Tampereen yliopisto

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IMPROVEMENT OF INTERNET OF THINGS MATURITY IN MEDIUM SIZE TECHNOLOGY COMPANY

Master of Science Thesis
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ABSTRACT

Noora Kurkinen: Improvement of internet of things maturity in medium size technology company
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The purpose of this research is to find out how Internet of Things maturity models can be used in organizations to determine the current level and target level of the Internet of Things. By defining the current level and the target level, it is possible to find out what kind of development steps the organization should take to reach the desired level. In addition, the research aims at identifying the benefits of the Internet of Things for the business operations of organizations.

With the help of models, the maturity of the organization can be determined from several different subject areas of the Internet of Things. In this case study, an Internet of Things maturity model is customized for the target organization. The model evaluates the maturity of the organization in the dimensions of governance, technology and connectivity, data-analytics based decision making, people and processes. These areas are divided into even smaller sub-dimensions, the maturity of which is assessed separately. In addition, the research also investigates the current level and target level of the Internet of Things maturity of the target organization through interviews conducted in the target organization. Based on the definitions of the current level and the target level, a road map is created for the target organization.

The target organization's current maturity is between levels 2–3 in each dimension. Levels 3–4 were initially defined as the target. The research also revealed that to develop the target organization's maturity, improving the governance dimension is critical to raise the maturity of other dimensions. A 6-phase plan was drawn up for the target organization to reach the target level.

Keywords: Internet of Things, Industry 4.0, maturity model

TIIVISTELMÄ

Noora Kurkinen: Esineiden internetin kypsyyden parantaminen keskikokoisessa teknologiayrityksessä
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Tämän tutkimuksen tarkoituksena on selvittää, miten esineiden internetin kypsyysmalleja voidaan hyödyntää organisaatioissa esineiden internetin nykytilan ja tavoitetilan selvittämiseksi. Nykytila ja tavoitetila määrittelemällä voidaan selvittää millaisia kehitysaskeleita organisaation tulisi ottaa päästäkseen haluamaansa tilaan. Lisäksi tutkimuksessa halutaan selvittää mitä hyötyä organisaatioiden liiketoiminnalle on esineiden internetistä.

Organisaation kypsyys voidaan mallien avulla selvittää useammalta eri esineiden internetin aihealueelta. Tässä tapaustutkimuksessa räätälöidään kohdeorganisaatiolle esineiden internetin kypsyysmalli, jossa arvioidaan organisaation kypsyyttä hallinnon, teknologian ja liitettävyyden, data-analytiikkaan perustuvan päätöksen teon, ihmisten ja prosessien alueilla. Nämä alueet on jaettu vielä pienempiin alakohtiin, joiden kypsyyttä arvioidaan erikseen. Lisäksi tutkimuksessa selvitetään myös kohdeorganisaation esineiden internetin kypsyyden nykytila ja tavoitetila kohdeorganisaatiossa tehtävien haastattelujen avulla. Nykytilan ja tavoitetilan määrittelyjen perusteella kohdeorganisaatiolle luodaan tiekartta nykytilasta tavoitetilaan pääsemiseksi.

Kohdeorganisaatio sijoittui arvioiduissa aihealueissa nykyhetkellä pääasiassa tasoille 2–3. Tavoitetilaksi määriteltiin lähtökohtaisesti tasot 3–4. Tutkimuksessa selvisi myös, että kohdeorganisaation kypsyyden kehityksessä erityisesti hallintoalueen parantaminen on kriittistä muiden aihealueiden kypsyyden nostamisen näkökulmasta. Kohdeorganisaatiolle laadittiin 6-vaiheinen suunnitelma kohdetasolle pääsemiseksi.

Avainsanat: esineiden internet, teollisuus 4.0, kypsyysmalli

PREFACE

This master’s thesis journey started in autumn 2023 and has continued until summer 2023. The process has been kind of onerous and long with full-time employment but at the same time instructive and rewarding now when looking back. It has been great to notice how things learned during the studies could be used and combined in this thesis.

Now when this journey is over, I would like to thank professor Hannu Kärkkäinen for guiding me through this process and helping me making important choices during my way. Special thanks for keeping me on the road while customizing the maturity model for the target organization for several long months which caused me a bit of frustration at times. In addition, I would like to thank my colleagues from the case company for supporting me in this thesis in multiple ways. Thanks for your feedback and your participation in the interviews, without them this thesis would not be ready today. Lastly, I would like to also thank my friends and family who have supported me in my studies and especially in completing this master’s thesis.

Tampere, 30.6.2023

Noora Kurkinen

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LIST OF SYMBOLS AND ABBREVIATIONS

ADC	Analog to Digital Converter
AI	Artificial Intelligence
AWS	Amazon Web Services
BLE	Bluetooth Low Energy
BT v5	Bluetooth 5.0
BPI	Business Process Improvement
BPM	Business Process Management
CMM	Capability Maturity Model
ERP	Enterprise Resource Planning
IIoT	Industrial Internet of Things
IoT	Internet of Things
IP	Internet Protocol
JUFO	Publication Forum
KPI	Key Performance Indicator
LAN	Local Area Network
LoRa	Long Range
LPWAN	Low Power Wide Area Network
MES	Manufacturing Execution System
MM	Maturity Model
M2M	Machine to Machine
NFC	Near Field Communications
NPD	New Product Development
PAN	Personal Area Network
RFID	Radio Frequency Identification
SCADA	Supervisory Control And Data Acquisition
SoC	System-on-Chip
TCP	Transmission Control Protocol
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network

1. INTRODUCTION

In this chapter the introduction to this research is presented. First, research objectives, limitations, and research questions are introduced. After that the structure of this research is presented. The function of this chapter is to present the background of the research, what is left out of the scope, which are the research problems and how the research is structured.

1.1 Research background

The terms Internet of Things (IoT), Industrial Internet of Things (IIoT) and Industry 4.0 describe in different levels the products that can be connected to internet through varying communication technologies (Kalsoom et al. 2021; Madugula 2021; Schumacher et al. 2016). These technical revolutions have affected the nowadays highly competitive markets and many companies are utilizing these technologies in their business. From the IoT adaptation point of view, organizations may have challenges in utilizing new technologies and fitting them into their business models. (Stoiber & Schönig 2022; Kalsoom et al. 2021)

Organizations can also struggle to recognize their current state of IoT maturity (Stoiber & Schönig 2022). For solving these kinds of problems maturity models can be beneficial tools. Maturity models are management tools which help organizations to recognize their readiness in certain domains. (Felch et al. 2019) For example, IoT and Industry 4.0 have their own maturity models. Schumacher et al. (2016), Colli et al. (2018) and Stoiber and Schnönig (2022) have developed their own IoT or Industry 4.0 maturity models which are used as base for new customized maturity models designed for a target organization's needs.

1.2 Research objectives, limitations and research questions

As mentioned earlier, many organizations struggle to identify their current state of IoT maturity (Stoiber & Schönig 2022). Also, the target organization does not have appropriate understanding of their current state of the IoT maturity. In the target organization the IoT and Industry 4.0 possibilities from the business and technical point of view have not been reviewed before. The research goal is to customize IoT maturity model based on existing maturity models and according to target organization's needs. Furthermore, the customized maturity model is used as a management tool to clarify the current IoT maturity level in the organization. By using the same customized maturity model, the target organization's target maturity levels are also defined. These IoT maturity level clarifications are done to understand where the target company currently is and what steps need to be taken to reach the target state in each dimension.

In addition, a roadmap is designed for the target organization to achieve the target level in a short period of time, which means a couple of years. What is more, the target organization has a desire to utilize IoT better and probably develop new products with IoT technologies in the future. Thus, based on these goals and problems, the research questions are:

- How can IoT be used to utilize business?
- How can the current and target state of IoT maturity be determined by using maturity models?

Maturity dimension's which are found interesting in the target organizations point of view are delimited to five dimensions which are governance, technology and connectivity, data-analytics based decision making, people and processes. These dimensions and their sub-dimensions are chosen by using the principle of critical few. That means that only the most critical few dimensions are considered in the customized maturity model. For example, from the scope of the developed maturity models, security and management commitment to IoT projects are left out.

The research strategy used is a case study. The customized maturity model is also useable to other product development and manufacturing companies, but the developed roadmap is designed just for the target organization. Thus, the roadmap is not suitable for other companies. Interviews are selected as data collection methodology used in the research for defining the current and target IoT maturity levels. The most significant achievements of this research are customized maturity model and analysis of the target organizations current and target maturity levels.

1.3 Structure

This research has 8 chapters including introduction, literature re-view, developing a construction, results, and conclusion. Chapter 1 works as an introduction to research where the reader gets to know the subject area, understands the research's goals and scope, and finds out the research structure. Chapters 2-3 are research's literature review. The goal of those chapters is to familiarize the reader with needed concepts of IoT, data analytics and maturity models so that the reader can understand the rest of the research. Those chapters also set the ground and give the reader the view why adaptation of IoT is important to the target organization. In chapter 3 the maturity models chosen to base for the new customized model are presented.

In chapter 4 the chosen maturity models are evaluated and a new maturity model for the target organization developed. Chapter 4.1 is a literature review for identifying a couple of ways for developing new maturity model. The actual customized model is presented in chapter 4.4.

In chapter 5 the research process of the thesis is presented. Chapter 6 includes results of the research. Chapter 7 includes discussion, answers to research questions and recommendations for the target organization.

2. INTERNET OF THINGS AND INDUSTRY 4.0

In this chapter, a couple of definitions of Internet of Things, Industry 4.0 and short history of IoT are presented. Also, different IoT technologies, IoT architecture examples and data analytics are introduced. This chapter's function is to help the reader to understand what is meant by the different features of IoT and which concepts are related to it. This chapter gives the reader the ability to understand the later chapters in this thesis.

2.1 Definition of Internet of Things

IoT is a multidisciplinary paradigm which has multiple different kinds of definitions that are related to connecting things to Internet (Samie et al. 2016). Shortly, Internet of Things can be defined as devices connected to each other. These devices can also be connected to network and cloud services. For connecting to the network communication protocols are used to share data and enhance functionalities. (Samuel & Sipes 2019) According to Oriwoh et al (2013) Internet of Things can also be defined to be interconnection of things which are connected for features like identification, data collection, communication, and sensing. The data should be detected and transferred autonomously to humans or other devices in the IoT solutions. The third definition of Internet of Things is that IoT is an entity which consists of machines, sensors, systems, and connected products which are designed to collect and transmit data, enabling the tracking and monitoring devices that are integrated. (Reis et al. 2022)

Furthermore, physical and digital worlds are connected to each other via IoT applications for improving services (Kalsoom et al. 2021). IoT enables connectivity and data collection to organizations (Stoiber & Schönig 2022). Data and information about "things" context, environment and location can be provided through wireless sensors technologies (Ng & Wakenshaw 2017). Thus, connectivity is one of the core features associated with IoT in every definition.

In the term "Internet of Things" word thing usually does not mean traditional computing devices like personal computers which have had connection to internet already before Internet of Things era (Oriwoh et al. 2013). According to Stoiber and Schönig (2022) the "things" should also be uniquely identifiable to be defined as a IoT "things". The word internet signifies the things ability to build a network of interconnected objects. (Stoiber & Schönig 2022) The connection is usually based on Transmission Control Protocol (TCP) or Internet protocol (IP) protocols (Ghasempour 2019).

IoT is not only a technological revolution but is also affecting the business for example by enabling customer insights and better and optimized products to end customers (dos Reis et al. 2022; Samuel & Sipes 2019). Moreover, IoT has impacts in all social, technological, and economic areas (Stoiber & Schönig 2022). From the technical perspective, IoT includes technical innovations from wireless sensors to nanotechnology (Madugula 2021).

IoT can be used in organizations, for example measuring, identifying, tracking, and monitoring connected products (Uckelmann et al. 2011). Connected things contain sensors and actuators which enable gathering the data for storing and processing. In industrial companies IoT revolution is usually seen as an opportunity of digital transformation and on the other hand as an opportunity of digital innovation. (Stoiber & Schönig 2022)

In addition to the term IoT there exist almost similar term Industrial Internet of Things (IIoT). IIoT also uses sensors and other connected objects but the use is specified in enhancing industrial processes and manufacturing industry. (Madugula 2021)

2.2 Definition of Industry 4.0

Industry 4.0 can described to be the fourth revolution in the manufacturing industry that has risen based on new exponential growth of emerging technologies such as IoT, cloud computing, wireless sensors, embedded systems, and big data (Coili et al. 2018; Kalsoom et al. 2021). As a result of this revolution, manufacturing organizations have put more advanced technologies into use to control machines, services, factories, and infrastructure. Advanced technologies have also affected intelligent procedurals and strategic decisions. (Kalsoom et al. 2021)

Industry 4.0 refers to the integration of objects, humans, machines, and processes through internet connection and technology to form an agile and smart value chain. It increases the complexity of manufacturing processes and presents challenges for small-medium sized companies in terms of financial effort and impact on business. Companies usually struggle to understand Industry 4.0 and its concepts, relating it to their own domain and strategy, and determining their development towards the Industry 4.0 vision. To address these uncertainties, new methods and tools are required to align business strategies and operations with the Industry 4.0 concept. (Schumacher et al. 2016)

IoT is also an essential requirement for organizations who wish to implement Industry 4.0 successfully (Reis et al. 2022). For example, changing customer demands have driven the Industry 4.0 changes (Kalsoom et al. 2021). Also, Industry 4.0 provides possibilities for organizations to develop new products, processes, and services to competitive markets (Coili et al. 2018).

2.3 Adopting of Internet of Things

Organizations adopting of Internet of things can be divided into different maturity levels (Reis et al. 2022). The adoption of IoT can be split to the business and technology drivers. These drivers can be utilized in the first steps of designing and implementing the IoT. Drivers help the adopting company to get the best results in the end of the adaptation process. The business drivers of adopting IoT are transformation, efficiency, monetization and new products and capabilities. (Samuel & Sipes 2019)

Transformation means developing new business processes, new products or new strategies utilizing IoT. The second business driver is efficiency which means that IoT adoption needs to have an ability to create efficiency in the organization's functions. These functions can be customer management or supply chain (Samuel & Sipes 2019).

The third business driver is monetization. The organization should find new business model opportunities or even possibilities to create new business units. Monetization can also enhance existing business models. Adoption of IoT can also create opportunities for new products or developing existing products better with IoT. (Samuel & Sipes 2019) With IoT. existing products can be enhanced, for example creating better features based on data collected to the cloud via IoT.

Technology drivers are scalability, manageability, security, reliability, privacy, architectural diversity, and compliance. The technology driver’s selection is based on the selected business drivers. (Samuel & Sipes 2019)

Business drivers are important to consider because the IoT adoption must produce some business advantages which are greater than the costs of the adoption (Samuel & Sipes 2019). Taking Samuel and Sipes (2019) model in the consideration, the IoT adaptation is more business revolution than technology revolution, the technology is enabler for IoT based business models. That is why business potential and business case should be evaluated first. Moreover, Leminen et al. (2012) summarize that successful IoT adaptation is dependent on the right combination of business models, technology and acceptability of users.

2.4 IoT core technologies

IoT devices can also be seen as connected and intelligent or smart products. Intelligent connected products are formed of physical, intelligent and connectivity components. Products' mechanical and electrical parts are the physical components of the product. Intelligent components are the products' software, sensors, processors, data storage, controls, user interfaces and embedded operating systems. The software can be also used to replace some physical components. Connectivity components are the products antennae, wireless or wired connection protocols and ports. (Porter & Heppelmann 2014)

Organization's IoT ecosystems include combinations of system architectures, other software layers and hardware layers (Routh & Pal 2018). Smart technologies such as sensor technology and Radiofrequency Frequency Identification (RFID) are embedded in the organization's applications. (Chen et al. 2014) Sensors are used to collect data anytime and anywhere from objects (Ghasempour 2019). Sensors enable people to interact with things remotely anywhere and anytime (Chen et al. 2014).

The things which are connected to the IoT are following communication standards. These communication standards enable the data transfer between interfaces. Radiofrequency tags and Wireless Sensor Network (WSN) are examples of technologies which are used for transferring data. (Reis et al. 2022) RFID works using electromagnetic fields to send data attached to it. RFID supports automated identification and tags tracking. RFID-tags always include chip, antenna, and some memory. (Shah & Yaqoob 2018) What is more, RFID enables object-identification whit low costs (Samie et al. 2016).

In addition, tags can be added to the product in the engineering phase, or they can also be added later. These tags can be read in different frequencies and the readers can read the information from the tag. Thus, there is usually always one device needed to work as a tag and a second one as a reader. (Yang et al. 2016; Shah & Yaqoob 2016) Similar technologies with RFID are Near Field Communications (NFC), Machine to Machine (M2M) and vehicular communications. NFC is similar for RFID configuration, but the reader can be integrated to mobile phones. (Coskun et al. 2012; Shah & Yaqoob 2016)

Wireless communication technologies are technologies such as ZigBee, Z-Wave, Wi-Fi, Bluetooth, NFC, Cellular network, and Low Power Wide Area Network (LPWAN) (Routh & Pal 2018; Samie et al. 2016). Wireless technologies are used connecting the IoT things as local networks and connecting these networks to the internet. (Samie et al. 2016)

Features of different wireless communication technologies are presented in Table 1. According to Samie et al. (2016), the best solutions for IoT applications could be hybrid communications, which includes multiple different communication technologies.

Table 1. *Communication technologies and their features (adapted from Samie et al. 2016)*

Wireless communication technology	Features
ZigBee	Low-cost, small-size, low-power, wide transmission range (depends on output power), some market barriers
Classic Bluetooth	Data stream applications, limited number of nodes
Bluetooth Low Energy (BLE)	IoT applications with short-range, low bandwidth, low latency, lower power consumption and setup time than classic Bluetooth, unlimited nodes
Bluetooth 5.0 (BT v5)	Bigger range, better broadcasts capacity, low energy connections speed doubles
Conventional WiFi	High bandwidth, urban district availability, high energy consumption
Low-power WiFi or HaLow	Less interference because of different frequency, extended range of transmission compared to conventional WiFi
Cellular network	High consumption profile, no support for M2M or local network communication, reliable high-speed connectivity to Internet
LPWAN	Suitable for long range transmission and low power applications, very low data rate, lack of globally available band for LPWAN
NFC	Short-range, devices must be close proximity to each other, tag that contains some data

Network infrastructure is also needed for data processing and analysis. IoT Network architecture can be divided into three stages which are sensing, delivery and analytics. IoT

Network architecture is presented in Figure 1. Collecting data, aggregation and delivery are done in between the sensing and delivery networks. Security and networks are also related between sensing and delivery network. (Verma et al. 2017)

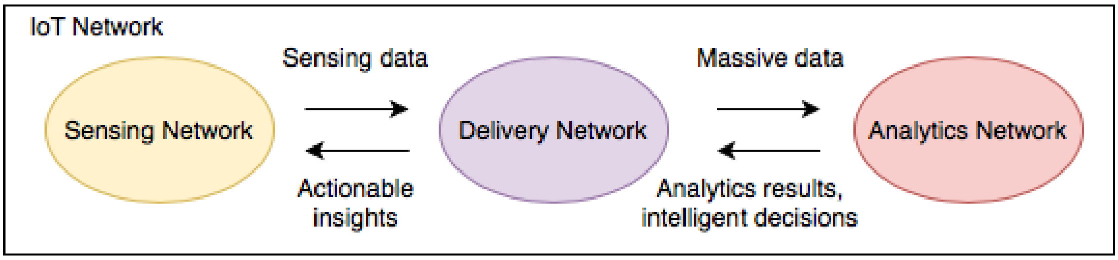

Figure 1. *IoT Network Architecture (adapted from Verma et al. 2017)*

2.5 IoT architecture

IoT systems and their intelligence can be split into three levels. The first level covers endpoints that can gather and process data. The second level concerns gateway devices. Gateways are aggregating traffic and serving commands. The highest level includes cloud and needs backend infrastructures. Endpoints and gateway devices are sending data to cloud and backend infrastructure over backhaul connection. (Markkanen 2015)

IoT architecture can be divided also into four stages in the software and hardware point of view. Those stages are data acquisition, data processing, data storage and data transmission. Data acquisition and data transmission should exist in every IoT application. Data processing and data storage are optional in IoT applications. IoT applications' general stages are presented in Figure 2. (Samie et al. 2016)

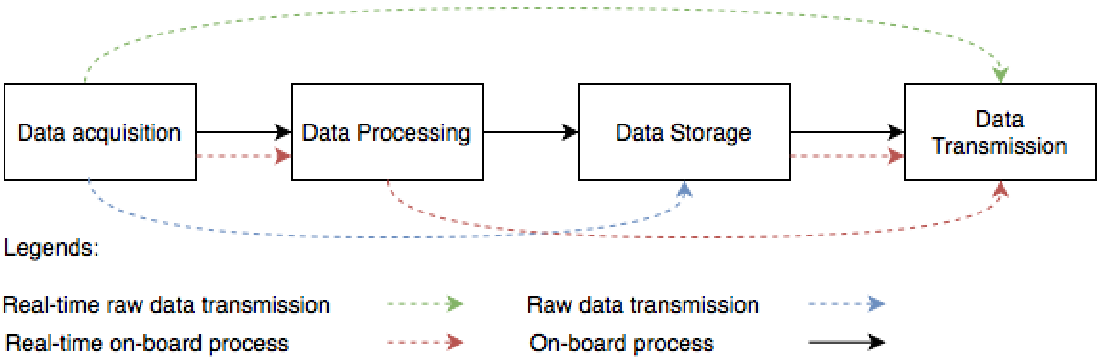

Figure 2. *IoT applications general stages (adapted from Samie et al. 2016)*

The general architecture of IoT System-on-Chip (SoC) platform is described in Figure 3. Embedded IoT devices have at least RF component for enabling devices connectivity. (Samie et al. 2016) Also IoT platforms minimal requirements are wireless radio, analog to digital (ADC) sensor, analog filters, and amplifiers. IoT platforms can interact with the surrounding physical world and communicate. (Qu & Yuan 2014)

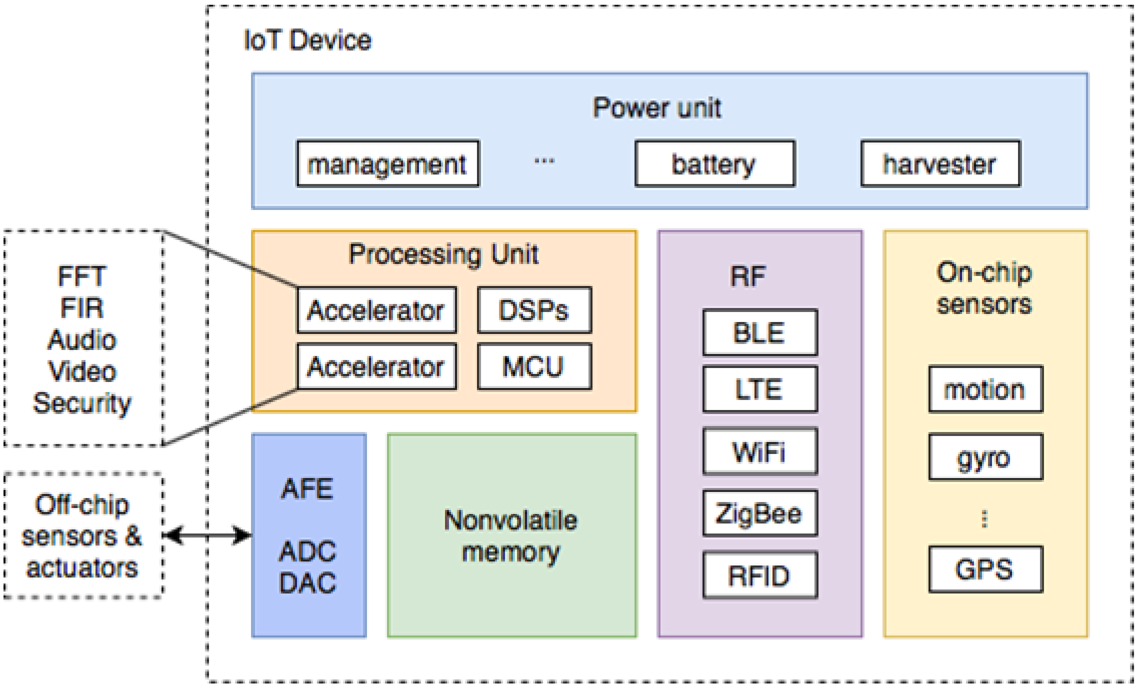

Figure 3. *IoT embedded device's general architecture (adapted from Samie et al. 2016)*

Data processing can be done in the gateway or in IoT device itself. Choosing the computation place is one of the challenges in data processing. (Samie et al. 2016; Kim 2015) The elements which are affecting the selection of the processing place, are for example energy consumption, transmission delays, energy efficiency, requirements of real-time etc. (Samie et al. 2016) Different layers and platforms where computing can be done are device (microcontroller of IoT device), gateway, fog, cloud, or hybrid approach. All these layers have their challenges and strengths in processing the data. (Samie et al. 2016)

Cloud based platforms for analytics are, for example Amazon Web Services (AWS), IBM Bluemix and Microsoft Azure IoT Suite. These platforms enable data visualization and device management possibilities to organizations. Sensors send data over the network to these cloud platforms. High latency and high bandwidth are challenges in cloud platforms. Some computation tasks can also be done at the level of device or gateway. In the fog computing the processing tasks are pushed to the edge of network. (Patel et al. 2017)

Cloud computing can be used to analyze huge amounts of IoT data (Ghasempour 2019). Cloud computing can work as an infrastructural element which integrates and computes monitored devices, storage devices, tools of analytics, platforms of visualization and delivery to customers (Gubbi et al. 2013).

2.6 Data-analytics

IoT systems enable organizations to assess huge volumes of data which can be used for example to assist optimal decision making (Yang et al. 2016) and optimizing organization's processes (Lade et al. 2017). Analytics can help organizations to create business value by making intelligent decisions quicker and better than without it (Lepenioti et al. 2020). For IoT analytics data sources are connected devices such as sensors, objects, computing devices, mechanical instruments, and other smart applications (Madu-gula 2021).

Data-analytics can be divided into four phases which have a relationship between each other. That relationship is hierarchical which means that to reach the upper phase, the lower levels should also be reached. From the bottom to top the analytics phases are descriptive analytics, diagnostics analytics, predictive analytics, and prescriptive analytics. So, for example to reach predictive level of analytics, descriptive and diagnostic analytics should be already handled. (Markannen 2015; ur Reuhman et al. 2019; Verma et al. 2017) The relationship between these analytics phases is presented in Figure 4.

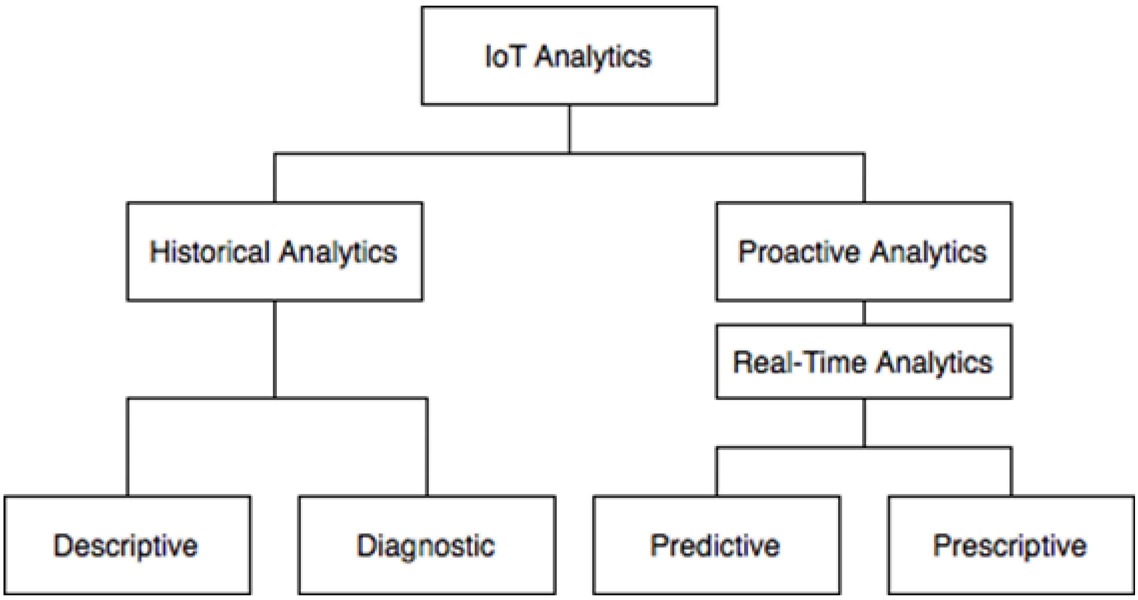

Figure 4. *IoT analytics taxonomy (Verma et al. 2017)*

Descriptive, diagnostic, predictive and prescriptive analytics answer different questions presented in Table 2. Descriptive and diagnostic analytics are basic-level analytics related to historical data. Instead, predictive and prescriptive analytics are advanced analytics and based on real-time data analysis. (Markkanen 2015; ur Rehman et al. 2019)

Table 2. *Analytics phases (adapted from Markkanen 2015)*

Analytics phase	Question to be answered	Advance-level
Descriptive	What has happened?	Basic
Diagnostic	Why did it happen?	Basic
Predictive	What is likely to happen next?	Advanced
Prescriptive	How it can be encouraged or prevented?	Advanced

Descriptive analytics focuses on the past, and it tries to give information about history by highlighting and patterning data. In descriptive analytics insights are gained based on the historical data. Historical data can be, for example, numbers and reasons of the defective items. (ur Rehman et al. 2019) Descriptive analytics usually gives opportunity for detecting deviations compared to normal situations (Pospieszny 2017). Also, descriptive analytics can be used to make summaries and data visualizations to support decision making. Generally, in descriptive analytics, different kinds of dashboards, key performance indicators etc. can be used. (Appelbaum et al. 2017)

Diagnostic analytics considers current situations and enables some real-time analytics. Data can be for example current location and status of the detective item. (ur Rehman et al. 2019) Diagnostic analytics focuses on clarifying what happened and why and what was the reason. (Markkanen 2015; Pospieszny 2017; ur Rehman et al. 2019) Diagnostic analytics can help for example to find specific place from the organization's processes where some abnormal event happened (Ge et al. 2017).

Predictive analytics can identify possible issues that can occur. Predictive analytics includes, for example, machine learning and statistical techniques. Used data can be for example expected levels of inventory, anticipated demand level and machine failure prediction or quality. (ur Rehman 2019) Predictive analytics can help organizations to optimize processes, minimize risks, cut operative costs and recognize trends (Pospieszny 2017).

Prescriptive analytics is the highest of the levels of analytics and it contains all the lower-level analytic phases and their methods. It gives suggestions or advice of what are the best possible actions and practices to take. (Pospieszny 2017; ur Rehman 2019)

Data-analytics enables, for example, machine monitoring which can be done based on machine operating parameters such as run time, actual operating speed etc. Data can be for example from sensors or Supervisory Control And Data Acquisition (SCADA). Usually, real time collected data is transmitted to the cloud and processed there into insights. Insights can be based on the Key Performance Indicators (KPI) used in the field. After that the data can be visualized. (Madugula 2021)

Other monitored parameters can be for example vibration, temperature or humidity which are reacted upon when they go beyond normal thresholds. Predictive maintenance can be done based on condition monitoring. In the predictive maintenance data is gathered from equipment's' sensors and stored, for example to the cloud. In the cloud sensors' data is combined with the equipment's metadata. Metadata can be for example model of the equipment, operational settings, and configuration. Equipment-related data can also be fetched from the organization's Enterprise Resource Planning (ERP) system. Data from ERP can be, for example, equipment usage history, maintenance data etc. Combined data sets can be run through Machine Learning (ML) algorithms to find abnormal patterns. These patterns can lead to failures of the equipment. (Madgula 2021; Marjani et al. 2017) Machine learning techniques can also be used for applications for predictive maintenance, test time reduction, optimizing supply chain and optimizing process flows. Example environment for analyzing data is presented in Figure 5. Data is gathered from the different databases and IoT devices. (Lade et al. 2017)

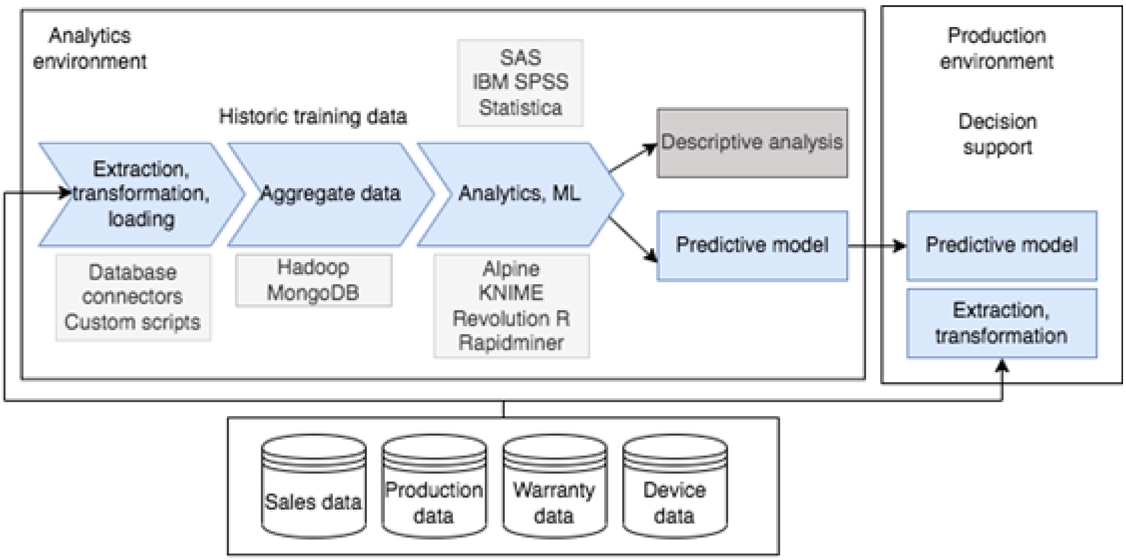

Figure 5. *Data analyzing environment (adapted from Lade et al. 2017)*

2.7 New product development and business advantages of Internet of Things

Developing new products is highly important to organizations to keep their business profitable. New products are also a way to keep along in the competition with other firms. (Reis et al. 2022). Manufacturing companies are facing nowadays multiple pressures such as severe competition, counterparts in product price, quality, cost, functions and lead-time.

Moreover, they must meet rising environmental standards and be sustainability. At the same moment resources of nature are decreasing and prices of energy increasing. (Ganzarain & Errasti, 2016) In addition, customer needs are rising, and customized products wanted (Reis et al. 2022). Customers are demanding products whit variety, quality standards, support services, immediacy, or satisfaction (Ganzarain & Errasti 2016). So that means that the companies should continuously improve their products and services to keep competitive in the globalization of markets.

The new product development process includes steps such as ideation, concept design, development, testing and product manufacturing (Reis et al. 2022). According to Ulrich and Eppinger (2012) the new product development can be divided into “planning, concept development, system-level design, detail design, test and refinement and production ramp-up”.

In the new product development, it is extremely important to understand market demands and capture customer needs. When the possibilities for new products are identified it's also important to evaluate the ideas before starting the actual development process. The outcome of the evaluation should be based on knowledge or at least information about the best solution. The most valuable products should be picked for development. Identifying possibilities in multiple sources will probably produce successful product launches. (Reis et al. 2022)

Business models are tools to describe how organizations can create and deliver more value to customers with business. Business models are shaped based for example on the organizations' key processes, activities, resources, value proposition and customer needs. (Metallo et al. 2018) Adopting IoT can cause new opportunities to create new kinds of effective business models and so on new revenues. According to Kalsoom et al. (2021) new business models designed based on innovations and new emerging technologies can improve manufacturing organizations' performance and sustainability. Adopting IoT also helps manufacturing organizations to stay competitive in the changing markets. (Felch et al. 2019; Kalsoom et al. 2021)

Organizations business models can include two important features: value creation and value capture. With these functions the organization can identify how to create value for customers and how to change it to profit. These features are useful when an organization is interested, especially regarding a company's competitive advantage and performance. (Metallo et al. 2018) According to Zott et al. (2011) business models should be designed based on creating value with partners. Designing business models should also consider different stakeholders such as suppliers, partners, distribution channels and other coalitions. Business models' key features can also be connecting information technology and customer needs. With new technologies to customers new value can be delivered and that value can be converted to marketing outcome. According to technologies new business models can be created also based on new innovations (Metallo et al. 2018)

Customers are linked to the organization via organizations selling products. That is an important way to create better customer relationships and offer even better products, solving existing customer needs. Product can be seen as a window to the customers' problems and use habits. The main goal is to deliver customer products which truly satisfy them and have features which are easy and beneficial to use. (Porter & Heppelmann 2014)

When the organization truly and deeply understands how the customer uses the product, the organization can even develop new kinds of business models. That can for example be moving from the traditional product business to selling products as a service. (Porter & Heppelmann 2014) So, IoT has major impacts on business models and processes.

IoT can help organizations to stay competitive, design new business models, develop and design new products or services, extend the market base and improve productivity (Lee 2019) What is more, IoT can assist in developing the New Product Development (NPD) process or identifying whole new product opportunities. (Reis et al. 2022) Due to IoT new kinds of business models can be implemented and value created to customers via new products and services (Coili et al. 2018).

In the traditional mindset of developing products, the starting points of the new products are solving customer’s existing problems and probably offering them solutions which helps them reach lifestyle they want. Traditionally products are standalone products which have a clear lifecycle, and the product will be obsolete over time. The company can pursue some advantages whit the product such as commodity interest, IP-ownership, or brand. Developing the capabilities focuses on leveraging the existing competencies, resources, and business processes. (Metallo et al. 2018)

Industry 4.0 and IoT are providing multiple new possibilities in manner of new product development, and also new services and process development (Colli et al. 2018). IoT implementation and digital transformation has enabled manufacturing companies to better customer understanding, efficient productivity, automation, competitive advantage and speedy returns (Kalsoom et al. 2012). In the IoT mindset of product development value creation focuses on addressing real-time needs using predictive solutions. Products are updated over-the-air wireless. (Metallo et al. 2018)

Using big data analytics, gathered data can be changed to form actionable data that can be used for example predictive maintenance and asset management. Predictive maintenance can be used for avoiding breaking and extensive repairs. With IoT, analyzed and collected data can be used to identify fragile parts. Real-time data can also be used to avoid downtime. (Kalsoom et al. 2021) Organizations can also improve design and manufacturing processes based on data (Yang et al. 2016).

According to Kalsoom et al. (2021) and Markkanen (2015) IoT enables remote performance monitoring and controlling via sensors and devices collaborating via the internet. For example, ABB Robotics' industrial machines can be monitored remotely. Machines can also be adjusted remotely during operation by end users. (Porter & Heppelmann 2014)

Moreover, IoT can be utilized for predictive maintenance of machines and optimizing NPD processes. New product development optimization with IoT focuses on understanding better how to create value to clients and how to reduce costs in the NPD process. The improvement is based on real time data analytics. (Reis et al. 2022)

As different features will point out, the new product development belongs to multiple different organization units or “activities”. Adopting IoT for NPR-process could be useful for increasing productivity and supporting process by combining information collected by the organization's different units (Reis et al. 2022).

When IoT is used in product development the organization can analyze the information gathered from multiple sources to create knowledge for supporting future development. The knowledge can be used for example designing new product lines and optimizing products' internal components. One benefit of adopting the IoT is also that the company's knowledge about the market can be increased. (Reis et al. 2022).

The data gathered from the smart connected product can give the organization information about how the customer really uses the product. It can be found out for example which features the customer uses often and prefers and which features the customer is failing to use. This kind of information can help segmentation of different customer-based things such as industry, geography, organizational unit and so on. Marketers can use this knowledge for example after sales or to make customized offers (Porter & Heppelmann 2014)

For example, consumers' experience about companies IoT products or services can be analyzed. With this customer data analysis, the customer's experience can be improved, which is also beneficial to the company and the consumer itself. (Reis, et al. 2022). According to Markkanen (2020) “IoT truly becomes transformative to business is when it crosses over with analytic tools and modelling”. For example, if an organization has knowledge that using machines heavily will cause premature faults which will lead to a need for an expensive warranty fix, the organization can try to make preventive maintenance beforehand. (Porter & Heppelmann 2014)

Also, information gathered from the sensors, for example in the machine’s engine temperature and vibration or power consumption can show how the performance of the machine is correlated to the technical specifications of the machine. This might be useful for developing new even better specifications for the future machines with better performance. (Porter & Heppelmann 2014) Connected sensors and devices can enable organizations monitoring and remote controlling (Kalsoom et al. 2021; Yang et al. 2016). In addition, upgrades for smart connected products can be done via software. Using IoT the upgrades can be done remotely (Porter & Heppelmann 2014).

2.8 Challenges of IoT adaptation and data analytics

Challenges of IoT can be technical or business related or combinations of business, social or technical challenges (Ghasempour 2019). According to Routh and Pal (2018) the technical challenges of IoT can be divided into security, privacy, connectivity, compatibility, complexity, data management, data flow and longevity related challenges. What is more, organizations usually already have existing organizational structures, IT architectures, process landscapes and corporate cultures which can make IoT implementation more complicated. IoT architectures can also be siloed, and organizational structures fragmented. (Stoiber & Schönig 2022)

In addition, organizations might have challenges to recognize their current state and maturity of IoT. That can lead also to challenges developing IoT roadmaps or IoT related projects. (Stoiber & Schönig 2022) Organizations can also have challenges identifying what Industry 4.0 means to them and what should be done to gain business advantages (Kalsoom et al. 2021). Practical implementation of IoT can be challenging to companies.

Organizations can also have challenges in identifying and developing their business processes (Yang et al. 2016).

To enable sensing in real time organizations, there is need to deploy large amounts of different sensors etc. (Yang et al. 2016). Adopting IoT needs some huge investments in hardware such as sensors and gateways, connectivity, cloud or other storage, technical support and other labor. Business needs to consider how fast new solutions can be reached and how fast they will bring some revenue and value. (Madgula 2021) Much effort is needed when organization’s management is considering the implementation’s cost and benefits of different applications. Deployment of RFID, WSNs and cloud can also be complicated. (Yang et al. 2016)

About 60% of IIoT adopters think that the risk of data security issues has risen through IIoT (Madgula 2021). Large IoT applications are not suitable also for some organizations because of tight regulations and security concerns about data sharing (Patel et al. 2017). IoT gadgets and other information should be secure in customers’ IoT solutions (Ravikumar et al. 2022). Organizations can also lack knowledge of analytics, embedded software development, embedded electronics, IT security and AI. Organizations can struggle moreover with integration of operational technologies and legacy systems. (Madgula 2021)

According to LaValle et al. (2010) the most common reason for organizations to obstacle the adoption of data analytics is lack of understanding how the analytics can be utilized to improve business. So, the data itself is not a problem. In the other hand, the data quality can be also a challenge and hard to manage. Moreover, a challenge could also be data flows, which can be discontinuous. (Stoiber & Schönig 2022) Barriers of data analytics adoption is also related to an organization’s culture and management rather than technology or data availability (LaVille et al. 2010). On the other hand, data gathered from smart connected products can often be unstructured and it can be related to internal and external data (Porter & Heppelmann 2014).

Also, companies are focusing too much on the Industry 4.0 technological aspects to reach short-term business advantages. Instead, Industry 4.0 and IoT should be seen more as a business revolution than technology-based improvement of products. (Ganzarain & Errasti, 2016)

3. MATURITY MODELS

3.1 Maturity models in general

Maturity level models are important management tools, and they describe the organizations readiness (Felch et al. 2019), perfectness, completeness (Ngai et al. 2013) level of sophistication or competency (De Bruin et al. 2005) on some target state. However, Schumacher et al. (2016) makes the difference between readiness and maturity. According to Schumacher et al. (2016) the main difference is that readiness is determined before starting the maturity process and the maturity during the process. Moreover, maturity models also work for identifying the organization's current state and help create development processes. Maturity can also mean how complete the target state is. (Schumacher et al. 2016; Felch et al. 2019; Becker et al. 2009) Thus, there are multiple words which are related to maturity models. In simple terms, they describe the organizations' readiness in some perspective.

Maturity models are also used for identifying the need for change. It is used as a structured framework for initiating, for example, tactical changes, long-term strategic changes, and operational projects. (Felch et al. 2019) Maturity models are guiding organization's development, identification and prioritization of their capabilities (Stoiber & Schönig 2022). Also, maturity models are beneficial to identify how high-quality organization's processes currently are (Wendler 2012). Therefore, maturity models are valuable tools especially for IT managers. IT managers can gain reasonable improvement measurements thought maturity models. Multiple maturity models are designed to support IT management. (Becker et al. 2009) As a role model to nowadays maturity models can be thought to be Capability Maturity Model (CMM) from the 1990s which were developed for the software engineering field. (Mettler et al. 2015) General structure of maturity models is presented in Table 3.

Pöppelbuß and Röglinger (2011) summarize that maturity models are utilized to describe the current and desired level of the organization's maturity. Moreover, models help to identify which improvements need to be made to reach the desired level of maturity. Also, according to Mettler (2009) maturity models work as tools for identifying what improvements an organization should make to reach an upper level of maturity. Maturity models are also beneficial as a competitor benchmarking base (Stoiber & Schönig 2022). De Bruin et al. (2005) summarize that maturity models are tools for facing pressures through improving quality, reducing costs, and gaining competitive advantage. So, maturity models are assisting organizations to improve their activities in the changing markets.

Maturity models are usually built by using states or levels which are together building the path from the maturity's starting phase to the desired state (Pöppelbuß & Röglinger 2011). Usually, the lowest level is the organization's starting point, and the top level describes the state where the organization has reached the uppermost maturity and the desired level (Becker et al. 2009).

The maturity levels are evaluated in different dimensions based on the organization's interests. Maturity models describe the organization's maturity in these different dimensions and the model also presents differences in the maturity of different areas. (Becker et al. 2009) Organization can for example have great maturity of technology but still lack in the suitable culture. In that kind of situation, the maturity model identifies to an organization that they must develop their culture to reach upper maturity in the maturity model's high-level subject.

Table 3. *Maturity models structure in general (adapted from Mettler et al. 2015)*

	Dimension 1	Dimension 2	Dimension n
Level 1			
Level 2			
Level n			

3.2 Maturity models of Internet of Things and Industry 4.0

According to Colli et al. (2018) there are differences in different maturity model's levels, number of dimensions and strategy of implementation. Models are used as a framework to map an organization's different digital IoT capabilities. There are several different kinds of IoT and Industry 4.0 maturity models or digital maturity models published. (Colli et al. 2018)

Three different kinds of Internet of Things or Industry 4.0 maturity models found in the literature are used in this thesis as a base for the customized maturity model made for the target organization. These chosen maturity models are presented in the next sections.

3.2.1 Maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises

Schumacher et al. (2016) have developed maturity model for assessing industry 4.0 readiness and maturity of manufacturing readiness. Their goal was to develop a model which would consider also organizational aspects of Industry 4.0 and not only technology focused aspects. The dimensions of their model are "Products", "Customers", "Operations", "Technology", "Strategy", "Leadership", "Governance", "Culture" and "People".

After developing the model, it was changed to a practical tool and tested in the real organizational environment. The model helps manufacturing firms to gain data about their current state in the Industry 4.0 point of view. It also helps determine the critical success factors. (Schumacher et al., 2016) So, one limitation of this model is that it is targeted only to manufacturing companies.

The dimensions are evaluated in the maturity's' state 1-5. According to Schumacher et al. (2016) 1 means "a complete lack of attributes supporting the concepts of Industry 4.0" and level 5 means that the attributes achieved the "state-of-the-art". The idea of the dimensions and the levels are presented in Table 4.

Table 4. *Maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises (adapted from Schumacher et al. 2016)*

Level	1	2	3	4	5
Strategy					
Leadership					
Customers					
Products					
Operations					
Culture					
People					
Governance					
Technology					

The process starts by determining the maturity dimensions and their items. Per item one standardized question is generated. The specialists in the organization are answering those questions in the Likert-scale 1-5. State 1 means that the item is not implemented and state 5 that the item is fully implemented. In the model it is required that the respondents understand the concept of the Industry 4.0. The answers to questionaries are used as a data input to determine the maturity level by using software tool.

Because all the maturity level items do not have same importance for the dimensions' Industry 4.0 maturity, the importance of the items is evaluated by the experts. The outcome of these evaluations is a weighted factor for each item.

Schumacher et al. (2016) developed a software tool for determining the maturity level of each dimension. This was done to make the process easier for the organization's employees. When the maturity levels are specified, the results are used to create representations and visualizations of maturity via software tools report. Each dimension can be represented individually, and the tool focuses on making visualizations about maturity of dimensions. The procedure to assess the Industry 4.0 maturity is presented in Figure 6.

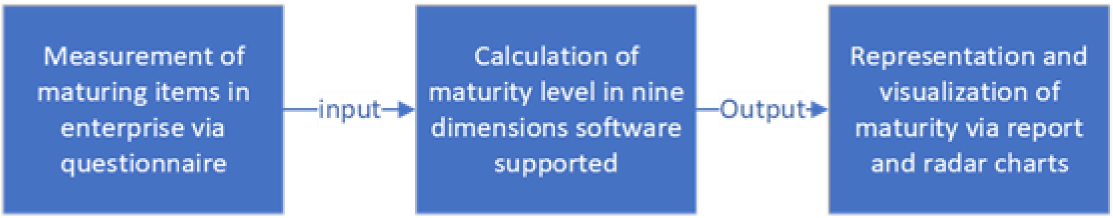

Figure 6. *Procedure to assess the Industry 4.0 maturity (adapted from Schumacher et al. 2016)*

3.2.2 Maturity model for Industry 4.0

Colli et al. (2018) maturity model includes five dimensions and six digital maturity stages (Table 5). The model is built based on multiple existing maturity models found in literature. Digital maturity stages are none, basic, transparent, aware, autonomous and integrated. Digital dimensions which maturity is evaluated are grouped into five areas and they are governance, technology, connectivity, value creation and competence. In the Colli et al. (2018) model the levels are named as stages.

Table 5. *Maturity model for Industry 4.0 (Colli et al. 2018)*

Stage	None	Basic	Transpar-ent	Aware	Autono-mous	Integrated
Govern-ance						
Technol-ogy						
Connec-tivity						
Value cre-ation						
Compe-tence						

Each stage has its own description (Table 6). In the Colli et al. (2018) model, to get to a certain stage, all the features of the preceding stages must be completed. That means that to reach for example transparent stage also basic level has to be achieved.

Table 6. *Stages and descriptions of Industry 4.0 maturity model (adapted from Colli et al. 2018)*

Stage	Description
None	No digital awareness, no idea or plan, no willingness to use data in the organization, documentation is done in paper or not done at all
Basic	Digital processes exist, processes generate digital data, management's willingness on the digital transformation
Transparent	Collected data is shared, management has digitalization plan
Aware	Data is analyzed to capture insights for business, clear digitalization agenda shared through the whole organization
Autonomous	Decision making is autonomously and based on data from the organization and its main stakeholders, digital development is well established in the whole company's practices
Integrated	Decision making is autonomously and based on data from the organization and its all networks, digital development is well established in the whole company's and stakeholders practices

Industry 4.0 maturity model has 5 digital dimensions which are governance, technology, connectivity, value creation and competence. Each of these digital dimension's contents has its own description presented in Table 7.

Table 7. *Digital dimensions definitions (adapted Colli et al. 2018)*

Digital dimension	Contents
Governance	Strategy and plan, resource allocation, digital awareness, engagement on different hierarchical levels
Technology	Business intelligence tool, cloud computing platform, Manufacturing Execution System (MES), ERP, augmented and virtual reality tools
Connectivity	Data sharing capabilities, IT security, standard data structuring or data transmission architectures
Value Creation	Pay-per-use or pay-per-save business model, take-back program, data usage for orders forecasting or product usage monitoring to enable predictive maintenance or guide the product design
Competence	Digital competences, training culture, learning culture

3.2.3 Maturity model for assessing readiness in digital transformation and business processes improvement

Stoiber and Schönig (2022) have developed maturity model for "assessing readiness to effectively exploit IoT-based BPI (Business Process Improvement)". Their model includes 21 dimensions of capability which describes organization's action areas. Each of these dimensions has its own capabilities described in the four levels. In addition, an organization's fitness to exploit IoT for BPI is also evaluated with the formulated five maturity levels. To reach a certain maturity level organization must reach a set of particular capability levels defined by Stoiber and Schönig (2022). Stoiber and Schönig (2022) have used translation metric to present which capability levels are needed to achieve each of the maturity levels. Stoiber and Schönig's (2022) capability matrix is presented in Table 8.

In the maturity model the maturity levels are initial (1), managed (2), defined (3), quantitatively managed (4) and optimized (5). Focus areas are "Strategy & Leadership", "Culture, Ethics & Behavior", "People, Skills & Competences", "Infrastructure and Data", "Business Process Management", "IoT Application Maturity" and "IoT Integration into Business Processes".

Each focus area is divided to capability dimensions. In the “Strategy & Leadership” focus area the capability dimensions are:

- IoT vision,
- decision making.

In the “Culture, Ethics& Behavior” focus area the capability dimensions are:

- technology affinity,
- continuous improvement culture,
- interdisciplinary, interdepartmental collaboration.

In the “People, Skills & Competences” focus area the capability dimensions are:

- knowledge management,
- IoT competences along employees,
- dedicated teams for IoT,
- dedicated teams for Business Process Management (BPM).

In the “Infrastructure and Data” focus area the capability dimensions are:

- enterprise software systems,
- networking,
- data processing,
- data analytics and interpretation.

In the “Business Process Management” focus area the capability dimensions are:

- alignment and methods,
- process performance controlling,
- process documentation.

In the “IoT Application Maturity” focus area the capability dimensions are:

- IoT architecture,
- IoT technology.

In the “IoT Integration into Business Processes” focus area the capability dimensions are:

- system integration,

- behavioral and organizational impact,
- functional and operational impact.

Each of these capability dimensions are evaluated in levels 1-4. After that the levels are compared to translation metric. (Stoiber & Schönig 2022)

Table 8. *Capability Matrix (adapted from Stoiber & Schönig 2022)*

Focus Area	Capability dimension	Level 1	Level 2	Level 3	Level 4
Strategy & Leadership					
Culture, Ethics & Behavior					
People, Skills & Competences					
Infrastructure and Data					
Business Process Management					
IoT Application Maturity					
IoT integration into Business Processes					

4. MATURITY MODELS' EVALUATION AND NEW MODEL DEVELOPMENT BASED ON EXISTING MATURITY MODELS

In this chapter, maturity model (MM) customization in general and for the target organization are described. The target organization is also introduced. The customized maturity model is based on the maturity models presented in chapter 4. In this chapter the process of customizing the maturity model and the outcome of the customization is presented. The used maturity model is first introduced as a matrix that includes dimensions and maturity levels. After that the dimensions and each dimension's maturity levels are introduced specifically.

4.1 Designing and customizing maturity models in general

Every organization is different on some level than others. At least the organization's requirements and goals differ, so the maturity models can be customized to fit each organization's needs. (Colli et al. 2018) Numerous different kinds of maturity models are developed to help organizations to find suitable models for their domain (De Bruin et al. 2005). In addition, it is important to highlight that developed maturity models should be updated continuously to ensure the model usability and that it is measuring the right things (De Bruin et al. 2005).

In general maturity models' qualities should be correctness, relevance, flexibility, understandability, implementability and economic efficiency. The model itself should be valid, reliable, and cost efficient. Maturity models which include features such as software tool support, standardization, flexibility, benchmarking, or certification, are more probable leading to success of the maturity model's adoption and performance (Pöppelbuß & Röglinger 2011). Usually, maturity models are described as matrices that include different dimensions on one axis and levels or stages on the other axis (Stoiber & Schönig 2022).

According to Wendler (2012) it is beneficial to test the maturity model in its development phase to ensure applicability. Tests results may have influence on already designed parts of the maturity model which should be re-engineered based on the tests. Schumacher et al. (2016), Colli et al. (2018) and Stoiber and Schönig (2022) models which are used as bases for the customized maturity model, are all tested.

Customizing maturity models is started with determining the basic information. Basic information are things such as “application domain and prerequisites for applicability, purpose of use, target group, class of entities under investigation, differentiation from related maturity models and design process and extent of empirical validation” (Pöppelbuß & Röglinger, 2011)

Mettler (2009) has defined that maturity model development cycle has four phases:

- define scope,
- design model,
- evaluate design,
- reflect evolution.

These phases are implemented with the iterative cycle presented in Figure 7. In the design scope phase, the model’s developer needs to make some important decision about the maturity model’s scope and limitations. The define scope phase should include for example model’s focus, level of analysis, novelty, audience and dissemination. Model focus can for example be generalistic or a more specific subject-matter. In the design model phase decision is made about model’s maturity definitions, goal functions, design process, design product, application method and respondents. So, the design model phase is all about developing the actual maturity model. In the evaluation design phase, decisions are made about the subject of evaluation, timeframe and evaluation method. In that phase the model’s verification and validation are concerned. Reflect evolution phase is about model’s subject of change, frequency, and structure of change. (Mettler 2009)

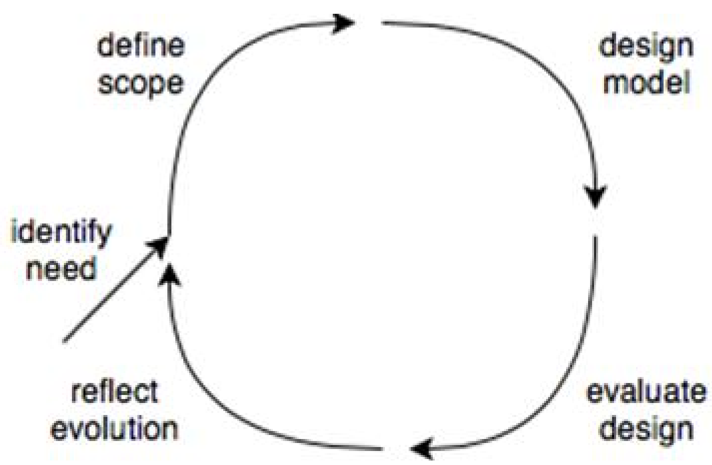

Figure 7. *Maturity model development iterative phases (adapted from Mettler 2009)*

De Bruin et al. (2005) maturity model development phases differ from the Mettler's (2009) development phases. De Bruin et al. (2005) have identified that developing maturity models have six phases which are presented in Figure 8. De Bruin et al. (2005) model is suitable for different industries' maturity model development.

Maturity assessment can be divided into descriptive, prescriptive, or comparative nature. Purely descriptive models are good for assessing an organization's as-is situation. Descriptive model's application can be seen "as single point encounters with no provision for improving maturity or providing relationships performance". A prescriptive model starting point is to highlight domain's business performance and how improving organization's maturity can affect creating better value. The model is a great tool for creating roadmaps for organizations to enable better business. Comparative models are great tools for benchmarking. Benchmarking can be done between different industries. (De Bruin et al. 2005)

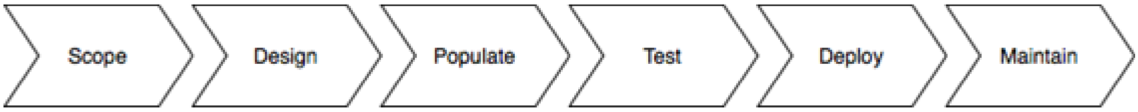

Figure 8. *Six phases of developing maturity model (adapted from De Bruin et al. 2005)*

The order of the phases is important but some of the phases can on the other hand have iterations. For example, phase's design, populate and tests may be iterative. Iteration means that even if some earlier phase is already implemented, there is possibly to revisit and adjust the decision made in that earlier phase. The main actions related to phases, which De bruin et al. (2005) has identified in maturity model development, are presented in the Table Ö.

In phase one, the scope and the main focus of the model are determined, and boundaries set for application and use of the model. The model's focus can be domain specific or general. The development stakeholder is chosen from academia, practioners, government or combination of those. In the second phase, the model's design architecture is chosen. In that phase the model's audience, method and driver of application, respondents are also defined. In the populate phase, what is measured and how that can be measured is identified. In the testing phase the model's validity, reliability and generalizability are tested. In the deploy phase, the model is made available for use. The maintain phase contains continuous development of the model. (De Bruin et al. 2005) Rafael et al. (2020) has also introduced a framework for selection and adaptation of the maturity model. The framework is presented in Table 9. The framework has six phases:

- the selection of the maturity model,
- diagnosis,
- criteria setting,
- implementation design: the case study approach,
- company selection,
- maturity model testing and evaluation process.

Table 9. *Framework for developing maturity model (adapted from Rafael et al. 2022)*

Phase	Role	Method
The selection of the maturity model	Maturity model value assessing. Existing MM evaluation.	Literature review and analysis. Consensus decision making.
Diagnosis	Dimensions and sub-dimensions design and adaptation.	Consensus decision making.
Criteria setting	Choice's validation, question definition, maturity levels definition	Concept sorting
Implementation design: the case study approach	Research method validation	Literature review and analysis
Company selection	Selecting company	Consensus decision making
Maturity model testing and evaluation process	Testing and validation	Face to face meetings, interview, consensus decision making

4.2 Target organization

The target organization is a Finnish welding company which designs and manufactures manual arc welding equipment, safety equipment for welding, and software and automated welding machines. One of the target organization’s core competences is in product development. The customized maturity model is designed based on the organization's need to understand their current IoT and Industry 4.0 maturity, recognize opportunities to improve their business and new product development and tackle some challenges.

Target organization’s personnel are participating in customizing the maturity model in some phases of the model development. In that way the goal is get feedback about possible needs of making improvements to the final model so that it will support the target organization interests. The target organization also participates in the determination of the organization’s current maturity levels by interviews.

4.3 Customizing maturity model for target organization

The maturity model for the target organization was created using Rafael et al. (2020) MM development framework. Rafael et al. (2020) developed their Industry 4.0 maturity model based on existing models found in literature. Because this thesis also handles IoT and there are already many existing maturity models about IoT and Industry 4.0 in the literature, those already existing models are used as a base of the customized model. Also, developing phases introduced in the Rafael et al. (2020) framework are also suitable for this thesis and the maturity model is built based on those phases. De Bruin et al. (2005) presented that maturity models can be descriptive, prescriptive, or comparative. For developing the maturity model for the target organization, the starting point of the model is built to be descriptive because from the target organization's point of view improving their business through IoT is beneficial.

In the first phase, existing maturity models from the literature were chosen to be the base of the developed maturity model. Existing maturity models were reviewed and two Industry 4.0 / IoT maturity models were chosen to be the base of the new model. The models were chosen because they were available, tested, easy to use, at least got Publication Forum ratings level one, and they were related to Industry 4.0 or IoT. Optional criteria were that the model was developed for manufacturing enterprises. In addition, the chosen models' dimensions were interesting in the target organization's point of view. Colli et al. (2018) maturity model was selected as the base on which to build the adapted model. Also, Schumacher et al. (2016) model was chosen to be used together with Colli et al. model.

In the second phase, diagnosis, the models were reviewed together with the thesis's supervisor from the Tampere University. Colli et al. (2018) model was simple and easy to use, dimensions were easy to understand so the model was great starting point for developing new model. Schumacher et al. (2016) model got little more into detail and there were nine dimensions which were quite a lot more than in Colli et al. (2018) model. On the other hand, Schumacher et al. (2016) did not describe different maturity levels in detail. So, maturity level definitions were dome adapting Colli et al. (2018) model.

In the third phase the maturity model's dimensions, sub-dimensions and maturity levels were designed based on the existing models. Each of these objects was presented in detail. Dimensions which were chosen to develop the model were widely used in the IoT maturity models. In phase four, the MM's implementation design was done. Some suitable data collection methods were identified such as workshops, interviews, and discussions. Open individual interviews were chosen to be the method for data collection. The method was chosen based on the target organization's busy employees' calendars. Also, they were chosen because individual interviews were seen as a safe way to determine the organization's current state without pressure on other participants.

The fifth phase was skipped because the target company was already selected in the beginning of the thesis journey. In the sixth phase maturity model was evaluated together with the thesis supervisor and with the target organization's IoT experts. Collected feedback was gathered through the open discussion from the qualitive form. In phase six it was found that the maturity model under development did not include the organization's process. Based on that feedback the necessity of the processes was evaluated and they were identified important as they generate and enable data flows in the organizations. So, processes were chosen to be added to the maturity model. Because Colli et al. (2018) and Schumacher et al. (2016) models did not include process dimensions, a new maturity model was chosen. Stoiber & Schönig (2022) maturity model which considers organization's processes and IoT was chosen from the literature. Process dimensions were added based on that model. The model had some suitable information about other dimensions, so those were also updated. Other maturity models were evaluated again after those modifications. Some phases were implemented multiple times so Rafael et al. (2020) framework was used in iterative way.

4.4 Customized maturity model for target organization

Colli et al. (2016) maturity model works as a base for the maturity model developed for the target organization. Also, Schumacher et al. (2016) Industry 4.0 maturity model is used in some points of the development of the maturity model for the target organization.

The Schumacher et al. (2016) model has nine dimensions, so it is laborious to go through all the dimensions in the target organization. There is also opportunity to unite some of the Schumacher et al. (2016) dimensions to each other such as people and culture. This research has limitations on its timeline and the organization's interviewees strict schedules. Colli et al. (2018) model has five dimensions: governance, technology, connectivity, value creation and competence. These dimensions are used in this research. Schumacher et al. (2016) dimensions are seen as a subset of Colli et al. (2018) dimensions. For example, in the customized model, Colli et al. (2018) governance dimension includes Schumacher et al. (2016) leadership, strategy and governance dimensions. Also, Colli et al. (2018) value creation dimension includes Schumacher et al. (2016) products and customers dimensions. Schumacher et al. (2016) people and culture dimensions are seen as a part of the Colli et al. (2018) competence dimension. So, Schumacher et al

(2016) and Colli et al. (2018) maturity model's dimensions are combined in appropriate parts based on literature research.

In the Schumacher et al. (2016) model, the maturity model levels are defined in a non-specific way from 1 to 5. To get a more precise result of the target organization's maturity, the levels need to be more specifically defined. Colli et al. (2018) model includes six IoT maturity stages which are used same way as Schumacher et al. (2016) levels. In this master's thesis digital maturity stages are called levels according to Schumacher et al. (2016). The levels are according to Colli et al. (2018) none, basic, transparent, aware and autonomous. The final customized maturity models' structure is presented in Table 10,

Table 10. *Customized maturity model for target organization (adapted Colli et al. 2018; Schumacher et al. 2017; Stoiber & Schönig 2022)*

	Governance	Technology & Connectivity	Data-analytics based decision making	People	Processes
None = 1					
Basic = 2					
Transparent = 3					
Aware = 4					
Integrated = 5					

4.4.1 Governance

Governance dimension includes for example according to Colli et al. (2018) organization's strategy, plan, resource allocation, digital awareness and engagement on different hierarchical levels concerning IoT. Colli et al. (2018) maturity model's governance dimension combines Schumacher et al. (2016) dimensions of strategy, leadership, and governance. Schumacher et al. (2016) has listed that these three dimensions include items such as implementation of IoT roadmap, resources for IoT realization, adaption of business models, management competences, labor regulations for IoT, suitability of technological standards and intellectual property protection. Also, according to Stoiber and Schönig (2022), organization's management and strategy have importance in the selection of IoT projects. Summary of governance dimensions' level description is presented in Table 11.

The target organization's customized model sub-dimensions are chosen based on Schumacher et al. (2016) and Colli et al. (2016) maturity models. Sub-dimensions are chosen using "critical few"-principle so all the items are not evaluated. Rather, the most important ones are picked based on the target organization. The chosen items are IoT plan and roadmap, resource allocation for IoT realization, business models IoT adaptation and data governance.

Organization's data governance is included in the governance dimension. Data governance describes for example decision rights for defining data quality standards and practices on how data is gathered, processed, and disposed of. Data governance also includes business process management, data management, security, and architecture. (Khatri & Brown 2010) Because of the huge scope of data governance, only existence of data governance is considered in the governance dimension of the target organization. Some subsets of data governance such as data quality and business processes are considered in the other dimensions.

In the maturity level 1, the organization does not have a plan or idea concerning Industry 4.0 or IoT transformation. Organization's strategy does not include IoT related projects or other actions. There are no resources for working in the IoT related work tasks. (Colli et al. 2018) In this level organization's business models do not include IoT activities. (Schumacher et al. 2016) Organization does not have either data governance actions or structure.

In maturity level 2, the organization's management has a willingness to implement and plan strategy for IoT. In this level the organization has not defined a specific plan or strategy for IoT. (Schumacher et al. 2016; Colli et al. 2018). Organizations management knows what IoT is and understands how it can be used for creating value (Stoiber & Schönig 2022). The organization has not defined any resources for the IoT development yet. (Schumacher et al. 2016; Colli et al. 2018) In addition, business models do not include any IoT activities yet, but management has willingness to consider them. (Schumacher et al. 2016) In the organization, data is governed informally and there is no structure for data governance.

In maturity level 3, the organization has IoT roadmap shared at the management level. IoT resources and activities are defined in the organization and the information is shared mainly at the management level. The agenda and development direction of IoT is defined at the management level. (Schumacher et al. 2016; Colli et al. 2018) Organization has planned and brainstormed possible business models related to IoT. (Schumacher et al. 2016) In addition, informal data governance is formalized.

In the maturity level 4, organization has a detailed roadmap and vision for digitalization and IoT (Colli et al. 2018; Stoiber & Schönig 2022). The organization has already defined needed resources and activities. In addition, the plans and agenda related to IoT are shared at the organization's hierarchical levels. (Colli et al. 2018) Organization's business models include IoT activities. (Schumacher et al. 2016) In that level the data governance is carefully planned and implemented and data owning responsibilities are determined.

In the maturity level 5, IoT development is well established within the whole organization. Management has strong support and willingness for IoT related programs and projects. IoT has central coordination at the management level. Management has needed competences and methods to support IoT actions and strategy, technological standards are suitable for IoT and related actions. Organization has carefully planned and implemented IoT roadmap. Organization has the needed resources for implementing and supporting the IoT goals and action. The organization has dedicated teams for IoT development and management. (Stoiber & Schönig 2022) Also, organization business models are fully adapted and customized to fit IoT. (Schumacher et al. 2016; Colli et al. 2018) Data governance is carefully planned, in action, and reviewed time by time, and data is seen as a strategic element in the whole organization.

Table 11. *Level descriptions summary of governance dimension*

	Governance
Levels	Sub-dimensions: IoT plan, resource allocation for IoT realization, IoT adaptation of business models, data governance.
None = 1	No IoT plan, no resources or activities allocated, business models don't include IoT, no data governance actions or structure.
Basic = 2	Management has a willingness to plan IoT roadmap, no resources or activities allocated yet, business models do not include IoT but there is willingness to do so, data is governed informally and there is no structure.
Transparent = 3	IoT roadmap planned but only shared in the management level, preliminary resources and activities are defined and shared in the management level, IoT related business models are identified, informal data governance is formalized.
Aware= 4	Detailed plan for IoT implementation is done and shared in the organization, IoT related activities and resources are defined and shared in all the organization's hierarchical levels, IoT related business models is carefully planned, data governance structure planned and data owning responsibilities determined.
Integrated = 5	IoT development is well established in the whole organization's level and is in the development phase, dedicated teams and roles defined for IoT management and development projects, business models are fully adapted and customized to fit IoT, data governance is carefully planned and in action, data is seen as a strategic element.

4.4.2 Technology and connectivity

Technology and connectivity dimensions are combined, because they both represent the organization's ability to process and generate data in digital form. The dimension describes the organization's inside and outside infrastructural elements which are needed to transfer data. These mean things such as architectures for data transfer. (Colli et al. 2018; Stoiber & Schönig 2022) Sub-dimensions evaluated in this dimension are IoT technology, IoT architecture and networking. Summary of technology and connectivity dimensions' level description is presented in Table 12.

Used technologies can be, for example, business intelligence tools, cloud computing platforms or augmented and virtual reality tools. (Colli et al. 2018) In general, this means that in an organization IoT technology must exist to enable IoT activities.

From the connectivity point of view, networking capabilities are also evaluated in this dimension. (Stoiber & Schönig 2022) Because the target organization is interested in their digital products' connectivity and IoT level, the networking is evaluated in the perspective of the products.

In the maturity level 1, the organization does not have the technology needed for IoT realization. Everything in the organization is registered and documented on paper manually or not registered at all. Organization does not have capabilities to generate digital data and no capabilities or no idea how it should be enabled. (Colli et al. 2018)

In maturity level 2, organization has some elements which are needed to generate and process digital data. The organization has a willingness to develop and take into use more modern IoT technology. Also, the organization adopts a basic IoT layer architecture. Organization uses RFID or sensors but with limited functionality. Networking technologies such as basic wired Local Area Network (LAN) and wireless (Wi-Fi) are implemented to products and processes. (Stoiber & Schönig 2022)

In maturity level 3, infrastructural elements that make it possible to generate and process digital data exist in the organization. The organization uses for example cloud computing and middleware layer that enables interoperability and device technology. In addition, organization's products and processes are implemented with more advanced technologies such as 2G/3G/4G/5G or Bluetooth. (Stoiber & Schönig 2022) There are some lacks in the existing technology. Some of the information systems can be, for example, out-of-date and some of them missing. Organization has a plan for acquiring or developing new needed technologies. (Schumacher et al. 2016; Colli et al. 2018)

In the maturity level 4, organization's technology is enabling them to produce valuable information and to understand business insights based on the captured data. Some of the technologies could be chosen better to make business insights. The organization has an availability of infrastructural elements needed for internal and external data transmission. Products and assets communicate horizontally and directly within a closed environment. (Shumacher et al 2016, Colli et al. 2018) Organization has in use more advanced technologies such as low-energy Personal Area Network (PAN) communication protocols, e.g., ZigBee, BLE or Long Range (LoRA) (Stoiber & Schönig 2022).

In the maturity level 5, organization has in use (all needed) modern suitable technologies for creating value through IoT. Technology is not a bottleneck for IoT development, and technology is enabling new possibilities for Industry 4.0 solutions. IoT architecture is prepared to be reused in different applications within the company. Organization's products are integrated into other systems. In addition, the organization has in use enhanced mobile broadband, massive machine communication and ultrareliable low-latency communication. The organization also adopts Hadoop and Storm technologies for big data processing, neural network-based methods for prediction. (Stoiber & Schönig 2022)

Table

Table 12. *Level description summary of technology and connectivity dimension*

	Technology and connectivity
Levels	Sub-dimensions: IoT technology, IoT architecture, networking.
None = 1	No required technology for IoT implementation, no IoT architecture, no data transmission possibilities.
Basic = 2	Organization has some technical elements needed for IoT implementation and willingness to take more advanced technology to use, organization adapts basic IoT layer architecture, some use of RFID or sensors but with limited functionality, basic wired (LAN) and wireless (Wi-Fi) networking technologies implemented to products and processes.
Transparent = 3	Organization has needed technology for IoT implementation, availability of the infrastructural elements needed for internal data transmission exist, cloud computing, middleware layer that enables interoperability and device technology, basic and more advanced technologies such as 2G/3G/4G and Bluetooth implemented to products and processes.
Aware= 4	Elements that make it possible to generate and process digital data existing in the organization and they are in active use, technology enables making business insights based on data, availability of the infrastructural elements needed for data transmission internal and external, basic and more advanced technologies such as low-energy PAN communication protocols, e.g. ZigBee, BLE or LoRa are in use.
Integrated = 5	Organization has (all needed) modern suitable IoT technology for creating value, IoT architecture is prepared to be reused in different applications within the company, products are integrated to other systems, enhanced mobile broadband, massive machine communication and ultrareliable low-latency communications are in use, Hadoop and Storm technologies for big data processing, neural network-based methods for prediction.

4.4.3 Data-analytics based decision making

Data-analytics based decision making refers to the organization’s capability to create and capture value from available data. Value can also be created through the products designed or predictive maintenance which are based on the product usage monitoring.

(Colli et al. 2018) Business models' adaptation is evaluated in the governance dimension. Sub-dimensions evaluated in this dimension are insights/value creation based on data, data-analytics phase, data's availability, and data's quality. Summary of data-analytics based decision making dimensions' level description is presented in Table 12.

In the maturity level 1, the organization does not have the ability or willingness to capture value from the available data. Value creation possibilities are not identified in the organization. Data is not used either for designing new products or predictive maintenance. Data's quality can be poor, and data is not available. (Colli et al. 2018; Stoiber & Schönig 2022)

In maturity level 2, the organization has the willingness to capture value from the available data. In this level data is not yet used for value creation but value creation possibilities are identified in the organization. (Colli et al. 2018) Organization has established preliminary data-analytics which are sparsely implemented. (Colli et al. 2018; Stoiber & Schönig 2022) Some needed data can be gathered and stored and some simple processing is performed. Some data required for analytics is available but there might be some limitations. (Colli et al. 2018; Stoiber & Schönig 2022)

In maturity level 3, the organization is collecting and sharing data according to value stream needs. (Colli et al. 2018) Organization is able to create value through analytics. The organization is conducting basic level IoT analytics, but it is still mainly ad hoc. Organization has established descriptive analytics. IoT is capable of aggregating data into simple context data. Used data can be, for example, alert data from the equipment. Data is available but with no full potential. (Stoiber & Schönig 2022)

In the maturity level 4, the organization is creating and capturing value through the collected data. Insights are made based on, for example, proactive activities identification by crossing error data, product number and machine downtime data. (Colli et al. 2018) The organization has established diagnostic analytics. (Markkanen 2015) All the required data is available. (Stoiber & Schönig 2022) In addition, techniques for ensuring data quality are applied. Through data analytics data-based insights are produced for business. (Colli et al. 2018)

In the maturity level 5, decision making is based on the automatically synchronized data gathered from the organization's whole network. The organization is for example utilizing customer data. The organization has created individualized products based on the analyzed data and the products are integrated to other systems. Data is analyzed to be used in product usage monitoring to enable predictive maintenance or guide the product design. (Colli et al. 2018) Organization's data analytics are at least in the predictive level, also some prescriptive elements can be already reached. (Markkanen 2015; Colli et al. 2018) Organization sales and services are utilizing digitalization (Colli et al. 2018). Data has become critical and important to manage. (Stoiber & Schönig 2022) High-frequency event data from heterogenous sources can be processed and complex event processing is applied. (Colli et al. 2018)

Table 13. *Level description summary of data-analytics based decision making dimension*

	Data-analytics based decision making
Levels	Sub-dimensions: Insights/value creation based on data, data-analytics phase, data's availability, data's quality.
None = 1	No value created through IoT data, and no value creation possibilities identified, no data-analytics, data isn't available, data quality is poor.
Basic = 2	Value creation possibilities identified based on IoT, preliminary data-analytics, data-analytics are sparsely implemented, data can be stored, and simple processing is performed, some needed data for analytics is available but there are some limitations, with data quality might be some problems.
Transparent = 3	Insights based on historic data to support business, basic analysis of IoT data is conducted but IoT analytics is mainly still ad hoc, descriptive analytics, IoT is capable of aggregating data into simple context data, data is available but not in full potential, data quality is mostly good.
Aware= 4	Value created through the analytics, diagnostic analytics (data mining, correlations etc.), analyses based on calculations and co-relations, patterns based on rules, proactive activities identification by crossing error data, product number, machine downtime etc., aggregation of data into complex context data, techniques for ensuring data quality are applied.
Integrated = 5	Customer's and product's data are utilized to guide product design and decision making, predictive analytics (machine learning, Artificial Intelligence (AI), algorithms etc.), data is critical and important to manage, all the needed data is available and data quality is high and actively managed.

4.4.4 People

People dimension includes organization's skills and digital competences needed for making the digital transformation and handling technology (Colli et al. 2018). Schumacher et al. (2016) people dimension is included in the Colli et al. (2018) competence dimension. Schumacher et al. determine people dimension to include employees' ICT competences, employee's openness, and willingness to take new technologies into use and overall autonomy and self-control of organization's employees. In addition, according to Stoiber and Schönig (2022), continuous improvement culture can be seen as a part of the dimension. Sub-dimensions in this dimension are IoT skills and competences, openness to new technologies and self-learning. and knowledge sharing culture. Summary of people dimensions' level description is presented in Table 14.

As a summary, having a workforce with the necessary competence to implement IoT technologies can greatly support company's IoT adaptation. On the other hand, if a company's workforce lacks the necessary skills and knowledge about IoT, only basic technologies can be implemented and full potential and all the benefits cannot be reached. This can also make it more difficult for a company to adopt advanced technologies and fully embrace Industry 4.0. (Colli et al. 2018; Stoiber & Schönig 2022) Organization culture is also affecting employees' willingness to take new technologies to use (Stoiber & Schönig 2022).

Effective governance can help to ensure that Industry 4.0 and IoT initiatives are aligned with the overall strategy and objectives of the company, and that they are implemented in a way that is consistent with the company's values and culture. This can include having clear policies and procedures in place for data collection, storage, and analysis, as well as for the implementation and maintenance of Industry 4.0 and IoT technologies. (Schumacher et al. 2016) If an organization is willing to develop and redesign their business processes, expertise in that area is also required. (Stoiber & Schönig 2022)

In the maturity level 1, the organization's employees do not have the skills needed for IoT technology development. Employees do not have openness to new technologies. (Colli et al. 2018) Organization's employees are not motivated for improvements (Stoiber & Schönig 2022). No knowledge sharing culture exist in the organization (Colli et al. 2018).

In maturity level 2, the organization's employees have basic level skills needed for IoT technology (Colli et al. 2018). These skills can be for example initial experience based on past projects. Employees are neutral about new technologies, they do not resist them, but they are also not fully accepted. (Stoiber & Schönig 2022) Knowledge is shared rarely in the organization, for example through trainings where they are asked to do so. (Colli et al. 2018; Stoiber & Schönig 2022).

In maturity level 3, the organization's employees have average skills with IoT technologies, and they can for example have experience through isolated projects related to IoT. (Colli et al. 2018; Stoiber & Schönig 2022) Also, new technologies are accepted by employees. Knowledge is shared between most of the team at some level in the organization. Knowledge management practices are planned, and benefits are observed and monitored time by time. (Colli et al. 2018)

In the maturity level 4, the employees have experience and knowledge about IoT internal and external. The employees have the possibility to educate themselves through IoT-related trainings. They are also interested in new technologies, and they are learning them continuously. Organization culture also supports learning new technologies. Knowledge about IoT is changed between experts. (Stoiber & Schönig 2022) In addition, organization culture supports knowledge sharing and knowledge is shared through all the teams effectively. Knowledge is reused at project levels. (Stoiber & Schönig 2022)

In the maturity level 5, the employees have great IoT technology skills, and they are continuously and autonomously learning new technologies by themself. The organization is organizing their employees' education possibilities and employees are already experienced IoT through targeted IoT trainings and current ongoing projects. (Colli et al. 2018; Stoiber & Schönig 2022) Organization's employees can recognize their education and skill competence needs themselves. Effective knowledge sharing and open-innovation are daily-basis in the organization's culture. (Colli et al. 2018) Organizations knowledge is seen as a critical asset and it is important to manage. (Stoiber & Schönig 2022). Also, tacit knowledge can be shared effectively in the organization and employees have willingness to do that. (Colli et al. 2018)

Table 14. *Level description summary of people dimension*

	People
Levels	Sub-dimensions: IoT skills and competences, openness to new technologies and self-learning, knowledge sharing culture.
None = 1	No needed skills and experience about IoT technologies, employees don't have openness to new technologies and no motivation for improvements, no knowledge sharing culture.
Basic = 2	Basic level IoT skills which can be based on initial experience from past isolated projects, employees are neutral for new technologies, not full acceptance but not resistance, knowledge is shared rarely through trainings where they are asked to do so, no formal knowledge management practices.
Transparent = 3	Average IoT technology related skills from isolated current IoT related projects, new technologies accepted by employees, knowledge is shared between most of the teams, knowledge management practices are planned, and benefits are observed and monitored.
Aware= 4	Employees have experience and knowledge about IoT technologies internal and external, organizations employees' have possibility to educate themselves through IoT related trainings, employees are interested in new technologies, and they are learning them continuously, IoT knowledge is changed between experts, organization culture supports knowledge sharing and knowledge is shared through all the teams effectively, knowledge is reused at project levels.
Integrated = 5	Employees have great IoT skills and employees are able to recognize IoT education and skills needed themselves, organization is organizing employees education possibilities and they already have experience in IoT through targeted IoT trainings, employees are continuously and autonomously learning new technologies by themselves, tacit knowledge is shared effectively and employees have willingness to do so, in the organization the knowledge is seen as a critical asset and knowledge sharing comes from the organization's culture.

4.4.5 Processes

Managing business processes and re-engineering them is one of the most popular strategic methods for improving business profitability in organizations. (Jha et al. 2016) Re-engineering is usually done based on poor working processes or because of changing environment or markets. Business processes include an organization's main activities which are using the organization's resources. (Park et al. 2017) That is why managing business processes is important and the connection to business profitability exists. Business process re-engineering is part of business process management. Business process re-engineering is a method for developing better working processes for enabling better performance of the processes or other strategic goals. (Fasna & Gunatilake 2019) Also organization's data gathering and utilizing is done through the processes, so process-driven thinking is important in the IoT context. Summary of processes dimensions' level description is presented in Table 15.

In the processes dimension organization's ability to manage and utilize IoT data in the process-perceptive is evaluated. Processes management is important for an organization to understand process sequences and workflows. Processes can be seen as concrete process steps, activities, and events. Methods of managing business processes are also included in the dimension's scope. The existence of proper process documentation is also highly important for managing processes in the organization. (Stoiber & Schönig 2022) Sub-dimensions evaluated in this dimension are business process documentation, processes for enabling and utilizing data, and business process re-engineering based on data.

In the maturity level 1, organization's processes are not documented at all or documented on paper. The organization does not have designed processes for enabling and utilizing data. IoT is not affecting organization's activities and processes are not reviewed or re-engineered. (Stoiber & Schnönig 2022) §

In the maturity level 2, organization's processes are not structured and lack clear definitions. Some processes for enabling data exist but processes for utilizing the data are unclear. In addition, IoT is not influencing the actual process activities and its execution yet but there is planning to do so in the future. Importance of processes is noticed at the management level. (Stoiber & Schönig 2022; Colli et al. 2018)

In the maturity level 3, the process documentation is primarily functional but identifies the interconnections among process entities. Processes are actively managed and reviewed. (Stoiber & Schnönig 2022) Processes for enabling and utilizing data exist for descriptive analytics. (Stoiber & Schnöig 2022; Markkanen 2015) Also, process activities are changed and improved by implementing basic IoT technology. (Stoiber & Schönig 2022)

In the maturity level 4, there is a description of interfaces with other processes and enterprise systems as well as the architecture (Stoiber & Schönig 2022). Also, processes for enabling and utilizing data exist for diagnostic analytics (Markkanen 2015; Stoiber & Schönig 2022). Process task execution is directly influenced by providing user interfaces (Stoiber & Schönig 2022).

In the maturity level 5, there is an electric representation of the process design which supports process reconfiguration. Processes for enabling and utilizing data exist and processes are continuously managed and seen as critical and important in the organization. (Stoiber & Schönig 2022) Organization's processes enable predictive analytics (Stoiber & Schönig 2022; Markkanen 2015). In addition, organization's process activities and interactions with process entities are redesigned by integrating IoT (Stoiber & Schönig 2022).

Table 15. *Level description summary of processes dimension*

	Processes
Levels	Sub-dimensions: Business process documentation, processes for enabling and utilizing data, business process re-engineering based on data.
None = 1	Processes are not documented at all, processes for enabling and utilizing data are not designed, IoT is not affecting organization's processes.
Basic = 2	Processes are not structured and lack clear definitions, processes for enabling data exist but processes for utilizing data are unclear, IoT is not influencing the actual process activities and its execution yet but there is willingness to do so.
Transparent = 3	Documentation is primarily functional, but it identifies the interconnections among process entities, processes for enabling and utilizing data are existing for descriptive analytics, process activities are changed and improved by implementing IoT technology.
Aware= 4	There is description of interfaces with other processes and enterprise systems as well as the architecture, processes for enabling and utilizing data exist for diagnostic analytics, process task execution is directly influenced by providing user interfaces.
Integrated = 5	An electric representation of the process design supports process reconfiguration, processes for enabling and utilizing data exist and processes are continuously managed and seen as critical and important, processes enable predictive analytics, process activities and interactions with process entities are redesigned by integrating IoT.

5. RESEARCH PROCESS

Research methodology used in this thesis is explained and presented in this chapter. First, chosen research strategy, approaches to theory development, research philosophy and research ethics are presented. After that, data collection and analyzation are explained.

5.1 Research methodology and philosophy

Research methodology describes what methodologies are used in the research process to answer the research questions. Different research methodologies are for example research philosophy, research strategy, time horizon, approach to theory development etc. (Saunders et al. 2019)

According to Saunders et al. (2019) there are seven research strategies that can be used for answering research questions. These strategies are case study, action re-search, grounded theory, survey, ethnography, archival research, and experiment. In this thesis the used research strategy is a case study. Case study is a suitable research strategy when there is specific in-depth research problem. However, case studies are not suitable when the findings should be generalizable to other cases. (Saunders et al. 2019)

The case under research is the target organization. The research case is the defining of the organization's current and target IoT maturity and creating a roadmap to achieve the target level. The case study started with the pre-understanding stage where the phenomena behind the scenes were tried to understand. After that, the research topic and problem were determined. Next, a literature review was done to get to know the topic better and to familiarize what was already researched. The research problem was again screened and focused. After that, the research methods were planned. The maturity model was developed, and data was collected and analyzed. Then, the results and conclusions were drawn, and further development ideas thought. At the end of the research results were reported.

Saunders et al. (2019) has also defined approaches for theory development including induction, deduction, and abduction. Induction is about developing new theory based on observations and materials. Instead, deductive reasoning starts with a general premises or theory and its goal is to test the theory and hypothesis. In addition, abduction combines induction and deduction. In this thesis the used approach of theory development is induction.

In the research methodology point of view, the time horizon, when the data is collected and when the research is done, should also be chosen. According to Saunders et al. (2019) time horizon options are longitudinal or cross-sectional time horizon. Longitudinal research is done during a long term and the cross-sectional research is done at a certain point in time. In this research the time horizon is chosen to be cross-sectional because of the limited timeline of the research.

During the research process ethical choices for research were also made. For example, chosen literature was reviewed before using to enable reliability of the references. Publication forum (JUFO) classifications were used to ensure the quality of the references. The used references should be at least in the JUFO-level one. In addition, research's scope, data collection, data analysis and results were reviewed from the research ethics point of view. Also, attempts were made to identify and minimize subjective tendencies.

Research philosophy refers to how the researchers see and review the world. In addition, research philosophy helps the researcher to figure out the scope of the research. Different research philosophies are for example interpretivism, positivism, realism, and pragmatism. (Saunders et al. 2019)

Because the research's target is a single organization and the reviewing and improvement of their IoT maturity, the chosen research philosophy is interpretivism. In the interpretivism the people and surrounding world are seen based on interpretations. Interpretivism strives to create richer understanding based on the matters to be researched. In addition, in interpretivism the research is subjective, and value bound. (Saunders et al. 2019) In this research that means that single organization's maturity is reviewed in different perspectives. Usually, in research where research philosophy is seen as interpretivism, the samples are small and qualitive with in-depth investigations. (Saunders et al. 2019) In this research the amount of data collected is small and qualitive, so also in that point of view the interpretivism is applicable research philosophy to this research.

5.2 Data collection and analysis

The data collection methodology is chosen based on the target organization's need to better understand their current IoT maturity and state of will to develop new IoT solutions in the future. To determine current ant target levels of maturity it is needed to understand what is currently happening in the organization. Interviews were chosen to be data collection methodology of this research. The interviews were conducted to understand the current and target levels of the organizations IoT maturity. Interviews are suitable methodologies when the goal is to understand what people think and what kind of experiences they have (Saunders et al. 2019)

Most of the interviews were conducted face to face and a couple of them were done by phone. All the interviews were one-to-one interviews so that interviewees could not affect each other's answers. The interviews' length varied from 45 minutes to 1 hour and 30 minutes. Interviews were organized for three weeks starting from the end of May.

During the interviews the answers were documented to memos. After the interviews the memos were reviewed and analyzed. Summarizing and categorization were used, which are qualitative data analysis methods according to Saunders et al. (2019). Summarized data was categorized to its own document based on the maturity model's dimensions and sub-dimensions. In the data analysis, software tools such as spreadsheets and other online visual platforms for creating visualizations were used. In the analysis phase, cause-effect relationships and different dependencies were identified. In the data analysis phase, the current and target maturity levels were determined to each sub-dimension based on the information gathered and analyzed.

6. RESULTS

After the IoT maturity model for the target organization was built, interviews were conducted in the target organization. Interviewees were chosen based on their roles and understanding of the organization's IoT capabilities. For choosing interviewees, their understanding about IoT and models' capability dimensions was a crucial factor.

In the interviews the organization's maturity was evaluated in the five dimensions and their sub-dimensions. Each dimension has three to five sub-dimensions which were evaluated individually. Each interviewee gave their opinion in the individual open interview. There was room to open discussion about dimensions and their scope. Each sub-dimension's current and target maturity levels are presented separately. Also in this chapter the results of the data collection are presented.

6.1 Current state of the IoT maturity

6.1.1 Governance

Governance dimensions' sub-dimensions are IoT plan, resource allocation for IoT realization and IoT adaptation of business models. The maturity level was determined in the interviewees for all these sub-dimensions.

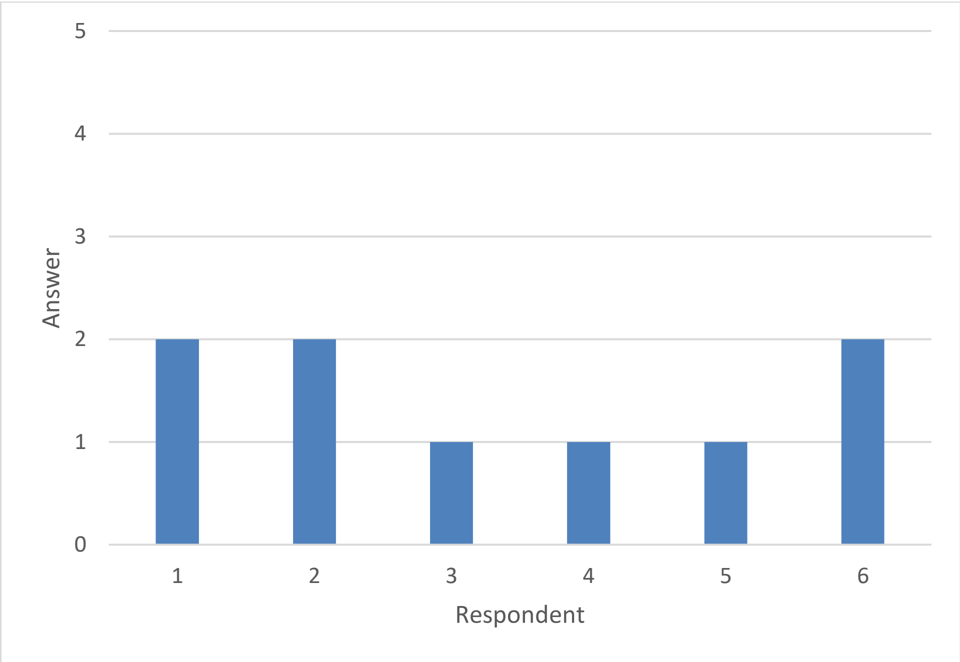

Figure 9. *Current maturity level of IoT plan*

The current maturity of the IoT plan was seen to be between levels 1 and 2 in the target organization (Figure 9). The average level of this sub-dimension is 1,5. That means that some of the respondents think that IoT plan does not exist at all and some that the plan is not yet created but there is willingness to do so. Some of the respondents commented that if there was willingness to create IoT plan, it should have been already created in the organization so this sub-dimension cannot even reach level 2 from this point of view. Also, it was recognized that IoT plan sub-dimension affects other dimensions.

Some interviewees said that IoT features already exist in the other plans or roadmaps but there is not a specific roadmap for the IoT. A question about how necessary this kind of IoT roadmap would be and are the already existing roadmaps enough was also presented. Some interviewees were also concerned if there have already been some lost business possibilities and markets because of the lack of IoT roadmap in the organization.

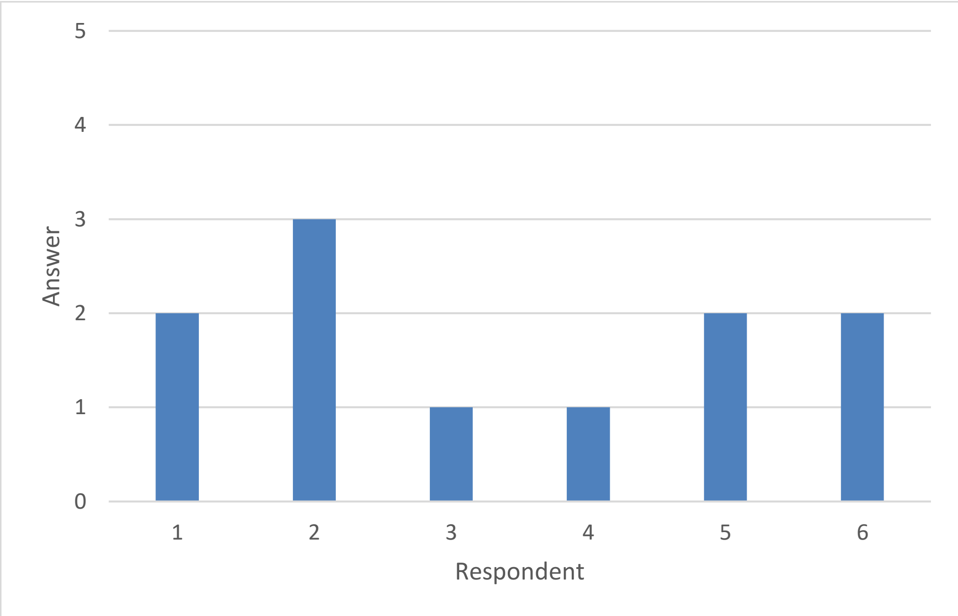

Figure 10. *Current maturity level of the resource allocation for IoT realization*

The current maturity level of resource allocation for IoT realization was seen to be between levels 1 and 3 (Figure 10). The average level of the whole sub-dimension is 1,6. Some of the respondents argued that because there is not yet even an IoT plan, the resources cannot be allocated to IoT projects. That is why the maturity of the resource allocation cannot reach upper than level 2, and there probably is dependency between resource allocation for IoT realization and IoT plan sub-dimensions. In that point of view, IoT plan could be seen as a bottleneck. The respondents who estimated this sub-dimension to be higher than 1 mentioned that there are still IoT related projects going on and resources allocated to them, even when there is no specific plan for IoT.

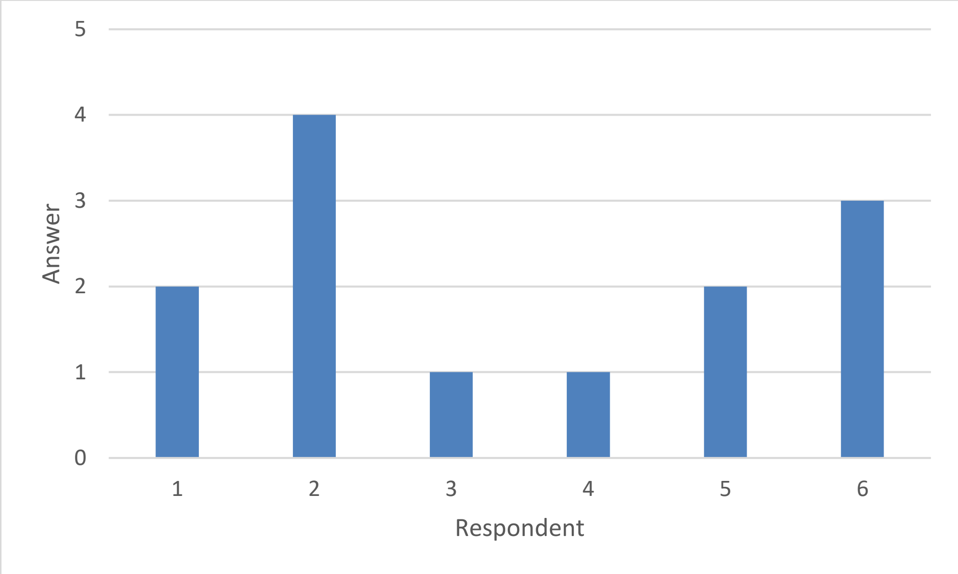

Figure 11. *Current maturity level of IoT adaptation of business models*

The target organization's respondents estimated that the current maturity level of IoT adaptation of business models is between 1-4 (Figure 11). The average level for the sub-dimension is 2,1. There is quite a high amount of variation between answers. The organization has one solution for managing welding production which is the main reason for some of the respondent's higher maturity levels. The average level of this sub-dimension is about 2 which means that business models do not include IoT yet, but there is willingness to do so. There are still some higher levels which show that something is already done for adding IoT to business models. The lowest answers were level 1, which describes that IoT is not included in the business models.

Probably, there are no IoT business models in the organization, because sub-dimension's maturity level evaluations differ from each other remarkably. Or if those IoT business models exist, there is no transparency between different organizational levels. One higher maturity level was given based on the organization's existing IoT related solution, where the business model includes IoT.

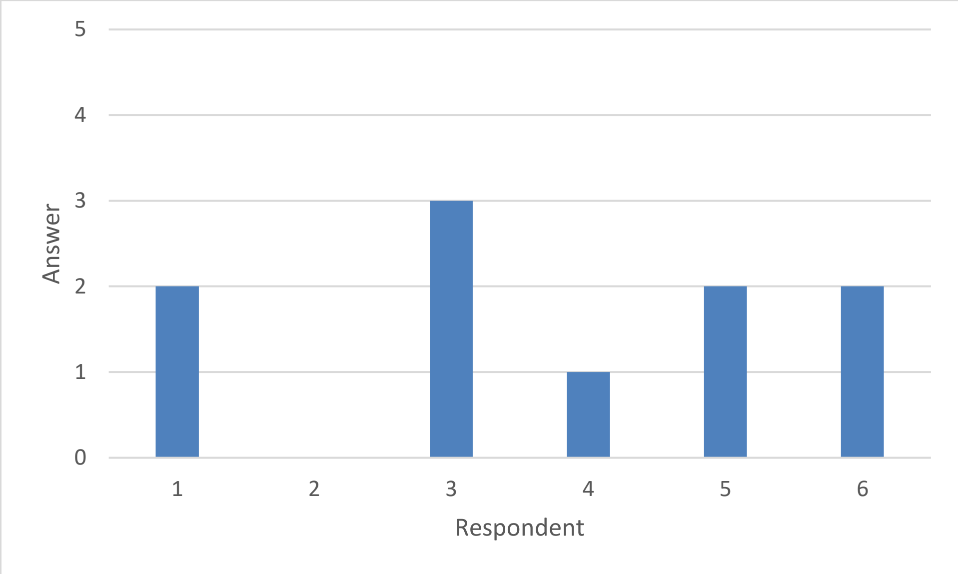

Figure 12. *Current maturity level of data governance*

Data governance's maturity level was seen to be between levels 1-3 (Figure 12). The average level of the sub-dimension is 2 which shows that data is governed in the organization informally and there is no structure. One respondent did not know about the organization's data governance, so they didn't give an answer about that sub-dimension. Some of the respondents were not familiar with the idea of data governance before the interview. In the organization data governance has not been thought about and data governing practices are not shared between organization's levels. One respondent mentioned that there is a data governance model already existing, but all of the respondents were not aware of it.

6.1.2 Technology and connectivity

Sub-dimensions of technology and connectivity are IoT technology, IoT architecture and networking. Each of them is presented individually.

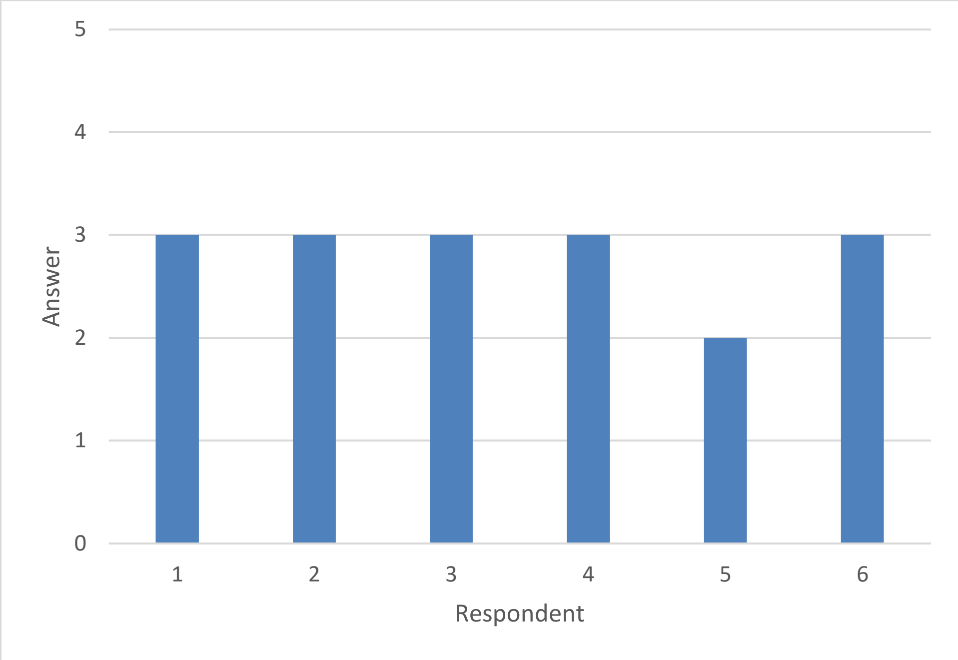

Figure 13. *Current maturity level of IoT technology*

IoT technology's maturity level was estimated to be between levels 2 and 3 (Figure 13). The average maturity level is about 2,8. Most of the respondents thought that the maturity level is 3. In most of the respondents' opinion, the technology needed for IoT implementation already exists in the organization. One respondent answered that maturity level is 2 which describes that for IoT implementation some technical elements are missing. Because the respondent in question has strong technical expertise and knows the organization's technical aspects, it may be so that the organization does not really belong to the level 3 in this sub-dimension.

Some of the respondents mentioned that IoT technology is not a barrier for organization's IoT development. Technology is just a tool which should be chosen right. The current IoT technology situation was seen sufficient for IoT development establishing.

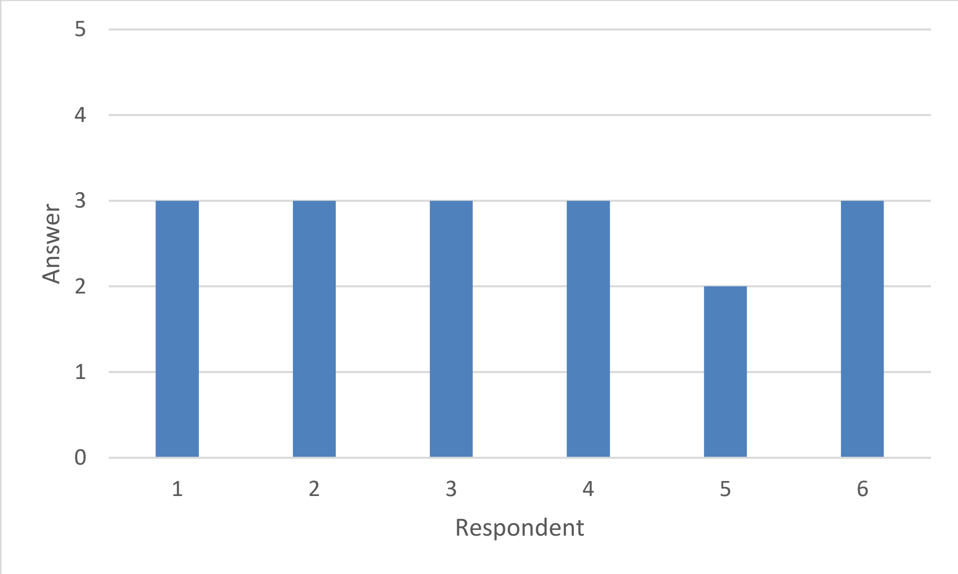

Figure 14. *Current maturity level of IoT architecture*

In the target organization the IoT architecture's maturity level was seen to be between 2 and 3 (Figure 14). The average maturity level is about 2,8. Most of the respondents thought that IoT architecture's maturity is in the level 3. That means that needed infra-structural elements already exist in the organization. Like IoT technology sub-dimension, IoT architecture is not a problem in the respondent's opinion. All the respondents thought that the organization adopts basic IoT layer architecture.

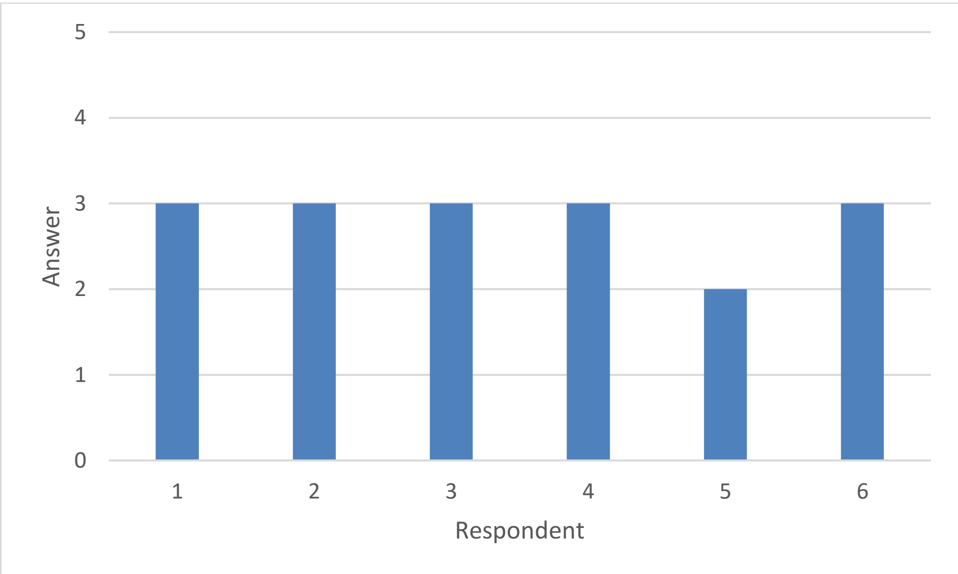

Figure 15. *Current maturity level of networking*

The current maturity level of networking was seen to be between maturity levels 2 and 3 (Figure 15). The average of this sub-dimension is 2,8. Most of the respondents thought that networking's maturity is in the level 3. That means that the organization has some advanced communication technologies such as 2G/3G/4G and Bluetooth. It was mentioned in the interviews that like other technology dimension's sub-dimensions, the networking is enabler for IoT solutions.

6.1.3 Data-analytics based decision making

Sub-dimensions of data-analytics based decision making are value creation based on data, data-analytics phase, data's availability, and data's quality.

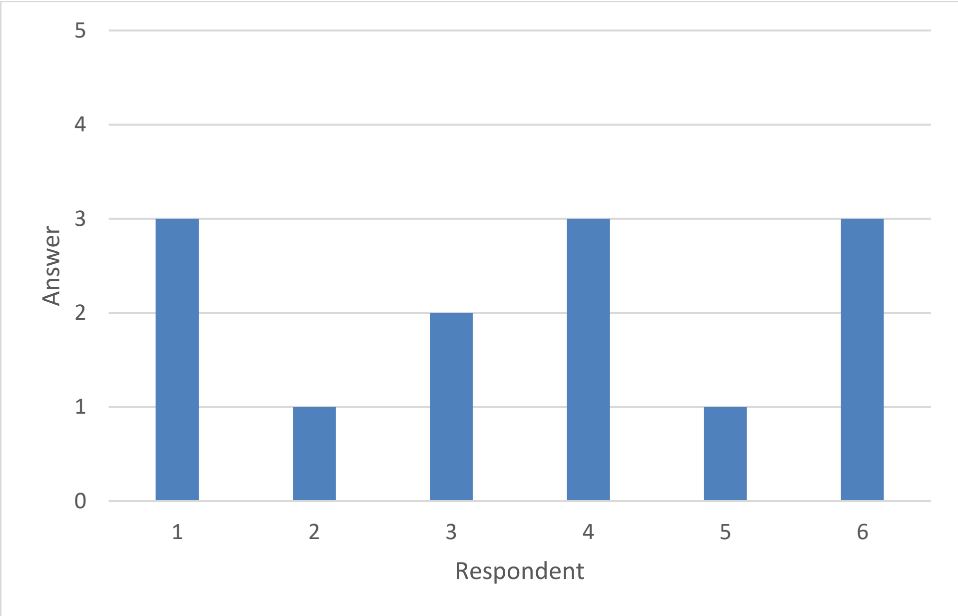

Figure 16. *Current maturity level of value creation based on data*

The current maturity level of value creation based on data was seen to be between levels 1 and 3 (Figure 16). Some of the respondents thought that in the target organization decisions are not based on data and value is not created at all. Some of the respondents thought that data can be used in the organization for making insights and creating value. The average maturity level of the sub-dimension is about 2,2 which means that value creation possibilities are already identified in the organization. One of the interviewees mentioned that the data's value is not understood in the organization for supporting decisions. There is some varying in the respondent's answers, so it can be possible that value creating processes are not transparent to all organization's employees, and they are visible only in some positions in the organization.

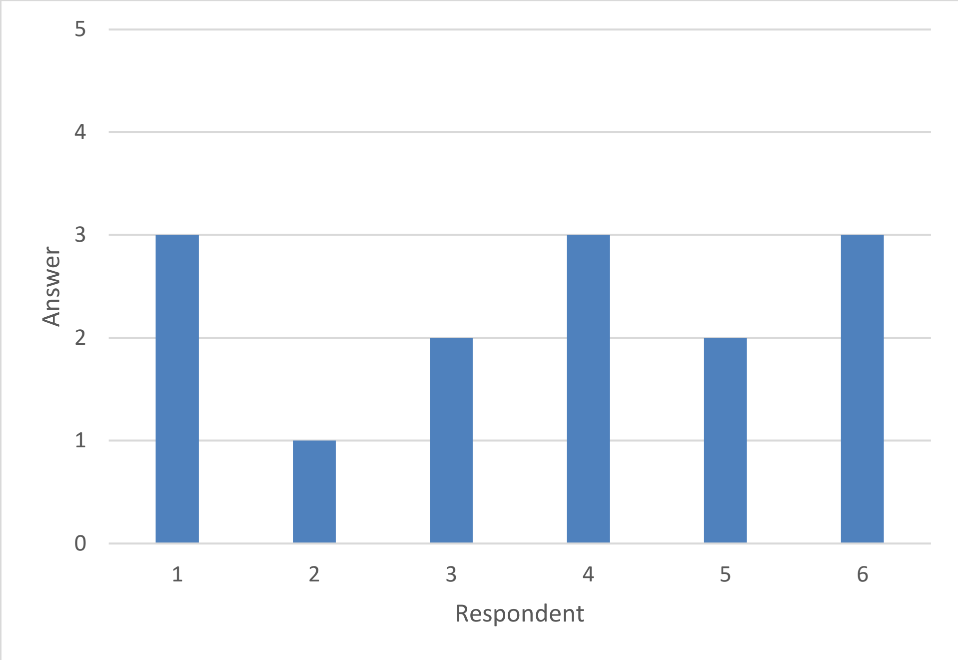

Figure 17. *Current maturity level of data-analytics phase*

In the target organization the current maturity level of data-analytics was seen to be between 1 and 3 (Figure 17). Most of the respondents thought that there is already descriptive analytics and historical data analyzation at some point. A couple of respondents thought that preliminary data analytics are rarely done. One respondent mentioned that based on data, for example, some dashboards were created to support management. Other respondents thought that data was not analyzed at all. The average maturity level of this sub-dimension is 2,3 which shows that overall preliminary data-analytics is not often implemented. Most of the interviewees were not familiar before the interview with descriptive diagnostic and predictive analytics. The phases were introduced to them.

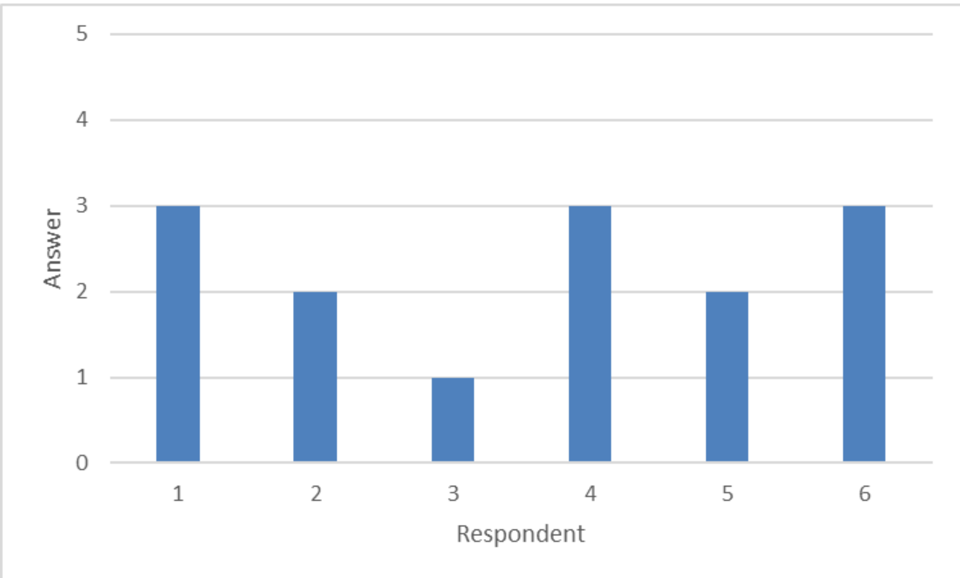

Figure 18. *Current maturity level of data's availability*

The current maturity level of the data's availability was seen to be between 1 and 3 in the target organization (Figure 18). Most of the respondents thought that data is currently available but not in its full potential. So, there should be room for improvements. A couple of the respondents thought that some of the data is available but there are some limitations. One respondent thought that the needed data is not available at all. The average level of maturity is 2,3.

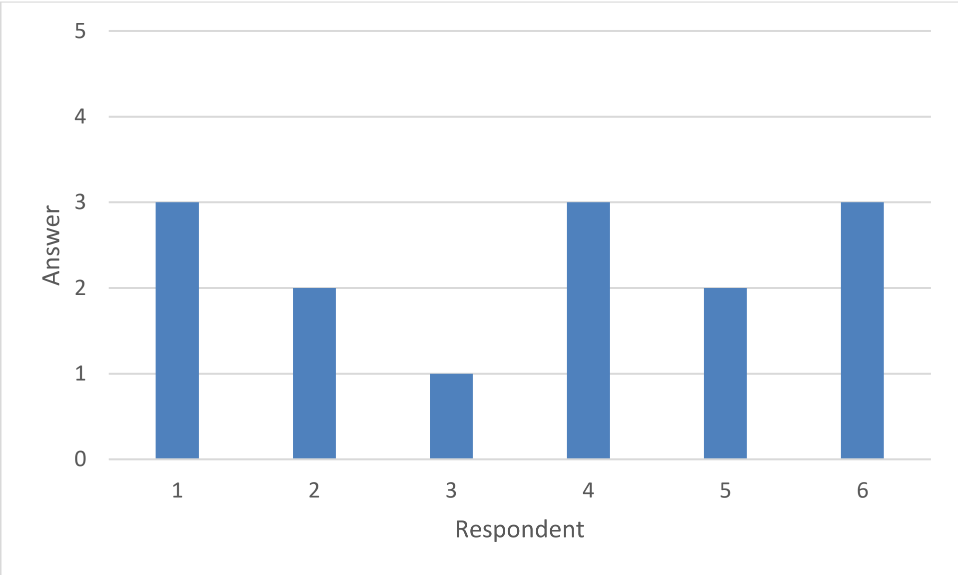

Figure 19. *Current maturity level of data's quality*

In the target organization the data's quality was estimated to be between levels 1 and 3 (Figure 19). The average level of this maturity sub-dimension is 2,3. Most of the respondents thought that data quality is mostly good. A couple of the respondents answered that there are some problems with data quality. On the other hand, one respondent thought that data quality is basically just not good. Data quality dimension is related to governance dimension's data governance sub-dimension. Data quality handling is part of data governance, so if data governance was carefully planned and implemented, the data quality could be managed through that.

6.1.4 People

People dimension's sub-dimensions are IoT skills and competences, openness to new technologies and self-learning and knowledge sharing culture.

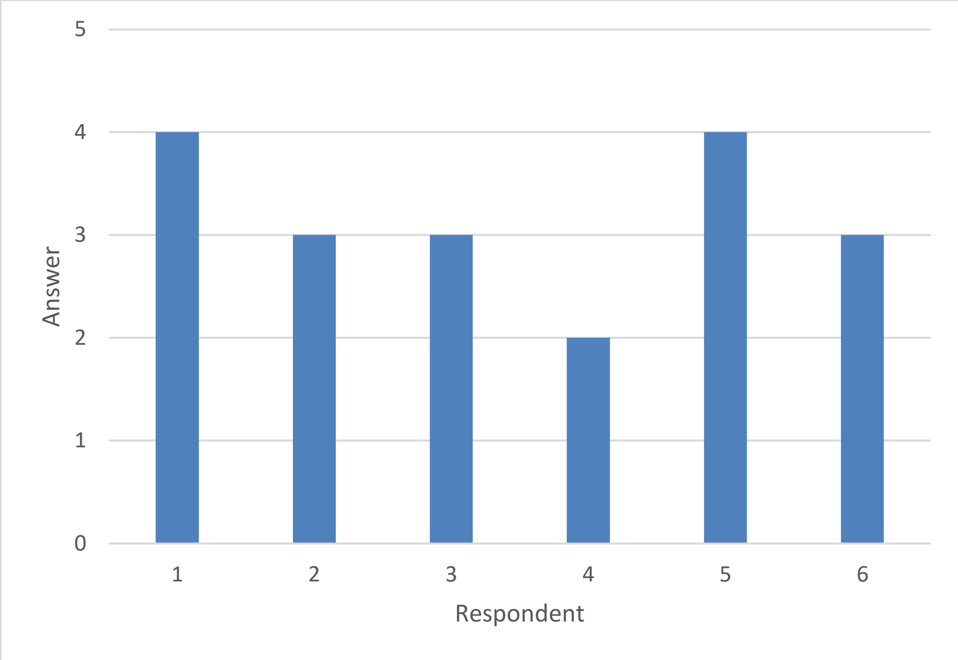

Figure 20. *Current maturity level of IoT skills and competences*

The maturity level of the organization's employees' IoT skills and competences was seen to be between levels 2 and 4 (Figure 20). The average maturity level of the sub-dimension is 3,2. One respondent mentioned that there could be more employees with IoT skills in the organization for designing and implementing future IoT projects. Some of the employees are highly skilled with IoT technologies and some need more skills in the future. Between the organization's teams the IoT competences differ a lot. Overall, the analysis shows that an organization's employees have average IoT skills and competences. Sub-dimension's current maturity is not a barrier for the development of IoT projects according to respondents.

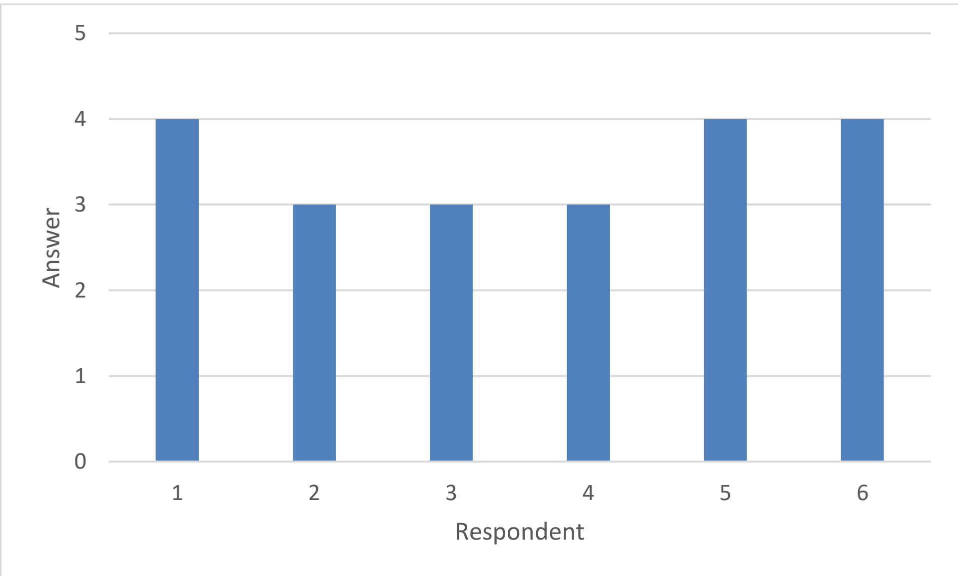

Figure 21. *Current maturity level of openness to new technologies and self-learning*

In the organization the current maturity level of openness to new technologies and self-learning was seen to be between levels 3 and 4 (Figure 21). The average maturity level of the sub-dimension is 3,5. New technologies are accepted by employees and some of the respondents even thought that employees are interested in new technologies and are continuously learning them by themself. Some respondents mentioned that the self-learning culture is limited to some people and there are also differences between different teams. Others are more interested in learning new technologies than others but at least there is no resistance to new technologies. Openness to new technologies and self-learning are not bottlenecks for IoT development.

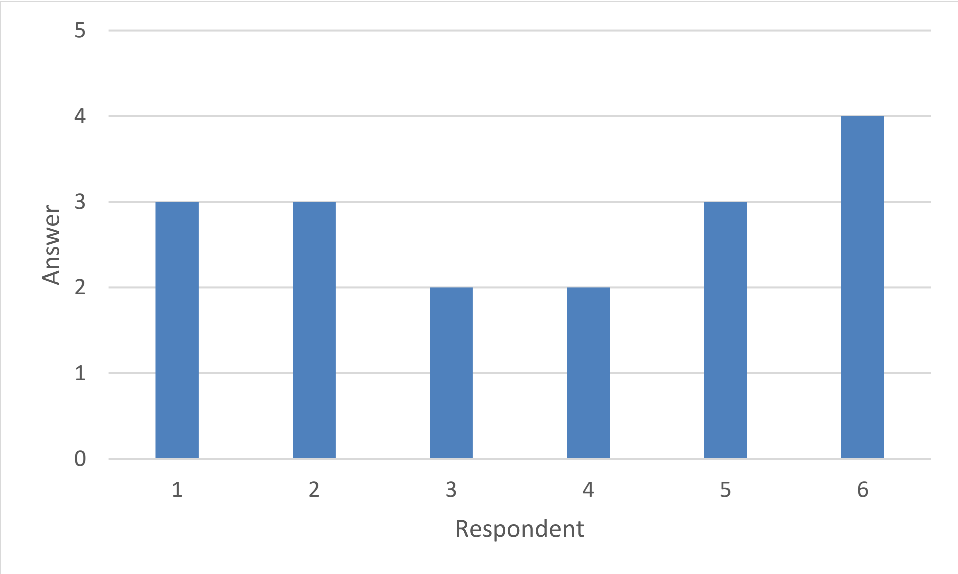

Figure 22. *Current maturity level of knowledge sharing culture*

The target organization's knowledge sharing culture's current maturity level was seen to be between levels 2 and 4 (Figure 22). The average maturity level is 2,8. That describes that organization almost reaches levels 3 where knowledge is shared between most of the teams and knowledge management practices are planned.

Some of the respondents said that knowledge sharing is sometimes limited between some teams. Between the "own" team, the knowledge is shared but the sharing does not cross the team borders so easily, at least in between some teams. Some of the respondents did not recognize that kind of challenge and thought that knowledge is shared greatly in the organization. The respondents were organization's Vice Presidents, Technology Managers and Technology Center Managers from different business units and teams which would probably explain the different experiences about the knowledge sharing.

6.1.5 Processes

Processes dimension's sub-dimensions are business process documentation, processes for enabling and utilizing data and business process re-engineering based on data.

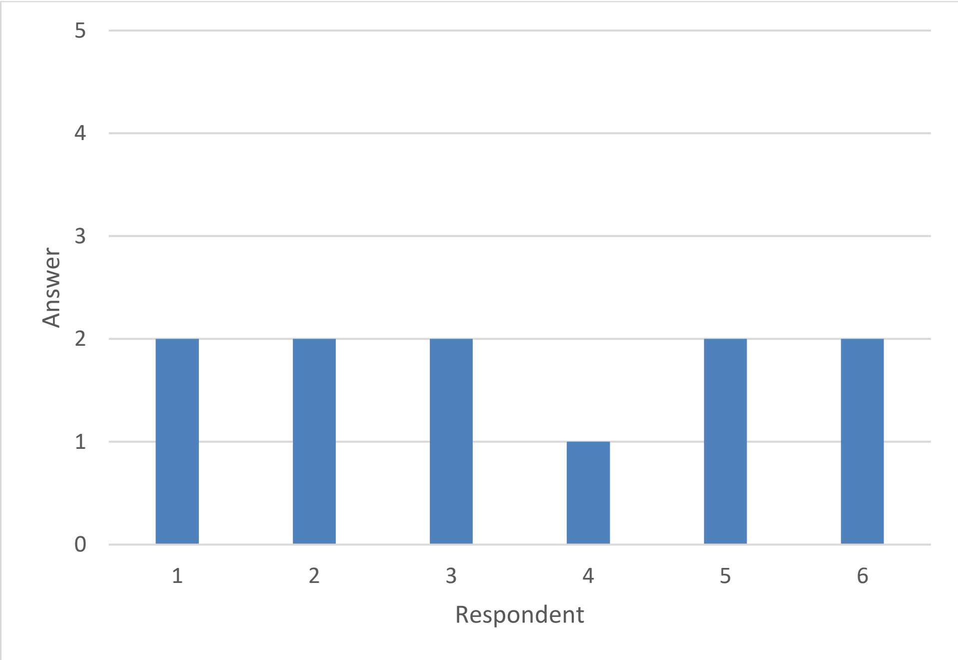

Figure 23. *Current maturity level of business process documentation*

In the organization the current maturity level of business process documentation was seen to be between levels 1 and 2 (Figure 23). Average maturity level of the sub-dimension is about 1,8. Most of the respondents thought that the maturity level is 2, which means that processes are not structured, and they lack clear definitions. This result shows that process documentation is not done formally in the organization. One interviewee said that in the organization the process-thinking is poor, and that the organization does not identify organization's processes and evaluate organization's activities through them.

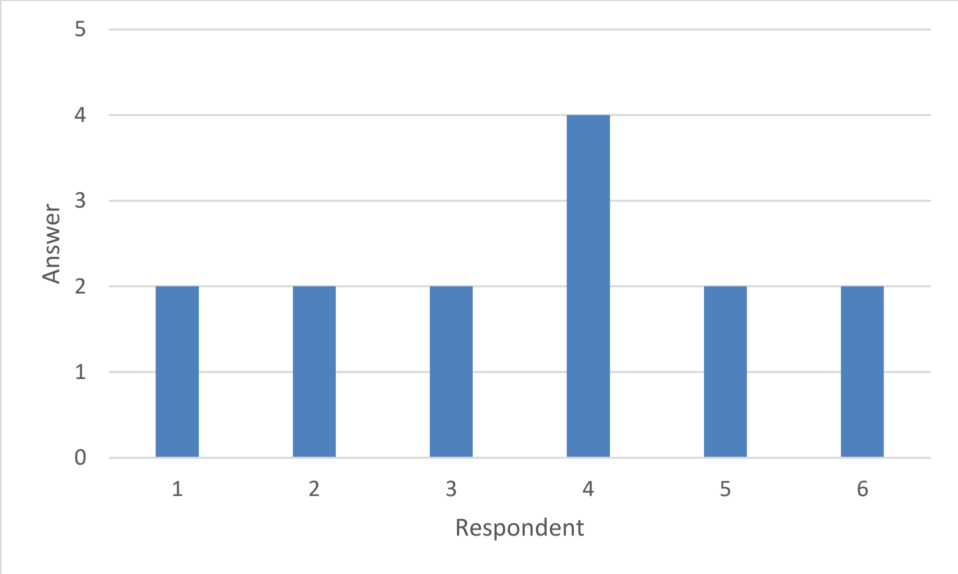

Figure 24. *Current maturity level of processes for enabling and utilizing data*

The current maturity level of processes for enabling and utilizing data was estimated to be between 2 and 4 (Figure 24). The sub-dimension's average maturity level is about 2,3. One of the respondents thought that processes for enabling and utilizing data exist for diagnostic analytics. All the rest thought that processes for enabling use of data existed but processes for utilizing data are still missing. One of the respondents thought that in the target organization data management is not thought through the processes. Overall, processes or activities can be behind individual people and are not shared with others.

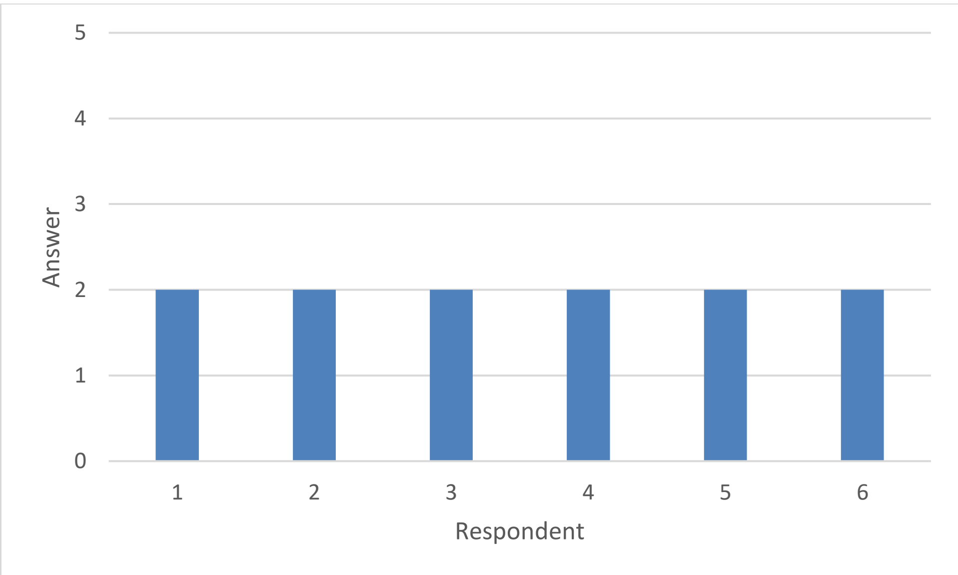

Figure 25. *Current maturity level of business process re-engineering based on data*

The current maturity level of business process re-engineering based on data was seen to be in the level 2 in the organization (Figure 25). The average maturity level of this sub-dimension is 2. All the respondents thought that the sub-dimension's level is 2. In the organization IoT is not influencing in the organization's process activities and their execution but there is willingness to do so. One of the respondents mentioned that the organization processes are not designed based on data but experience from the past.

6.2 Target state of the IoT maturity

Also, the organization's target maturity state was resolved through interviews. The current levels are presented together with target levels.

6.2.1 Governance

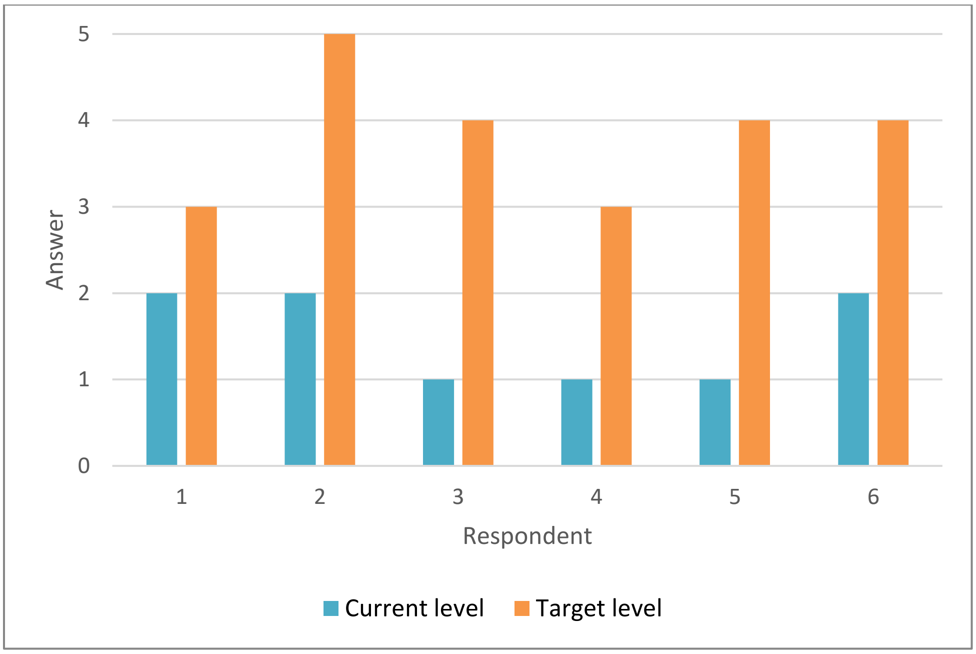

Figure 26. *Current and target maturity levels of IoT plan*

The organization's target maturity level for IoT plan was seen to be between 3 and 5. (Figure 26) Most of the respondents thought that the target maturity level should be 4. A couple of the respondents thought that level 3 is enough and one of the respondents said that reaching level 5 would be beneficial. The average of the respondents' answers is a little under 4. So, the organization's target level should have a detailed IoT plan for IoT implementation which is shared in the whole organization's level.

The current maturity level is estimated to be between 1 and 2, which means that the organization must reach level first 2 and then level 3 to reach level 4. Some of the interviewees mentioned that there is a lot to do to reach the target level, because there is not even a willingness from the starting point. When the IoT plan's current level was considered, it was recognized that IoT plan is bottleneck for other dimension's maturity. Without

IoT plan for example resources cannot be allocated straight to IoT projects. That's why upgrading this sub-dimension's maturity is seen as an important step.

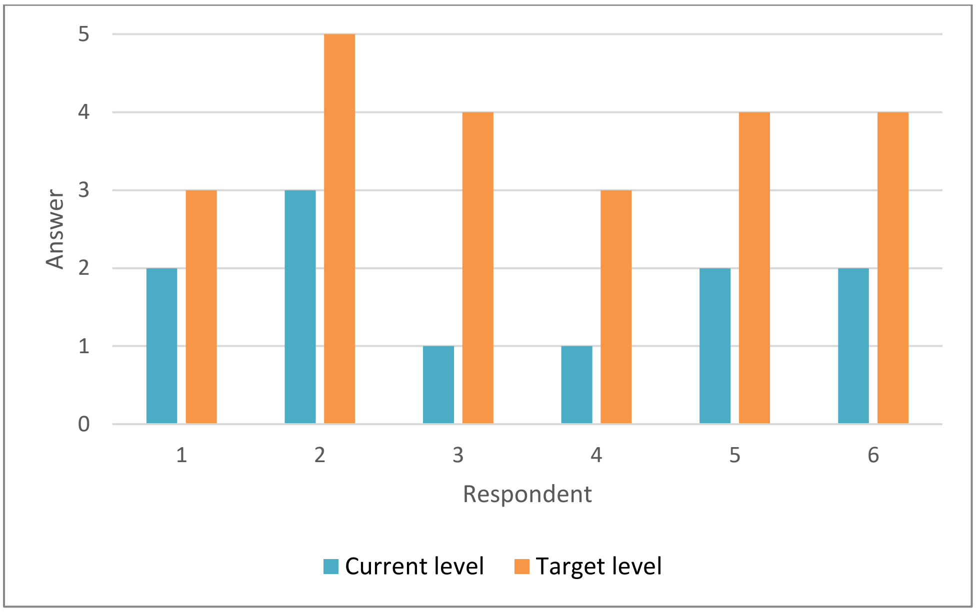

Figure 27. *Current and target maturity levels of resource allocation for IoT realization*

The target organization's target level for resource allocation for IoT realization was estimated to be between levels 3 and 5 (Figure 27). The average of the target maturity level is about 3,8, so the organization's target state is about level 4. Level 4 means that an organization's IoT related activities and resources should be defined and shared in the whole organization's hierarchical level. To reach this level, the organization must first reach level 3 where resources and activities are defined and shared at the management level. Some of the interviewees argued that IoT resource allocation for IoT projects is not done because there is not even an IoT roadmap. Still, some others argued that some resources are working with IoT related work duties but that is just not documented in the specific IoT roadmap, the work is just done under some other roadmap. Some of the respondents said that upgrading this sub-dimension's maturity is important because without any allocated employees to IoT projects, no work is done.

In the sub-dimension the respondents who answered with higher target levels are probably working themselves in teams where people are working in IoT-related work duties. So that means that team-level visions differ from each other. If IoT-development is not considered in respondent's own work duties, it probably is not seen so important to allocate resources to IoT projects.

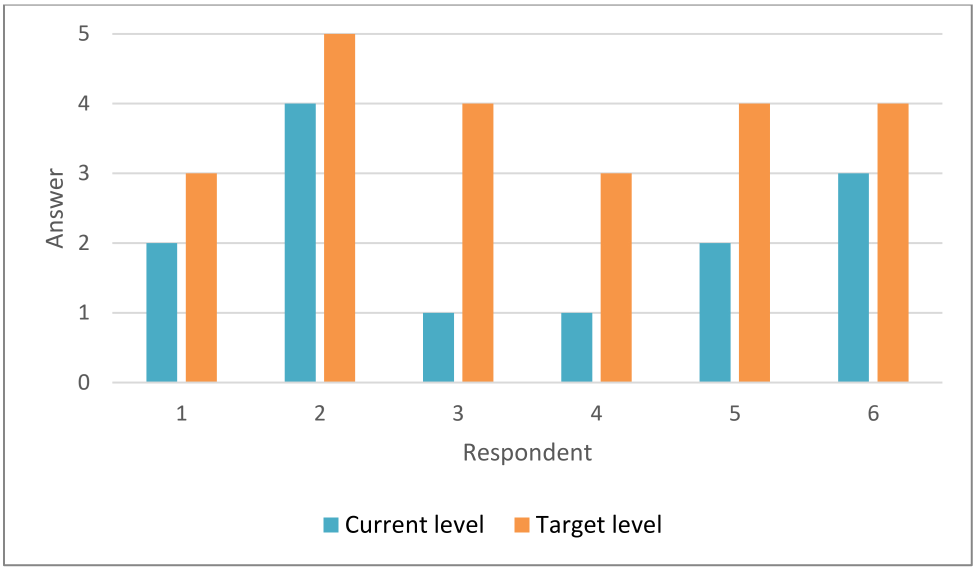

Figure 28. *Current and target maturity levels of IoT adaptation of business models*

The target level for the IoT adaptation of business models was seen to be between levels 3 and 5 (Figure 28). The average for the sub-dimension is about 3,8 which means that the organization would like to reach almost level 4. The current maturity level of the sub-dimension is about 1,8 which is almost level 2. So, the organization should also reach level 3 first to also reach level 4. To reach level 3 the organization must identify IoT related business models and to reach level 4, the organization must already have planned those business models. Some interviewees said that there are some IoT elements existing in the current business models. The organization also has one product, which business model is IoT related.

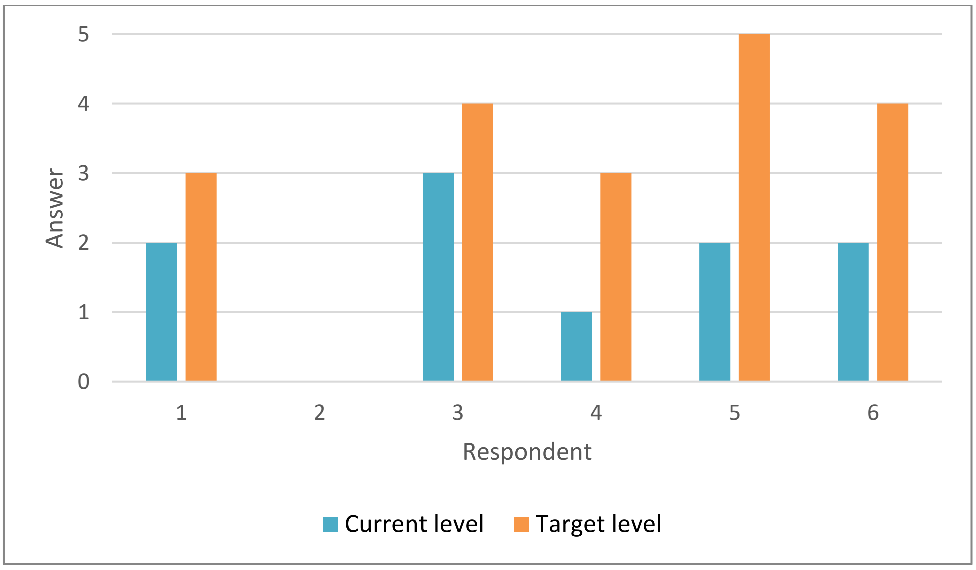

Figure 29. *Current and target maturity levels of data governance*

Target level of the maturity level of data governance was seen to be between levels 3 and 5. The average of the sub-dimension is about 3,8 which means that the organization would like to reach about level 4. The current level's average is 2, which means that organization has to first reach level 3 to also reach level 4. To reach level 3 the organization should formalize informal data governance and after that to reach level 4 the organization should plan data governance structure and determine data owning responsibilities.

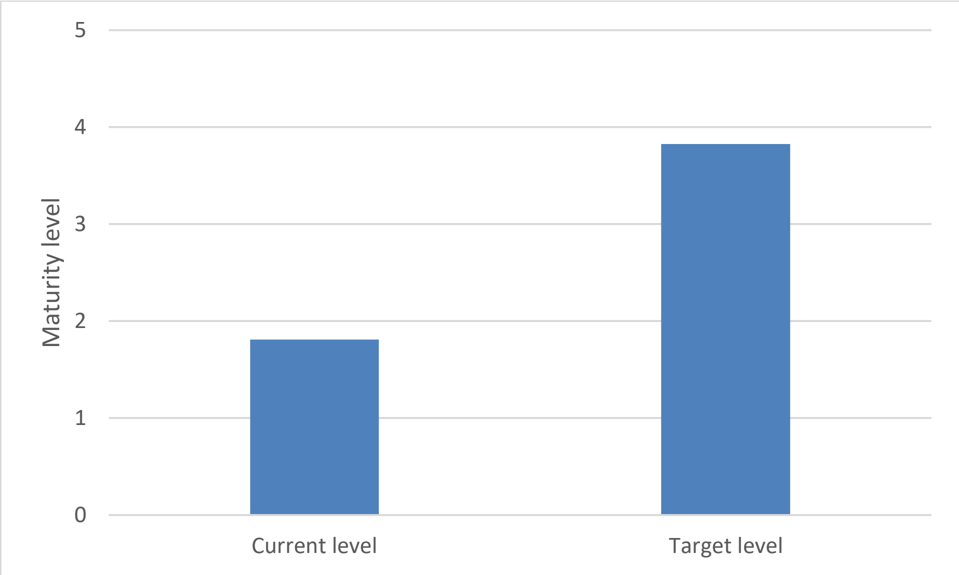

Figure 30. *Governance dimensions average current and target maturity levels*

The governance dimension's average current maturity level is less than level 2 (Figure 30). The target level for the dimension is about level 4, which means that the organization should upgrade their level two levels to reach the target level. Some interviewees mentioned that governance is one of the main challenges in the IoT implementation because of its effect to all the other dimensions and without management support and roadmaps, it's hard to develop more advanced IoT solutions. Some of the interviewees mentioned that there is a lot to do to reach the target level, because there is not even a willingness from the starting point.

6.2.2 Technology and connectivity

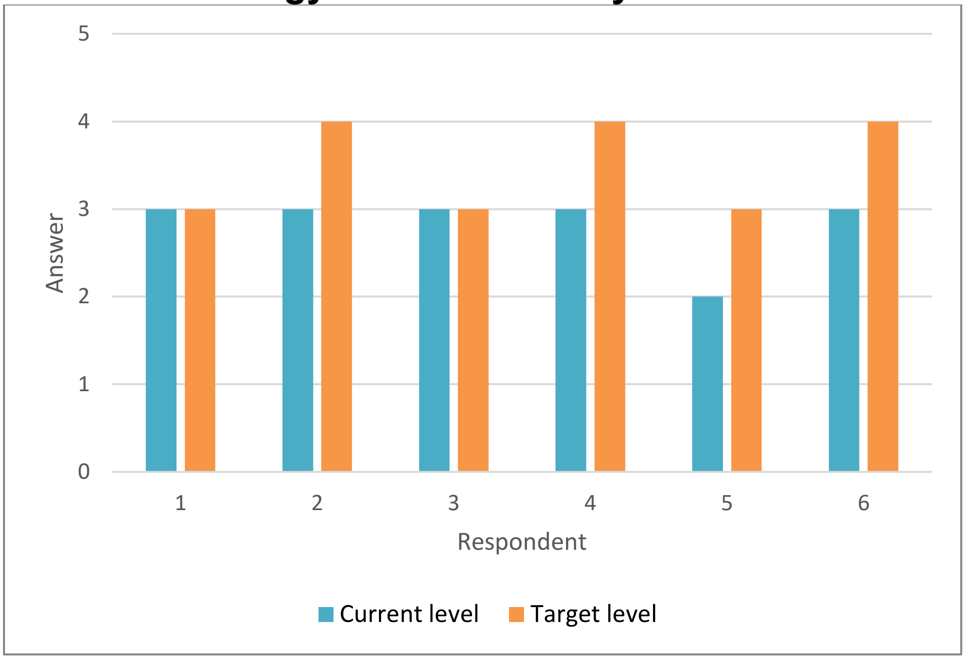

Figure 31. *Current and target maturity levels of IoT technology*

The target organization's IoT technology's target maturity level was seen to be between levels 3 and 4 (Figure 31). The average target maturity level is 3,5. That means that the organization would like to be between levels 3 and 4. The organization's current maturity level is already almost 3. That means that IoT technology sub-dimension's maturity is almost at the target level. This shows that IoT technology is not the biggest challenge to improve in the target organization.

A couple of the respondents thought that the current situation in the IoT technology sub-dimension is enough. Some of the respondents thought that the sub-dimension's maturity level should be risen step by step. The technical respondents thought that there is still something to do, and new technologies should be actively screened and followed which technologies are forming to be standard technologies in the field.

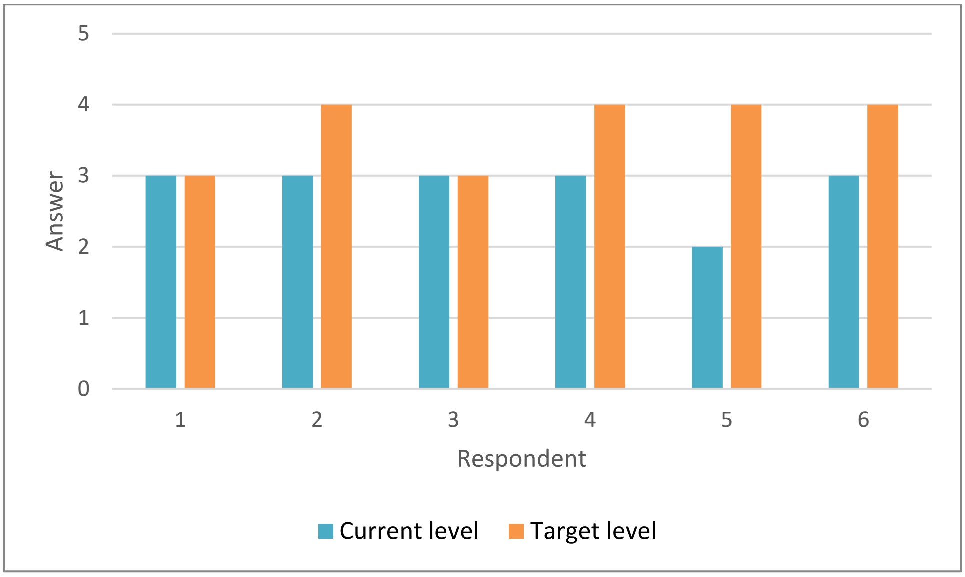

Figure 32. *Current and target maturity levels of IoT architecture*

The target maturity level of IoT architecture was seen to be between levels 3 and 4 (Figure 32). The average level of this sub-dimension is about 3,7. The organization's current maturity level in the sub-dimension is about 2,8 which means that the organization should upgrade their maturity about one level. The interviewees also mentioned that IoT architecture is not the main challenge in the IoT adaptation.

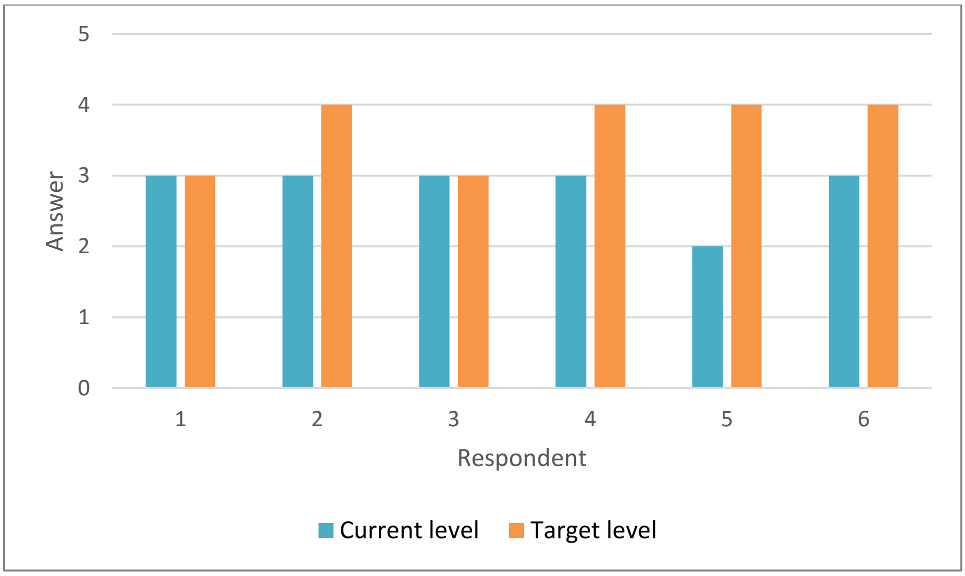

Figure 33. *Current and target maturity levels of networking*

The organization's target maturity level of networking was seen to be between levels 3 and 4 (Figure 33). The average target maturity level is about 3,7. So the organization would like to reach almost level 4. The current maturity level is about 2,8, so organization should level up about one level. That means that organizations should take into use more advanced communication technologies to reach level 4. Like other Technology dimensions, networking is also not the major challenge for the organization's IoT solutions.

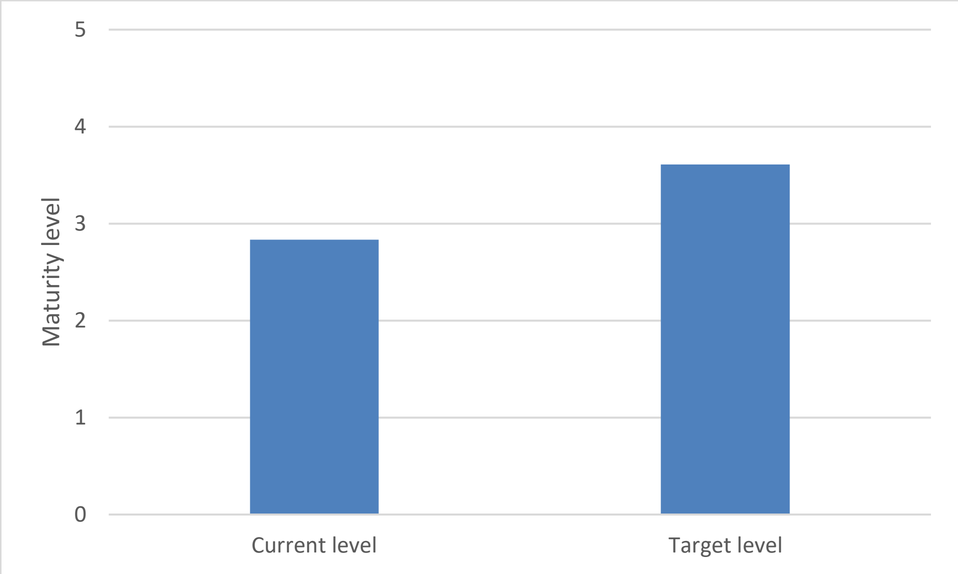

Figure 34. *Technology dimensions average current and target maturity levels*

When the maturity level is reviewed in the whole technology dimension's level, the dimension's maturity level should be upgraded by slightly below one level (Figure 34). The result shows that the whole dimension is almost in level 3, transparent and the distance to the target level is not enormous.

This average probably does not describe enough about the dimension's maturity. The respondents were mostly from the management so there could be some lack in their knowledge about technical details.

6.2.3 Data-analytics based decision making

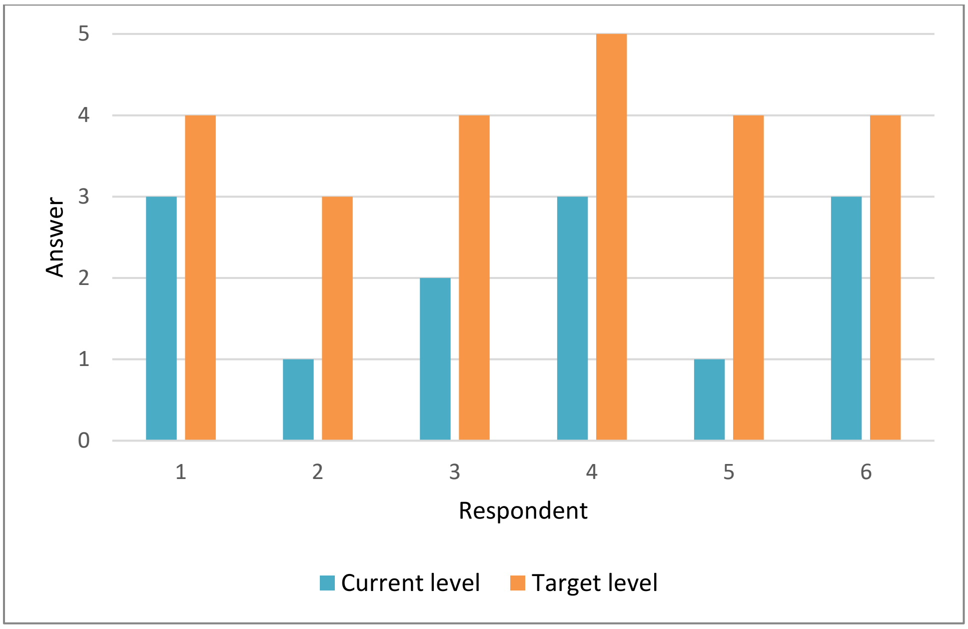

Figure 35. *Current and target maturity levels of value creation based on data*

The target maturity level of value creation based on data sub-dimension was seen to be between levels 3 and 5 (Figure 35). The average target maturity level is 4. The current maturity level of the sub-dimension is about 2,2. That means that the organization should upgrade their level by 2 levels. So, the organization should first reach level 3 and then level 4.

One interviewee mentioned that level 5 is more like “a dream”. Achieving it in short period of time that is not possible. Even though some of the interviewees mentioned that data’s value is not fully understood in the organization. Still, most of the respondents thought that the sub-dimensions target level is at least level 4.

Some of the respondents had knowledge about how value can be created from the data. These respondents answered lower current levels and higher target levels. These factors can explain the variation in the evaluated maturity levels.

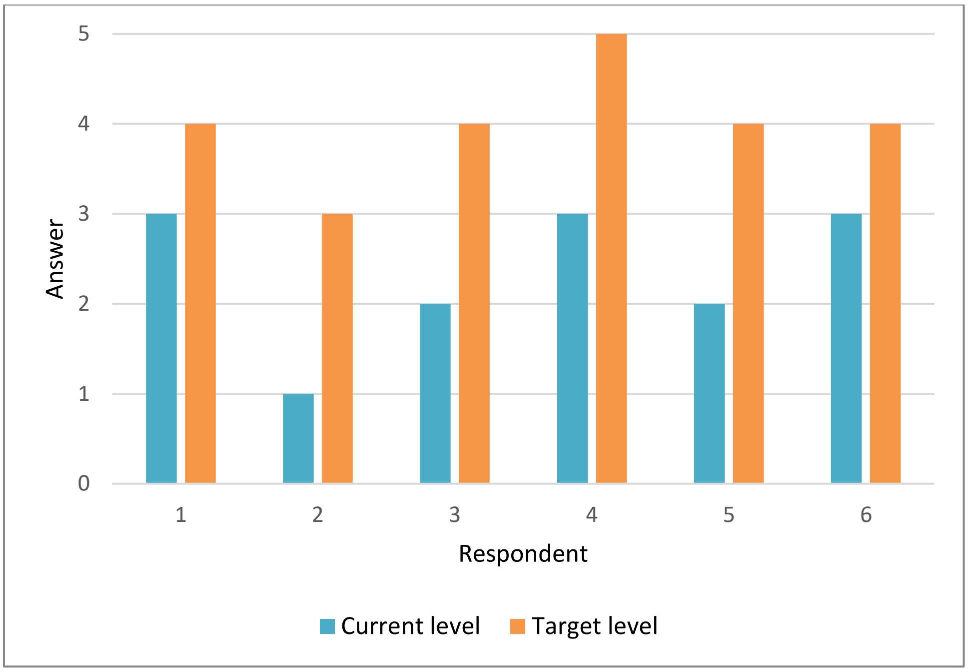

Figure 36. *Current and target maturity levels of data-analytics phase*

The target maturity level of data-analytics sub-dimension was seen to be between levels 3 and 5 (Figure 36). The average target maturity level is 4. The current maturity level is about 2,3 so the organization should reach level 3 first to upgrade themselves to level 4. Most of the respondents thought that diagnostic data analytics would be the pursued data-analytics' phase for the organization. That means that the organization do not only want to analyze historical data, but they want to understand also why something happened. Thus, this analytics phase is still classified as basic level analytics. On the other hand, that is still a big step from the starting point.

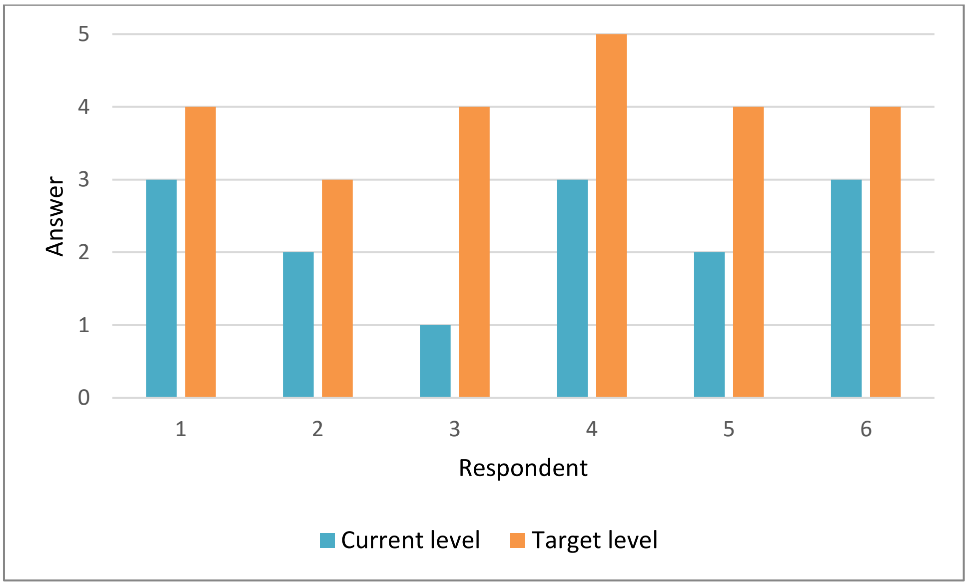

Figure 37. *Current and target maturity levels of data's availability*

The target maturity level of data's availability sub-dimension was seen to be between levels 3 and 5 (Figure 37). The average target maturity level is 4. The current maturity level of data's availability is about 2,3. That means that the organization must reach first level 3 to reach level 4. That means that the organization should have data available.

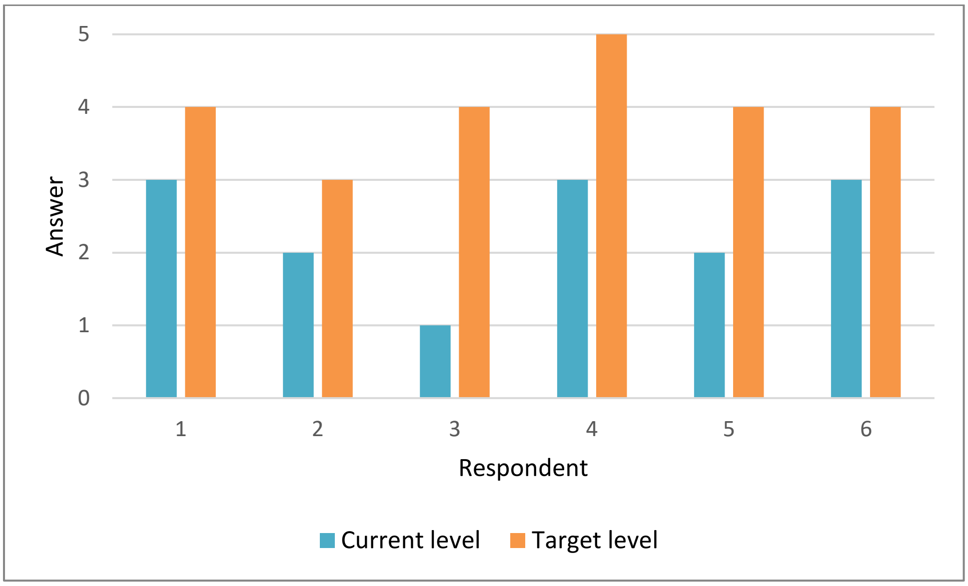

Figure 38. *Current and target maturity levels of data's quality*

The target maturity level of data's quality sub-dimension was seen to be between levels 3 and 5 (Figure 38). The average target maturity level is 4. The current maturity level of the sub-dimension is about 2,3. That means that the organization must reach first level 3 and then level 4. In the level 4 organization should have some methods for ensuring the quality of the data.

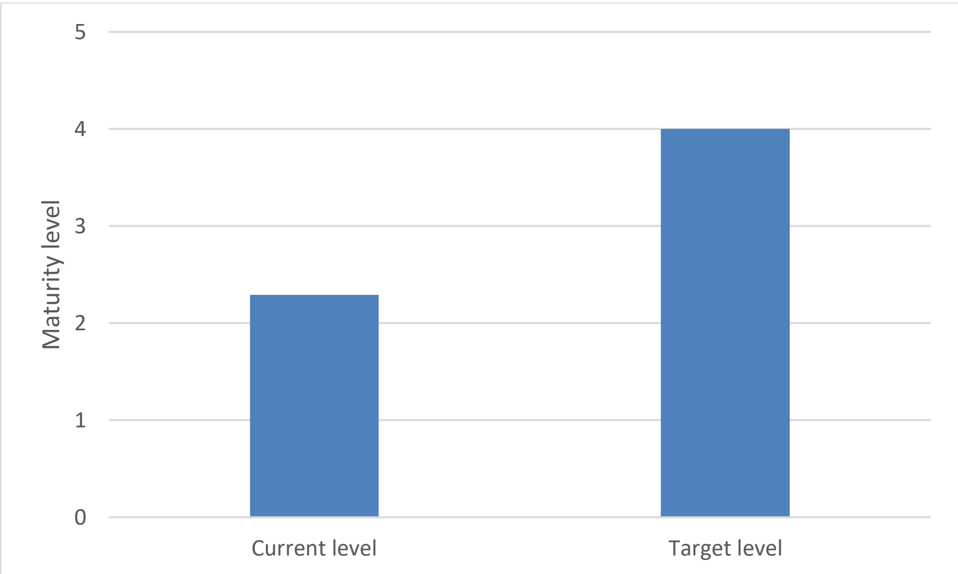

Figure 39. *Data-analytics based decision making dimensions average current and target maturity levels*

There are almost two levels to upgrade to reach the target level. In this dimension the average shows that overall organization must improve their data-analytics based decision making to reach their target levels (Figure 39).

6.2.4 People

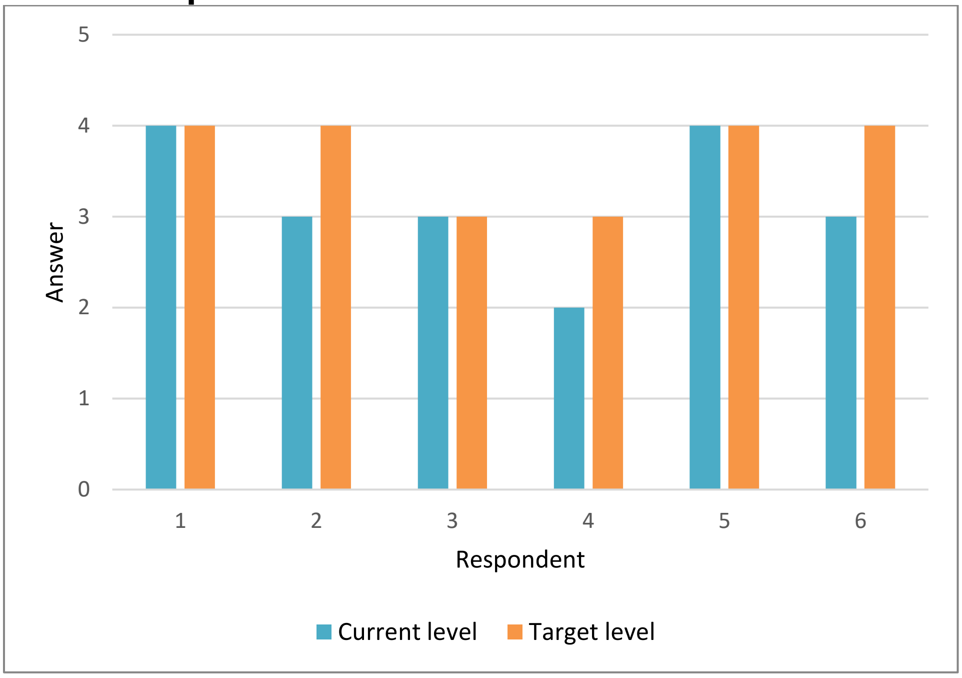

Figure 40. *Current and target maturity levels of IoT skills and competences*

Target organization's target level for IoT skills and competences was seen to be between levels 3 and 4 (Figure 40). The average level of the sub-dimension is about 3,7 so, target organization would like to reach almost level 4. The sub-dimension's current state is about 3,2 which means that the organization is already almost in their target state. Maybe some little improvements could be made. Respondents did not think that this sub-dimension would be a challenge in IoT development. Also, one respondent mentioned that it is highly important to stay at the current level in this sub-dimension also in the future.

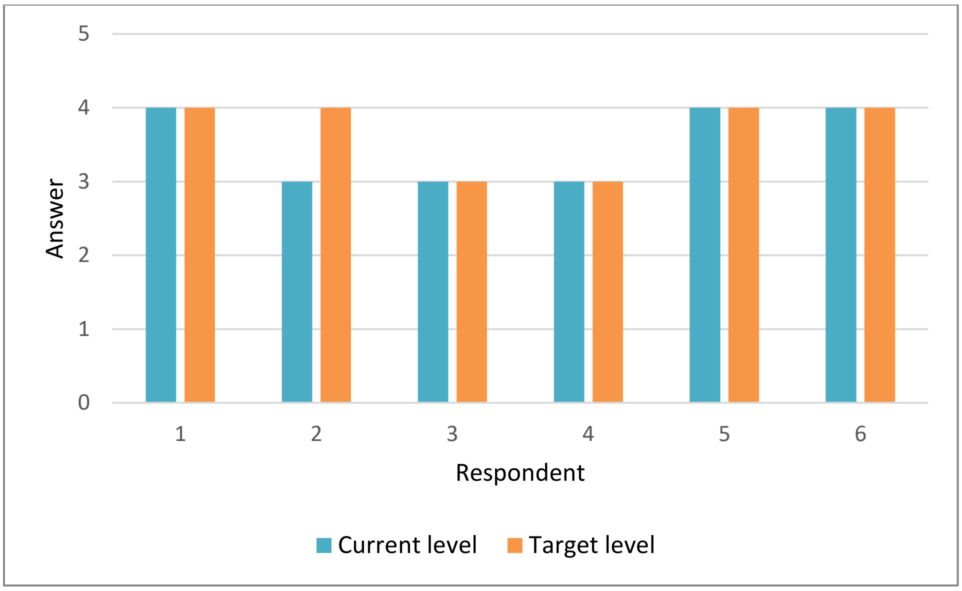

Figure 41. *Current and target maturity levels of openness to new technologies and self-learning*

The target maturity level of openness to new technologies and self-learning was seen to be between levels 3 and 4 (Figure 41). The average target level of this sub-dimension is about 3,7. The current maturity level is about 3,5. So the organization is just a little behind the target state. Almost all the respondents thought that the current level of maturity is enough in this sub-dimension, and improvements are not needed.

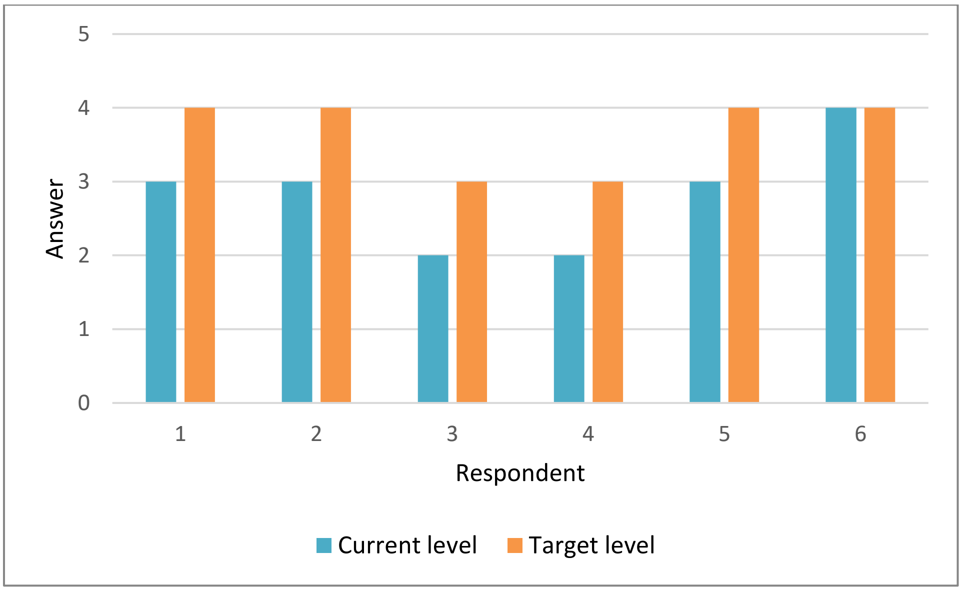

Figure 42. *Current and target maturity levels of knowledge sharing culture*

Target organization's target maturity level of knowledge sharing was seen to be between levels 3 and 4 (Figure 42). The average of the sub-dimension's level is about 3,6. The current maturity level of the sub-dimension is about 2,8. That is the lowest level of people dimension's sub-dimensions. To reach the target maturity level the sub-dimension should at least fill the level 3 descriptions and some features from level 4.

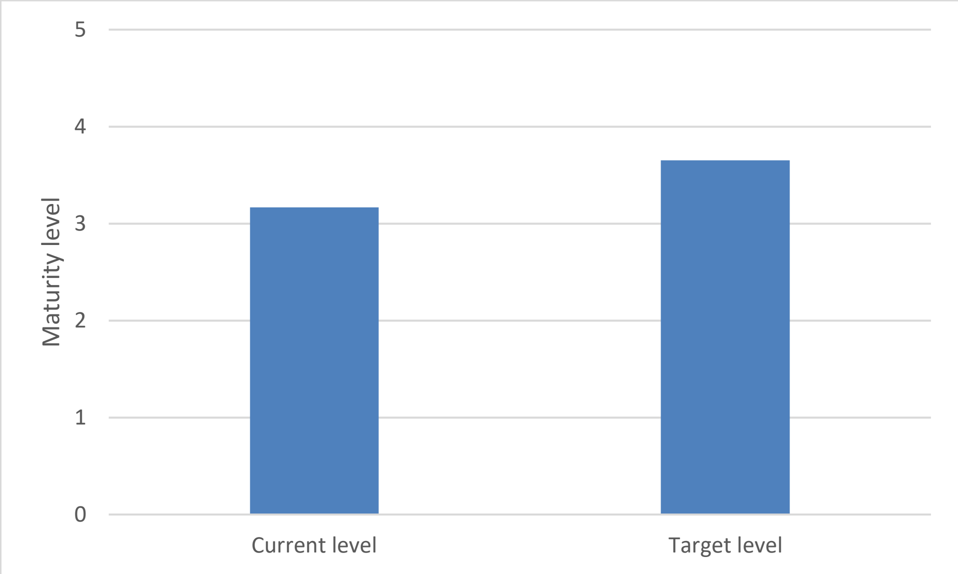

Figure 43. *People dimensions average current and target maturity levels*

Overall, the people dimension's current average maturity level is not far from the target average maturity level. Both the target level and current level are about at level 3 (Figure 43). Some little improvements could be made to reach the target level. These improvements are mainly recommended to be made in the knowledge sharing culture sub-dimension based on the results.

6.2.5 Processes

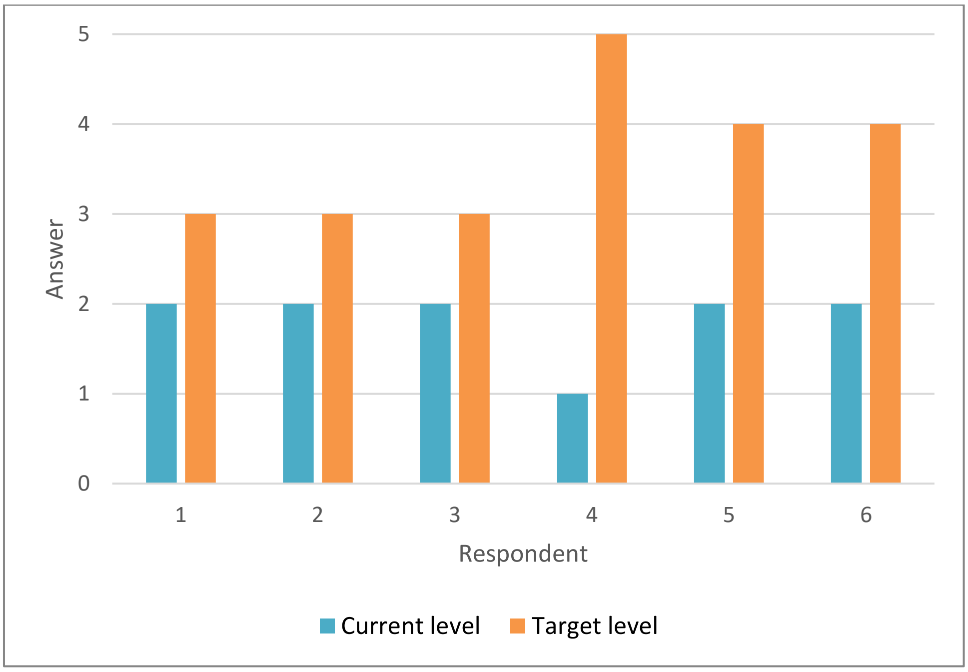

Figure 44. *Current and target maturity levels of business process documentation*

The target maturity level of business process documentation was seen to be between levels 3 and 5 (Figure 44). The average maturity level of the sub-dimension is about 3,7. The current level is 1.8, which means that the organization must reach first level 2, and then level 3 to reach the target level. Also, some features from level 4 could be beneficial for reaching the target state. One respondent thought that processes are highly important and for transparency they should also be documented well.

The target levels given differ from each other quite a lot. That may be due to differences in understanding about organizations processes. Also, respondents background may matter. If respondents have, for example, worked with processes and have seen how process documentation can help organization in managing processes, probably higher target levels are given.

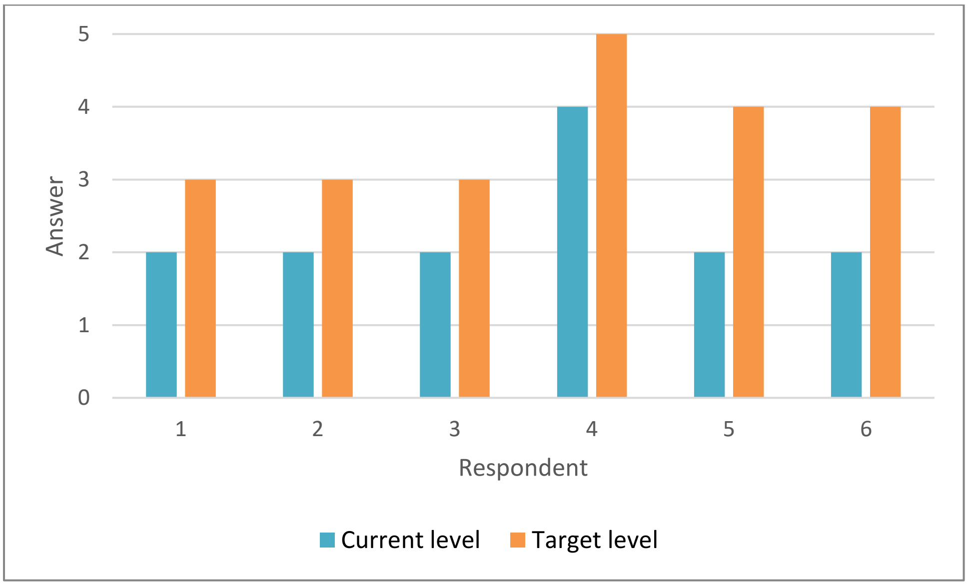

Figure 45. *Current and target maturity levels of processes for enabling and utilizing data*

The target organization's target maturity level of processes for enabling and utilizing data was seen to be between levels 3 and 5 (Figure 45). The average of the sub-dimension is about 3,7. So, the organization would like to almost reach level 4. The current average level for sub-dimension is about 2,3. That's why the organization should upgrade the level to at least level 3. Some of the respondents mentioned that these processes for enabling and utilizing data exist in some level in the current situation, but they should be developed, and they should be more transparent. This sub-dimension can be seen important also for enabling maturity development in the data-analytics based decision making dimension. Without this process, data cannot be analyzed.

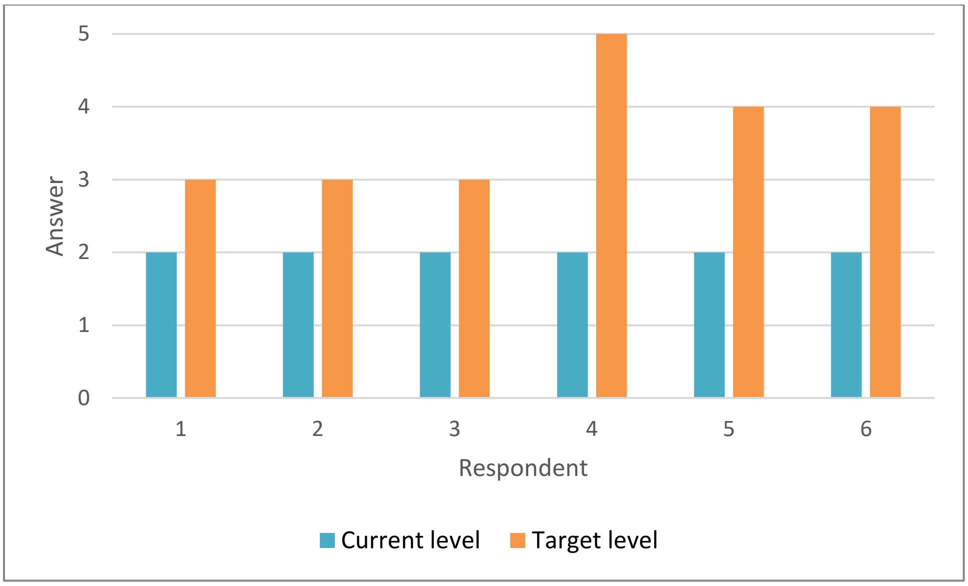

Figure 46. *Current and target maturity levels of business process re-engineering based on data*

The target maturity level of business process re-engineering based on data was seen to be between levels 3 and 5 (Figure 46). The target maturity levels average is about 3,7. The current average level was evaluated to be 2. So, the organization should reach at least level 3 and maybe some elements from level 4. From level 3 the process activities are changed and improved by implementing IoT. Some of the respondents thought that this kind of re-engineering could be beneficial, but they did not think that it is realistic in the organization, for example because of poor process driven culture.

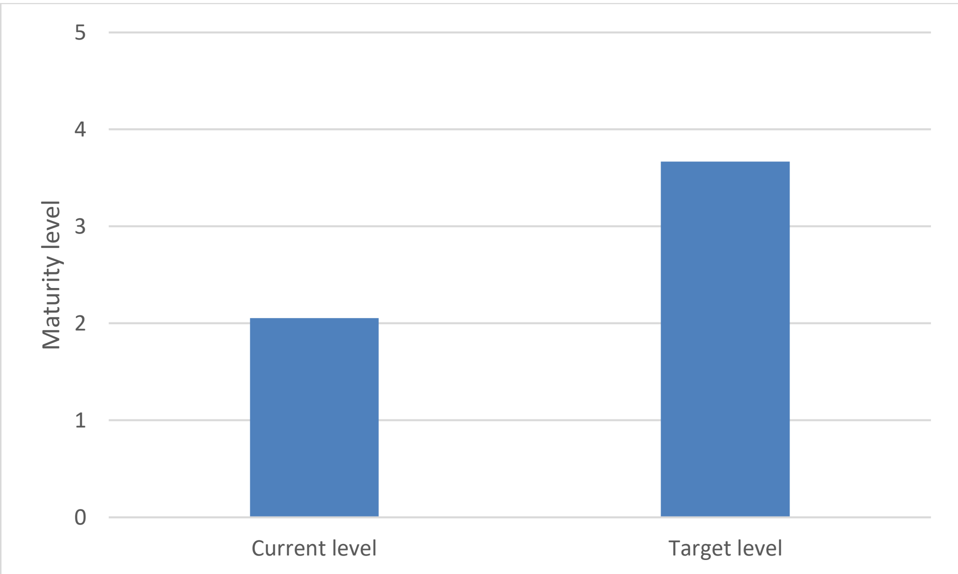

Figure 47. *Process dimension's average current and target maturity levels*

The current average dimension’s maturity level is about 1,5 levels behind the average target maturity level (Figure 47). This dimension’s results may be distorted by some respondents' poor understanding of organizations processes and process management.

7. CONCLUSIONS

This chapter goes through the discussion in different dimensions. In addition, a roadmap for reaching target maturity level is presented.

7.1 Discussion

During the interviews it was noticed that an organization's most significant maturity development needs are in governance, data-analytics based decision making and processes. Those dimensions' current maturity levels were mostly seen to be in level 2. In addition, the organization has a state of will to improve those dimensions mainly to level 4, except for a couple of sub-dimensions. Technology and connectivity and people dimensions' current maturity levels were almost in the target state already, level 3. It was mentioned that in those dimensions it is highly important to at least stay at the current levels and maturity levels should be reviewed time by time.

The results reflect that the target organization's employees may have differences in how they understand IoT and business potential related to it. Respondents background may also have effect on how they determined the maturity levels. Respondents who have a more technical background have better understanding about organizations technology and connectivity. Also, respondents who have experience in data-analytics and process management had perspective on what benefits organization can gain by improving data analysis and processes.

Some of the respondents mentioned that security is one of the concerns when thinking about gathering IoT data more often and analyzing it. Security was left out of the developed maturity model's scope, but it can be considered as a part of data governance. Some of the organization's products' end users do not want their data to be gathered from product usage. Some of the customers do not either want to connect their products to internet. It was mentioned that the industry in this field is currently quite traditional and new innovations are adapted slowly and there might be some resistance to change. Still, one of the respondents thought that the industry can change in the future suddenly by generation change and demand for products with connectivity can rise. The organization should be ready for these kinds of changes.

During the interviews it was recognized that some maturity models' dimensions and sub-dimensions have dependencies with each other. That means that those dimensions influence another dimension's maturity level. For example, IoT architecture can affect organization's data's availability. These dependencies are presented in the Figure 48. Dependencies are presented in more detail under each dimension.

CAUSE \ EFFECT		Governance				Technology & connectivity			Data-analytics based decision making				People			Processes		
		IoT plan	Resource allocation for IoT realization	IoT adaptation of business models	Data governance	IoT technology	IoT architecture	Networking	Value creation based on data	Data-analytics phase	Data's availability	Data's quality	IoT skills and competences	Openness to new technologies and self-learning	Knowledge sharing culture	Business process documentation	Processes for enabling and utilizing data	Business process re-engineering based on data
Governance	IoT plan		2	1		1	1	1	2	2					1			
	Resource allocation for IoT realization								?									
	IoT adaptation of business models								2	2								
	Data governance																	
Technology & connectivity	IoT technology						1	1	1	1	1	1					1	1
	IoT architecture				1	1		1		1	2	2				1	1	1
	Networking					1	1			1	1	1					1	1
Data-analytics based decision making	Value creation based on data																	
	Data-analytics phase								2									
	Data's availability								2	2							2	2
	Data's quality								2	2							2	2
People	IoT skills and competences	1	1	1	1	1	1	1	1	1	1	1				1	1	1
	Openness to new technologies and self-learning	1		1		2	1	2	1	1			2					
	Knowledge sharing culture	1		1		1	1	1	1	1			1	1		1	1	
Processes	Business process documentation																	1
	Processes for enabling and utilizing data								2	2	2	2						
	Business process re-engineering based on data																	

blank: no probability
1: moderate probability of causing a change (30%< change <70%)
2: high probability of causing a change (>70%)

Figure 48. *Dependence matrix*

7.1.1 Governance

Governance was seen as an enabler to other dimension's maturity. That means that governance dimension's maturity's development can be bottleneck to other dimension's maturity too. For example, IoT plan can affect other governance dimension's sub-dimensions and it can also affect technology and connectivity dimension and value creation based on data and knowledge sharing culture sub-dimensions. Thus, the governance dimension's maturity could be considered immediately in the roadmap's starting phase. Overall, the current state of the governance dimension's maturity level can be argued to be in level 2 and the target in level 4. Some of the respondents mentioned that level 5 could also be beneficial but not possible soon.

Besides, the organization already has one solution which is utilizing IoT technology. On the distribution of responses can be seen that people who are working with that existing solution gave higher maturity levels in the governance dimension than others who thought about the organization’s bigger picture. This solution has its own plan and business model. However, the organization does not have IoT plan or business models considering IoT solutions in general according to respondents.

Some of the respondents also had thought about organization’s management’s commitment to IoT projects. This subject was presented in the literature in some of the maturity models but left out of the customized maturity model’s scope. It is noticeable that IoT projects should have management’s support and commitment to reach the project goals.

7.1.2 Technology and connectivity

Organization’s technology and connectivity’s current maturity level was seen to be about 3. The target level was seen to be between 3 and 4. That means that some of the respondents thought that there is no need for improvements in the technology dimension and the current level is sufficient. About half of the respondents thought that the current situation is not enough, and improvements should be made.

One of the respondents mentioned that the organization should use standard communication technologies in the field in enabling connectivity. The markets’ needs should be the main reason for choosing the technologies. IoT technologies can be seen as enablers for IoT adaptation. New technologies should be put into use when needed. Architectures should be designed for enabling collecting, storing, transforming, and analyzing data. In addition, interfaces to required information systems such as ERPs or CRMs should be included in infrastructure.

Also, it was noticed that technology and connectivity are affecting other dimensions’ maturities too. For example, data-analytics phase, data’s availability, and data’s quality are related to technology and connectivity dimension.

7.1.3 Data-analytics based decision making

Responds to data-analytics based decision making dimension differs from each other quite a lot. Some of the respondents thought that dimension should be in the level 4 and a couple of respondents answered the highest level or level 3. However, there are two levels to upgrade from the current maturity level 2 to level 4. Some of the respondents thought that level 5 could also be beneficial, but impossible to reach in a short period of time.

Some of the respondents mentioned that the organization may have a lack of understanding about data analytics also in the management level. People who make the decisions about organization's actions are probably not even thinking about data driven decision making. The value of data is not fully understood in the organization. Also, it was considered how much advantage data analytics can bring to current situation compared to costs it will cause in the development phase. Still, some of the respondents recognized that there is huge potential in the data. Other considerations were data's availability and quality. An organization may not have available data with required quality for analytics. Data-analytics based decision making dimension has dependencies between its' own sub-dimensions. For example, data's availability and data's quality affect data-analytics phase and value creation based on data dimensions. On the other hand, the data-analytics phase also affects maturity of the value creation based on data.

7.1.4 People

The respondents thought that people dimension is almost in the target state already. Organization knowledge sharing culture was the lowest area in the dimension. There were some differences in the comments about organization's knowledge sharing. Some of the respondents thought that the organization's knowledge sharing is transparent and there are not any problems. Still, some of the respondents mentioned that the knowledge or even information is not moving between some of the teams and some needed information may be missing. These comments and differences in the respondent's thoughts may reflect that in the organization there are no common knowledge sharing practices or even if there are, they are not operating as they should. Also, some of the respondents thought that there may be a lack of communication between different hierarchical levels.

Because people dimension current maturity level differs just a little from the target maturity level there is not a huge pressure to develop it. People dimension is not obstructing other dimensions maturity levels. If any, the organization could focus on developing their knowledge sharing culture, so that all the teams got the information they needed, and knowledge could be reused at the project level. Also, it could be beneficial to give employees possibilities to educate themselves through IoT-related training in the future. In people dimension it is important to stay in level 3 so that the dimension will not become a bottleneck in the future either. That is also important to follow up, because the organization's employees may change at some point in time.

People dimension's sub-dimensions have effect on multiple other dimensions. IoT skills and competences can affect management's ability to create IoT plans or allocate resources to projects. Also, openness to new technologies can have effect on IoT technology's level and IoT adaptation of business levels.

7.1.5 Processes

Processes were recognized to be one of the major dimensions which should be improved in the organization. The dimension's current maturity level was evaluated to be in level 2 and target level in 4, except for one of the sub-dimensions. The business process re-engineering based on data was seen to be enough to be at level 3. That is justified because even the basic processes and data related dimensions are at a basic maturity level in the organization. So, the business process re-engineering based on data is left in the future and not considered in the short timeline roadmap for improvements.

In the processes dimension business process documentation and processes for enabling and utilizing data sub-dimensions are also evaluated. Through the interviews it appeared that most of the respondents were not very familiar with the process thinking. To all of them, it was not clear what was meant by the organization's business processes and how processes could be managed to generate value to end customers as efficiently as possible. It could be beneficial to start moving in the organization to the process driven direction or even observe what kind of improvements process dimension's developing could bring. From the IoT point of view, the main review should be enabling processes and utilizing data and how these processes could be improved. Also, a good starting point could be recognizing an organization's business processes and documenting them.

Also, processes dimension has some dependencies to other dimensions. For example, processes for enabling and utilizing data can have effect on data-analytics phase sub-dimension's maturity.

7.2 Answers to research questions

In this thesis is tried to answer couple of research questions. The research questions are "How can IoT be used to utilize business" and "How can the current and target state of IoT maturity be determined by using maturity models".

IoT can be utilized in the organizations' business, for example by supporting new product development. IoT can help recognize new business and product opportunities and that way help the organization to stay competitive. (Reis et al. 2022) Nowadays highly competitive markets are pushing organizations to redesign their processes and to utilize new technologies such as IoT. IoT can also help the organizations to get better customer focus, efficient productivity, automation, and some speedy returns (Kalsoom et al. 2012).

IoT can also offer organizations opportunities related to data-analytics. IoT can be for example used for predictive maintenance. Organizations can also gather data from the IoT devices to create knowledge for supporting the future development. (Reis et al. 2022) Data creates multiple opportunities such as better customer understanding and markets understanding. New business models can also be created based on IoT.

IoT maturity can be determined by using different maturity models found in the literature or by customizing maturity model for the target organization's needs. Maturity models are important managements tools (Felch et al. 2019) which supports organizations to determine their current state and target state in the different areas. In the customized models are focused to understand the states or levels of areas or dimensions which are the most important in the target organization's point of view. In this thesis the target organization's maturity of IoT were determined based on governance, technology and connectivity, data-analytics based decision-making, people and processes dimensions. These are not the only options for determining the IoT maturity, as different maturity models found in the literature shows.

Maturity models also typically have different levels or states which describe the organization's maturity's current or target level. The way in which these levels are determined affects the maturity results significantly. From literature can be found different ways to design these levels, some models have levels 1 to 4 and others for example 1 to 5 or 1 to 6. Just the level's number does not always describe the current or target level enough so it's important and recommendable to design the level descriptions carefully and so that they are down the line with other dimensions levels. In that way the organization can get reliable information about their readiness.

The current state and target state of each area or dimension can be determined in the interviews or workshops done in the target organization. Organization's experts can determine what is the current state in each area and where the organization should be. Based on the expert's answers the current state can be determined by using different methods found in the literature. Different data visualization methods can be used while determining the current and target states.

7.3 Recommendations for the target company

Based on the results, a roadmap was created for the organization to reach their target maturity levels. The roadmap was created for short term, maximum of a couple of years timeline. The IoT maturity's development work is divided into different phases so that the development load can be split. The roadmap presents which work is planned to do and in which order. The roadmap includes 6 phases. The roadmap is a suggestion for improving maturity in the organization. The roadmap is presented in Figure 49.

Figure 49. *Roadmap for IoT maturity development in the target organization*

7.3.1 Phase 1

In the beginning of the mature development the organization's governance is improved. Governance was seen as a bottleneck for other dimensions development. That is why it's beneficial to start maturity development from it. In phase 1 governance's maturity level is upgraded from level 2 to level 3.

First, the detailed IoT plan is created in the organization. People who are responsible for roadmaps and plans should organize meetings for the IoT plan's development and invite all the needed stakeholders. When the plan is developed, it should be shared at the management level. When the plan is in the implementation phase, it should be reviewed and optimized if needed. Also, in this phase, the organization should recognize possible IoT related business models. Business models are not included in this phase, but business possibilities should be identified by employees who are responsible for business models. It may be beneficial to do benchmarking about other companies' IoT solutions and business models. In addition, IoT resources should be identified and preliminary defined. IoT resources allocated are still shared only in the management level. In this phase, team managers can participate to resource planning.

Because the organization is also desiring to improve their data governance, in this phase the informal data governance is formalized. That means that actions made in the current situation are presented in some formalized form. A good starting point may be to gather and document all the already existing procedures and identify missing ones. For formalizing data governance it could be beneficial to organize a workshop or meeting for recognizing current procedures and brainstorming what is probably missing.

7.3.2 Phase 2

In phase 2 the organization has already reviewed and optimized the IoT plan at the management level. In this phase the IoT plan is shared at the whole organization's level. This improves the transparency of the plan and the management. Also, business model possibilities which were identified in phase 1 are in this level developed to actual business models. Business models can be planned using simple business model canvases and after that presented as business cases. Business cases help IoT project responsible project managers or product owners to understand what the purpose of the project is and what are the benefits of it.

In addition, all the resources which were allocated in phase 1 are in phase 2 shared in the whole organization's level. In this phase the organization should also create their own model and structure about data governance. Data governance will for example include organization's data owning responsibilities, data quality management and security aspects. From the literature can be found great examples for developing data governance which are recommendable for the organization to explore before developing their own model. For example, Khatri and Brown (2010) present design guides for data governance development and Alhassan et al. (2019) consider critical success factors for data governance. When phase 2 is completed, the organization has reached their target level in the governance dimension's maturity.

7.3.3 Phase 3

In phase 3 data's availability and data's quality sub-dimensions are upgraded from level 2 to level 4. Phase 3 focuses on ensuring that organization has high-quality and available data in use. Data's quality aspects are already defined in the organization's data governance which was developed in phases 1 and 2. Also, the organization can create a quality assurance plan for ensuring data quality. Two levels are upgraded in the same phase so that in the next phases the organization does not have to worry anymore about poor data and data availability issues. Technical experts are needed to evaluate organization's current data streams. In the same phase processes for enabling and utilizing data from level 2 to level 3 are also upgraded. Currently these processes are unclear. That is why it is important that the processes for data needed in descriptive analytics already exist in the organization. Also processes for enabling and utilizing data are improved from level 3 to level 4.

Technology and connectivity were not seen as critical for an organization's IoT maturity. However, because technology and connectivity dimension got basic level maturity evaluation by respondent with strong technical background, dimension's possible improvement needs are reviewed in phase 3. It could be beneficial to check technology and connectivity dimension too. If it appears that the technology and connectivity maturity is too low to enable more advanced data analytics, the organization can detect that technology and connectivity is bottleneck. That is why the technology and connectivity dimension should be reviewed by technical experts of the organization. If it appears that dimension's maturity should be improved, it is done in phase 4.

7.3.4 Phase 4

In phase 4, the organization will improve their processes so that data can be utilized through descriptive data-analytics. That means that the organization already has some historical data in their use and processes for use and utilization of data are developed already in phase 3. Descriptive analytics enables the organization to create insights based on data for business. Through descriptive analytics organization can create value, for example using dashboards for supporting decision making.

In the current situation organization's processes lack clear definitions. In phase 4 interconnections among process entities are identified. The organization can for example design simple process documentation where business processes are identified and it is also recognized how they are related to each other. Business process documentation is upgraded from level 2 to level 3.

In phase 4 processes for enabling and utilizing data for diagnostic analytics are also designed. The organization may need data through processes, for example for remote updates or remote monitoring. Processes needed for that kind of data utilizing are designed. Processes for enabling and utilizing data are upgraded from level 3 to level 4.

7.3.5 Phase 5

In phase 5, the organization should improve their data-analytics phase from level 3 to level 4. In phase 5, the organization should be able to utilize diagnostic analytics. That means that the organization can make analysis based on calculations and co-relations and create patterns based on rules. Processes for that kind of analytics are already designed in phase 4. Diagnostic analytics can be used for example remote updates and remote monitoring.

Moreover, in phase 5 business process documentation is upgraded from level 3 to level 4. To reach level 4 an organization must make descriptions for different interfaces between processes and enterprise systems. Also, architecture should be included in those descriptions. For example, Business Process Model and Notation (BPMN) can be used for presenting the processes. It is recommendable to use standardized notation so that the description gives everyone a clear view of processes. Additionally, a written description of processes should also be included. It is noticeable that business process documentation should be updated when needed, so it may be beneficial to determine the people responsible for doing that. The documentation also gives a basis for business process re-engineering based on data, which could be considered later in phase 6.

7.3.6 Phase 6

In phase 6, organization’s possibilities for business process re-engineering based on data are reviewed. That means that organization’s process activities are changed and improved by implementing IoT technology. To reach this level the organization should have recognized their business processes and needed qualitive data available. This development is left further because of the limited timeline.

Also, in phase 6 it is reviewed again that the organization’s people dimension is still at the needed level. Some improvements can be made for the lowest sub-dimension, knowledge sharing culture. To improve that sub-dimension organization should evaluate their knowledge management practices and discuss how knowledge could be shared through all the teams.

After phase 6 it is important to come back from time-to-time reviewing if the organization is still at the target level or if there is some need for levelling up. Also, the model itself should be reviewed time-to-time to ensure that the right things are measured. For example, new technologies for IoT development may appear soon.

7.4 Future research topics

Interesting future research topics could be, for example, IoT security related topics. IoT security was mentioned often in the literature and in the target organizations interviews. End customers want products and services where the security side is considered and managed carefully.

Also, data governance or IoT roadmap could be interesting future research topics. Data governance model or IoT roadmap could be created to target organization based on the literature.

Also, the developed maturity model could be tested, and some dimensions added or expanded. For example, management commitment and security could be added to dimensions or sub-dimensions.

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