition of a business model in the "Embedded AI" project is: "A business model is the logic of how a company does business, including the core value proposition, value creation, value capture, and value delivery."

Section 3 discusses the evolution of IoT business models and their progression through different stages in the form of a maturity model. It begins with IoT as a retrofitted limited component to a stage where IoT enables a network of companies to collectively create and capture value. The emergence of AIoT and embedded AI could be particularly significant at the ecosystem level, as they enhance connectivity and communication among businesses. According to this model, in the first stage, known as Additive IoT, companies retrofit IoT devices into existing products. This enables limited data collection and slightly enhanced communications. In the second stage, Integrated IoT, companies such as Gardena integrate IoT into their products from the beginning, which leads to tracking, optimization, and improved customer relationships. In the third stage, Servitized IoT, companies such as Hilti utilize the extensive integration of IoT devices which enables real-time monitoring, product service systems, and new revenue models. Finally, in the fourth stage, products are integrated into an ecosystem where data becomes foundational for value proposition. Solution co-creation, interoperability, autonomy, and data-driven services are emphasized and the development of platforms, data markets, and cross-divisional collaborations becomes possible.

Section 4 provides an overview of the business models of VELUX, MAN Energy Solutions, and Grundfos. It examines the key elements of their business models, including value proposition, creation, capture, and delivery. MAN Energy Solutions specializes in marine propulsion technologies, electric energy generation and storage, and industrial processes. The company operates in several countries and collaborates with various stakeholders globally. The company proposes value by providing innovative and environmentally friendly solutions to its customers. To create value, it offers a range of products, services, and digital solutions. Its revenue model includes one-off sales of engines and a subscription-based model for services such as PrimeServ Assist. Primarily, it targets customers such as ship owners and ship managers. VELUX operates with a business model focused on providing high-quality windows, natural lighting solutions, and associated accessories to customers worldwide. Their value proposition revolves around delivering products that optimize natural light intake, enhance indoor air quality, and provide ventilation for different environments. VELUX offers a diverse range of products, including windows, sun tunnels, blinds, and smart home automation solutions. They collaborate with professionals in the field to drive innovation in building design. VELUX primarily relies on one-off sales of its products and aims to expand its smart features and electronic options. The company operates production facilities in multiple countries and has a diverse distribution network to ensure the widespread availability of its offerings. Finally, Grundfos is a company that specializes in producing advanced pump solutions and water technology. They propose value by providing solutions to manage, advance and protect the flow of water in various environments, from homes and commercial buildings to large industrial factories. The company focuses on sustainability and the environment and invests in research and development to drive innovation. Grundfos manufactures most of its components and distributes its products through a network of retailers and wholesalers. The revenue model primarily relies on one-off sales to capture value.

The fifth section describes our next step as part of deliverable II in the embedded AI project. This upcoming study aims at exploring AIoT-enabled value propositions and intends to address a gap in the existing literature regarding AIoT-related business models. The study will investigate the current landscape of AIoT solution providers and their value propositions by analyzing secondary data collected from company websites, blogs, reports, and newsletters. The research aims to identify and categorize the value proposition archetypes within the AIoT domain which can contribute to both academia and practitioners. The study seeks to address the imbalance resulting by focusing on technical AIoT research works while there is limited research on AioT from the business model perspective. The results are expected to provide valuable insights for managers and business developers on integrating AIoT within their organizations, offering guidance for devising value propositions that capture the potential of AIoT. The report is finally concluded in the sixth section.

1. INTRODUCTION

The recent advancements in technology have paved the way for the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) and given rise to a new paradigm known as the Artificial Intelligence of Things or AIoT. This technology combines the power of AI algorithms with the vast network of interconnected devices in IoT, enabling smart, intelligent, and autonomous systems. This potent convergence is no longer a prospect, but rather, an existing reality (Kuguoglu et al., 2021). Both AI and IoT individually possess remarkable capabilities, yet their convergence has introduced new possibilities and opportunities for businesses in all industries, necessitating a reevaluation of traditional business models and the core value propositions. The primary goal of this work is to study the business models associated with AIoT, particularly focusing on the impact of embedded AI on business models and business scenarios. In traditional business models, normally once the product is sold and installed through regular sales channels, there are limited interactions between the manufacturer, the user, and the product. However, with the emergence of AIoT, the dynamics of the business landscape have started to change.

Specifically embedded AI systems have unique characteristics that challenge traditional business models. Unlike conventional models, where a product's value is derived from its standalone capabilities, embedded AI products operate within an ecosystem comprised of interconnected devices. Thus, the value proposition of each product becomes less apparent, as it contributes to the collective intelligence and performance of the system with a bigger synergy from its components. Consequently, existing business models struggle to articulate the value generated by products within such distributed and interdependent architectures. Moreover, embedded AI environments are characterized by hardware complexities and shared infrastructures, further necessitating the transformation of business models. The distributed nature of these systems requires novel approaches to address the challenges posed by resource allocation, scalability, and interoperability.

As the first deliverable of the three planned deliverables in the CBS work package of the overall DIREC Embedded AI project, this work intends to provide a comprehensive understanding of the business models in the context of AIoT and embedded AI. Primarily, it provides an overview of the main concepts such as business model, value proposition, AIoT, embedded AI, etc. to create a theoretical foundation for this report in addition to unifying the understanding and providing a common language among the stakeholders of this project. Moreover, it will provide an overview of the maturity of IoT business models as the foundation for AIoT and embedded AI and the corresponding business models. And finally, this work focuses on examining existing case companies – Grundfos, MAN, and VELUX. The main objective is to describe and analyze their current business models, considering the evolving landscape of technology and value propositions. By exploring the existing business models in the AIoT domain and examining their evolution, this report aims to shed light on the impact of AIoT on businesses and pave the way for the next phase which is the assessment of business scenarios and possible use cases for AIoT companies. In addition, the fifth section of this report is dedicated to discussing our next step which is studying AIoT value propositions based on the analysis of current pioneer AIoT companies. The findings of this study will contribute to the understanding of how businesses can effectively adapt their business models to leverage the potential of embedded AI, facilitate business model innovation, and propose, create, capture, and deliver value in this fast-growing paradigm. In the following sections of this report, we will focus on the core concepts and ideas, central to the project, we will provide an overview of the evolution of IoT business models, and finally, we will look into the detail of the partner companies' business models.

2. CONCEPTS AND DEFINITIONS

This section intends to provide definitions and a theoretical foundation for the main concepts in the embedded AI project. By establishing a robust theoretical foundation, we strive to enhance our understanding of the phenomena under investigation and lay the foundation for an insightful interpretation of the ideas. Developing such a foundation and developing clear definitions not only facilitates comprehension of the subject matter but also allows one to gain a deeper perspective into complexities and nuances. By establishing a shared understanding of key concepts, we intend to help the readers grasp the meaning and significance of the terminology employed throughout this work. Moreover, by doing so, we intend to develop a common language to facilitate effective communication and collaboration between the researchers and practitioners in this project. It is essential to establish a common and unified language that both academics and practitioners understand and use since it helps to prevent confusion, misunderstandings, and miscommunication. This is particularly critical in projects (such as the embedded AI project) that address complex concepts and technical terminology, such as those related to artificial intelligence, the Internet of things, edge computing, and business models.

The establishment of a common language involves identifying key terms, ideas, and concepts that are central to the project, and defining them clearly for all the involved members. A unified language can also help to bridge the gap between academics and practitioners, by facilitating the transfer of knowledge and insights between the two. By establishing a shared vocabulary (covering the main terms) and understanding key concepts, researchers can communicate their findings and recommendations to practitioners in a way that is actionable and relevant. Similarly, practitioners can provide profound feedback and important insights to researchers and help them to shape the direction and focus of their research endeavor.

2.1. FROM IOT TO ARTIFICIAL INTELLIGENCE OF THINGS

IoT has emerged as a pervasive computing paradigm, encompassing a multitude of interconnected technologies and computing domains. These include hardware, software, and communication technologies, such as networking, mobile computing, low-power devices, data processing, data streams, security and privacy, and quality of service (QoS), among others (Xhafa, 2023). As an ecosystem (Habiba et al., 2023), IoT exhibits disruptive characteristics, permeating various spheres of human activity and exerting a significant impact on society as a whole. It continues to evolve and expand, encompassing new types of computing paradigms and technologies, while concurrently bridging gaps within the broader computing ecosystem. This development contributes to what is commonly referred to as the "computing continuum" (Balouek-Thomert et al., 2019; Beckman et al., 2020; Dustdar et al., 2023; Pujol et al., 2021) or the progression from cloud-based computing to edge computing in the context of the Cloud-to-thing continuum (Xhafa, 2023).

IoT initially gained prominence through the deployment of sensor networks and simple connected devices (Chandnani & Khairnar, 2022; Hughes-Lartey et al., 2021; Khan & Mailewa, 2023), which served as platforms for gathering observations and data measurements from the physical world. Since then, IoT has experienced exponential growth, both in terms of the sheer number of connected devices, which now accounts for billions and in the enhanced computing capabilities of these interconnected devices. These ongoing advancements have resulted in a notable transformation within the field of IoT computing, particularly toward the concept of Intelligent IoT and Intelligent Edge (Xhafa, 2023).

While the extraction of intelligence from the data collected by IoT devices (Agi et al., 2021), will remain a fundamental aspect of IoT computing, the ecosystem is increasingly focusing on endowing devices with more sophisticated and intelligent services at both the individual device level and in a collective manner. This paradigm shift towards intelligent edge computing entails facilitating decision-making at the periphery of the Internet, in close proximity to end-users and data sources, thereby shifting the burden of intelligence away from traditional cloud servers and data centers (Xhafa, 2023). To achieve this transition, AI and ML play critical roles, serving as essential means for realizing the potential of the IoT ecosystem. Consider, for instance, the implementation of self-driving cars (e.g, Waymo, and Tesla, which propose unique value propositions as discussed in the next section), autonomous traffic management systems, smart grids and utility pipelines, industrial edge computing, precision agriculture, and numerous other applications where the intelligent edge serves as the focal point for real-time decision-making. Consequently, the integration of AI and ML within the IoT framework enables the fulfillment of the overarching principle that the "intelligent edge is where the action is" (Xhafa, 2023).

AI heavily relies on large quantities of data. And IoT has emerged as a significant contributor to the generation of substantial data volumes. Although despite this seemingly symbiotic relationship between AI and IoT, numerous organizations encounter challenges in collecting and managing the vast amount of data generated (Kuguoglu et al., 2021). As Nozari et al. (2023) argue, IoT generates huge amounts of data through its large network of connected devices. AI uses data and provides insights for optimal analysis such as past behaviors to identify patterns. It creates models that help predict future behaviors and events. AI finds the power to gather responses and provides the ground for intelligent action, and thus, businesses can make informed decisions. AIoT based on machine learning (Sudharsan, 2022) specifically succeeds in achieving agile solutions. It is under these circumstances that machine learning and AI, along with IoT technology, become the world's superpowers of technology. In this case, machine learning can eliminate hidden IoT data patterns by analyzing large volumes of data using sophisticated algorithms. Machine learning inference can complement or replace manual processes with automated systems using statistical measures in critical processes.

Through IoT, many applications such as smart cities remotely track and optimize their systems and assets, a groundbreaking achievement. However, the challenge of comprehending the vast amounts of data generated by sensors remains a daunting task for human operators (Kuguoglu et al., 2021). This is where AI assumes a crucial role. By leveraging its capacity to swiftly derive valuable insights from data, AI complements the expanding network of interconnected devices and systems that contribute to the IoT. Consequently, smart city applications can mitigate unforeseen downtime, enhance operational efficiency, and facilitate the development of improved products and services. In essence, IoT functions as a digital nervous system, with AI acting as the cognitive center that drives informed decision-making (Kuguoglu et al., 2021).

2.2. AIOT, EDGE COMPUTING AND EMBEDDED AI

As mentioned, AIoT refers to the integration of artificial intelligence technologies into the Internet of Things ecosystem. The integration of AI, sensor networks, and IoT has resulted in the emergence of a new and promising technology known as Artificial Intelligence of Things, which has received significant attention from both industry and academia (Xu et al., 2021). AIoT devices are equipped with sensors and other IoT technologies that collect and transmit data, which is then processed and analyzed using AI algorithms. The advent of the AIoT improves decision-making and enhances numerous intelligent applications (Wang et al., 2021). AIoT allows users to develop various applications using AI techniques on different devices, which further sense and utilize real-world data in different environments (Xu et al., 2021).

Edge computing is a distributed computing paradigm that enables data generation and analysis at the edge of the network, where the data is generated, it is believed to be able to cope with the demands of the ever-growing IoT and mobile devices (Xiao et al., 2019). The fundamental concept of edge computing is to utilize a hierarchy of edge servers, each possessing enhanced computational capabilities. These servers are designed to manage and process mobile and heterogeneous computation tasks that are offloaded by low-end IoT and mobile devices, commonly referred to as edge devices. (Xiao et al., 2019). The architecture of edge computing involves the utilization of heterogeneous devices with varying computational power and storage capacities for computing purposes (Cicirelli et al., 2017). Thus, it has the potential to deliver a range of location-aware, bandwidth-sufficient, real-time, privacy-savvy, and low-cost services to support emerging smart city applications (Xiao et al., 2019). It can include multiple devices for data collection, processing, and analysis, all located at the edge of the network. Inclination towards edge computing has various reasons such as network bandwidth limitations and the privacy concerns of data, transfering the majority of the collected data to a central database on fog or cloud is impractical and often unnecessary, and it is estimated that over 90% of the data will be stored and processed locally (Wang et al., 2021).

As a rapidly growing technology, edge computing satisfies business needs in many areas such as smart agriculture, smart cities, smart manufacturing, or any other smart business (Saini & Raj, 2022). The exponential growth of Internet-connected devices within the IoT ecosystems, and the increasing demand for real-time computational capabilities in emerging technologies, have propelled the advancement of edge computing systems, therefore, the future of edge computing holds tremendous potential, as it can be tailored and adapted to further enhance various existing technologies (Sonone et al., 2022). This adaptability positions edge computing as a pivotal asset for driving innovation and progress across multiple domains (Sonone et al., 2022).

Finally, embedded AI involves the integration of AI algorithms directly into individual hardware, such as sensors, cameras, or other IoT devices. By integrating AI algorithms into the hardware of the devices, they will be capable of generating, processing, and analyzing data locally, without the need to transfer it to a central processing unit, fog, or cloud server. “Within the edge and fog computing paradigms, embedded AI refers to embedding artificial intelligence algorithms into low-power and computationally constrained devices” (Metwaly et al., 2019, p.2). And since the data analysis results contain the most critical information, a viable approach to mitigate unnecessary data transfer to the cloud involves offloading a portion of the computational tasks to the network edge. By distributing the computation closer to the data source, the need for transmitting raw data to the cloud can be circumvented. This strategic shift allows for more efficient utilization of resources and minimizes latency, ultimately enhancing the overall data processing and analysis workflow (Metwaly et al., 2019). The benefits of moving data analysis from the cloud (and fog) architectures towards embedded systems include 1) energy efficiency and lower costs plus reduced impact on network traffic, 2) reduction in server load latency, higher safety, and reliability for time-critical applications, and finally, 3) improved privacy and security, in addition to a lower risk of raw data exposure (Jägare, 2019).

The main difference between these concepts is the scope of devices, the locus of operations, and the focus of their applications. AIoT is concerned with the integration of AI technologies into the IoT ecosystem, while edge computing is focused on the infrastructure and architecture for processing and analyzing data at the edge of the network. Embedded AI, on the other hand, is fundamentally concerned with integrating AI algorithms directly into individual hardware devices. While both embedded AI and edge computing involves local processing and analysis of data, they differ in terms of their scale and focus. Embedded AI focuses on integrating AI algorithms directly into individual hardware devices, while edge computing focuses on the broader infrastructure and architecture for processing and analyzing data at the edge of the network. Moreover, edge computing can involve multiple devices for the purpose of generating, storing, and analysis of data, while embedded AI involves the use of AI in individual devices where all three functions of data generation, data storage, and data analysis occur. Figure 1 provides an overview of the scope of the three concepts.

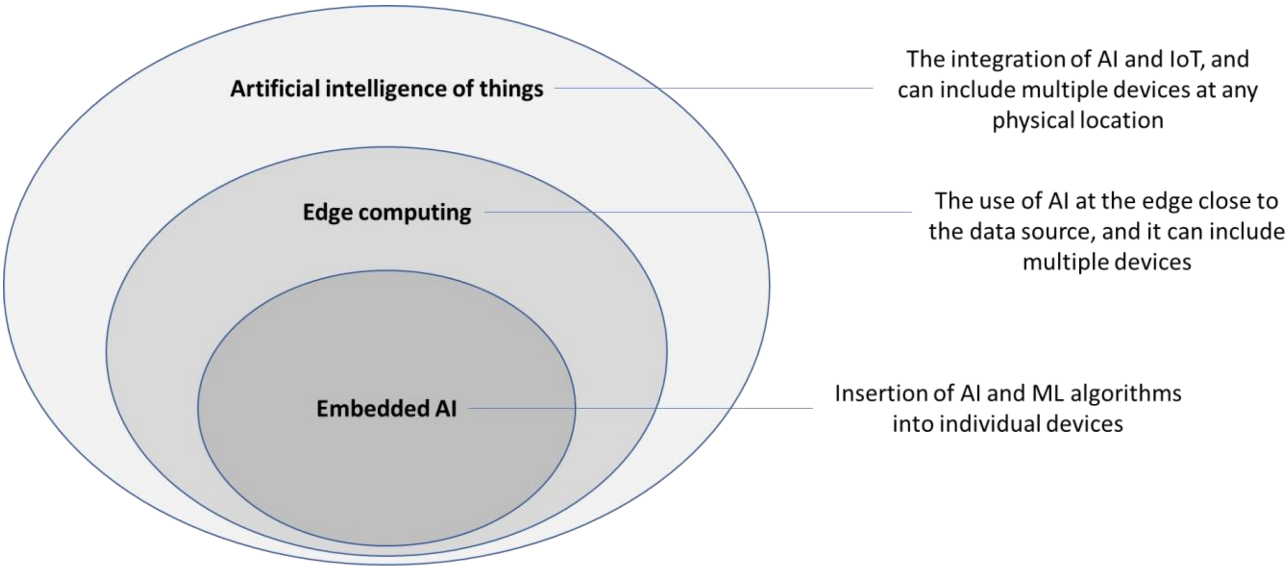

Figure 1, An overview of AIoT, edge computing and embedded AI

2.3. BUSINESS MODELS AND VALUE PROPOSITIONS

This subsection is focusing on business models and intends to provide a common definition of a "business model" that facilitates communication and prevents misunderstandings in the "Embedded AI" project. However, before discussing this concept, it is important to mention the fickle nature of business model definition and why this concept can be foundationally slippery to work with.

- *Multiple definitions and individual ideas about the concept:* the first problem with the business model is that the number of definitions and descriptions for this concept is almost equal to the number of people who use it both in academia and industry. Coined by Drucker (1954) and popularized in the 90s with the boom of dotcom companies, the idea of business models started to gain traction ever since. The emergence of innovative business ideas and the advent of new technologies has necessitated the development of new business models. This, coupled with the enormous research attempting to define a business model has led to a plethora of definitions and descriptions that not only make it unclear and slippery but also sometimes lead to confusion, specifically when there is an attempt to communicate the concept between academics and the practitioners.

- *Lack of established theories in the academic literature:* although numerous researchers have studied business models (Amit & Zott, 2020; Burström et al., 2021; Endres et al., 2019a; Osterwalder, 2013; Osterwalder & Pigneur, 2010; Sandqvist, 2015; Zott et al., 2011) there exist a lack of robust theories for around this concept. While there are strong correlations between some established theories such as Resource-based view (RBV), dynamic capabilities, or disruptive innovation theory with business models, there's still a lack of a unique and individual theory of business models. This makes it more difficult and vaguer to conduct research on business models and provide a clear contribution to the literature.

Aside from the aforementioned limitations, the literature on business models provides different frameworks and tools to view a business model. During the past twenty years, numerous scholars have explored the composition of business models and have outlined various components, elements, types, and ontologies associated with them (Endres et al., 2019a). However, the core element of any business model is value. In 1960, Harvard Business School professor Theodore Levitt argued that businesses should focus on delivering value to customers rather than just producing goods and services (Levitt, 1960, p.2). This idea strived to shift the focus of businesses from production towards value for customers and their needs and preferences. In the 1980s and 1990s, several researchers started to explore the idea of a "business model" as a means to describe the fundamental structure and mechanism of a business (H. W. Chesbrough, 2003; Drucker, 1985; Hamel, 1996). In the late 1990s and early 2000s, the rise of the internet and digital technologies fostered a new generation of business models based on digital marketplaces, online platforms, and other forms of internet-based businesses and e-commerce websites. It was in this era that new concepts such as "freemium", "long tail" and "network effects" emerged.

The concept of “business model” continues to evolve, as businesses seek new ways to create value and adapt to ever-changing market conditions. Therefore, the business model remains one of the focal elements of strategy and is an important tool for entrepreneurs, investors, business developers, and managers seeking to understand and modify the performance of their companies. The business model can be seen as an interconnected activity system, wherein the comprising elements namely, value creation, value proposition, and value capture are intricately linked (Zott and Amit, 2010). And it serves as a foundation for efficiency, enabling firms, particularly entrepreneurs, to maximize value creation and value capture both internally and externally, surpassing the boundaries of the organization (Haaker et al., 2021). The concept of the business model is defined and referred to in different ways in the academic literature (Foss & Saebi, 2018). The variation of definitions and understandings is even more complicated in the industry as every practitioner looks at the business from a different perspective. However, it is almost generally accepted that a business model simply represents the mechanism with which a firm proposes, creates, delivers, and captures value (Amit & Zott, 2001; Teece, 2010; Zott et al., 2011). Thus, a business model represents the business logic of the firm and, more specifically, the way it works to create value (Matricano, 2020; Moschetti & Brattebø, 2016).

Value creation is the positive contribution to the utility of the target user that can be in the form of novel, efficient, or complementary solutions (Canhoto & Clear, 2020; Rai & Tang, 2014). Value capture determines how offerings are converted into revenue streams and then captured as profits by firms (Clauss, 2017) which is critical to a firm’s success (H. Chesbrough, 2007). Value delivery envisions interaction with the customers and encompasses issues related to the relationship with stakeholders and communication, sales, and distribution channels (de Pádua Pieroni et al., 2018; Teece, 2010). "Value proposition" is a term developed by Michael Lanning in 1983 (Lanning & Michaels, 1988), and defined as “a strategic tool facilitating communication of an organization's ability to share resources and offer a superior value package to targeted customers” (Payne et al., 2017), is the most important component of the business model (Cui et al., 2022; Jones & Coates, 2020; Metallo et al., 2018). In their study on IoT business models, Dijkman et al. (2015) present a business model framework for IoT applications and argue that the value proposition is the most important component of the IoT business model and suggests that “zooming in on particular value propositions provides some potentially interesting insights” (p.677). Figure 1 presents a basic, yet comprehensive overview of the business model elements.

Here, we propose a definition of "business model" that covers the main aspects and elements of any company and conveys our idea of a “business model” in the “embedded AI project”:

> “A business model is the logic of how a company does business, including the core value proposition, vlaue creation, value capture and value delivery.”

According to this definition, the core value proposition is the solution to the customers’ problems. In other words, it is the unique benefits that an offering (product or service) provides for the customers and outlines how it meets the needs and desires of the target customers. Value creation refers to the main offering (product or service) that is valuable to the customer and how it is created. Value capture refers to the value that the company gets by providing the offering and it includes revenue model, monetization methods, pricing, and cost structure. Finally, value delivery refers to the mechanisms through which the offerings are delivered to the customer, and it includes partnerships, collaborations, channels, supply chain, and logistic issues. Figure 2 represents a visual schema of the business model concept that we use in this project. It is noteworthy that in the “embedded AI” project, the emphasis is on the value propositions enabled by embedded AI and the correlated value capture mechanisms. Figure 2 illustrates the components of a business model according to our definition.

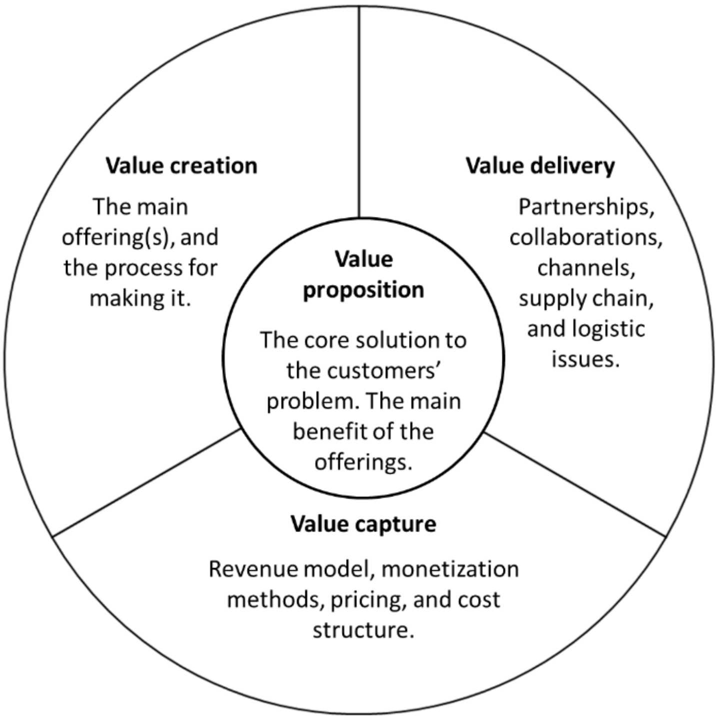

Figure 2, Components of a business model

3. MATURITY MODEL

IoT business models and the evolution of data-driven value propositions

In this section, we focus on the evolution of IoT business models and how they mature through different stages. The evolution of the business models normally starts with limited uses of IoT, and it improves to the final stages where there is an ecosystem of companies creating and proposing value through competition. The ecosystem level is where the role of AIoT and embedded AI becomes even more significant due to their potential for connectivity and improvement of communication between the stakeholders. To develop such a maturity model that addresses the evolution of business models, we present our latest research work on this topic which is submitted to an academic peer-review conference. This study suggests a conceptual model that has an evolutionary four-stage structure, covering IoT business model elements and characteristics. The model is devised by developing domain and method theory based on existing literature and empirical examples from the industry. Each stage is then explained and discussed further.

3.1. IOT AND BUSINESS MODELS

As an important emerging technology, IoT is said to have the potential to improve lives and save time and money (I. Lee, 2019; Whitmore et al., 2015). It has also received significant recognition in academic discourse as a preeminent emergent technological paradigm. This recognition can also be seen in the significant growth of IoT market size and IoT adoption in recent years. According to industry reports, the IoT market has witnessed noticeable expansion, with forecasts indicating a continued surge in its adoption and deployment. The global market for industrial IoT was sized at over $263 billion in 2021. The market is expected to reach $1.11 trillion by 2028. In addition to market growth, the proliferation of IoT is reflected in the escalating number of active device connections. The number of IoT-connected devices worldwide is forecast to triple from 2020 to 2030 (Statista, 2023). The total installed base of IoT-connected devices worldwide is projected to amount to 30.9 billion units by 2025 (Vailshery, 2022). Such statistics signal the mounting recognition of IoT's potential in driving technological advancements and generating substantial business value in various industries.

One of the major drivers of IoT technologies is the concept of business model, which motivates companies to invest, reach new markets and generate new revenues (Bucherer & Uckelmann, 2011; Cranmer et al., 2022) while enabling the reengineering of business competencies for adaptation to the changing environments (Haaker et al., 2021). IoT provides new opportunities for value creation and captures with a focus on enhanced customer experiences. Thus, well-structured IoT business models allow companies to identify novel use cases, address customer needs, and serve potential market segments that they couldn't serve before. This occurs through the IoT's transformative power in generating, collecting, and analyzing vast amounts of data. Understanding and designing adequate business models enable organizations to harness the generated data and create value for the relevant users. The generated data also enables the developing customized solutions and tailored offerings for the customers, leading to higher customer satisfaction and loyalty in addition to new ways of revenue generation and monetization.

3.2. METHODS OF THE RESEARCH

Current research intends to outline and explain the stages of IoT business models through the evolution of data-driven value propositions. Being conceptual in nature (Gilson and Goldberg, 2015; Jaakkola, 2020), this paper enables unconstrained theory building by circumventing the constraints imposed by empirical requirements, such as the time required for data accumulation and the restrictions to generalize the outcomes (Jaakkola, 2020). The complex nature of IoT, its adoption, and business models (AlDoaies & Almagwashi, 2018; J. Lee et al., 2018; Surange & Khatri, 2022) necessitates unrestricted conceptualization and theory development and moving away from limitations of empirical data. Therefore, current research integrates constructs derived from previous research on IoT and Business models to "identify novel connections between existing constructs" (Jaakkola, 2020, p. 22) which logically explain how IoT business models and data-driven value propositions evolve. Moreover, this aligns with Weber (2012), as he perceives the definition of constructs and the establishment of relations between them as the core of theoretical development.

To build our conceptual model, we chose an approach that is informed by the broader management literature (Gilson and Goldberg, 2015; Hulland, 2020; Jaakkola, 2020). This approach consists of four steps. The first step was to identify and define the focal phenomenon for our research, where we inductively identified various conceptualizations of the phenomenon, and figured out how the aspects of interest are best addressed in terms of broad concepts or theories (Jaakkola, 2020). We, therefore, reviewed the literature on IoT and its business models to get a grasp of the relevant body of knowledge and the aspects of IoT business models. In the second step, we chose the domain theory, which describes the key constructs, theories, and assumptions that characterize the main area of the study (MacInnis, 2011). We started by analyzing the business model literature and identified the main pillars of a business model including value proposition, creation, capture, and delivery. We had a focus on a value proposition as the main element in the business model and how data can enable new forms of the value proposition. In the third step, method theory was chosen, which provides concepts to study the "substantive issue(s) of the domain theory at hand" (Lukka and Vinnari, 2014, p. 1309). At this point, we narrowed our focus down to the literature specifically on IoT business models and the sub-elements that characterize these business models. We also observed an evolutionary progression of the IoT business models that was implied by the literature in various terms. This step led to the tabulation of the business model elements (domain theory from the previous step) and sub-elements (method theory) that provides a deeper view of the IoT business models as well as a primary model that presents the four stages of IoT business model evolution based on the progression of data and its role in value propositions. Finally, the fourth step was dedicated to analysis, model construction, and argumentation. In this step, we developed the final conceptual model through the synthesis of the inputs from previous steps. We started by defining IoT and analyzing IoT types, which led to the creation of a guiding four-quadrant framework that differentiates IoT types based on the IoT scope (light vs. heavy integration) and IoT form (retrofitted vs. built-in). Using this framework and the IoT business model characteristics and stages from the previous steps the final conceptual model was developed. We provided logic-driven, theory-based arguments for the association between constructs from the domain and method theories (Gilson & Goldberg, 2015) that form the foundation of our model.

3.3. THE MATURITY MODEL

The evolution of IoT business models and the possibility to propose different data-driven values to develop different types of business models has already been mentioned in the literature. Endres et al. (2019) identified four different business model archetypes in the context of industrial IoT: digical which uses IoT to optimize their existing value creation processes but without a radical change in the industry logic; service-centered, which is a blend of the physical and the digital world that intends to increase service-orientation; data-driven, enabled by the direct integration of sensors and efficient analysis of data; and platform, which connects the market players and enable the exchange of best practices and to create new niche markets with new customer segments. Paiola and Gebauer, (2020) argue "In fact, being able to connect hundreds of products directly within the end-user firms' premises all over the world can provide firms with information that may transform the business models in different ways - enhance the product and or the system/solution; develop new products and services; optimize customer segmentation, positioning, and pricing strategies; develop the capability to dynamically modify business models' component configurations over time (p.246). In explanatory sequential mixed-method research, Delgosha et al. (2022) study IoT business models and suggests that conducting studies on the IoT business models' evolution and their effect on long-term performance is critical. And Glova et al., 2014) argue that “a firm with a strong business model has a much better foundation for understanding the challenges of the IoT environment and sharing its understanding among stakeholders. Mapping and using business models facilitate change because designers can easily modify certain elements of an existing model and simulate new businesses” (p.1124). we argue that there are different stages of IoT business models in which different data-driven value propositions are formulated. Each stage has specific characteristics, rooted in the nature of IoT technology utilized, and the amount and quality of data generated. To develop a foundation for our domain theory, a primary framework representing various stages of the IoT business model is developed to guide our research. Figure 2 depicts the primary guiding framework.

IoT technology can be defined as a connection between objects, humans, and computers. It uses information-sensing equipment such as sensors, RFID, GPS, and scanners to connect the items under internet protocol (IP) for communication and information that enables tracking, intelligent positioning, monitoring, and management of “things” (Ding et al., 2023). From the use case perspective, the IoT hardware which is the physical part, normally made of actuators and sensors (Jain et al., 2021; Kumar & Patel, 2014), can be used in products in different ways and with different scopes. IoT technology can be added to a product after it is produced as a retrofitted device (Mayer et al., 2020; Thomasian & Adashi, 2021) or it can be built-in the product (Picone et al., 2021; Yeole & Kalbande, 2016) as a fixed component in the production process. Moreover, the number of IoT nodes can be different based on the needs and the uses. While some products are equipped with only a few basic sensors, others are packed with multiple sensors and actuators that not only generate bigger volumes of data but also can influence the functionality of the product. IoT supports new business models through various mechanisms (Voulgaridis et al., 2022), and current literature has already identified several IoT business models that describe how IoT technologies are used to facilitate business activities between customers and businesses (Cheryl et al., 2021) and create and capture value through new business models (Endres et al., 2019a; Leiting et al., 2022; Leminen et al., 2018).

To capture the characteristics of IoT business models and to develop the method theory part of our model, we have conducted a literature review on the IoT business model literature. Although the intention was not to conduct an exhaustive systematic literature view (Toorajipour et al., 2021), we strove to be as comprehensive as possible. To this end, a search string was formed to result in as many papers as possible. Thus, “business model” AND “IoT” was searched through title, abstract, and keywords sections on ScienceDirect plus backward/forward search based on the relevance of the cited/citing papers. The primary search led to 134 papers plus another 10 papers from a backward/forward search. To select the final set of characteristics, the collected papers went through a number of inclusion/exclusion criteria. First, non-English papers were removed, second, the papers that didn’t have a focus on IoT business models were excluded, as some papers only mentioned the terms, without a major contribution or link to business models. Third, the papers that mentioned IoT business model characteristics were selected, as some papers had a focus on IoT business models, however, didn’t provide any details about the elements or the building blocks of the models. From the remaining papers, the IoT business model characteristics were identified and compared. To eliminate redundancy and repetition, and foster conciseness and precision, similar characteristics were merged or combined. The final set of characteristics was put together.

To develop the conceptual model, a top-down approach is employed, where we identify and argue for the stages of IoT business model evolution. Then, we identify and assign the business model elements for each stage. To form the IoT business model stages, we adopt the IoT maturity model by Klisenko and Serral Asensio

(2022), which is rooted in the CMM model, and introduces a four-stage maturity model (plus a stage before adoption where IoT is non-existent: level 0) with respect to four dimensions. The reason for choosing this model is threefold. First, this model has a strong focus on data and regards it as a measure of a firm's capability "in collecting, managing, analyzing, obtaining insights, and extracting value from the IoT" (p.14) which is in complete congruence with our paper's perspective toward data as the key element for the value proposition. Second, the model has a strong theoretical foundation as it is rooted in the COBIT framework (Information Systems Audit and Control Association, 2018) and the well-known capability maturity model (CMM) by Paulk et al. (1993). It is also validated by experts and case studies. And third, it is composed of four dimensions of data, technology, organization, and communication which corresponds with our domain and method theory and allows us to identify and assign our IoT business model sub-elements. The stages of our conceptual model are linked to a maturity level (from 1 to 4) plus the synthesis of the domain and method theory, which describes the evolutionary model. Each stage is characterized by specific value proposition, creation, capture, and delivery sub-elements and is linked to the type of IoT and the role of data. Each stage is supplemented with an industry example to help understand how a business model can practically work in the context of real-world business.

3.3.1. Stage one: Additive IoT

In the first stage (level 1), the IoT is at an initial/ad hoc state where technology is less developed, data collection is limited and communication with customers is minimal. IoT business models at this stage are not significantly different from the company's business model before the integration of IoT technology. At this stage, normally IoT devices are retrofitted into the product after it has been produced. Therefore, IoT integration is not part of the production process. Normally at this stage, which we call additive IoT, there is a light IoT integration which means the number of sensors (or actuators, if any) is not so vast. Therefore, the amount of data generated by these devices is limited. At this stage data has the supplementation role, meaning that the generated data supplements the existing offering and its business model, however, doesn't significantly change how value is proposed. Business models at this stage, allow collection of data from retrofitted devices for data management (Haaker et al., 2021) and analysis of the collected data. The value is fundamentally created through the generation and collection of real-time accurate data and is delivered through the enhanced communication resulting from the integration of IoT. This allows a new revenue source, which is selling data (analyzed or raw) while the inflicted costs are limited to IT expenses such as the IoT device and the implantation costs.

The industry example for this stage is Grundfos, the world's biggest producer of pumps. In collaboration with a supplier, Grundfos has adapted an IoT device, called Alpha Reader, which can be retrofitted to selected existing Grundfos pumps such as circulation pumps Alpha2 and Alpha3. Alpha Reader is offered to customers for an additional fee. Alpha Reader can be added to an existing pump and collect data from it. Data is then displayed in the Grundfos app.

3.3.2. Stage two: integrated IoT

In the second stage (level 2), procedures are repeatable but intuitive, IoT technology has improved in comparison to the previous stage but still has many limitations. More data is collected which leads to enhanced communications (Noronha et al., 2014) with customers. Accordingly organizational and managerial capacity increases in response to more data and the possibility to create more value with it. With the second stage of business models, IoT integration is expanded, covering more aspects of the offering and it is normally integrated into the product from the beginning and through the production process. At this stage, which we call integrated IoT, the enhanced presence of IoT in the products allows tracking and optimization aside from the simple data generation and management from the first stage. By tracking (Cranmer et al., 2022), the focal company and the customer can observe the product's behavior over time, and by optimization (Ferrández-

Pastor et al., 2022), it is possible to increase the efficiency of procedures and improve goal-based operations that can be controlled by data analysis and using algorithms. Value creation occurs through the generation and collection of real-time data (Ingemarsdotter et al., 2020) and upgrading the design of a product (Marcon et al., 2022) according to data feedback which might include functional or routing modifications/upgrades. Similar to the previous stage, new revenue sources include collected data, and the costs are IT expenses. Value delivery is impacted by the enhanced relationships (Lombardi, 2019) with the customer due to the bigger scale of data and better overview of the product behavior and customer usage patterns. At this stage, the role of data is not just to supplement the offering, rather, it complements the value that can be proposed to customers, using the offering. In other words, the data allows the customer, to not only have an overview of the simple product's performance data but also to use it for optimization of the performance and track its behavior in the long run.

The industry example for this stage is Gardena, a German company that is the leading brand of high-quality garden tools in Europe. Gardena has integrated IoT into several of its products. For example, they have built IoT (sensors and radio transmitters) into their robot lawnmowers, but the mower also works without IoT enabled. In addition, if customers request advanced IoT features, it is possible to purchase the smart device (e.g., gateway), which via Gardena's app, provides access to the robot lawn mower's GPS signal, mowing zones, and usage history. The smart device creates Gardena's own local network, and the gateway connects via WiFi to the Internet and thus to Gardena's app.

3.3.3. Stage three: servitized IoT

At the third stage (level 3), procedures are managed and measurable, and the state of data, IoT technology, organizational capacity, and communications are standardized and consistent, leading to an established data-driven business model. At this stage, business models have a jump in terms of value proposition and value capture, as it is at this stage, that servitization and product service systems (PSS) are possible. At this stage, IoT devices (various types of sensors and actuators) are integrated into the product in a way that allows the focal company to not only collect and analyze data for optimization but also to monitor the product and its performance in real time. The vast use of IoT integrated deeply into the product, allows the focal company to control (Cranmer et al., 2022) the product and define various uses and functionalities based on the customer needs and budget. Moreover, it enables a new level of customer relationships that has a significant focus on customers' feedback and meeting their expectations (Ingemarsdotter et al., 2020). The IoT-enabled product service systems have a significant impact on revenues and costs. At this stage, in addition to new revenue sources, new revenue models are also possible. While a revenue source is the "what" for making money, a revenue model is the "how". PSSs enable the company to provide the products as a service rather than selling them to the customer. This means that not only the company can generate revenue by selling data (or insights from the data) but also it can offer it in the form of a PSS. On the cost structure side, maintenance costs are added, as the company will retain the ownership of the product and only needs to maintain it. Moreover, as the IoT is now extensively used in the product, several of the tasks formerly performed by human resources can now be delegated to the IoT which leads to a reduction in human resource costs (Marcon et al., 2022). At this stage, the importance of data is emphasized due to its role in enabling servitization and PSSs. Therefore, data is central to the functionality of business models at this stage.

The industry example of this stage is Hilti. Hilti is a Liechtensteiner-based company that manufactures, and markets tools for the construction, building maintenance, energy, and manufacturing industries. Hilti's Fleet Management service allows customers to use most of its products without buying or owning them. While Hilti retains ownership of the product, the customer gets the right to use them by paying a fixed monthly fee. The service concept includes a wide range of services such as gratis and quick repair, calibration, theft coverage, and general maintenance. In addition, QR marking of all tools has made it possible to conduct administration and monitoring (Ingemarsdotter et al., 2020).

3.3.4. Satge four: Ecosystem IoT

In the fourth stage (level 4), the status of IoT business models is optimal and robust. IoT technology is well-established, large-high-quality data is generated and collected and organizational and managerial capacity for utilizing IoT business models and data-driven value propositions is at its highest. In the first two stages, the data serves as a benefit that is added to the main product. In the third stage, data is essential for the particular value propositions and business models of this stage. However, at the fourth stage, the role of data is so foundational, that it is not possible to develop the relevant business models without the extensive use of data. In other words, the mere existence of the business models is dependant on the data, and it has the highest level of importance compared to other stages. Therefore, in the fourth stage, data functions as the foundation of the ecosystem business models.

At this stage, the product is integrated into an ecosystem of products and the value is created through the symbiosis of these products. The business models at this stage heavily rely on solution co-creation (Marcon et al., 2022) to better address customer needs and improve cooperation in the ecosystem. Other value creation sub-elements include interoperability and autonomy (Ingemarsdotter et al., 2020) which become significantly important as the products need to be homogenously integrated into the product ecosystem otherwise the survival of the business model might be at stake. At this stage, the symbiotic functionality of products and the extensive availability of data can lead to the creation of platforms and data markets where novel, data-driven services are developed. Companies can utilize such platforms and data markets to generate new sources of revenue and scale. On the cost structure side, the costs of developing platforms and infrastructures (Dijkman et al., 2015) and are imposed which can be covered through enhanced revenue models. Moreover, value can be delivered through cross-divisional (Leiting et al., 2022) collaborations with ecosystem actors and partners and expand the reach of the offerings to new markets.

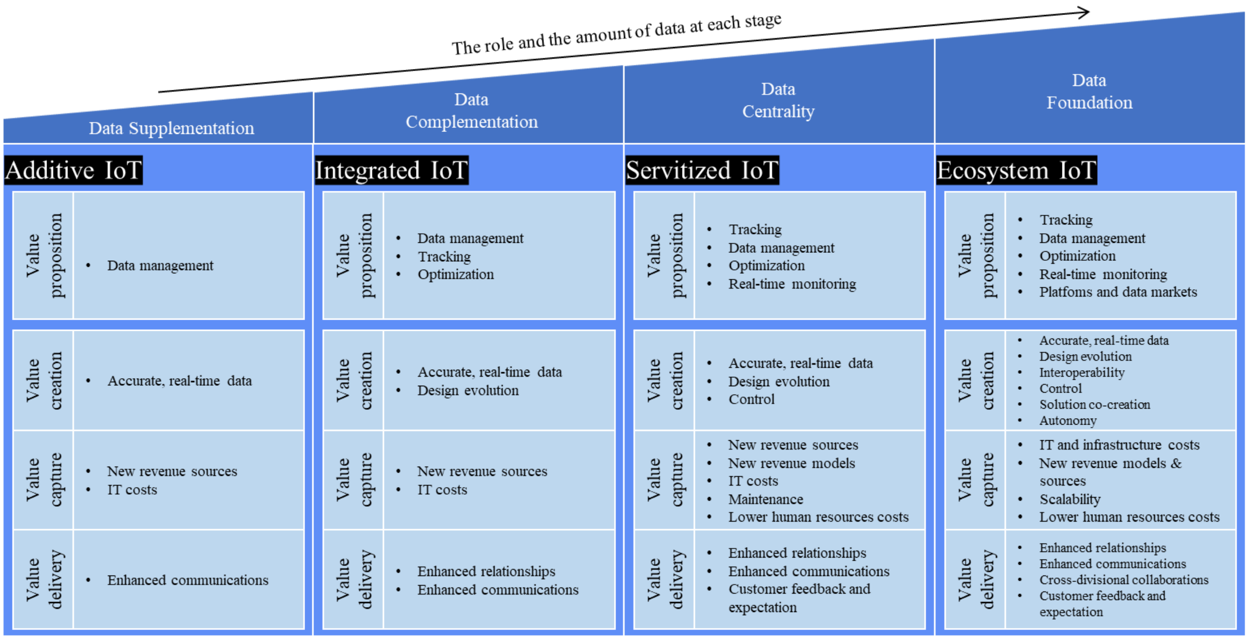

Figure 3, Conceptual model of the evolution of IoT business models

An industry example for this stage is the ecosystem around Netatmo. Netatmo develops, designs, and manufactures weather stations such as rain, wind, and temperature meters that are easily integrated into other products. Velux produces roof windows and has implemented IoT devices that enable the opening and closing of windows and rolling up and down roller blinds. The two companies' products can be connected using APIs. This way, they can collaborate and create new solutions where several collaborating products cocreate the best possible indoor climate. Thus, the VELUX products can obtain information about the outdoor weather from Netatmo, with which they can calculate when the skylights should open or close and/or the roller blinds are rolled up or down. Using APIs, the built-in IoT devices in the products can communicate so that everything is automatic to achieve the best possible indoor climate. Figure 3 depicts the conceptual model of the evolution of IoT business models.

3.4. DISCUSSION

Until recently, products have been separated islands with no connection to each other or to the Internet. IoT marks a paradigm shift for manufacturing companies if they want to develop and take advantage of the opportunities that this technology presents. To utilize these opportunities, companies must understand the prevailing business models and the related value propositions and how they can evolve through the enhancement of IoT technology and the prevalence of data. Having an evolutionary perspective on the utilization of IoT business models and data-driven value propositions is crucial for two reasons. First, it provides an understanding of how various configurations of IoT technology can be used to unlock new business models with specific data-driven value propositions. This is important since companies can align their short-term and long-term goals with specific technological requirements, business goals, and strategic plans. Second, it allows the companies to analyze each business model stage and implement the one that is the best choice for them based on their needs, capabilities, resources, and strategies. Such an approach can be significantly beneficial since it prevents a trial-and-error type of technology implementation and business model innovation and enhances efficiency and effectiveness.

3.4.1. Reflections on the conceptual model

This conceptual model describes four IoT business model stages, each with a core data-driven value proposition. Each stage has specific characteristics that make it unique. In the first stage - additive IoT - a separate IoT unit is retrofitted to an already existing product that does not undergo any change. the value creation is slightly upgraded, and a new revenue stream is added. However, this stream is not a fixed and large source, because normally IoT at this stage is retrofitted with limited nodes. Companies might even provide IoT as an option and many customers might not choose to integrate IoT into their products, which means the opportunity for data generation is lost for some of the products. At this stage, the organizational structures, business model, and relationships with partners will have small changes. Moreover, due to the retrofitted limited nature of the IoT, there is no need for sharp technological shifts in the product or the production system. Hence, the level of sophistication at this stage is lower than others. The second stage is similar to the first in many ways. The main difference is the integration of the IoT as an inseparable part of the product from the beginning. This means all the products are equipped with the IoT and the company (and customers) can use the data from all the products which makes it possible to compare, analyze and get insights at a larger scale.

At the third stage – serviced IoT – not only are the IoT devices are built-into the product as a fixed component, but also the number of IoT devices, functionalities, and nodes is significantly increased to the extent that allows the company to provide it as a service and impose full control on it. At this stage, IoT enables PSSs and possibilities for new revenue models such as subscriptions, pay-per-use, pay-per-project, pay-per-hour, rents, and more. This not only benefits the company but also benefits the customers in several ways. First, it allows the customers to reduce costs since they no longer need to pay for an entire product that might get obsolete, broken, or incompatible. Therefore, they can pay for the specific use and based on the available options, pay based on time, project, number of uses, etc. the second benefit is that customers can test and try various products in a short period of time and make sure that they use a service that best matches their needs as they are no longer committed to a single product just because they have paid for the full ownership. Third, as the products turn into services, the focus moves towards providing solutions that solve the customers' problems rather than focusing on push/pull marketing campaigns just to sell the product. This way, customers can focus on the main problem (the reason why they needed to buy the product in the first place) and producers can focus on a PSS that effectively solves customers' problems. Finally, moving to PSSs and servitization significantly contributes to sustainability as this help prevent different types of obsolescence. Products are prone to different types of obsolescence including indirect obsolescence, planned or premature obsolescence, incompatibility obsolescence, and style obsolescence (Armstrong et al., 2021; Canals Casals et al., 2019; Henry, 2018; Wuyts et al., 2019). By moving towards services rather than products, producers will shift their focus towards the solutions that customers are buying the products for. Moreover, the producers will retain the ownership of the products and customers will only get the rights to use them. Therefore, producers of the products are incentivized to make durable, long-lasting products that solve problems rather than producing products that are marketed to be sold and make a profit as a percentage of the price.

With the last stage, the focus moves toward platforms and the ecosystem of products. This stage involves the highest level of interaction with different stakeholders, which leads to competition. Competition refers to "a competitive strategy wherein growth and profits are pursued by simultaneously combining the advantages of cooperation and competition" (Lee and Roh, 2023, p.411) or "War and Peace-simultaneously" (Brandenburger and Nalebuff, 2011, p.28). Competition is a situation where cooperation and competition take place at the same time. Therefore, it is possible that competitors, at some point, contribute to each other's value creation, capture, and delivery. Thus, not only do companies continuously adapt the product to customers' needs, but also, they have mutual adaptations with other IoT products in the so-called cyber-physical systems. At this stage, companies focus on how their product or service can benefit others and realize how the product can help other producers to create and capture value. It significantly increases a product's chances of survival if it is part of a symbiosis of mutually reinforcing services and products. In other words, each product shares the fate of the other products in the ecosystem.

Current literature also highlights the emergence of a hybrid technology which is the result of the integration of AI into IoT. This technology, namely, the artificial intelligence of things (AIoT) (Mian et al., 2023), is fundamentally transforming business and digital ecosystems as it enables better use of IoT-generated data (Davison et al., 2023; Wu et al., 2019). As Chen et al. (2022) argue "most of the current IoTs are Internet of Targets rather than Internet of Things. The problem with the Internet of Targets is that it lacks interoperability (Haaker et al., 2021) due to incompatible communication protocols and interface features among a variety of "devices" leading to different barriers and thus hindering its applicability". And thus, in spite of contributing to the swift development of IoT applications, the current IoT-centric architecture has led to the creation of numerous isolated data silos (Pal & Yasar, 2020). The IoT platform business archetype is an answer to this isolation. This archetype utilizes platforms including AIoT applications to bring not only different ecosystem actors but also different sectors together (Endres et al., 2019b) and by making synergy leads to stronger industries with faster growth rates. "Autonomous products can act in coordination with other products and systems. The value of these capabilities can grow exponentially as more and more products become connected" (Porter & Heppelmann, 2014). In addition to AIoT, edge computing (Xue et al., 2023) and embedded AI (Anastasi et al., 2021) is also driving the business ecosystems leading to new novel business models that were not possible before (Bruschi et al., 2021; Sandeep et al., 2022; Sarah et al., 2023).

3.4.2. Data, costs, and the ratchet effect

Data is the focal part of any IoT system. In fact, it is the data that determines the type and structure of the IoT business models. "The primary goal of IoT is to have a network of devices which can communicate with each other and process the data and return a suitable result" (Chandrashekar and Krishnadoss, 2022, p.4896). As the sophistication of IoT technology increases, companies get better equipped with tools for data generation and collection, which leads to more use of data in business models to propose value. This allows companies to gradually move towards servitization and ecosystems where higher values can be created and captured. As the companies progress in this spectrum, their dependence on data and data-driven value propositions increases. To this, costs of IoT integration must be added which increase with the more advanced and sophisticated IoT nodes are integrated into the products. the dependence on data for value proposition and business model development in addition to costs and implementation activities that companies undergo to add IoT to their offerings create a "ratchet effect" that makes companies reluctant to downgrade to previous stages. This means while companies can choose any stage of IoT business models to enter, the costs, the efforts, and the importance of data prevent backward movements or downgrade to previous stages.

3.4.3. Theoretical contribution and empirical implication

Our paper contributes to the existing body of literature on IoT business models by suggesting and describing a conceptual model that shows the evolution of IoT business models and data-driven value propositions. In this conceptual model, we provide the main elements of a business model including value proposition, creation, capture, and delivery, and provide the unique IoT business model characteristics for each element. In addition, we discuss the role of data and its growing importance at each stage and argue that data is the most important factor for value proposition in IoT business models.

Our results are in congruence with the current literature such as Endres et al. (2019) who suggest four classifications for industrial IoT business models. Our study also adds to the works of Leminen et al. (2018) who developed a conceptual framework to categorize different types of business model innovation, Şimşek et al. (2022) who explored the dynamics of business model transformations from a traditional business model to a cloud-based digital IoT platform and Leiting et al. (2022) who studied IoT business model transformation, by providing an evolutionary view to IoT business model in addition to describing the IoT business model elements at each stage and in accordance to the IoT types.

This study also contributes to managers and business developers as well. From a practical standpoint, this study offers valuable insights for business owners and managers, by assessing the elements and characteristics of IoT business models and understanding how they can migrate to other stages based on data generated from IoT technologies. The conceptual model can also lead to the identification of novel use cases, address customer needs, and serve previously untapped market segments using data-driven value propositions, thereby driving technological advancements, enhancing customer experiences, and generating substantial business value.

4. CURRENT BUSINESS MODELS

Reflections on the existing business models of MAN ES, VELUX, and Grundfos

This section provides an overview of the business models employed by three partner companies: VELUX, MAN Energy Solutions, and Grundfos. The purpose of this section is to identify the key elements of the company's business models, including the value proposition, value creation, value delivery, and value capture. Understanding the business models of these companies is crucial as it offers valuable insights into their strategic approaches, operational frameworks, and value-generation mechanisms. By examining these components, researchers, industry professionals, and stakeholders gain a comprehensive understanding of how these companies create and deliver value to their customers, while also capturing value for sustainable growth and profitability. However, an important caveat is that this section is developed based on a limited number of interviews with informants from the aforementioned companies in addition to the secondary information available on company websites, blogs, and other online sources. Therefore, this section intends to provide an overall view and might have some limitations that will be addressed and improved throughout the project.

4.1. MAN ENERGY SOLUTIONS

MAN Energy Solutions is a German multinational company headquartered in Augsburg. It was formed in 2010 through the merger of MAN Diesel and MAN Turbo. It operates as a subsidiary of the renowned German automotive manufacturer, Volkswagen Group. This strategic consolidation brought together the expertise and capabilities of both MAN Diesel and MAN Turbo under the umbrella of MAN Energy Solutions, further strengthening the company's position in the market. It has a rich history that dates back to the 18th century. The company can trace its roots to the establishment of the world's first industrial-scale manufacturing plant for steam engines. Over the years, MAN ES has evolved and expanded its offerings to become a leading provider of sustainable energy solutions and marine engines.

In addition to marine propulsion technologies, electric energy generation, and storage solutions, MAN Energy Solutions offers a wide range of products and services. This includes gas engines, turbochargers, compressors, power plants, and industrial equipment, among others. With a strong emphasis on decarbonization and sustainability, MAN actively develops and promotes eco-friendly technologies, such as dual-fuel and gas engines, which help reduce emissions and improve energy efficiency. The company also invests in research and development to advance its product offerings, improve efficiency, and stay at the forefront of technological advancements. MAN, also actively fosters digitalization as a core part of its business strategy. Thus, through the integration of digital technologies and data analytics, the company aims to optimize performance, enhance operational efficiency, and provide value-added services to improve its value proposition. MAN operates on a global scale with a presence in numerous countries around the world. The company collaborates with various stakeholders, including shipyards, shipowners, energy providers, and industry partners, to develop innovative solutions for their customers. Partnerships with other companies and research institutions help expand the company's capabilities and bring about technological advancements. Moreover, it promotes sustainable business practices. With a focus on reducing its environmental footprint, adhering to quality and safety standards, and promoting social responsibility through various initiatives and projects. The main offerings of MAN's business model include marine propulsion technologies, electric energy generation and storage, and industrial processes. The value proposition of MAN Energy Solutions can be viewed as providing sustainable solutions in the areas of marine propulsion technologies, electric energy generation and storage, and industrial processes. By addressing the importance of decarbonization and digitalization, MAN aims to deliver innovative and environmentally friendly solutions to its customers. In terms of value creation, MAN has a multi-faceted structure. In the marine sector, the company offers two and four-stroke marine engines, turbochargers, complete propulsion solutions, and research and development services, among others. MAN has also developed a platform called CEON that functions as a centralized database for its services, including connectivity to vessels. Data is collected from sensors installed in the engines, which is then analyzed and presented to customers through a user interface called PrimeServ Assist. Customers can access this service and get advice and monitor the data. PrimeServ Assist which is a digital solution provided by MAN, plays a role in decarbonization efforts while enhancing economic efficiency. It utilizes data-driven solutions and software, allowing customers to monitor the data from their assets. Currently, the data is generated using normal IoT devices and not AIoT or embedded AI devices. By optimizing MAN equipment, software, and systems, PrimeServ Assist provides operational insights and proactive advice, enabling customers to avoid the significant costs of downtime (both in terms of maintenance and lost revenue) as well as improving performance, availability, efficiency, and safety in their equipment.

The primary target customers for MAN's solutions are ship owners and ship managers, however, in the future other entities such as insurance companies could also be added. The engines designed by MAN are manufactured under license in Japan, Korea, or China, although the initial design process takes place in Copenhagen. The company collaborates with partners such as Hyundai, Mitsui, and Kosco. Normally, MAN provides the license and specifications, partners build the engines and sell them to shipyards, and from there, the engines are eventually sold to ship owners. One of the most important points that should be taken into consideration with regard to MAN’s business model is that significant changes in products are not easily accepted by users and partners. The marine industry is a very conservative industry and any change in the status quo that comes with extra costs must be well justified. Therefore, changes in the products and production processes often encounter resistance due to the associated costs and complexities of manufacturing.

In terms of value capture, MAN's revenue model is based on one-off sales and a subscription-based model. The subscription model includes services such as PrimeServ Assist, offering 24/7 expert advice and access to the user platform. While the subscription fee for PrimeServ Assist is relatively low (around 6000 euros), negotiations of terms and conditions with customers can be time-consuming, sometimes taking more than a year to finalize due to concerns about data ownership. In terms of financials, MAN's current products adhere to industry standards of having a lifespan of 8 years or 64,000 running hours (8,000 hours per year). The operating expenses (OPEX) for running a vessel amount to 2 million USD per year, while the subscription fee for PrimeServ Assist is significantly lower. However, as mentioned, the main challenge is rooted in establishing the terms and conditions with customers, as there are currently concerns about data ownership. Currently, the raw data collected from the products through IoT sensors include measuring parameters such as RPM, temperature, and pressure. However, with the integration of intelligence, it would be possible to process and enrich the data and make it more valuable and probably another element for new value creation and proposition. In this regard, it can be a future scenario for MAN’s business model to offer enriched analytical data, using AI models and algorithms, as the highest level of analysis, which could be sold to third parties and customers. Figure 4 shows an over voew of MAN’s business model.

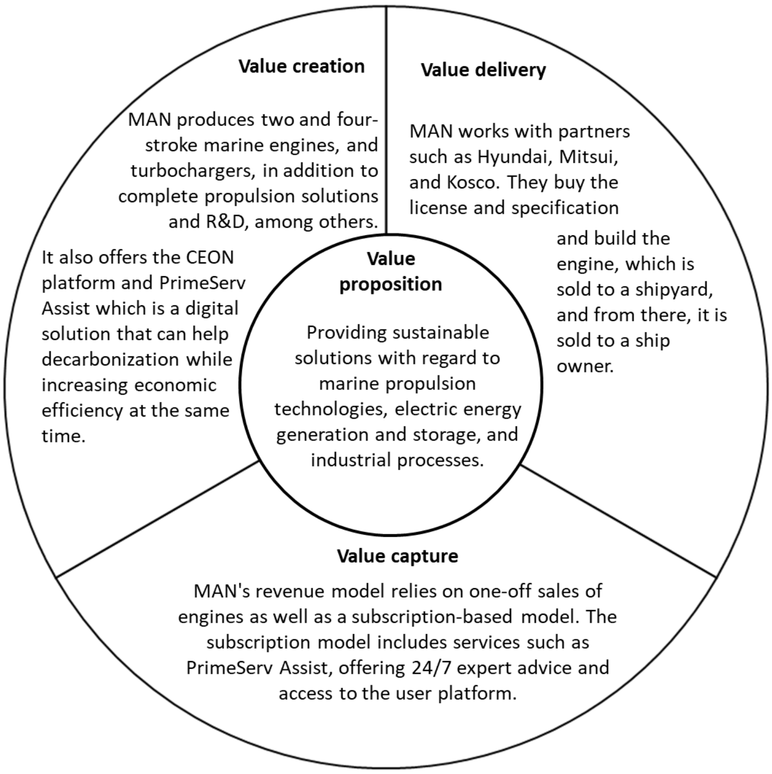

Figure 4, MAN ES business model

4.2. VELUX

VELUX is a Danish manufacturing company specializing in the production of roof windows, skylights, sun tunnels, and other related accessories. Headquartered in Hørsholm, Denmark, VELUX operates as a subsidiary of VKR Holding A/S, with a focus on providing high-quality daylight and ventilation solutions and established as a leading player in the industry with a large market share. It was founded in 1941 by Danish engineer Villum Kann Rasmussen. The company's name is a combination of "VE" (ventilation) and "LU" (light), reflecting its core products' purpose and functionality. VELUX is known for its high-quality roof windows and skylights, which are designed to bring natural light and fresh air into residential and commercial buildings. These products are installed on rooftops and provide a mixture of aesthetic appeal, energy efficiency, and improved indoor comfort. VELUX offers a diverse range of products for various architectural and functional designs and purposes. This includes center-pivot windows, top-hung windows, flat roof windows, sun tunnels, blinds, shutters, and smart home automation solutions. VELUX products have a strong emphasis on the importance of daylight and fresh air to foster healthy living environments. Their products are designed to optimize natural light intake, enhance indoor air quality, and provide sufficient ventilation to create a pleasant and comfortable atmosphere. The company collaborates with architects, engineers, and researchers to advance knowledge in the field and drive innovation in design and production. VELUX operates globally and has a strong international presence. The company has manufacturing facilities, and distribution networks in various countries, enabling it to serve customers globally.

VELUX's business model incorporates a strong value proposition which is to provide high-quality windows, natural lighting solutions, and associated accessories to its customers with a strong focus on customer satisfaction. This value proposition is centered on delivering products that enhance indoor environments with high quality while maintaining its customer-centric approach. Regarding value creation, VELUX has a product portfolio including a range of offerings. These include roof windows, skylights, sun tunnels, blinds, solar shading, and related accessories. By covering various architectural preferences and functional requirements, the company ensures that its products meet the diverse needs of its customers. VELUX has introduced a line of remote-controlled skylights called VELUX Active, which enables customers to easily ventilate their surroundings and control their indoor climate in an energy-efficient manner. The integration of electronic windows, along with the VELUX Active package, comes with a higher level of control and monitoring, that allows customers to have precise indoor climate control, personalized scheduling, and more. Moreover, VELUX is actively engaged in developing an ecosystem that brings together various applications with a unified interface to enhance home control and deliver an exceptional customer experience.

The company's revenue model primarily relies on one-off sales of its products. As mentioned, the company has a significant market share with limited competition. While the majority of the sales come from manual products such as Windows, VELUX intends to advance the intelligence of its products and aims to offer smart features across a wider spectrum of offerings. Prices vary across products, with manual options typically priced around 1000 DKK, while electronic versions can reach up to approximately 4200 DKK, with VELUX Active package positioned at around 2000 DKK. Regarding value delivery, VELUX operates production facilities in multiple countries, expanding beyond its Danish headquarters. The company retains control over a substantial portion of the production process but procures raw materials from external suppliers. VELUX has established a diverse distribution network, allowing customers to purchase their products through contractors, the official VELUX online retailer, or VELUX dealers. This multi-channel approach ensures accessibility and widespread availability of VELUX's offerings to customers. Figure 5 illustrates an overview of VELUX’s business model.

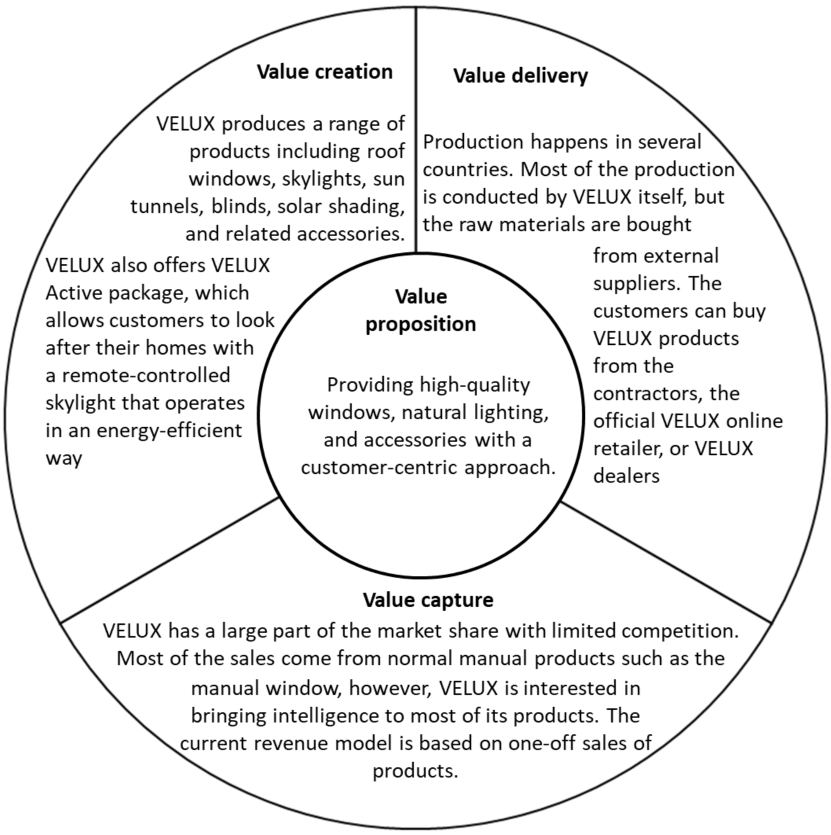

Figure 5, VELUX business model

4.3. GRUNDFOS

Grundfos is a Danish multinational company that produces advanced pump solutions and water technology. Grundfos was founded in 1944 by Poul Due Jensen in Bjerringbro, Denmark. It started as a small family-owned business and has since grown into a global corporation. Grundfos has an international presence with operations in more than 80 countries, with a network of production facilities and sales offices worldwide. They offer a wide variety of pumps designed for various applications, including water supply, wastewater management, and industrial processes, among others. The company has established a strong brand known for efficiency, reliability, and innovative features as well as the high quality of its products. Grundfos also places a strong emphasis on sustainability and positive environmental contribution and strives to develop energy-efficient products that minimize the impact on the environment and reduce carbon emissions. Grundfos is also involved in promoting sustainable water management practices globally. The company invests in research and development activities to improve their products and technologies and there are collaborations with partners, universities, and research institutions to drive innovation and stay at the forefront of the industry. In recent years, Grundfos has been focusing on digitalization and the integration of smart technologies.

Grundfos is a leading company in the water management industry and operates with a business model that has led the company to be one of the world's biggest producers of pumps. The value proposition offered by Grundfos centers around the provision of innovative solutions with the aim of managing, advancing, and safeguarding the efficient flow of water across diverse environments. The offerings portfolio targets a wide range of segments from residential and commercial settings to large-scale industrial factories. And thus, by addressing the needs of various customers, Grundfos seeks to optimize water utilization and enhance overall operational efficiency. Regarding value creation, Grundfos has a strategy to mass-produce high-quality water pumps. These pumps are categorized into four distinct types: domestic, commercial, industrial, and utility. Domestic refers to the pumps that are designed for residential units, homes, and smaller buildings. Commercial pumps are used by larger buildings such as hotels, hospitals, towers, and airports. The offerings for this category cover a big range including commercial air conditioning, fire protection, heating, hot water recirculation, wastewater, and more. Industrial offerings refer to products used by large factories and production plants and include products for industrial cleaning, process liquids transfer, desalination, industrial process water treatment, water supply and transfer, wastewater treatment, and reuse, among others. Utility offerings refer to products used by municipalities at a larger scale that covers drinking water treatment, irrigation, groundwater intake, solar water solutions, surface water intake, community water supply, water distribution, etc. Grundfos places a strong emphasis on innovation, durability, and energy efficiency in its products. while the company manufactures a significant portion of the components used in its products, they procure some parts and raw materials such as metal and steel sheets, and electronic parts.

Regarding value delivery, Grundfos adopts a channel strategy that involves indirect sales. Meaning that instead of selling products directly to customers, Grundfos makes their products available through a network of retailers and wholesalers. And thus, Grundfos has a presence in more than 56 countries utilizing the strength of its network of partners, distributors, and sub-dealers globally. The distribution of products varies depending on the product category. For instance, domestic products designed for homes and small units are suggested and sold by retailers and plumbers. On the other hand, larger and more advanced products can be obtained through industrial suppliers. Fundamentally, Grundfos's revenue model relies on a traditional one-off sales system for capturing value. Currently, the company does not offer rental options, subscriptions, or product service systems to its customers. Leveraging the trust and reputation Grundfos has in the industry, its market goes beyond 50 countries. Most of the parts used in their products are manufactured in-house, ensuring the quality and requirements of the customers. Through mass production, global presence, indirect sales channels, and an established sales system, Grundfos optimizes value creation, delivery, and capture, ensuring its position as a leading provider in the water management industry. Figure 6 shows an overview of Grundfos's business model.

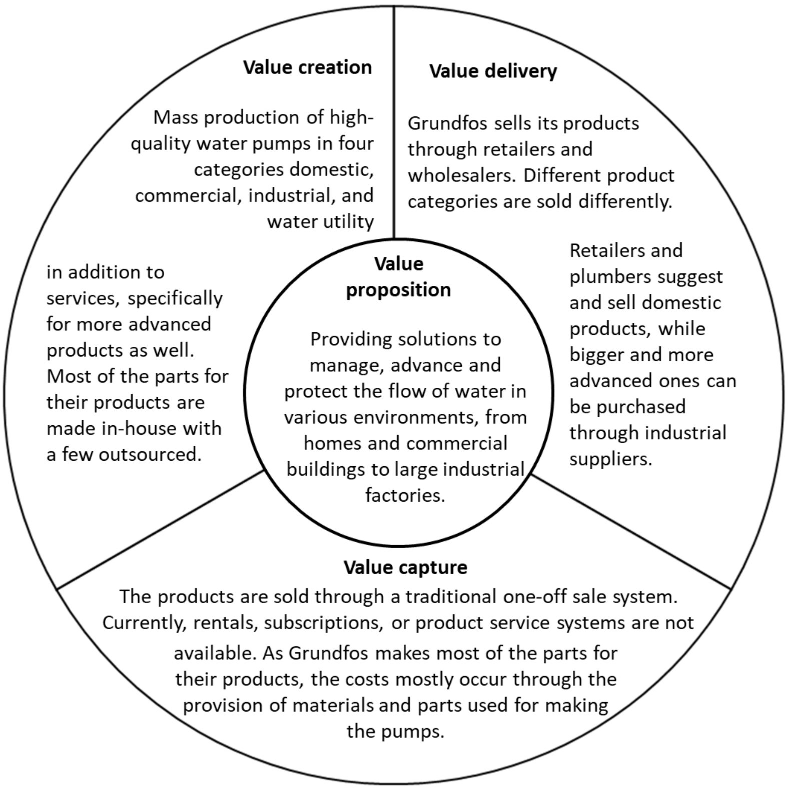

Figure 6, Grundfos's business model

5. FUTURE WORK

The upcoming study on value propositions for AIoT

In line with our research objectives, the next step of our study focuses on exploring AIoT-enabled value propositions. This research addresses a significant gap in the existing literature, as it represents the first comprehensive investigation of AIoT-related business models. By utilizing secondary data, we aim to shed light on the current landscape of AIoT solution providers and their value propositions. This work will be part of the deliverable II.

5.1. NEXT STEP: INVESTIGATING AIOT-ENABLED VALUE PROPOSITIONS

To fully harness the potential of AIoT, the development of appropriate business models becomes essential. And to capture the value this technology offers; it is important to formulate a unique and compelling value proposition. The upcoming research emphasizes that AIoT, as a technological innovation, requires business models that not only address unmet customer needs but also enable market breakthroughs. It is evident throughout history that firms, regardless of their remarkable innovations, cannot achieve success unless they can present customers with a compelling value proposition and establish efficient business models to satisfy their needs with superior quality. "A good business model yields value propositions that are compelling to customers, achieves advantageous cost and risk structures, and enables significant value capture by the business that generates and delivers products and services" (Teece, 2010, p.174). While some companies have begun leveraging AIoT for value propositions and value creation (e.g., Bosch, 2022; Sharp, 2022), the widespread adoption of this technology across industries is still in its early stages. Unfortunately, research on AIoT business models and value propositions lags behind this movement, resulting in a limited understanding of its potential. To bridge this gap and shed light on AIoT-enabled value propositions, our next study addresses this gap and asks:

How can AIoT enable new value propositions?

5.2. EXPECTED RESULTS AND CONTRIBUTIONS

To conduct this study, we will carefully screen active companies in the field and select those offering AIoT solutions. Through thematic analysis, we will analyze the collected data to identify and categorize the existing value proposition archetypes. These archetypes will serve as representations of the current value propositions within the AIoT domain, contributing to both academic literature and practical insights.

The intention is to conduct a qualitative analysis of the secondary data collected from prominent AIoT companies. We aim to contribute in two significant ways. Firstly, we aim to rectify the imbalance between the dominance of technically oriented AIoT research and the lack of research on AIoT-enabled business models. Our study examines real-world AIoT business models employed by pioneering companies to identify value proposition archetypes and categories while also suggesting avenues for future research. Secondly, our work holds implications for business practice by providing valuable insights into novel AIoT-enabled value propositions. We will meticulously describe each value proposition category and its corresponding archetypes, offering a deeper perspective for managers and business owners seeking to integrate AIoT within their organizations. The identified value proposition archetypes can serve as a guide for both startups and established companies on their journey toward formulating a value proposition and a sustainable business model. Furthermore, we elucidate the benefits associated with AIoT-enabled value propositions, offering practical insights for practitioners considering the adoption of this technology.

This research endeavors to unlock the potential of AIoT as an asset by focusing on the development of effective business models. By exploring AIoT-enabled value propositions through qualitative analysis, we contribute to both the academic understanding of this domain and its practical application. The insights gained from our study pave the way for future research, while also equipping managers and business owners with the knowledge to leverage AIoT for enhanced value creation and market success.

6. CONCLUSIONS

This report is the first deliverable from a three-part package from CBS in the “embedded AI” project. In this deliverable three main steps are taken. First, the main concepts are defined and explained to develop a solid theoretical foundation for the study and provide a common ground for the stakeholders of this project with different backgrounds and expertise. In this regard, AioT, edge computing, and embedded AI are defined and distinguished. In addition, the concept of “business model” is discussed and explained with a focus on its elements including value proposition, value creation, and value capture. The importance of business models and having a business perspective in studying new technologies is already mentioned in the literature and acknowledged by practitioners. And the reason is that companies need to be more responsive to changes and disruptions to survive and stay ahead of the competition. However, this cannot be achieved by merely utilizing advanced new technologies, but also it necessitates the capability to integrate such technologies to re-interpret how businesses operate and create value.

The second step was to study and analyze the evolution of IoT business models and understand the maturity of the business models at four different levels of sophistication. This step was a crucial one as current literature doesn’t clearly differentiate between various types of IoT and the corresponding value propositions. Different types of IoT integration and sophistication both in terms of technology and value proposition structure can lead to completely different business models. As mentioned, many IoT business model papers have a general perspective towards IoT types, meaning that they don’t differentiate between how and why the IoT technology is used for. For instance, when a company uses IoT in its production system, the corresponding value proposition will change in a completely different way, in comparison to a situation where a company adds IoT to its products to enable real-time tracking for the customer. Moreover, there is a lack of explanations and definitions of different IoT business model stages and how such business models evolve from simple IoT-based business models with limited value propositions to complex IoT ecosystems where multiple actors can create and propose value. Despite a couple of attempts to classify IoT business models, there is limited work on the links between these business models and how each business model is described and formulated. In addition to the previous limitations, the role of data for each category or stage of the IoT business model is not explained. Data is the ultimate element that leads to business model innovation and finding ways to create value for the customers and generate revenue for the focal company. In other words, most of the recent advanced technologies such as AI, blockchain, cloud, IoT, and embedded AI revolve around data, and without it, these technologies are practically useless. Therefore, the role of data and how it is connected to the core value proposition is of high importance and criticality. The section on IoT business model maturity strives to address all these crucial aspects and provide new insights that can be used by various stakeholders in the project.

In the third step, the current business models of partner companies are studied and described. MAN energy solutions, VELUX, and Grundfos are the partner companies whose business model has been described according to the business model definition proposed in the first step. Although the available data for the assessment and analysis of the business models were limited, there was an attempt to be as comprehensive as possible and provide a thorough view of their business models in addition to providing some relevant background that makes it possible for the reader to get to know the companies better. This analysis, while describing the status quo, could be very valuable as it is the basis for the next steps in the project (developing business scenarios and future business models) as well as providing a simple tool to view the business models and compare them with other companies in the respective industries or the competitors.

In conclusion, this work intends to provide a foundational understanding of the major concepts discussed in the embedded AI project and pave the way for the next steps where the idea is to develop scenarios for different types of business models in an ecosystem of AI services, and ultimately, develop a business model where the distributed and shared nature of embedded AI is captured. It is noteworthy that academic publication is an ongoing activity during the project in addition to the empirical studies and reports, and we strive (and hope) to be able to improve our collaborations with the partner companies to be able to gather more empirical data for the development of both DIREC deliverables and the academic papers.

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