Kaunas University of Technology
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Process of Development of Digitalization Capabilities: a Process Mining Approach

Master's Final Degree Project

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Kaunas, 2022

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International Business (6211LX029)

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Summary

Digital transformation currently disrupting the global market demands modern organizations to adopt digitalization capabilities. Therefore, the need for an outlined process for the development of digitalization capabilities arises. Throughout the review of digitalization dimensions literature three the most desirable areas for digital improvements were identified: products and services, manufacturing and operations and supply chain. Resource-based theoretical lenses provided that these dimensions withhold seven key capabilities. The theoretical presumptions were validated by empirical research. Sample data from EMS consisting of 789 cases from Central and Eastern European firms was prepared and ran through process mining – Fluxicon Disco. Descriptive analysis of the findings provided a look into currently adoptable process for the development of digitalization capabilities.

Research question: What is the process of the development of digitalization capabilities?

Aim: To reveal the process of development of digitalization capabilities using process mining approach.

Objectives:

1. Conduct literature review revealing the dimensions of digitalization;
2. Background the model with resource-based theory constituting the process of development of digitalization capabilities;
3. Ground methodology to verify the process of development of digitalization capabilities;
4. Conduct empirical analysis using process mining approach;
5. Present results of the empirical research directed to revel the process of development of digitalization capabilities.

Revealed sequence: controlled process capability, software augmentation capability, connect capability, analytics capability, industrial robots capability and 3D printing capability. The current common process on average runs for 5 years and 6 months. Further analysis might uncover, what and how capabilities in other dimensions are being developed, how capabilities vary between industries or how digitalization affects company's financial performance.

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Santrauka

Šiuo metu pasaulinę rinką vis dar veikianti skaitmeninė transformacija modernioms įmonėms diktuoja reikalavimus vystyti skaitmenizacijos gebėjimus. Todėl, kyla poreikis nubrėžti vieningą skaitmenizacijos gebėjimų plėtros procesą. Apžvelgiant skaitmenizacijos dimensijoms dedikuotą mokslinę literatūrą buvo nustatytos trys labiausiai pageidaujamos skaitmenizacijos tobulinimo sritys: produktai ir paslaugos, gamyba ir operacijos, tiekimo grandinės. Ištekliais pagrįsta teorinė prieiga leido identifikuoti septynis pagrindinius skaitmenizavimo gebėjimus. Duomenys, gauti iš EMS susidedantys iš 798 Centrinės ir Rytų Europos įmonių buvo paruošti procesų tyrybos metodui ir sukelti į Fluxicon Disco programinę įrangą. Aprašomoji duomenų analizė suteikė įžvalgų į šiuo metu paplitusį skaitmenizacijos gebėjimų plėtros procesą.

Tyrimo klausimas: Koks yra skaitmenizacijos gebėjimų vystymo procesas?

Tikslas: Atskleisti skaitmenizacijos gebėjimų vystymo procesą, taikant procesų tyrybos prieigą.

Uždaviniai:

1. Atlikti literatūros, iliustruojančios skaitmenizacijos dimensijas apžvalgą;
2. Pagrįsti skaitmenizacijos gebėjimų kūrimo procesą ištekliais grįsta teorija;
3. Aprašyti metodiką skaitmenizacijos gebėjimų vystymo procesui patikrinti;
4. Atlikti empirinę analizę taikant procesų tyrybos metodą;
5. Pateikti empirinio tyrimo, skirto atskleisti skaitmenizacijos gebėjimų vystymo procesui, rezultatus.

Atskleista skaitmenizacijos gebėjimų plėtros seka: procesų valdymo gebėjimas, programinės įrangos paplitimo gebėjimas, sujungimo gebėjimas, analitinis gebėjimas, pramoninių robotų gebėjimas ir 3D spausdinimo gebėjimas. Dabartinis procesas vidutiniškai trunka 5 metus ir 6 mėnesius. Tolimesnė temos analizė galėtų atskleisti, kokie ir kaip yra plėtojami kitų dimensijų gebėjimai, kaip gebėjimų plėtra skiriasi įvairiose pramonės šakose bei, kaip skaitmenizacija veikia įmonės finansinius rezultatus.

Table of Content

Introduction 11
I part. Systematic review of dimensions of digitalization of organizations 13
1.1 Impuls model 13
1.1.1 Strategy and corporate culture critical to launch into the Industry 4.0 14
1.1.2 Smart factory that enables distributed, highly automated production 14
1.1.3 Smart workpieces guiding the production process 15
1.1.4 Physical products equipped with ICT components 15
1.1.5 Data-driven services built into the business models 16
1.1.6 Successful implementation of Industry 4.0 requires qualified personnel 17
1.1.7 Summary of Impuls model 17
1.2 WMG model 18
1.2.1 Products and services 19
1.2.2 Manufacturing and operations 20
1.2.3 Strategy and organisation 22
1.2.4 Supply chain 23
1.2.5 Business model 24
1.2.6 Legal Considerations 26
1.2.7 Summary of WMG model 27
1.3 Maturity model 28
1.3.1 Summary 28
1.4 Summary of the systematic review of dimensions of digitalization of organizations 29
II part. Theoretical solutions of the process of development of digitalization capabilities 31
2.1 Theoretical approach: resource-based theory 31
2.1.1 Controlled processes capability 33
2.1.2 Software augmentation capability 34
2.1.3 Connect capability 35
2.1.4 Analytics capability 36
2.1.5 Energy efficiency capability 37
2.1.6 Industrial robots capability 37
2.1.7 3D printing capability 38
2.2 Summary of the resource based theory: defining digitalization capabilities 39
III part. Methodology for evaluation of the process of development of digitalization capabilities .. 42
3.1 The approach 42
3.2. Data collection procedures: data collection and questionnaire 42
3.3 Data analysis approach 43
3.3.1 Reliability and validity 43
3.3.2 Discriminant validity 44
3.3.3 Overview of variables assigned to factors 45
3.3.4 Computation of variables 46
3.3.4.1 Calculation of years variables 46
3.3.4.2 Calculation of average years variables 48
3.3.4.3 Transposing in Excel 49
3.3.4.3 Ranking 49
3.3.4.4 Running method: fuzzy miner (Fluxicon Disco) 49
3.4 Summary of the methodology for evaluation of the process of development of digitalization capabilities 50
IV part. The results of empirical research of the analysis of process of development of digitalization capabilities 50

4.1 Descriptive analysis of diffusion of digitalization capabilities 50
4.1.1 Descriptive analysis of dispersion of digitalization capabilities per sets of events in frequencies 50
4.1.2 Descriptive analysis of dispersion of digitalization capabilities per cases throughout time 53
4.1.2.1 Mean example 53
4.1.2.2 Outlier examples 54
4.1.3 Descriptive analysis of dispersion of digitalization capabilities per countries....................... 56
4.2 The process of development of digitalization capabilities 57
4.2.1 Process of the development of digitalization capabilities through frequencies....................... 57
4.2.2 Process of the development of digitalization capabilities through timeframes 61
4.2.3 Additional note on the process of the development of digitalization capabilities 62
4.3 Summary of the results of empirical research of the analysis of process of development of digitalization capabilities 64
Conclusions 65
References 67
List of information sources 70

List of Tables

Table 1.0 The ‘Smart’ part of the six key digitaliztion dimensions, (Impuls) 17
Table 2.0 The six key dimensions and sub-dimensions of digitalization development, (Impuls) 18
Table 3.0 The most commonly adoped forms of technology were computer networks and databases used by 70% respondents, (WMG) 19
Table 4.0 Products and services: Readiness level & sub-dimensions, (WMG) 20
Table 5.0 Manufacturing and operations: Readiness level & sub-dimensions, (WMG) 21
Table 6.0 Strategy and organisation: Readiness level & sub-dimensions, (WMG) 23
Table 7.0 Suply chain: Readiness level & sub-dimensions, (WMG) 24
Table 8.0 Business model: Readiness level & sub-dimensions, (WMG) 25
Table 9.0 Business model: Readiness level & sub-dimensions, (WMG) 27
Table 10.0 Overall readiness 28
Table 11.0 Structure of the maturity model and importance weight for dimensions and items, (Maturity model) 29
Table 12.0 Resource-based Theory: Digitalization Capabilities 33
Table 13.0 Definitions of Capabilities 40
Table 14.0 Theory-based process of development of digitalization capabilities 41
Table 15.0 Questionnaire (Vilkas et al., 2021) 43
Table 16.0 Internal Consistency Variablity 44
Table 17.0 Discriminant Validity 45
Table 18.0 Variables assigned to the Factors 46
Table 19.0 Summated scales: spread of the items assigned to factors 47
Table 20.0 First Years Used Calculation 48
Table 21.0 Transposition of Variables 49
Table 22.0 Cases per Events 51
Table 23.0 Spread of Capabilitities: First Year Used Approach 51
Table 24.0 Capability Dispersion per Type ‘4 Events’ as Single Set I 52
Table 25.0 Capability Dispersion per Type ‘4 Events’ as Single Set II 52
Table 26.0 Capability Dispersion per Type ‘6 Events’ as Single Set I 53
Table 27.0 Mean Case Example I 54
Table 28.0 Mean Case Example II 54
Table 29.0 Outlier Case Example I 55
Table 30.0 Outlier Case Example II 55
Table 31.0 Outlier Case Example III 55
Table 32.0 Outlier Case Example IV 56
Table 33.0 Country Dispersion in Dataset 56
Table 34.0 The Process of the Development of Digitalization Capabilities through Frequencies.... 58
Table 35.0 Frequencies per capabilities 60
Table 36.0 The Process of the Development of Digitalization Capabilities through Timeframes.... 61
Table 37.0 Active Cases over Time 63
Table 38.0 Case Duration 63

List of Abbreviations and Terms

Abbreviations:

AI – Artificial Intelligence

BDA – Big Data Analytics

CAD – Computer-Aided Design

CAE – Computer-Aided Engineering

CAM – Computer-Aided Manufacturing

CAPP – Computer-Aided Process Planning

CC – Cloud Computing

CHM – Computer History Museum

CPS – Cyber-Physical Systems

CSR – Corporate Social Responsibility

ERP – Enterprise Resource Planning

ICT – Information and Communications Technology

ID – identification

IFS – Industrial and Financial Systems

IoT – Internet of Things

IP – Intellectual Property

IT – Information Technology

EDI – Electronic Data Interexchange

EMS – European Manufacturing Survey

FMS – Flexible Manufacturing Systems

KPI – Key Performance Indicator

M2M – Machine to Machine

MRP – Material Requirements Planning

NC – Numerical Control Machines

PPS – Production Planning Systems

R&D – Research and Development

RAS – Robotics and Autonomous Systems

RBV – Resource Based View

RESC – Renewable Energy Supply Chain

RFID – Radio Frequency Identification

ROI – Return of Investment

S&OP – Sales and Operations Planning

SAP – Systems Applications and Products

SCM – Supply Chain Management

SKU – Stock Keeping Unit

SPSS – Statistical Analysis Software

TMS – Transportation Management Systems

WMS – Warehouse Management Systems

Introduction

Digital transformation is infecting the world almost as fast or even faster than the Covid-19. Recent circumstances of global pandemic and events of national isolation rushed different industries to change their ways of operating towards digitized functioning. Therefore, organizations that want to stay competitive in the international market can no longer avoid digitalization.

The Industry 4.0 is spreading across the globe disruptively as technological advancements enhance different business areas. Consequentially, organizations are struggling to adapt to the ever changing virtual environments. Starting from production in retail, fashion, furniture and ending with online and on-site service businesses they are all forced to catch-up with the rapid and unprecedent changes in the technological processes. Nowadays, computers, machines and software are expected to communicate between each other, share information and perfect the automation of routine tasks. However, organizations either lack the information or the instruments available for them to streamline digitalization development.

In this regard, organizations must get equipped with necessary knowledge and tools to implement adjustments in production processes and the usage of resources. The focus of the Industry 4.0 is to find the most effective way of management whilst meeting the demands of the customer in an efficient manner. And in order to achieve and sustain alternative digital practices of organizing and sharing data new internal processes need to be established. As well as new ways to measure performance, manage supply chain, conduct individual and company-wide assignments, share information internally and externally. According to WMG, these changes require not only investments in technology or R&D yet also a major shift company culture wise.

Crimson & Co excelling in driving sustainable transformations throughout improving technical elements of the supply chain have established a certain way of leading companies through digitalization. As an example, the steps go as follow: assessing changes that need to be made, designing elements of the changes in need, embedding the changes into operations. This is rather a general high-level roadmap rather than instruction of how digitalization enters modern companies. In addition, there are a few digital maturity models or Industry 4.0 readiness models already circulating as a topic of discussions amongst scholars and practitioners. The models thoroughly cover the areas of the business or the digitalization capabilities that are desirable attributes to the current operational processes. However, the models do not deliver sequencing patterns or the process how particular digitalization capabilities are developed .

Therefore, the sequencing of the development of digitalization must not be taken for granted. Bearing in mind, that every organization differs and has unique capacities for implementation of changes, the need of an in-depth research arises in terms of finding the most common and/or practically applicable process of development of digitalization capabilities. Consequently, the following question constitutes the research question of the thesis: what is the process of the development of digitalization capabilities? The aim of the thesis is to reveal the process of development of digitalization capabilities using process mining approach.

Objectives:

1. Conduct literature review revealing the dimensions of digitalization;
2. Background the model with resource-based theory constituting the process of development of digitalization capabilities;
3. Ground methodology to verify the process of development of digitalization capabilities;
4. Conduct empirical analysis using process mining approach;
5. Present results of the empirical research directed to revel the process of development of digitalization capabilities.

In order to reveal the process of development of digitalization capabilities, the secondary data analysis method was chosen. The data from European manufacturing survey is going to be used with a sample consisting of 798 Eastern and Central European manufacturing companies Methods of descriptive statistics and process mining algorithm are going to interpret empirical findings.

The results of the empirical research should provide a look into a particular sequence or a process how the development of digitalization capabilities looks in the particular data set. On the other hand, the empirical findings might also show that there is no specific process of how the digitalization capabilities are being developed (which would in addition validate the need to look into the topic further). All in all, the findings are going to be matched against resource-based theory which is going to be used as theoretical lenses in the thesis. Subsequently, systemized insights on the process of the development of digitalization capabilities are going to be presented as a predictive model.

Regarding the structure of the thesis, first chapter is going to be dedicated to overview the literature on already existing Industry 4.0 readiness models. The second chapter is going to cover the resource-based theory in relation to digitalization capabilities. The third chapter is going to be devoted to the methodological grounding of the empirical data analysis. The fourth chapter is meant to discuss the empirical findings and provide the initial insights into the process of the development of digitalization capabilities. And the thesis is going to be concluded with systemized findings from the previous chapters.

I part. Systematic review of dimensions of digitalization of organizations

To start with, in the upcoming chapter, three digitalization models are going to be discussed in order to illustrate different approaches of how the process of development of digitalization of capabilities is seen at the moment in different schools of thought. In the first section, the Impuls model is described. This is an online tool for firms' to self-check the readiness to introduce digitalization capabilities. The section is divided to smaller sub-sections that give a deeper understanding of each of the family of capabilities. The mentioned model focuses on the steps required to prepare the organizations for the immersion into the Industry 4.0. The following section discusses WMG model. Which is also an assessment tool used in practice to determine what readiness level each organization has to introduce certain capabilities and its readiness to the Industry 4.0. However, WMG model has slightly broader criteria. And the last sub-section briefly touches upon Maturity model which has an extended look into organizations with precise variables and their scoring weights to measure the maturity of the companies in the light of Industry 4.0. All in all, these different models lay a ground to see how the digitalization development is looked at from the practical point of view and from different perspective on the company readiness for the Industry 4.0. This in turns provides a further need to conduct a theoretical overview of the resource-based theory. What do the resources or, in other words, capabilities mean in their terms and in a practical sense. This is going to be discussed in-depth in the chapter II.

1.1 Impuls model

To start with, the Impuls model researches the readiness of the organizations for the 'Industry 4.0'. The results derive from a study that was commissioned by the German Engineering Federation (VDMA) and its Foundation IMPULS (conducted by the subsidiary of the Cologne Institute for Economic Research – IW Consult and the Institute for Industrial Management (FIR) at RWTH Aachen University). Impuls model is an online self-check readiness for the Industry 4.0 tool. The tool allows organizations to complete thoroughly prepared questionnaires and check where does it stand in terms of the development of digitalization capabilities. It automatically calculates organizations' readiness score and permits to acknowledge were does the company in question has room for improvements.

The following six key dimensions of Industry 4.0 are the foundation for the readiness model:

a) Strategy and organization
b) Smart factory
c) Smart operations
d) Smart products
e) Data-driven services
f) Employees

In the following sub-sections the six key dimensions are going to be discussed in more detail to provide a deeper understanding of where the digitalization happens and is assessed in modern organizations.

1.1.1 Strategy and corporate culture critical to launch into the Industry 4.0

To follow through, what is commonly imagined is that products and processes are the most important part and focus of the development of digitalization. And they definitely are an important part, however, not the only concern when it comes to implementation of digitalization capabilities inside organizations. The Industry 4.0 is about creating and conducting entirely new business models. Therefore, the strategy of the company becomes one side of the coin. And the implementation of that strategy becomes another side of the coin. And they both play a vital role when starting to prepare the organization for the digital switch. Therefore, strategies must be reviewed or reinvented. And the openness of the current cultural settings of the organizations must be examined in order to reveal the scope of possible improvements in terms of interactions and connectedness. Subsequently, following criteria apply in this case:

- Implementation status of Industry 4.0 strategy;
- Operationalization and review of strategy through a system of indicators;
- Investment activity relating to Industry 4.0;
- Use of technology and innovation management.

The criteria is fairly broad and does not give too much information however the questionnaire has its checks and marks in order to give organizations a good check-in on how they are doing in terms of strategy and corporate culture. The next dimension to overlook in the following sub-section is a smart factory.

1.1.2 Smart factory that enables distributed, highly automated production

Next dimension in line, is automated production. This is the part, where the so called smart factories should be able to control, monitor and guide themselves autonomously throughout the production processes. Whereas nowadays, the traditional production lines still require constant human overlook, adjustments and improvements. In some cases, the overview processes are conducted only partly self-sufficiently and therefore still somewhat rely on the human touch. Without human intervention smart factories should be able to sustain environment where logistic and production systems organize themselves.

‘The smart factory relies on cyber-physical systems (CPS), which are the link between the physical and virtual words’. The links works through communication within IT infrastructure such as cloud sharing tools or Internet of Things as limited-access platforms.

The smart factory change also involves digital modeling with the usage of data. In this sense, the data needs to be gathered, stored and processed in a precise and accurate manner. Data here serves as a link between physical and virtual words. The open sharing of information, use of resources and delivery of innovation are the premise for the smart factory as well as for the grounding of the Industry 4.0.

And in order for these conditions to fall together real-time movement of knowledge, cross-team collaboration and connectedness amongst information, production and people systems is essential.

The decision making model travels beyond the usual board rooms and enters the world of analyzed, systemized and interpreted data which in a terms is a smart factory. Organization's progress regarding smart factory is measured by following criteria:

- Digital modeling;
- Equipment infrastructure;
- Data usage;
- IT systems.

The following sub-section overlooks the dimension of smart workpieces.

1.1.3 Smart workpieces guiding the production process

Smart workpieces' dimension refers to cross-enterprise as well as enterprise-wide collision between production strategy, production lines and products themselves. The wave of digitalization and glorification of data in recent years took over the world of production and logistics. And it made production planning systems (PPS) and supply chain management (SCM) systems turn into entirely separately functioning business entities. The technical backbones necessary in order to operate and navigate through these systems today are simplified into a term of smart operations. And these smart operations are determined by the use of the following criteria:

- Information sharing;
- Cloud usage;
- IT security;
- Autonomous processes.

1.1.4 Physical products equipped with ICT components

Fourth dimension to review is smart products. Smart products of course have all the same features and functionalities as the 'usual' or 'traditional' ones would have. However, the 'smart' part comes into light when we talk about the abilities of the products' to gather and translate the data into production process throughout the ICT add-ons such as sensors, communication interfaces or RFID. When infused with extra digital components the products can 'communicate' with higher-level systems and guide themselves autonomously as it becomes possible to monitor and optimize individual products.

In addition, the application of smart products travels beyond the production line and enters the real world in the hands of the customer. Smart product, in this sense, becomes a tool to also read the live-data in the process of usage which can suggest further product improvements or additional services. Which in turns creates the need of high focus onto IT security.

Moreover, the usage of the data gathered from the products can consequentially become a source of an extra revenue stream. Or in other words, smart products not only connect the production line and production management systems but also manufacturers and customers. The readiness for the smart products can be seen throughout the amount of ICT add-ons, functionalities of the product and the extent to which the data can be gathered from the devices and analyzed.

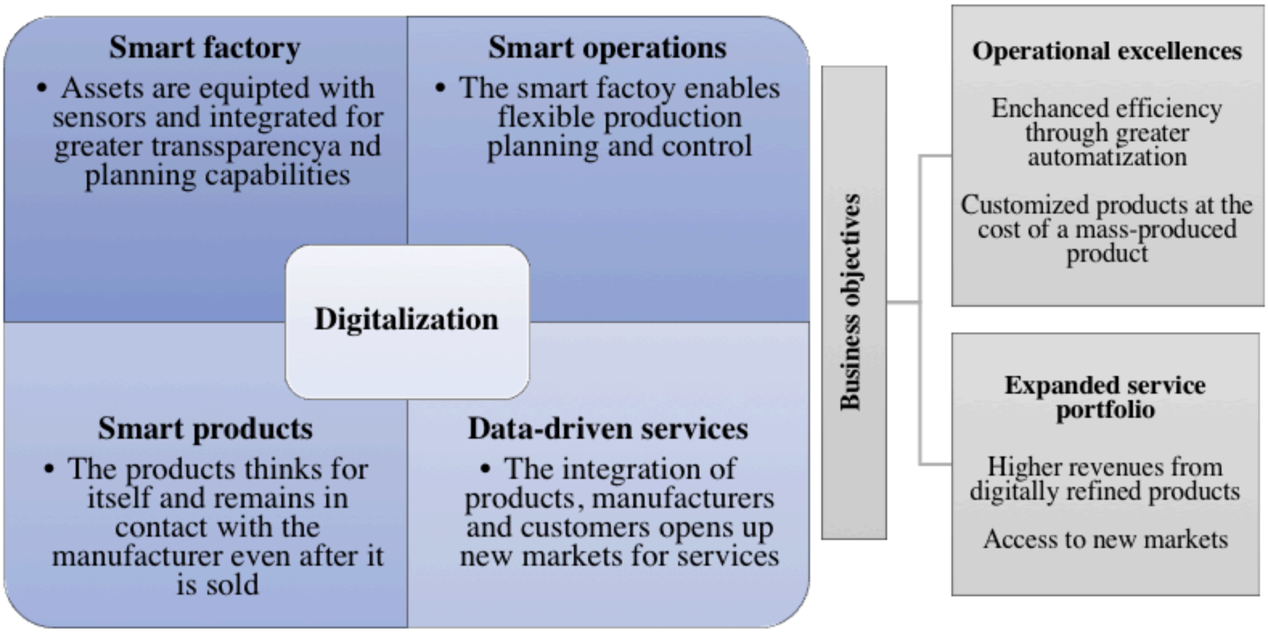
1.1.5 Data-driven services built into the business models

The following dimension is data-driven services. Data-driven services speak mostly about the alignment of the operating business model and the benefit that could be increasingly delivered to the client. Throughout the enterprise wide-integration of collected data its analysis and evaluation in different departments. For example, sales, marketing, delivery, planning, the after-sales – the services should be enhanced according to the data-based feedback and bring additional revenue streams. In order to implement this dimension fully the physical IT must be integrated in the products and a separate business entity established for the data to be received, processed and interpreted to make informed decisions. In other words, the physical and digital components should interacting with each other and upper management to bring the results of fully immersive customer experience. Readiness in the area of data-driven services is determined using the following criteria:

- Availability of data-driven services;
- Share of revenues derived from data-driven services;
- Share of data used.

In the Table 1.0 *The 'Smart' part of the six key digitaliztion dimensions* below the 'smart' part of the Industry 4.0 readiness dimensions is portrayed in structured and simplified manner. Besides the four 'smart' parts of the development of digitalization that were analyzed the motivation to the business in terms of deliverability's is also described. Amongst those, the efficiency through automation, customized products for the production price of mass-products, expanded service portfolio through the use of data when digitally refining products and in addition to that, access to new markets line up. The motivation or the benefits are in all fairness only one side of the coin when speaking about the development of digitalization. There are, of course, threats and challenges that come together with the introduction of digitalization capabilities. These are also going to be touched upon in the chapter III.

Table 1.0 The 'Smart' part of the six key digitaliztion dimensions, (Impuls)



1.1.6 Successful implementation of Industry 4.0 requires qualified personnel

The last dimension to review is qualified personnel. And workforce, without a doubt, becomes a subject to iteration when speaking about the development of digitalization. Digital transformation touches upon the working environment as it creates a need to adapt to new demands in terms of skills and qualifications. Therefore, appropriate training and sustainable education must also be a part of the digitalized reality. Readiness in the dimension of employees is determined by analyzing employees skills in various digital areas and the company's efforts to acquire new skill sets.

1.1.7 Summary of Impuls model

To back-up, these six dimension were used to develop a measurement set and evaluate the readiness for the Industry 4.0. The score might vary from 0 to 5. Level 0 is considered to be an outsider. The minimum requirements need to be met in order to complete and travel up-the-level. The Level 5 describes top performers – the ones who successfully implemented all Industry 4.0 activities.

To summarize, the Table 2.0 *The six key dimensions and sub-dimensions of digitalization development* represents the six dimensions in the form of the wheel. Each dimension has sub-dimensions ascribed to it. Strategy and organization, smart factory, smart operations, smart products, data-driven services, employees – all of these areas must be considered when organizations choose to score themselves in terms of the readiness for the Industry 4.0. However, it must be noted that the Impuls model is only one of already many existing self-evaluation tools and/or models and the dimensions and sub-dimensions depend on the method in use. Further, in the chapter the WMG model is examined in order to see common similarities or detect differences between varying models for scoring the readiness/preparedness for the development of digitalization capabilities.

Table 2.0 The six key dimensions and sub-dimensions of digitalization development, (Impuls)

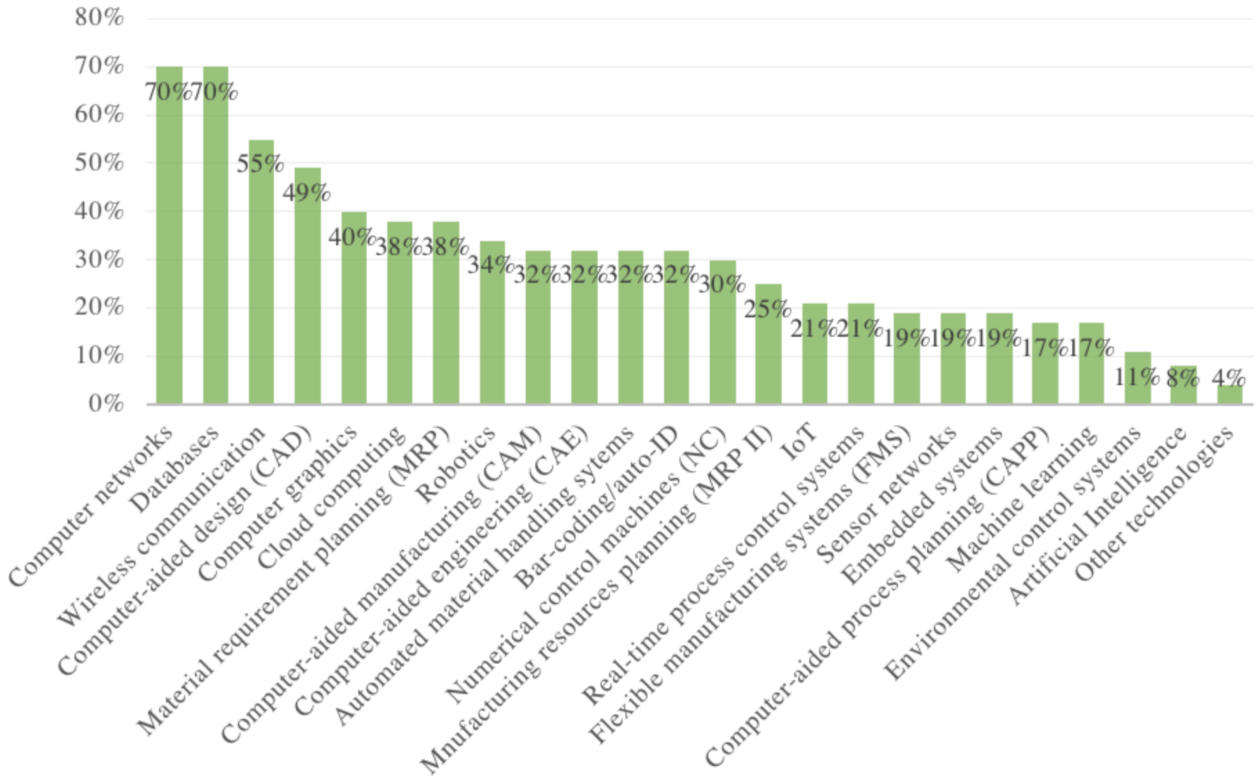
1.2 WMG model

The WMG model was developed as an Industry 4.0 readiness assessment tool with purpose to harness the potential of the cyber-physical age. It considers factors revolving not only around technology but extends beyond it and looks within 6 main dimensions and 37 sub-dimensions of the process of development of digitalization capabilities. The core dimensions include:

- Products and services;
- Manufacturing and operations;
- Strategy and organization;
- Supply chain;
- Business model;
- Legal considerations.

The model is based on four readiness levels (beginners, intermediate, experienced, and expert). Each sub-dimension has specific pre-defined criteria that need to be reached to obtain the desired level of readiness. Since the research was mainly conducted within production-oriented industries such as automotive, electronics, engineering & construction, food & beverages, aerospace, defense & security and electrical equipment which together constitute 62% of all participants in the survey this can also be reflected in the most commonly adopted forms of technology portrayed in the Table 3.0 *The most commonly adoped forms of technology were computer networks and databases used by 70% respondents, (WMG)*. In other words, such technologies as CAD, MRP, robotics, CAE, automated-material handling systems dominate the tendencies of highly-implementable digital systems. Yet, as noted above, the technological part reflects only one side of the coin in this model therefore a closer look to separate dimensions is needed in order to see differences between the WMG and Impuls models. The following sub-section is dedicated to discussing products and services as denominators to the readiness of the development of digitalization.

Table 3.0 The most commonly adoped forms of technology were computer networks and databases used by 70% respondents, (WMG)



1.2.1 Products and services

The emerging tendency of the Industry 4.0 is providing an opportunity for the customer to engage in subscription based services rather than owning the physical version of the product. Therefore, innovative alternatives of currently existing physical products are desirable. And this serviceable version is expected to meet certain quality requirements. Considering the fact that, paving the path into achieving the digitalization objectives one of the key presumptions is to maintain the 'batch size of one at the same unit cost as batch size of mass-production' the standardization of the physical product base is required.

However, in this instance the out-of-scope customizations of the commodities become a solution demanding issue. Here, is where the digital advancement of the organization comes into play and the plausible resolution of the situation might come through introduction of digital product features. This allows to connect with the consumers via the use of data driven services and enhance its user experience by utilizing product data usage.

The sub-dimensions of the products and services dimension are (as listed in Table 4.0 *Products and services: Readiness level & sub-dimensions*): product customization, digital features of products, data-driven services, level of product data usage, share of revenue. In the table provided below, each of the sub-dimensions and levels have a pre-defined criteria in order to navigate the current status quo of the organization. After scoring each sub-dimension separately companies are able to see where they have area for improvement and how specifically they can enhance it.

Table 4.0 Products and services: Readiness level & sub-dimensions, (WMG)

Readiness level	Level 1 Beginner	Level 2 Intermediate	Level 3 Experienced	Level 4 Expert
Product customization	Product allows for no individual standardized mass production	Majority of products are made in large batch sizes with limited late differentiation	Products can be largely customized but still have standardized base	Late differentiation available for most make-to-order products (batch size 1)
Digital features of products	Products show only physical value	Product show value only from intellectual property licensing	Products exhibit some digital features and value from intellectual property licensing	Products exhibit high digital features and value from intellectual property licensing
Data-driven services	Data-driven services are offered without customer integration	Data-driven services are offered with little customer integration	Data-driven services are offered with customer integration	Data-driven services are fully integrated with the customer
Level of product data usage	Data is not used	0-20% of collected data is used	20-50% of collected data is used	More than 50% of collected data is used
Share of revenue	Data-driven services account for an initial share of revenue (<2.5%)	Data-driven services account for a moderate share of revenue (2.5-7.5%)	Data-driven services account for a significant share of revenue (7.5-10%)	Data-driven services play an important role in revenue (>10%)

1.2.2 Manufacturing and operations

Next, manufacturing and operations. The WMG model considers the factory and the extreme optimization of its operations as the core focus of Industry 4.0. In addition, factory falls under a vision to develop fully customizable products produced autonomously and in self-advancing manner. To elaborate, physical and the cyber setting should collide and interact to create revolutionary results. Therefore this dimension has 10 sub-dimensions (presented in the Table 5.0 *Manufacturing and operations: Readiness level & sub-dimensions*) in total as it is one of the key components of development of digitalization capabilities. They can be categorized in 4 main areas:

- Technology integration: Automation, machine and operations system integration (M2M);
- Autonomous workplace: Self-optimizing processes, autonomously guided workpieces;
- Data: Operations data collection, operations data usage, cloud solution usage, IT and data security;
- Resource capability: Digital modelling, equipment readiness for Industry 4.0.

Table 5.0 Manufacturing and operations: Readiness level & sub-dimensions, (WMG)

Readiness level	Level 1 Beginner	Level 2 Intermediate	Level 3 Experienced	Level 4 Expert
Automation	Few machines can be controlled through automation	Some machines and system infrastructures can be controlled through automation	Most machines and system infrastructures can be controlled through automation	Machines and systems can be controlled completely through automation
Machine and operation system integration	Machines and systems have no M2M capability	Machines and systems are to some extent interoperable	Machines and systems are partially integrated	Machines and systems are fully integrated
Equipment readiness for Industry 4	Significant overhaul required to meet Industry 4.0 model	Some machines and systems can be upgraded	Machines already meet some of the requirements and can be upgraded where required	Machines and systems already meet all future requirements
Autonomously guided workpieces	Autonomously guided workpieces are not in use	Autonomously guided workpieces are not in use, but there are pilots underway	Autonomously guided workpieces used in selected areas	Autonomously guided workpieces are widely adopted
Self-optimizing processes	Self-optimization processes are not in use	Self-optimizing processes are not in use, but there are pilots in more advanced areas of business	Self-optimizing processes are used in selected areas	Self-optimizing processes are widely used
Digital modelling	No digital modeling	Some processes use digital modelling	Most processes use digital modelling	Complete digital modelling used for all relevant processes
Operations data collection	Data is collected manually when required e.g. sampling for quality control	Required data is collected digitally in certain areas	Comprehensive digital data collection in multiple areas	Comprehensive automated digital data collection across the entire process
Operations data usage	Data is only used for quality and regulatory purposes	Some data is used to control processes	Some data is used to control and optimize processes e.g. predictive maintenance	All data is used not only to optimize processes, but also for decision making
Cloud solution usage	Cloud solutions are not in use	Initial solutions planned for cloud-based software, data storage and data analysis	Pilot solutions implemented in some areas of the business	Multiple solutions implemented across the business
IT and data security	IT security solutions are planned	IT security solutions have been partially implemented	Comprehensive IT security solutions have been implemented with plans developed to close any gaps	IT security solutions have been implemented for all relevant areas and are reviewed frequently to ensure compliance

1.2.3 Strategy and organisation

Further follows dimension of strategy and organization. 'Businesses have to embed the concept of Industry 4.0 across functions and levels, ensuring that internal KPIs and the cross-functional collaborations are consistent to drive better adoption and financial returns.' Dimension regarding strategy and organization is directed towards single individuals who make the organization work, considering the higher-level perspectives, senior-mid-junior management, inter-department teams, different departments and cross-functions related efforts required to mediate between the outsides and insides of the business units.

Yet also, it is important to take into consideration the measurements to track the benefits of the improvements and closely watch how the return of investment rolls out throughout long-term perspective when making changes on the strategical and organizational level. This dimension includes 7 sub-dimensions (as presented in the Table 6.0 *Strategy and organisation: Readiness level & sub-dimensions*): degree of strategy implementation, measurement, investments, people capabilities, collaboration, leadership, finance.

The study conducted by WMG revealed that the dimension of strategy and organization amongst the participants of the survey had the lowest readiness level. Researchers uncovered that management of the organizations recognize the benefits of digitalization practices, however, they lack abilities to incorporate these values into 'business as usual'.

Moreover, even technologically advanced companies struggle to build up foundations to harness digital culture or accelerate digital skills. Furthermore, companies set boundaries or a ceiling to ensure that the cost of ownership of changes come hand in hand with financial business benefits. And to finish with, a personalized approach whilst seeking Industry 4.0 adoption is not helping the organizations to grow in a desirable trajectory since the change requires team efforts.

To sum up, even though the leadership is pro-change and willing to make adjustments budget and operations wise, actions do not always speak louder than words. And it seems like the middle road of open and trustworthy communication comes a long way when speaking about taking on new responsibilities regarding digital capacities.

Open cross-team communication, training programs, joint performance indicators, definition/ownership and rapport of change as well as accurate measurement of returns might be a step forward to ground the changes into practice. All in all, the transformation towards Industry 4.0 has potential to objectively better organizations in reducing operating costs while reaching for overall business efficiency and these benefits must not only be stated but also conveyed company-wide in a sense of measurements and feedback in order to move things forward.

Table 6.0 Strategy and organisation: Readiness level & sub-dimensions, (WMG)

Readiness level	Level 1 Beginner	Level 2 Intermediate	Level 3 Experienced	Level 4 Expert
Degree of strategy implementation	Industry 4.0 is recognized at departmental level but is not integrated into strategy	Industry 4.0 is included in the business strategy	Industry 4.0 strategy has been communicated to the business and is widely understood	Industry 4.0 strategy has been implemented across the business
Measurement	KPIs are not focused around Industry 4.0	Structured set of business metrics exist, with some measurement of Industry 4.0 drivers	Industry 4.0 metrics are widely understood in the business and used in monthly reporting	Business metrics and personal development plans are focused around Industry 4.0 objectives
Investments	Initial Industry 4.0 investments in one business area	Industry 4.0 investments in more advanced business areas	Industry 4.0 investments in multiple business areas	Industry 4.0 investments across the entire business
People capabilities	Employees have little or no experience with digital technologies	Technology focused areas of the business have employees with some digital skills	Developed digital and data analysis skills across most areas of the business e.g. production	Leading edge digital and analytics skills across the business
Collaboration	The business operates in functional silos	There is limited interaction between departments, e.g. S&OP process	Departments are open to cross functional collaboration	Departments are open to cross company collaboration to drive improvements
Leadership	Leadership team do not recognize the value of Industry 4.0 investments	Leadership teams are investigating potential Industry 4.0 benefits	Leadership team recognize the financial benefits to be obtained through Industry 4.0 and are developing plans to invest	Widespread support for Industry 4.0 within both the leadership team and across the wider business
Finance	No sizeable Industry 4.0 investment	No ongoing review of cost/benefit analysis for Industry 4.0 investment	Annual cost/benefit analysis of Industry 4.0 investment	Quarterly cost/benefit analysis of Industry 4.0 investment

1.2.4 Supply chain

To continue with, supply chain as one of the dimensions follows. The implementation of Industry 4.0 has its challenges such as adopting new technologies, adjusting cultural setting, re-organizing or making improvements to individual business functions. However, making the connection between the supplier and the customer throughout the supply chain is the most precise and essential issue to tackle from them all. Re-visiting management and operations of the supply chain in a light of the development of digitalization capabilities should bring down the walls between different business functions as well as include various stakeholders inside and outside the organization in order to employ processes, develop capabilities and find ways of maintaining and supporting newly established systems. This stretches far beyond the traditional supplier and customer relations.

Supply chain dimension encompass five sub-dimensions: inventory control using real-time data management, supply chain integration, supply chain visibility, supply chain flexibility and lead times (presented in the Table 7.0 *Suply chain: Readiness level & sub-dimensions*). Improving supply chain operations will mean quicker response time to the market fluctuations and ability to foster individual customer demands. In this sense, efficient supply chain would shorter lead to customer lifecycle and flexibility in providing services. However, on another end, this could either mean more inventory stock supply or higher operational costs.

Table 7.0 Suply chain: Readiness level & sub-dimensions, (WMG)

Readiness level	Level 1 Beginner	Level 2 Intermediate	Level 3 Experienced	Level 4 Expert
Inventory control using real-time data management	Inventory levels are understood	Computer database is used which is manually updated with inventory levels	Computer database used with smart devices updating inventory levels	Real-time database which is updated by smart devices
Supply chain integration	Ad hoc reactive communication with suppliers and customers	Basic communication and data sharing where required with suppliers and customers	Data transfer between key strategic suppliers/customers (e.g. customer inventory levels)	Fully integrated systems with suppliers/customers for appropriate processes (e.g. real-time integrated planning)
Supply chain visibility	No integration with suppliers and customer	Site location, capacity, inventory and operations are visible between first tier suppliers and customers	Site location, capacity, inventory and operations are visible throughout supply chain	Site location, capacity, inventory and operations are visible in real-time throughout supply chain and used for monitoring and optimization
Supply chain flexibility	Slow response to marker changes	Moderate response to market changes and general customer requirements shifts	Moderate response to changes in market environment and individual customer requirements	Immediate response to changes in market environment and individual customer requirements
Lead times	Long materials lead time resulting in high inventory levels	Improvements have been identifies to reduce lead times for some materials	Some improvements have been implemented to reduce lead times on key materials	Differentiated stocking policies and lead times to meet make-to-order efficiently

1.2.5 Business model

To follow through, dimension of business model revolves around several sub-topics (as documented in the Table 8.0 *Business model: Readiness level & sub-dimensions*): 'as a service' business model, data driven decisions, real-time tracking, real-time and automated scheduling, integrated marketing channels, IT supported business. The sub-dimensions signalize, that the shift here lays in the way the business is conducted. Or more importantly how the product reaches the customer. For example, catalogue based retailers move to online business, market mediators lend their houses and goods (Airbnb, Uber, eBay) or products get turned into services. A lot here dependends on the industry where the business operates.

Yet, the key ingredient to bear in mind is to keep the business model contemporary and regularly refreshable. This often pre-supposes, that together with developing digitalization capabilities companies parallelly should come-up with their own business model in order not to be pushed out of the market by disruptive entrants.

The recommendations worth considering for the organizations wanting to improve their business model is to continue investing and leveraging IT support by utilizing data to make decisions and improvements. And also, improve customer experience via different channels and bridge the gap between online and offline. Further, suggestion that might come in handy is discussing different business models internally. And making a choice for specific areas of investing based on iterations. For instance, real-time tracking or scheduling technologies.

Table 8.0 Business model: Readiness level & sub-dimensions, (WMG)

Readiness level	Level 1 Beginner	Level 2 Intermediate	Level 3 Experienced	Level 4 Expert
'As a service' business model	No awareness	Aware of concept with some initial plans for development	High awareness and implementation plans are in development	'As a service' has been implemented and is being offered to the customer
Data driven decisions	Data is not widely analyzed	Some data is analyzed and features in key business reports to review performance	Most data is analyzed and the result is considered when making business decisions	All relevant data is analyzed and informs business decisions
Real-time tracking	Limited product tracking	Product can be tracked as it moves between manufacturing and internal distribution sites	Product can be tracked through manufacturing and distribution until it reaches the customers distribution center	Product can be tracked along the complete lifecycle
Real-time and automated scheduling	Equipment is manually maintained in line with the maintenance schedule	Some machines alert operators of a performance issue which enables them to manually schedule a maintenance task	Some machines are self-diagnosing, automatically passing information to the maintenance scheduling system	Machines are generally self-diagnosing and the maintenance schedule adjusts itself based on real time data inputs from the machine
Integrated marketing channels	Online presence is separated from offline channels	Integration within the online and offline channels but not between them	Integrated channels and individualized customer approach	Integrated customer experience management across all channels
IT supported business	Main business process supported by IT systems	Some areas of the business are supported by IT systems and	Complete IT support of processes but not fully integrated	IT systems support all company processes and are integrated

1.2.6 Legal Considerations

The last dimension is legal considerations. They are assessed through four legal sub-dimensions (as listed in the Table 9.0 *Business model: Readiness level & sub-dimensions*): contracting models, legal risk, data and intellectual property. The traditional contracting model is limiting the parties of the contract with the premise of withholding from revealing both risks and reward. However, the Industry 4.0 suggests collaborative approach towards legal dealings. And that covers transparency and candor amongst multiple parties participating in the contracting agreements.

Regarding risk management, it must be taken into account that risk prevention is no longer an option but rather a must in the digital reality. Risk awareness together with an action plan on how to address those risks can grant businesses a competitive edge. 54% of the respondents in the WMG research did not consider or were not aware of the 'lurking' risks. Which consequently results in 'maximum scope of exposure' to the unknown unknows. In relation to that, there is no way to make informed decisions in the face of such threats and risks. Which only deepens the need of improving the level of legal considerations as it might effect companies not only in moral but legal and financial manner.

Data protection comes hand in hand to the legal considerations. Since the functioning of modern organization is highly dependent on the data usage and its protection as well. Therefore, the measures of complying with data protection regulations need to be adjusted, reviewed and documented repeatedly and accordingly to the ever changing digital reality as it is moving faster than companies manage to adapt and implement additional requirements.

To finish with, intellectual property is still an area too often taken in disregards and companies should fall into the habit of claiming their intellectual rights while being on the very first steps of their journey. The Industry 4.0 is built on innovative ideas that must be protected in order not to get crushed by disruptive competition.

Yet it is worth mentioning that responsibility within legal considerations when speaking about development of digitalization capabilities lay not only in the hands of business. It is also highly dependent on government entities, legislation and overall practice. Some areas in question still lack legal certainty and precedents. Such as decisions on robots as legal subjects. Which demonstrated the reluctance from the authorities to fully consider, immerse and adopt new technologies.

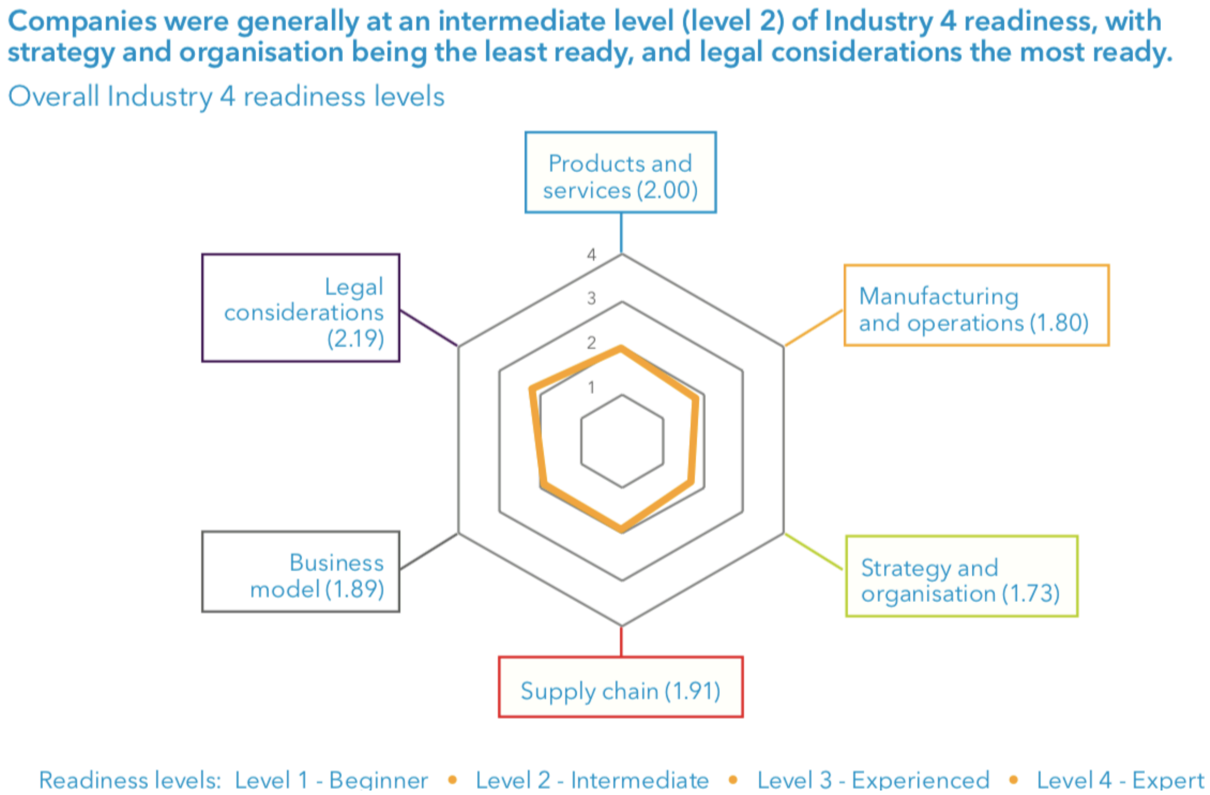
Table 9.0 Business model: Readiness level & sub-dimensions, (WMG)

Readiness level	Level 1 Beginner	Level 2 Intermediate	Level 3 Experienced	Level 4 Expert
Contracting models	Contracting processes are linear and unchanged	Some changes to contracting processes to reflect operational changes	Some 'flagship' projects utilize new contracting models but it is not standard across the board	All contracting is behavioral and incentivises parties to achieve the best results
Risk	New risks not identified or assessed	New risks identified and/or assessed but no mitigations planned	New risks identified and assessed, and limited mitigations put in place	Working party has assessed the changing risk profile and has procedures in place to mitigate these
Data protection	No data protection policies or procedures	Have internal policies but do not ensure compliance in engagement with suppliers/customers	Good understanding with robust policies and procedures but haven't updated for General Data Protection Regulation	Conducted a recent General Data Protection Regulation audit and are confident of compliance including in light of Industry 4.0
Intellectual property	Intellectual property in new products and services is not identified or protected	Awareness of intellectual property in new products and services, but no legal protections identified or applied for	Intellectual property in products and services is identified and in part assessments made as to whether registrations/contractual rights required, and if required, appropriate steps taken	Intellectual property in products and services is identified and assessments made as to whether registrations/contractual rights required and, if required, appropriate steps taken

1.2.7 Summary of WMG model

Looking through the WMG model (Table10.0 *Overall readiness*) and comparing it besides the Impuls model (Table 2.0) similarities can be found within products and services, manufacturing and operations, strategy and organization, supply chain and business model dimensions. These dimensions cover more or less similar topics with the previous model. However, in the WMG model some attention is given to the legal considerations of the development of digitalization capabilities and the subject is narrated in a great detail. Therefore, it also should be considered when determining the overall company readiness to immerse into the Industry 4.0.

Table 10.0 Overall readiness



1.3 Maturity model

The following model also seeks to determine different dimensions and sub-criteria in order to score the maturity of the companies in the light of Industry 4.0. The Table 11.0 *Structure of the maturity model and importance weight for dimensions and items* portrays the dimensions and measurement items together with the extensive description of the measurement items. The interesting part of this model is that every item has a specific and different scoring weight against overall maturity level.

1.3.1 Summary

However, the content of the categories mostly fall under the Impuls and WMG models described previously and therefore will not be repeated or elaborated on. So far, the analysis have shown main categories that need to be overlooked when making decisions toward the movement of the development of digitalization capabilities. And yet, the sequencing of how these capabilities should interact or be spread throughout the organization still remains unclear. Therefore, further research into the processes of the development of digitalization capabilities needs to be conducted. In order to do that, the following chapter is going to be dedicated to resource based theory and examination what capabilities (resources) fall under the dimensions described in the chapter II. What each capability is in its definition, what opportunities and challenges come with their implementation. In turns, theoretical part is going to provide a further ground for the methodological part of the thesis and give a perspective of how to interpret the empirical findings in the chapter III.

Table 11.0 Structure of the maturity model and importance weight for dimensions and items, (Maturity model)

Industry 4.0 dimension (FAHP weights)	Assessment criteria/ measurement item	Description for measurement item	Item weights (FAHP weights)
People and culture (0.12)	Leadership Support	The leadership support towards digital transformation activities	0.38
	Continuous Improvement Culture	The company's continuous improvement culture to adopt Industry 4.0	0.12
	Dedicated teams	The existence of dedicated teams in the company to drive digitalization across the organization	0.17
	Digital skills and qualification	The company's alignment towards employees' digital skills and qualifications to adopt Industry 4.0	0.33
Industry 4.0 awareness (0.06)	Familiarity with Industry 4.0	The Company's familiarity with the term 'Industry 4.0'	0.35
	Sensitivity towards the impact of digital transformation	The sensitivity of the company towards the impact of digital transformation through Industry 4.0	0.22
	Usefulness of Industry 4.0 to company	The perception regarding the usefulness of Industry 4.0 to company's performance	0.17
	Preparedness for Industry 4.0 adoption	The perception regarding the company's preparedness for the introduction of new technologies of Industry 4.0	0.26
...	...	...	...

1.4 Summary of the systematic review of dimensions of digitalization of organizations

To summarize the literature review, it can be seen that digitalization capabilities are being introduced in organizations focusing on specific business dimensions. Each of the areas have descriptive requirements in order to be fulfilled. An important note worth mentioning is that the scope of the thesis does not cover, for example, the role of employees, data-driven services or strategy and organization in introduction of digitalization capabilities into business processes. Rather, the focus of the thesis revolves around smart factory, smart operations and smart products with a goal to tap into the best practices in regards to sequencing the introduction of capabilities that are actually digital and on-demand in the market. Therefore, the next chapter is going to discuss the resource-based theory as the theoretical basis for the thesis. Another important note worth mentioning is that the aim of the thesis is leading to further considerations of sequencing of the introduction of digitalization capabilities rather than the effects that the capabilities have on business performance. In order to fulfill the aim of the thesis, therefore each capability is described separately and in-depth to uncover the theoretical presumptions towards the topic and build a ground for the interpretations from empirical findings.

II part. Theoretical solutions of the process of development of digitalization capabilities

2.1 Theoretical approach: resource-based theory

In the previous chapter, it was overlooked in which of the business areas the introduction of digitalization capabilities is the most desirable considering the context of the Industry 4.0. The chapter proved the relevance of the topic and a necessity to look into it with a closer look. Therefore, in the upcoming section the recourse-based theory will be touched upon to reveal what kind of capabilities are the most desirable and prominent from the theoretical perspective.

The traditional organizational approach through industrial lenses focuses on the market research and analysis when it comes to searching for solutions for the firms to stay competitive. Whilst resource-based approach turns to assets possessed by the organization. According to Das in *'A Resource-Based Theory of Strategic Alliances'* the firm is equivalent to a set of resources it owns and disposes. And resources in this case are both tangible and intangible and are tied to the firm at least on semi-permanent grounds (Das, 2000). To continue with, the RBV is closely linked with the 'capacity to continually reconfigure an organization's competitive advantage' (Barney, 2001). And in the realms of the Industry 4.0 the source of competitive advantage is considered to be dynamic capabilities or in other words firms' abilities to alter their resources according to the changes in the market, customer demand or competition. Therefore, in a sense RBV connects both market-focused and resource-focused approaches.

Moreover, Galbreath in *'Which resources matter the most to firm success? An exploratory study of resource-based theory'* using empirical findings goes even further and discovers that capabilities contribute more significantly to firm success than either intangible or tangible assets (Galbreath, 2005). Due to high levels of random ambiguity and barriers to replicate the digitalization capabilities modern firms seek to expand their knowledge base in processes and systems and empower the company to become a network for tacit knowledge over-spilling to the quality of its products and gains for the customers. The RBV in this regard provides an additional insight into 'the direction of company's diversification strategy' (Andersen, 1998). Since its defined by the ability to dispose its available capabilities while taking advantage of the opportunities in the market and by creating barriers to entry (Grant, 1991).

To continue with, in the recent years of hyper-growth in global markets, the resource-based functioning was codified in a form of the best operational practices not only in the pages of the company strategy but also implemented in real-life practices. However, the real-life practice still lacks the knowledge about the management of dynamic capabilities and competences to develop the right capabilities for the firm according to Knott Paul in *Integrating resource-based theory in a practice-relevant form*. Conner in *A Resource-based Theory of the Firm: Knowledge versus Opportunism* also considers the importance of operationalizing the RBV through organizational mode as the mode conditions the knowledge base that later gets applied to the business activity.

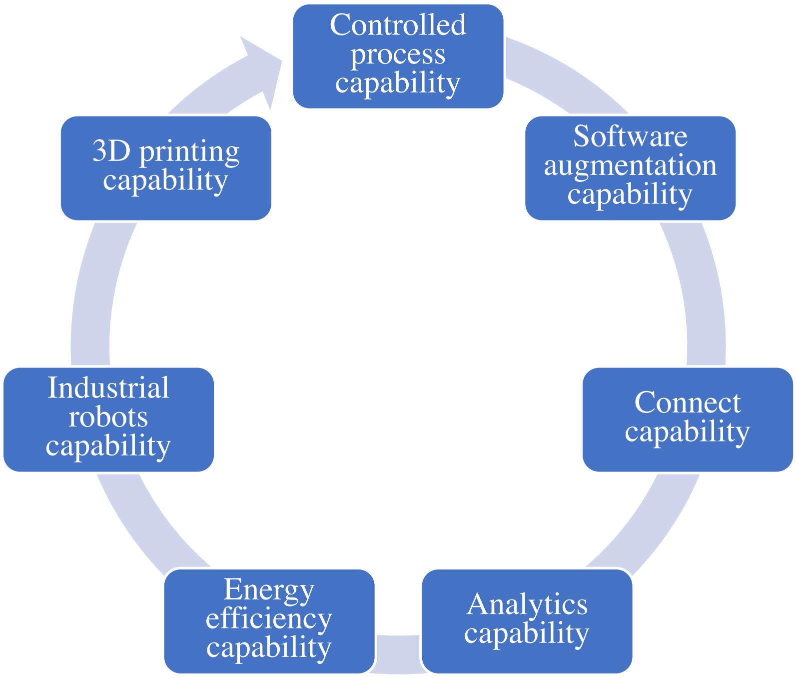
To build up upon the idea of digitalization capabilities Caldeira in '*Using resource-based theory to interpret the successful adoption and use of information systems and technology in manufacturing small and medium-sized enterprises'* analyzes further what criteria digitalization capabilities must dispose in order to satisfy the conditions of heterogenous and immobile resources (which are considered to be the requirements for capabilities in RBV to ensure sustainable competitive advantage). Caldeira proceeds with 4 criteria for the digitalization capabilities. They have to be valuable, rare, imperfectly imitable and non-substitutable. Another insight that the study delivers is that the composition of the resources also must be considered closely depending on the objectives set by the business strategy.

Speaking about the applicability of the resource-based approach it was analyzed as means of theoretical lenses in Acedo, 2006. Scholars analyzed the reoccurrence and depth of the topic of the resource-based theory in scholarly research using inductive empirical approach. The results showed that there is 'an exponential growth in the number of published papers that use this theory as a theoretical foundation'. The article also concludes that, most of the reoccurrences of the usage of this theory can be noticed in the fields of marketing, production management and organizational studies. To continue with, one of the main topics of the thesis is the question of the production management therefore the relevance of the theory proves to be within the scope of the research. To take a specific supply chain member for an illustration, Sergio in *Resource-based theory and strategic logistics research* repeats back the premise of RBV that firms who develop distinctive capabilities gain competitive advantage over the firms implementing generic ones. Therefore, scholars argue that, for example, in the area of logistics the relationship between hard-to-imitate capabilities should result in overall organizations' superior performance in terms of profits, sales or even market share.

To further, scholars started to question the premise of dynamic capabilities being a sustainable source of the competitive advantage. The questioning revolves around a concern that a firm can stay competitive only if it fulfills 'sooner rather than later' conditioning. In this sense, the firms' ability to quickly adapt to the changes and to be alert towards the changes in the market becomes interrelated with firms' financial value and/or gains. As well as these gains must be matched against the return of investments (ROI) and the expectations for the financial profits have to be within the accurate expectations (Barney, 2012). Considering the scholarly approach with some terms assigned to staying competitive in the market the sequencing of the introduction of digitalization capabilities becomes an even more relevant topic to discuss further.

With a short view to the relevance of the theory, a further in-depth look to the topic of resource-based theory must be conducted. Therefore, different resources or in other words – digitalization capabilities are going to be scrutinized in the upcoming section in order to uncover theoretical premises and build a stronger ground for the empirical part of the thesis. In the Table 12.0 *Resource-based Theory: Digitalization Capabilities* the capabilities are displayed that proved to be the most interrelated with the dimensions chosen for further research from the previous chapter. Each of these capabilities is going to be explained in its definition, examples and also benefits together with challenges arising with the implementation of the capability.

Table 12.0 Resource-based Theory: Digitalization Capabilities



2.1.1 Controlled processes capability

In the following sub-section the term of the capability of controlled processes will be examined as well as its implications practically together with challenges and disadvantages.

In the face of current worldwide challenges such as globalization, outsourcing, SKU proliferation, shorter product lifecycles there are many 'moving parts' in the smart factory or smart operations areas of the business. The stabilization of the processes and the collection of the data is required to be automated in the early stages of establishing the processes. Otherwise, inability to complete that would require manual, repeated data entry. Which is inefficient in many ways in regards of the consumption of time and people recourses but also inaccurate in its sense. Therefore, automation and stabilization systems need to be deployed to perform data entry in a manner of an automated task. This leads to definition of the capability of controlled processes. Controlled processes capability is an interlinked information system with 'identification of each physical item in the supply chain in a timely manner'. (McFarlane, 2006)

The collection of the intel from supply chain and its management can tell what is the state, location and status of each item in the production chain. In turns, the information can be used in different areas to improve the processes of the business such as: tracking, tracing, accountability, collection of historical data, improvements of the interconnectedness of the processes, improvements to internal workflows, information sharing, etc. More specific cases of the processes would be shipping, transportation, distribution, in-facility and receiving operations. This in result should help companies save time, resources, returns, churn, revenue lose and etc. Few of the examples of the controlled processes tools are Auto IDs, bar code readers and RFID readers, warehouse management systems (WMS), transportation management systems (TMS)

However, the introduction of the processes control capability also has its downsides as it requires data storage facilities (virtual and on-site), data access and data sharing functionalities. Which in turns presupposes the threats of information security in a sense of outside interference or risks of data inaccuracy. Therefore, the main source of these challenges are the costs as well as maintenance of the systems.

To finish this sub-section with, it is worth mentioning that the controlled processes capability is as far as the prior researchers' take-outs consider one of the base or key elements in order to implement the following capabilities. For example, in order to introduce the software augmentation capability prior preparation with regards to controlled process capability should already be in place. Software augmentation capability is going to be discussed in more detail in the next sub-section.

2.1.2 Software augmentation capability

In the following paragraphs the capability of software augmentation is going to be reviewed in more depth providing its definition and a few examples of the software supporting the capability. Also, the benefits and the challenges of introduction of software augmentation capability are going to be examined.

The traditional way of working and implementing action-plans is through live meetings, usage of outdated ICT and undocumented processes nowadays are insufficient to support decisional accuracy in front of complex problems such as global management of large international companies. Such business areas as risks connected to security, demand-fulfilling operations and sustainable development are now handled throughout advanced algorithms. Which in turns gives an ability to extract the information from millions of data points and sources. And to come to the definition of software augmentation capability it is what connects separate software systems from different business departments. And also, gathers their data into a common database which is easily readable, understandable and accurate. Therefore, software augmentation capability is a digital network of partners executing coordinated processes in an organized and informed way. (Merlino, 2016)

To be more specific software augmentation can enhance different areas of the business for example, demand planning, facility planning, supply network planning, detailed scheduling. Production planning, freight/container loading, dynamic traffic support, transportation optimization, repair and reverse logistics, procurement, sourcing and supplier management, supply chain analytics. Some examples of the software tools adding to the augmentation capability: 'E2open, SAP SCM, Perfect Commerce, Oracle SCM, Infor SCM, JDA SCM, Manhattan SCM, Epicor SCM, Dassault Systems SCM, Decartes SCM, Highjump SCM, IFS, Watson Supply Chain, BluJay SCM'. (Predictive Analytics Today)

Some challenges that arise together with the introduction of software augmentation capability could also be noted. Such as, implementation of poor programs, flawed integration with already existing tools and processes, lack of qualified staff to support the execution.

To finish this section with, software augmentation capability can lead to practical advantages in many different areas of the business. However, it also comes with conditions in regards to (re)allocation of financial, R&D and human capital and time resources. Right preparation, pre-implementation analysis and testing are also needed. In the next sub-section the connectedness capability will be scrutinized in more depth as a follow-up to already discussed controlled process and software augmentation capabilities.

2.1.3 Connect capability

In the next sub-section the definition of connect capability is going to be presented together with the use cases of the connectedness in the firms. Also, the opportunities this capability is providing and risks that might come with its introduction are going to be touched upon.

In the forefronts of the Industry 4.0 phenomena, the traditional businesses are forced to transform their SCM to digital functioning format. With this the need to establish control protocol, implement additional software tools and make the systems sufficiently interconnected arises. Which in turn should help the digital SCM to be eligible to deliver the desirable results. More often than not the process requires re-invention or re-design of internal management activities.

'The potential of integrated supply chain can only be realized if the connections and inter-relationships among different parts of the supply chain are recognized, and a proper alignment is ensured between the design and the execution of the company's strategy. (Kim, 2006) The common practice as well as scholarly research follows the presumption that in smaller firms, however, the interconnectedness of the supply chain management shows only relative contributions to the overall performance of the company. In other words, the cost and the value component has a rather low ratio. Whereas, in larger companies close relation between different capabilities is more significant in direct effects on financial and competitive gains.

However, it is also worth considering that in smaller firms the integration of supply chain is more desirable in the sense of connecting the moving parts of the process. In the meantime, in the larger firms the focus shifts to supply chain management. And in this regard, the later implies stronger emphasis on the shift of managerial practices internally. Entrepreneurial attitudes towards adoption of capabilities were considered by scholars in light of RBV. Top management is required to foster awareness towards opportunities, ability to acquire resources in a timely manner, re-organize homogenous resources and turn them into heterogenous outputs. (Alvarez, 2001). Therefore, connect capability probably more than others rely not only on the implementation of the systems or software themselves but also on training and re-invention of management practices as well as review of overall strategy. Also, integration of supply chain leads to consideration of an intervening variables such as strong strategic alignment as well as coordination with the partners involved in supply chain processes. So the emphasis here falls again under administrational and operational side of the business rather than technical. Connect capability enabling technologies include Big Data Analytics (BDA), Blochain-related technology, Artificial Intelligence (AI), Cloud Computing (CC), Cyber-physical systems (CPS), Internet of Things (IoT). All these enabler technologies together constitute the digital supply chain capability. Which means 'integrated capabilities with different supply chain members'. (Queiroz, 2019)

To sum this sub-section up, the connect capability comes with its on challenges related to re-invention of management practices yet the possible opportunities which comes with the company-wide deployment of the capability suggest high-returns. Yet, high returns mostly come together with high risks and costs of some sort. In the next sub-section the analytics capability is going to be discussed in a similar manner. A note worth mentioning, is that the outline of the sub-sections implies that the fore-front capability comes hand in hand with the subsequent capability. The relevance of the empirical research lies within the aim to compare the theoretical presumptions of the process of the development of digitalization capabilities with the real/in-practice sequencing of the introduction of the capabilities. This in line come together with an adjacent goal to uncover or pre-suggest good practices regarding the process of the development of digitalization capabilities.

2.1.4 Analytics capability

The following sub-section will cover the concept of analytics capability. Furthermore, practical examples of the implementation of analytics capability will be given as well as its possible positive and negative effects.

The need for the development of analytics capability derives from the current scaling-up speed and the desire from the upper management to make data-backed decisions. The most prominent backlogs of data nowadays come from supply chain operations and monitoring of user activity or in other words – digital performance analytics. Therefore, one of the technologies used in order to process this data is, for example, Big Data Analytics (BDA). 'Since Big Data consists of high-volume, high-velocity and high-variety data assets which in recent years became readable and available to process for almost all the business' (Jha, 2020) , the real-time capturing, transmitting and interpreting of the data is reachable within a hand.

The data can be presented in many forms and coming from different sources such as: social media usage, e-commerce shopping platforms, search engines, sensors, etc. In order to read the data an analytics capability is needed. As the analytics capability is business intelligence technology consisting of applying advanced analytics to the big data. Using analytics capability has implications to enhance decision-making in the company throughout proved insights within various domains of it. For example, shortening the distribution time by identifying biggest bottle necks, drawing customer-journey maps and making improvements to the process from there. For example, by identifying key activities relating to customer satisfaction, making improvements to the products based on collection of the user data, developing interrelations between the production or delivery teams and the customer in order to provide instant feedback and implement changes. As practical examples, enterprise resource planning (ERP) packages such as SAP or Oracle could be mentioned. There are also options in the market to implement build-in systems for forecasting and planning.

On the other hand, analytics capability also consists of few of the drawbacks regarding implementation practices. The technology covering the analytics capability is rather complex. And as it is evolving in great speeds it is hard to keep a track and a handle of the best tools for the business in the specific industry. Therefore, the upper management lacks the technological awareness. In this sense, often the user-friendly format of technological packages often overturns the choice for actual functionalities of the tools.

To conclude, the analytics capability is without a doubt a desirable add-on for many small or big companies to have. However, the complexity of the tools in use might make this capability slower to introduce and implement. And in this sense, tangible gains from its usage usually present themselves only in the long-run results. To fallback, empirical data analysis is going to be used as a step to either validate or disregard these presumptions at least in the scope of the given data set. In the upcoming sub-section the energy efficiency capability is going to be scrutinized in a more detailed way.

2.1.5 Energy efficiency capability

The subsequent sub-section is going to consider the energy efficiency capability throughout its definition, plausible application areas, risks and gains that come with its development. 'Climate change, energy issues, demand for carbon footprint assessments, and goals for energy efficiency improvements have increased the importance of energy efficiency as a research area in SCM'. (Kalenoja, 2011). The network around this capability involves both supplier-supplier and supplier-customer relationships. (Centobelli, 2018) In simple terms, energy efficiency capability is a sustainable supply chain management.

Speaking about positive effects of the energy efficiency capability. Energy efficiency practices can cover converting waste into energy to supply business' targets. And therefore alter energy consumption in areas such as raw material procurement, inbound logistics, production and outbound logistics. 'The introduction of energy efficiency capability enables organizations to reduce dependency on conventional energy sources.' (Fernando, 2018) The cumulative energy waste units can become a source of an implementation of the measurement system regarding the planning of energy efficiency. To be more specific, the cumulative energy waste units can be used in order to re-design products, change the logic of the planning of batch sizes, alter the choice of transportation mode or re-invent the planning of single shipments, etc.

Furthermore, energy efficiency capability is closely related to effects of energy management practices on renewable energy supply chain (RESC). Yudi Fernando in the research of the effects of energy management practices on renewable supply chain uncovers four dimensions required for the development of energy management. Which consists of: 'top management commitment, energy awareness, energy knowledge and energy auditing. As they are positively associated with the development of RESC initiatives'. (Fernando, 2018) Therefore, on the downside the implementation and adoption of energy management practices comes with complying to multiple factors. As well as the gains mostly appear in the long-run game. Firstly, through strengthened firm's reputation which in turns result to premium pricing and customer loyalty (McWilliams, 2011). However, these gains are harder to track or to measure. Therefore, 'companies do not tend to implement innovations linked to topics of sustainability' (Alvarez, 2011).

To sum this sub-section up, again the challenges arising together with the introduction of energy efficiency capability shifts to the higher level of the company management and requires main decision makers to separate time and effort to get insights and knowledge into the particular details of RESC. In the upcoming sub-section the industrial robots capability is going to be analyzed in more depth.

2.1.6 Industrial robots capability

The next sub-section is going to be dedicated to uncovering what is the industrial robots capability. How this capability can be exercised within the company and what challenges as well as opportunities lie within its implementation.

To start with a definition, industrial robots capability resembles ‘an autonomous robot that denotes a type of intelligent machine that conducts assigned tasks with a high degree of autonomy (e.g., absence of human control or influence)’. (Shamout, 2022) This in a positive sense can lead to an enhancement of the activities of individuals. Or in other words, save the time and energy of the workforce. And provide them with more space to focus on high-return, human-touch requiring activities e.g. high-level decision making.

Covering the specific areas in which the capability brings-in the most effects are surveillance, educational purposes, social companionship, logistics management, product line management, speedy delivery, reduction of costs in the long-term, increasing service levels, etc. In practice, industrial robots capability or in other words, robotics and autonomous systems (RAS) in recent years developed from single use functionality to multivariant of automations.

‘Critics of autonomous robotics point out concerns about the effects of robotics on the workforce and employment.’ (Shamout, 2022) The robotization of the processes might demoralize or demotivate the workforce in the short-run because of their reduced responsibilities. Also, the system relies heavily on the access to Internet, precision in data management and data privacy. Which in turns requires certain software and hardware applications and specific internal practices. Industrial robots capability is considered to be the most complex of the technical innovations. It is difficult to use and comprehend therefore requires additional efforts to develop it into already existing workflows.

In conclusion, the industrial robots capability requires advanced technological awareness and also re-design of SCM shifting further from the human-operated activities to automated and autonomous task-completion systems. Together with the challenges, the opportunity of saving valuable time and human capital resources arises as well as optimizing separate business areas turn by turn. The upcoming sub-section is going to be dedicated to the 3D printing capability.

2.1.7 3D printing capability

The last one from the seven capabilities to be covered is 3D printing capability with its definition, real-life application examples, gains and risks related to it.

‘In the era of industry 4.0, 3D printing unlocks a wide array of solutions to rapidly-produce spare parts for maintenance operations’. (Xu, 2021) In the recent years, the 3D printing process reached a more affordable level. Therefore, its implementation becomes more accessible. With the introduction of 3D printing capability the manufacturing can be adjusted in speedy ways regarding outlier cases and spare parts of the ordering batches. Which in turn presupposes, that the manufacturing process becomes additive, rapid and digitally direct. Therefore, the ‘3D printing capability is a digital technology utilizing an abstract digital design file that can be transformed to a physical object’. (Chan, 2018) Main benefiters of the technology are manufacturer, innovation and e-commerce companies.

When it comes to gains coming with the technology the researchers mostly uncover the power it brings to customization practices in a sense of the economies of one or the ‘produce of a quantity at the cost of the single unit’ (Chan, 2018) and vice versa. Another potential advantage of 3D printing is that the technology simplifies the production processes in general. ‘E.g. a module can be printed in one 3D printing process rather than by assembling several components which may require different supply chains'(Chan, 2018). Regarding the implementation, the 3D printing capability does not require a massive labor and time costs as the capabilities already mentioned before.

Speaking about the obstacles that furthers mass-scale application of 3D printing – as it is not yet massively applied or implemented – there is a lack of common 3D printing integration practices into the SCM. The other area of concern is related to intellectual property (IP) and inability to prevent counterfeiting. Therefore, the preparation for the introduction of this capability comes not only one-sidedly from the company but also legal back-base of the topic in question. When it comes to licensing the platforms providing 3D printed content it doesn't have many legal precedents. In this particular case, legalization is lacking behind the technology.

To sum the sub-section with, it is also worth mentioning that 3D printing does not aim to replace the current processes in the supply chain but work only in a way when efficiently and effectively incorporated to already existing practices. In this regard, the 3D printing capability is relatively easy to implement, however, requires attention and effort syncing it with existing operational processes to exploit its full potential.

2.2 Summary of the resource based theory: defining digitalization capabilities

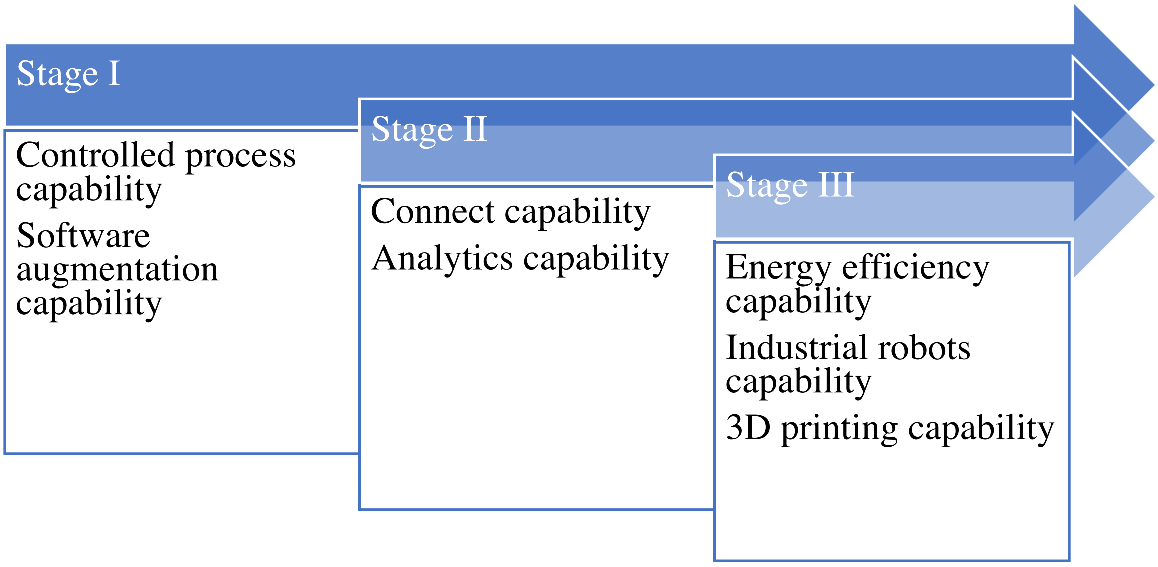
To summarize, each capability has its own specific challenges when it comes to the implementation. As well as each one brings an unique set of opportunities and possibilities. Mainly, the opportunities lie within perfecting and enhancing internal processes, making them more efficient and effective, linking the company wide operations and developing an interconnected technological network. According to the RBV 'firms' ability to develop distinct digitalization capabilities increases its chances to stay competitive in the international markets and improves its survival rates' (Esteve-Perez, 2006). However, most of the challenges come from the need for the top-management tech-awareness and savviness, costs of implementation, returns coming only in the long-run, technological complexities and reaching the desired interconnectedness between different capabilities. Down below in the Table 13.0 *Definitions of Capabilities*, the summary of the authors and the definitions of each capability are presented.

Table 13.0 Definitions of Capabilities

Capability	Authors	Definition
Controlled processes capability	Duncan McFarlane, Yossi Sheffi (2006)	interlinked information system with identification of each physical item
Software augmentation capability	Merlino Massimo (2016)	digital network of partners executing coordinated processes
Connect capability	Maciel M. Queiroz, Susana Carla Farias Pereira, Renato Telles and Marcio C. Machado (2019)	integration of capabilities within different supply chain members
Analytics capability	Ashish Kumar Jha, Maher A.N. Agi, Eric W.T. Ngai (2020)	business intelligence technology applying advanced analytics to the big data
Energy efficiency capability	Piera Centobelli, Roberto Cerchione, Emilio Esposito (2018)	environmental sustainability practices in supply chain management
Industrial robots capability	Mohamed Shamout, Rabeb Ben-Abdallahb, Muhammad Alshurideha,c, Haitham Alzoubid, Barween Al Kurdie and Samer Hamadnehc (2022)	intelligent machine system conducting repetitive tasks with a high degree of autonomy
3D printing capability	Kai Chana Hing, James Griffin, Jia Jia Lim, Fangli Zeng, Anthony S.F. Chiu (2018)	digital technology utilizing an abstract digital design file that can be transformed to a physical object

Theory discussed above presupposes that based on the complexity of the introduction of each capability in terms of managerial, time and financial resources there should be a path or a sequence in which organizations introduce these capabilities based on their readiness level for each. Table 14.0 *Theory-based process of development of digitalization capabilities* illustrates preliminary model of how the process of the introduction of digitalization capabilities might look from the theoretical perpective. The distinction between different kinds of relatedness amongst the capabilities is important as it might help to uncover the similarity/complementarity and the structure of the interconnectedness of the resources themselves (hierarchical, vertical, etc.) (Wan, 2011). The process presupposed in Table 14.0 implies that a firm as a Ist stage of digitalization development might aim to stabilize internal processes with control measures and conduct initial automations with appropriate (for the industry they operate in) software tooling. IInd stage should be dedicated to connecting already existing operational practices interdepartamentally. Next step – enchancing and optimizing the processes by analytics capability. And the last stage could be devoted to adding additional capabilities that at this point of time are rather nice-to-have rather than must-to-have such as energy efficiancy, industrial robots or 3D printing capabilities.

Table 14.0 Theory-based process of development of digitalization capabilities



Having the model in mind, the following chapter is going to be dedicated to uncovering whereas the theoretical presumptions presupposed in the previous section correspond with in-real-life practices. In other words, using empirical rather than theoretical linkage the common pattern of the process of the development of digitalization capabilities is going to be either validated or denied. Also, theoretical implications regarding the time-constrains and other challenges related to implementation of digitalization capabilities are going to be checked-against empirical data. 'Scholars debate that existing stocks of resources create asymmetries in the competition for new resources' (Barney, 2011). Therefore, a need arises to develop flexible but coordinated and synchronized process or a sequence to evolution of digitalization capabilities inn order to limit the challenges related to development of digitalization capabilities and provide superior value for the customers (Hitt, 2015).

III part. Methodology for evaluation of the process of development of digitalization capabilities

3.1 The approach

In order to reveal the process of development of digitalization capabilities, the secondary data analysis method was chosen. The data from European manufacturing survey was used. The survey was conducted across the EU. In this thesis data from 5 Eastern and Central European countries is used. The sample consists of 798 Eastern and Central European manufacturing companies. Methods of descriptive statistics and process mining algorithm are applied in order to analyze and present conclusions from the dataset.

3.2. Data collection procedures: data collection and questionnaire

The European manufacturing survey is the largest survey of the kind. It is aimed to track production practices across European manufacturing companies. EMS operates as a global network backed up by research institutes and universities that collect data in their countries since 2001. The data is collected every three years. 'The survey includes questions about production and information technologies, new organizational concepts and implementation of modern manufacturing/ management practices' (Palčič, 2020). The techno-organizational innovations in the manufacturing industry are also measured against key performance indicators (KPIs) such as productivity, flexibility, quality, sales. The survey is distributed to firms with at least 20 employees working on three-years in a row basis.

It is worth mentioning that items as well as scales in the survey are developed based on extensive scholarly research in terms of reviewing both literature related to the topic and current manufacturing practices. The draft of the questionnaire is presented to an experts' panel before deploying it to several firms. It is also checked against validity and reliability tests using usual statistical methods such as inter-correlation matrix, Cronbach's alpha test, factor analysis, canonical correlation and others.

A standardized questionnaire is used to collect data. It is prepared in English and later translated into local languages. Native institutions have limited capacity to adding national questions. The data is collected in individual manufacturing sites since each might present unique performance capabilities. The sample consists of 798 firms as cases with the data collected in Lithuania (Vilkas, 2021), Slovakia (Šebo, 2019), Austria (Zahradnik, 2019), Croatia and Slovenia (Palčič, 2020) as part of European manufacturing survey in 2019. The Table 15.0 *Questionnaire* illustrates a small portion of the questionnaire.

Table 15.0 Questionnaire (Vilkas et al., 2021)

Planned to be deployed until 2021	No <-	Capabilities Digital management of production	Yes ->	Started to be used in (Years)	Consistently invested in since 2015 (No, Yes)		The potential to use the technology (l=low, m=medium, h=high)		
☐	☐	Mobile/ wireless equipment used to program or control production devices (e.g. tablet)	☐		☐	☐	l	m	h
☐	☐	Digital solutions allowing to deploy plans or instructions directly to the working site	☐		☐	☐	l	m	h
☐	☐	Software for production planning and control (e.g. ERP systems)	☐		☐	☐	l	m	h
☐	☐	Sharing digital data about products/processes with clients/suppliers (e.g. Electronic Data Interexchange EDI)	☐		☐	☐	l	m	h
☐	☐	Real-time production planning and control systems	☐		☐	☐	l	m	h
☐	☐	Internal logistics automatization and control systems (e.g. RFID)	☐		☐	☐	l	m	h
☐	☐	Imitation product design and development modelling/simulation (e.g. Digital Prototyping)	☐		☐	☐	l	m	h

3.3 Data analysis approach

In the following section the data analysis approach is presented. The subsequent sub-sections are uncovering how the specific items were attributed to certain capabilities applying factoring computation. Also, variables that were meaningful to each capability are listed together with the connection presumptions. Furthermore, SPSS actions and computations are presented in order to reveal the data preparation process for the process mining part of the data analysis.

3.3.1 Reliability and validity

To start with, in this sub-section relevant factor reliability and validity are going to be described in order to uncover the process of how each capability was identified. The Table 16.0 *Internal Consistency Variability* presents consistency in scale items similar to Cronbach's Alpha test. In other words, composite reliability equals the total amount of true score variance relative to the total scale score variance. From the Table 16.0 *Internal Consistency Variablity* it can be recognized that the highest score belongs to 3D printing capability with 0,865, next in line controlled processes capability with the score of 0.814, further industrial robots capability with 0,807, then energy efficiency capability scoring 0,775, connect capability – 0,744, lastly analytics capability 0,737. All in all, it can be noticed that each capability has a score higher than 0,700 and the scores above that are considered being reliable and valid. Lower scores mean that factors might be explained by some other value items that for example weren't included in the data set.

Table 16.0 Internal Consistency Variablity

Capability	Composite Reliability (alternative to Cronbach's Alpha)
3D printing capability	0,865
Controlled processes capability	0,814
Industrial robots capability	0,807
Energy efficiency capability	0,794
Software augmentation capability	0,775
Connect capability	0,744
Analytics capability	0,737

3.3.2 Discriminant validity

To continue with, the following sub-section is uncovering how each capability was identified and what specific items were ascribed to each capability. To back up, separate capabilities had to be recognized through factor analysis using dimensions reduction option in SPSS. This technique extracts maximum common variance from all variables and puts them into a common score. Factor analysis in addition displays to what extent each item 'explains' the factor. The Table 17.0 *Discriminant Validity* shows that each factor has 1 to 2 items that explains it with valid discriminant. In other words, scores that are higher than 0,700 are considered to be valid in explaining each factor. For example, 3D printing capability has two items with the score above 0,700 which are k10l1 scoring to 0,859 and k10m1 scoring 0,887 (the relevant scores are bolded). Another example, industrial robots capability has one item with the reliable score. Its' ID code being k10k1 and score – 0,904. In the following sub-section each item is going to be briefly reviewed in order to illustrate how the items correspond to each factor.

Table 17.0 Discriminant Validity

	3D printing capability	Analytics capability	Connect capability	Controlled processes cap.	Energy efficiency capability	Industrial robots capability	Software augmentation cap.
k08b1	0,182	0,272	0,255	**0,737**	0,183	0,12	0,289
k08c1	0,171	0,301	0,23	**0,792**	0,238	0,176	0,341
k08g1	0,154	0,323	0,27	**0,763**	0,192	0,182	0,332
k08f1	0,129	**0,814**	0,286	0,383	0,197	0,158	0,357
k10h1	0,273	**0,710**	0,272	0,200	0,138	0,219	0,276
k10a1	0,147	0,234	**0,655**	0,196	0,127	0,141	0,27
k10b1	0,177	0,307	**0,755**	0,217	0,138	0,189	0,344
k10d1	0,135	0,222	**0,691**	0,276	0,174	0,188	0,368
k10c1	0,200	0,312	0,415	0,327	0,225	0,214	**0,747**
k10e1	0,151	0,323	0,329	0,303	0,240	0,153	**0,749**
k10f1	0,191	0,279	0,274	0,291	0,202	0,216	**0,695**
k10i1	0,235	0,189	0,211	0,143	0,183	**0,735**	0,184
k10k1	0,212	0,212	0,208	0,198	0,315	**0,906**	0,247
k10l1	**0,859**	0,267	0,205	0,18	0,142	0,256	0,249
k10m1	**0,892**	0,182	0,179	0,205	0,082	0,208	0,188
k10n1	0,088	0,197	0,156	0,229	**0,821**	0,253	0,248
k10o1	0,116	0,164	0,186	0,208	**0,805**	0,258	0,248

3.3.3 Overview of variables assigned to factors

To proceed with, this sub-section briefly touches upon variables that were assigned to each factor. For example, controlled process capability can mostly be explained by three items k08b1 with the label ‘measures to improve internal logistics’, k08c1 – ‘fixed process flows to reduce setup time or optimize change-over time’ and k08g1 – ‘methods of assuring quality in production’. For example, analytics capability consists of two items. If given a closer look to all capabilities and their variables it can be noticed that the ‘theme’ of the variable corresponds with the topic of the capability. Best case to illustrate that would be 3D printing capability with items k10k1 and k10m1 correspondingly labeled as ‘3D printing technologies for prototyping’ and ‘3D printing technologies for manufacturing’. The variables also correlate with the definitions listed in the II[nd] chapter of the thesis where theoretical analysis of definitions of each capability was conducted. The full list of variables can be seen in The Table 18.0 *Variables assigned to the Factors*.

Table 18.0 Variables assigned to the Factors

Capability	Item ID	Label
Controlled processes capability	k08b1	Measures to improve internal logistics
	k08c1	Fixed process flows to reduce setup time or optimize change-over time
	k08g1	Methods of assuring quality in production
Connect capability	k10b1	Digital solutions to provide drawings, work schedules or work
	k10a1	Mobile/wireless devices for programming and controlling facilities and machinery
	k10d1	Digital Exchange of product/process data with suppliers / customers
Analytics capability	k10h1	Virtual Reality or simulation for product design or product
	k08f1	Display boards in production to illustrate work processes and work
Software Augmentation	k10c1	Software for production planning and scheduling
	k10e1	Near real-time production control system
	k10f1	Systems for automation and management of internal logistics
Energy efficiency capability	k10n1	Technologies for recycling and re-use of water
	k10o1	Technologies to recuperate kinetic and process energy
Industrial robots capability	k10k1	Industrial robots for handling processes
	k10i1	Industrial robots for manufacturing processes
3D printing capability	k10l1	3D printing technologies for prototyping
	k10m1	3D printing technologies for manufacturing

3.3.4 Computation of variables

To carry on with, this sub-section presents an overview of how the variables were prepared for further data analysis using Fuzzy Miner method (Fluxicon Disco). Further computations of variables were needed in order to count the sum of the first years used variables and calculate the average of the years when each capability was introduced to the organization.

3.3.4.1 Calculation of years variables

Pairwise function for years variables was used in order to see when if ever each capability was introduced into organization. Through 'transform and compute new variable' function in SPSS new variables were created. New variables as an example countCP (count of control processes capability items) was introduced. An example of computation equation: countCP=COUNT(k08b3,k08c3,k08g3). The computation has 2 value outcomes: 0 – not using this capability, 1 – using capability and this requires further calculation of means. The Table 19.0 *Summated scales: spread of the items assigned to factors* represents the count of the items throughout the data set with their conversion rates (the item count versus the total count of sample). Therefore, it shows what percentage of organizations from the whole data set is not using or using certain item (but not capability yet).

Table 19.0 Summated scales: spread of the items assigned to factors

Capability	Label	Count	Conversion
Controlled processes capability	Measures to improve internal logistics	397	50%
	Fixed process flows to reduce setup time or optimize change-over time	359	45%
	Methods of assuring quality in production	507	64%
Connect capability	Digital solutions to provide drawings, work schedules or work	355	44%
	Mobile/wireless devices for programming and controlling facilities and machinery	267	33%
	Digital Exchange of product/process data with suppliers / customers	333	42%
Analytics capability	Virtual Reality or simulation for product design or product	196	25%
	Display boards in production to illustrate work processes and work	358	45%
Software Augmentation	Software for production planning and scheduling	477	60%
	Near real-time production control system	269	34%
	Systems for automation and management of internal logistics	214	27%
Energy efficiency capability	Technologies for recycling and re-use of water	193	24%
	Technologies to recuperate kinetic and process energy	224	28%
Industrial robots capability	Industrial robots for handling processes	188	24%
	Industrial robots for manufacturing processes	213	27%
3D printing capability	3D printing technologies for prototyping	119	15%
	3D printing technologies for manufacturing	79	10%

3.3.4.2 Calculation of average years variables

Furthermore, the counts of first years use of capabilities required average computation. Again, new variables were created throughout ‘recode into same variables’ function in SPSS. An example of the new variables that were created, computeCP.time. Example of the equation of the computation: computeCP.time=(SUM(k08b3,k08c3,k08g3)))/countCP. A note worth mentioning, that in the calculations of years variables the variable item codes changed with a number 3 in the end of the item ID code instead of 1. As the capabilities’ items have years items connected to them with the same beginning of identification code but different ending. Each of the capabilities of the time of first years used were re-calculated in the same manner.

The Table 20.0 *First Years Used Calculation* presents count of organizations which had their first years used of capabilities listed, next to the count of organizations there is conversion rate how many of the items’ years were listed versus the total count of cases in the data set. From the table it can be noticed that the most items were listed by controlled processes, software augmentation and connect capabilities. The least cases by energy efficiency, industrial robots and 3D printing capabilities.

Interesting observation can be extracted also from the average years section. For example, controlled process capability is the first one to be introduced on average, later follows energy efficiency, software augmentation, analytics and industrial robots capabilities and the latest are connect and 3D printing capability. This outcome also allows to connect the average years of the introduction with market trends and adoption as well as with dispersion with newest technologies. An area here for further research would be to follow the trends in historical perspective and match them with the given data. Yet, for now, the mentioned analysis does not fall into the scope of the thesis.

Table 20.0 First Years Used Calculation

Capability	Count of Organizations, count	Companies that started developing the capability, %	Average Years when companies started developing the capability, years
Controlled processes capability	**545**	68%	2006,63
Software Augmentation	488	61%	2008,68
Connect capability	**477**	60%	2010,50
Analytics capability	391	49%	**2009,47**
Energy efficiency capability	271	**34%**	2007,17
Industrial robots capability	259	**32%**	**2009,59**
3D printing capability	118	**15%**	2012,26

3.3.4.3 Transposing in Excel

Next step in the data preparation for fuzzy miner is transposing the variables in the excel dataset. This step was conducted manually by deconstructing each cases' capabilities into separate data rows. The Table 21.0 *Transposition of Variables* represents a short extract from the transposition process.

Table 21.0 Transposition of Variables

Case ID	Count	Controlled	Soft.Augment	Connect	Analytics	Efficiency.tec	Industrial.	DPrinting
1	0	2013,00	2016,00	2014,50	2013,00			
2	0	2003,33	2010,00	2008,00	2005,00	1998,00		2008,00
3	0					1999,00		
4	0	1998,00	2010,00	2008,00	2015,00	2008,00	2010,00	
5	0			2000,00				
6	0	2000,00						
7	0	2008,00	2016,00	2016,00	2016,00			
8	0	2018,00	2013,00	2013,00				
9	0	2001,00	2001,00	2013,00				
10	0	2012,33	2014,00	2008,00	2009,00	2004,00		

Country	Case ID	Capability	Timestamp
0	1	Controlled.Proc	2013,00
0	1	Analytics	2013,00
0	1	Connect	2014,50
0	1	Soft.Augment	2016,00
0	1	Efficiency.tech	
0	1	Industrial.robots	
0	1	DPrinting	
0	2	Efficiency.tech	1998,00
0	2	Controlled.Proc	2003,33
0	2	Analytics	2005,00
0	2	Connect	2008,00
0	2	DPrinting	2008,00
0	2	Soft.Augment	2010,00
0	2	Industrial.robots	
0	3	Efficiency.tech	1999,00
0	3	Controlled.Proc	
0	3	Soft.Augment	
0	3	Connect	
0	3	Analytics	
0	3	Industrial.robots	
0	3	DPrinting	
0	4	Controlled.Proc	1998,00
0	4	Connect	2008,00
0	4	Efficiency.tech	2008,00
0	4	Soft.Augment	2010,00
0	4	Industrial.robot	2010,00
0	4	Analytics	2015,00
0	4	DPrinting	
0	5	Connect	2000,00
0	5	Controlled.Proc	
0	5	Soft.Augment	
0	5	Analytics	
0	5	Efficiency.tech	
0	5	Industrial.robots	
0	5	DPrinting	

3.3.4.3 Ranking

To continue, the last step in the data preparation for fuzzy miner is to rank the years in ascending manner from the capabilities first years used that were introduced sooner to those that first years introduced were later. Ranking part of the data preparation was also conducted manually.

3.3.4.4 Running method: fuzzy miner (Fluxicon Disco)

To finish this section with and rewind the data preparation process: validity and reliability test for factor analysis was conducted, items that got assigned to each factor were checked and listed, the values of the years variables for each capability were re-counted into new average values and then the value set was transposed and ranked. The following chapter of the thesis is dedicated to overview the empirical findings from the analysis conducted using process mining algorithm. Process mining is used to extract insights from data of events in terms of start-to-end behavior patterns. Or in other words, process mining is meant to 'discover a process model that is representative for the set of the sequence of events' (Tax, 2016). The process mining method is applied through fuzzy mining – adaptive process simplification tool to illustrate and extract the data automatically. In the thesis, for fuzzy mining the Fluxicon Disco tool is used.

3.4 Summary of the methodology for evaluation of the process of development of digitalization capabilities

To summarize this chapter with, methodology for the thesis was laid down in continuous manner. First, data collection procedures together with questionnaire and the context of the survey that was conducted were presented. Then, data analysis approach was described with reliability and validity test, discriminant validity and factor analysis in relation to items ascribed to each factor. Lastly, computation of variables was reviewed with calculation of years variables and their average values, transposing and ranking in excel and data running method. The methodology part gave grounds to empirical analysis of the data which is going to be covered in the following chapter.

IV part. The results of empirical research of the analysis of process of development of digitalization capabilities

4.1 Descriptive analysis of diffusion of digitalization capabilities

4.1.1 Descriptive analysis of dispersion of digitalization capabilities per sets of events in frequencies

The IV chapter of the thesis is dedicated to laying down the results of empirical research of the analysis of the process of the development of digitalization capabilities. In other words, in this chapter the findings from running the prepared data set throughout Fluxicon Disco analytics tool are going to be presented.

Following sub-section is meant to observe the raw data from the set. Therefore, descriptive analysis of the diffusion and/or dispersion of digitalization capabilities is going to be conducted below. From the Table 22.0 *Cases per Events* it can be noticed that the highest ranking score is assigned to 4 events with 155 cases which substitutes to 19% of all data set cases (as listed in the Table 23.0 *Spread of Capabilities: First Years Used Approach*). Which means that almost fifth of the organizations from the dataset have 4 of previously described digitalization capabilities introduced in their daily operations.

Furthermore, organizations with 5 digitalization capabilities in their pocket follow with 122 cases constituting 15% from the full set. Later 0 capabilities can be traced back with the count of 115 organizations and 14% of cases. To track further, 3 digitalization capabilities with 113 cases and 14% can be recognized, 2 digitalization capabilities with 102 cases and 13%, 6 digitalization capabilities with 81 case and 10%, 1 capability with 80 cases and 10% and lastly 7 digitalization capabilities with 30 cases and 4% from the full data set.

Table 22.0 Cases per Events

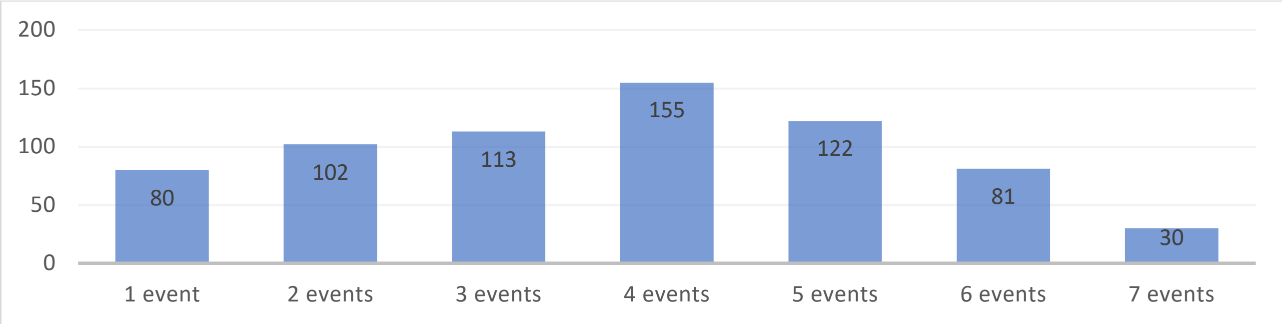


Table 23.0 Spread of Capabilitities: First Year Used Approach

Count of Capabilities	Count of Organizations	Conversion, %
0	115	14%
1	80	10%
2	102	13%
3	113	14%
4	155	19%
5	122	15%
6	81	10%
7	30	4%
Total	798	100%

The data can be interpreted from several angles. First of all, either the most dispersed or popular assembly of capabilities is between 3 and 5 digitalization capabilities which together constitute to almost 50% of all the cases from the data set. The next question in line here would be to look into which of the capabilities are the most popular to single event set. For example, in the Table 24.0 *Capability Dispersion per Type '4 Events' as Single Set I* we notice that there are all 7 type of activities within the event type. Minimal frequency of the capabilities is 13, maximum frequency is 141. Mean frequency is 88,57 which means that more than a half of the whole event cases consists of similar capabilities as components in the set.

Table 24.0 Capability Dispersion per Type '4 Events' as Single Set I

Activities	7
Minimal frequency	13
Median frequency	99
Mean frequency	88.57
Maximal frequency	141
Frequency std. deviation	50

To continue with, The Table 25.0 *Capability Dispersion per Type '4 Events' as Single Set II* represents the composition of the capabilities in the 4 Events set in descending order. From the data provided it can be observed that almost all of the cases contain software augmentation (frequency 141, relative frequency 22,74%), controlled processes (frequency 136, relative frequency 21,94%) and connect (frequency 127, relative frequency 20,48%) capabilities. Later composition is a mix of analytics (frequency 99, relative frequency 15,97%), energy efficiency technology (frequency 56, relative frequency 9,03%), industrial robots (frequency 48, relative frequency 7,74%) and 3D printing (frequency 13, relative frequency 2,1%) capabilities.

Therefore, from this data a conclusion could be presupposed that if an organization is choosing between introduction of 3 to 5 capabilities – the most popular ones to introduce would be software augmentation, controlled processes, connect capability and later ones probably vary depending on the pain-points or specific needs of the organization. However, the look was taken only to one type of a single set which consists of 4 events. Further explorations revealed that similar pattern of the dispersion of capabilities can be noticed also in the rest of the sets consisting of 2, 3 and 5 events.

Table 25.0 Capability Dispersion per Type '4 Events' as Single Set II

Activity	Frequency	Relative frequency
Software augmentation capability	141	22.74%
Controlled process capability	136	21.94%
Connect capability	127	20.48%
Analytics capability	99	15.97%
Energy efficiency capability	56	9.03%
Industrial robots capability	48	7.74%
3D printing capability	13	2.1%

Looking into outlier sets for example with 1 event – controlled process capability with frequency of 31 and relative frequency of 38,75% comes into play. The next capability in line which is connect capability has a way lower frequency of 17 and relative frequency of 21,25%. On another side, when looking to a set of 6 events analytics (frequency 80, relative frequency 16,46) and industrial robots (frequency 73, relative frequency 15,02) capabilities score almost the same rating as the rest and still 3D printing capability has the lowest frequencies illustrated in the Table 26.0 *Capability Dispersion per Type '6 Events' as Single Set I.*

That also validates the presumption that the more digitalization capabilities an organization is choosing to introduce the more it should correspond to the overall operations and demands from the industry. To close the sub-section with, frequency analysis represents how the capabilities are dispersed around the cases however it does not give information about the timeframe in which these capabilities are being implemented. Therefore, the following sub-section is going to be dedicated to conducting an overview of how the cases are spread throughout time, what are different variations of timeframes to introduce the capabilities together with the events division in mind.

Table 26.0 Capability Dispersion per Type '6 Events' as Single Set I

Activity	Frequency	Relative frequency
Analytics capability	80	16.46%
Software augmentation capability	80	16.46%
Controlled process capability	78	16.05%
Connect capability	78	16.05%
Industrial robots capability	73	15.02%
Energy efficiency capability	64	13.17%
3D printing capability	33	6.79%

4.1.2 Descriptive analysis of dispersion of digitalization capabilities per cases throughout time

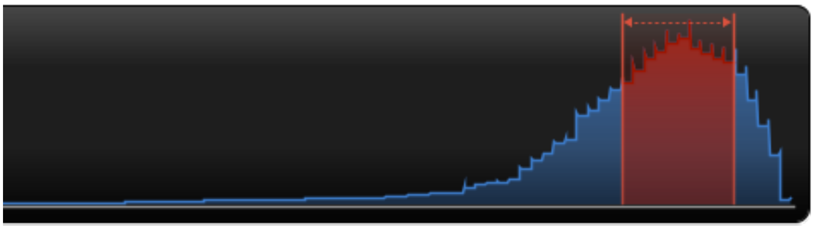
The next sub-section is devoted to describing the relation between different cases of the introduction of digitalization capabilities and their timeframe. A few examples of the mean-cases are going to be analyzed in order to identify a common pattern in the speed of introduction of digitalization capabilities. In addition, a few outlier cases are going to be discussed in order to illustrate how variants might differ between one another.

4.1.2.1 Mean example

To star with, for the identification of on average practice in the firm regarding the introduction of digitalization capabilities, mean cases having 3 to 5 events per case were filtered from the dataset. This left 1569 events from total of 2549 and 390 cases from 798 for further analysis. The mean duration of cases consisting of 3 to 5 events/activities/capabilities is 10,1 years, and median duration – 9,1 years. Minimum duration is 0 years when all capabilities were introduced in single year (this case with ID 618 and Variant 1 has 4 events per case). The maximum duration is 62 years and 15 days when the introduction of capabilities started dating back to 1949 and finished on 2011 (this precise case with ID 594 from Variant 57 has only 3 capabilities introduced throughout all of this time).

To continue with, a mean case with a Case ID 10 from Variant set 68 was chosen as an example to present. It consists of 5 events per case with close to mean duration of the introduction of capabilities which is 10 years and 3 days. As illustrated in the Table 27.0 *Mean Case Example I* this case approximately covers the scope of standard deviation from the mean. To observe further, Table 28.0 *Mean Case Example II* shows the sequence in which the capabilities were introduced starting from energy efficiency technology capability in 2004, connect capability in 2008, analytics capability in 2009, controlled process capability in 2012 and software augmentation capability in 2014. This sequence by itself does not give the data to generalize overall data set but gives a good example how the process of the development might look in a particular case which satisfies conditions of being average. In the next paragraph two outlier cases with 7 events per case are going to be touched upon briefly to deepen the understanding of the dataset values for further overall analysis.

Table 27.0 Mean Case Example I



Events	5
Start	01.01.2004
Duration	10 years, 3 days

Table 28.0 Mean Case Example II

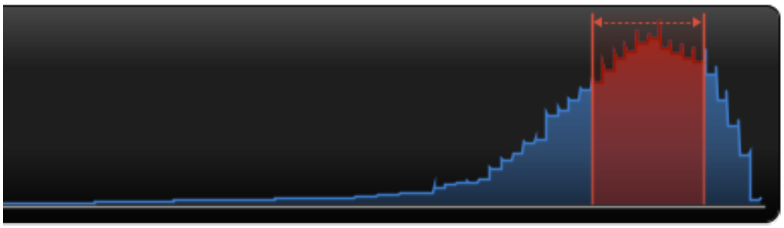
Activity	Date
Energy efficiency capability	01.01.2004
Connect capability	01.01.2008
Analytics capability	01.01.2009
Controlled process capability	01.01.2012
Software augmentation capability	01.01.2014

4.1.2.2 Outlier examples

To proceed with, outlier cases from the set of cases with 7 events were chosen to briefly go through and illustrate the possible variances. This left the set with 210 events and 30 cases. Mean duration of cases like that last for 12,4 years and median duration for 12 years. Which is not that vastly greater than mean and median duration of cases having between 2 to 5 events.

First selected case is the shortest from the set with ID 60 from, Variant 1 and it lasted for 2 years in total (Table 29.0 *Outlier Case Example I*). First capability that was introduced is controlled process dating back to 2009 and all the rest capabilities were introduced in single year of 2011 (Table 30.0 *Outlier Case Example II*).

Table 29.0 Outlier Case Example I



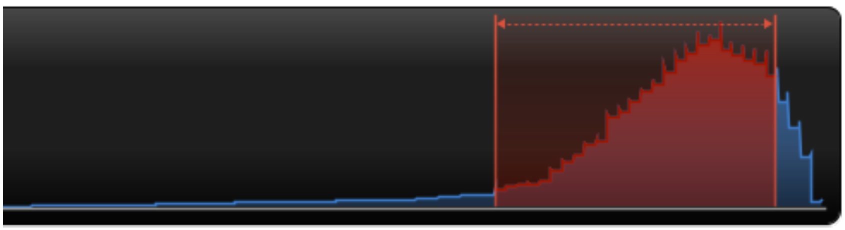
Events	7
Start	01.01.2009
Duration	2 years

Table 30.0 Outlier Case Example II

Activity	Date
Controlled process capability	01.01.2009
Software augmentation capability	01.01.2011
Connect capability	01.01.2011
Analytics capability	01.01.2011
Energy efficiency capability	01.01.2011
Industrial robots capability	01.01.2011
3D printing capability	01.01.2011

Second selected case for an example of outlier cases is the longest one from the set with 7 events cases. The Case ID is 287, Variant number – 12. This case duration is 25 years and six days and it covers the deviation of almost all the data set in a sense of the timeframe of introduction (Table 31.0 *Outlier Case Example III*). The sequence of the introduction of capabilities goes as follows: at first software augmentation, energy efficiency technology and 3D printing capabilities were implemented in 1990. After 10 years connect capability was introduced in 2000. Again 10 years later industrial robots capability applied in 2010. Lastly, controlled process capability in 2013 and analytics capability in 2015. Both outlier cases compared also to the average variant described in the a) paragraph show that there are many different orders and timeframes in which the capabilities are getting developed in the organizations. Therefore, the last sub-section in the chapter is going to be dedicated to uncovering the most frequent pattern amongst all the dataset. However, before that still one more way of slicing and/or dividing the raw data has to be considered which is dispersion of digitalization capabilities per countries.

Table 31.0 Outlier Case Example III



Events	7
Start	01.01.1990
Duration	25 years, 6 days

Table 32.0 Outlier Case Example IV

Activity	Date
Software augmentation capability	01.01.1990
Energy efficiency capability	01.01.1990
3D printing capability	01.01.1990
Connect capability	01.01.2000
Industrial robots capability	01.01.2010
Controlled process capability	01.01.2013
Analytics capability	01.01.2015

4.1.3 Descriptive analysis of dispersion of digitalization capabilities per countries

The last sub-section of the raw data analysis section is devoted to briefly touch upon the country dispersion amongst the capabilities. As listed in the Table 33.0 *Country Dispersion in Dataset* it can be observed that country code 0 has 199 organizations with conversion of 25% from the whole data set. Country code 1 lists to 127 organizations and 16% conversion, country code 2 to 105 organizations with 13% conversion and country code 3 – 114 organizations with 14% conversion. And the last and the largest chunk of the set belongs to country code 4 with 253 organizations and 32% conversion rate.

Itself this data is providing us with little to no intel except the fact that countries with codes 0 and 4 has slightly larger scores than countries with codes 1, 2 and 3. Further analysis might be conducted how cases and their variants differ depending on the country code and if there are any differences. However, the thesis is highly focused of finding the most prominent patterns in sequencing of the introduction of digitalization capabilities and that leaves contextual factor such as country aside. However, a closer look of the country as a distinguishing factor for variations of the results could be a solid ground for further analysis on the topic.

Table 33.0 Country Dispersion in Dataset

Country code	Count of Organizations	Conversion, %
0	199	25%
1	127	16%
2	105	13%
3	114	14%
4	253	32%

In this sub-section it was discussed how the capabilities are dispersed in the dataset in regards to their frequencies. Afterwards, the topic of dispersion of capabilities throughout different timeframes was described. The last part covered the dispersion of capabilities between countries. These steps provided some information about the raw data from the set. However, not yet provided the whole picture or the answer about combined data in order to uncover the common sequencing pattern of the development of digitalization capabilities (if there is one). Therefore, the following part of the chapter is designated for precisely that – answering the main question of the thesis: what is the process of development of digitalization capabilities?

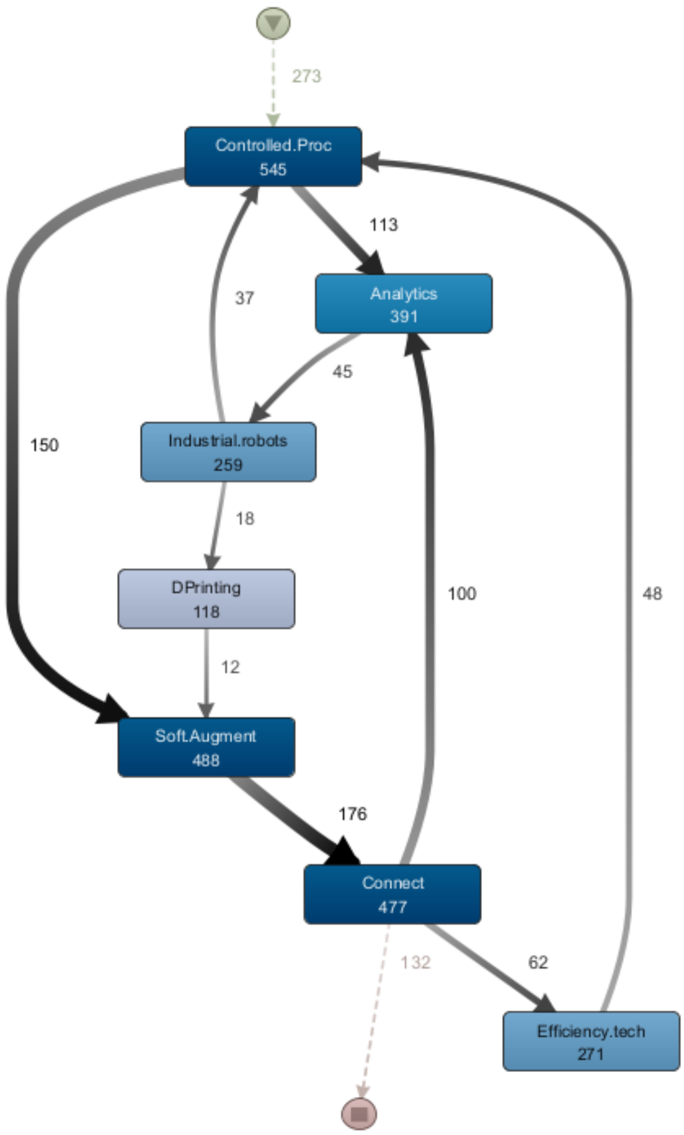
4.2 The process of development of digitalization capabilities

To end the IV chapter with the last section is dedicated to observe and interpret the data received from running the prepared data file through fuzzy miner – Fluxicon Disco. In the first sub-section the findings from the data set about the most common patterns in regards to frequencies of the events are discussed. Meaning the sequence or the process of the development of the digitalization capabilities is going to be deconstructed. And, in the following sub-section the average timeframes/performance for the events or in other words development timespan is going to be overviewed.

4.2.1 Process of the development of digitalization capabilities through frequencies

The Table 34.0 *The Process of the Development of Digitalization Capabilities through Frequencies* shows the most common pattern when it comes to the process of the development of digitalization capabilities into the organizations. To observe it from a high point, the capability with most cases that usually starts the process is controlled process capability with 273 cases. Afterwards, the process follows with software augmentation capability having 150 cases. Further, connect capability with 176 cases, analytics capability with 100, industrial robots with 45 cases and lastly 3D printing capability with 18 cases. The path can be detected by following the grey arrows – the darkness and the thickness of those represent the 'heaviness' of the score between the paths. There are also, different paths that could be read from the Table 34.0 *The Process of the Development of Digitalization Capabilities through Frequencies* as well. However, the one mentioned prior has the consistency in highest scores of paths. However, the energy efficiency capability is left behind in this particular path.

Table 34.0 The Process of the Development of Digitalization Capabilities through Frequencies



The observation of the most common path itself does not give too much clarity into the topic. That is why it is also important to turn back to the theoretical part of the thesis and consider, how does the common pattern correspond with already existing theoretical presumptions on the topic. Regarding the first step of development of controlled process capability researches also considered it to be the base element in order to implement the following capabilities. The data ran through Fluxicon Disco backs the presumption up.

Also, next capability in line in the theoretical part was software augmentation capability. And this also appears to be next in the mentioned pattern of the process of development of digitalization capabilities. Software augmentation capability was said to be associated with challenges in regards to flawed integration with already existing tools or operations. However with the prior introduction of controlled process capability the challenge minimizes itself and, therefore, has pre-checks and pre-marks to smooth its development into organizations.

To continue with, the next capability in terms of theory to usually make sense to introduce as a following step is connect capability. This also shows in the common path that is being scrutinized. The connectedness capability was mentioned to have only relative contribution when it is applied in firms of a smaller size but a greater impact when it is implemented in larger ones since it connects different capabilities with multiple supply chain members.

To follow through, next capability in the theoretical approach is analytics capability. And this one also comes next in the mentioned pattern. The analytics capability can work together with already existing digitalization practices because there is already a base from which to collect, read and interpret the data from. And to speculate, it might give higher returns when introduced exactly in this step prior to introduction of the rest of the capabilities which are a bit more complex in their technological implementation. It is as well worth mentioning that analytics capability has way lower case score than the previous ones. There are 100 events in the common pattern of analytics capability and it is almost double in reduction to the previous – connect capability. The reason for the lower number might be that the analytics capability amongst its downsides has the technological complexity component. Also, ROI from analytics capability implementation comes only in the long-term.

Moreover, the theoretical part pre-suppose that the next capability in line should be energy efficiency capability. However, this capability falls out of the most popular path as it seems to be introduced after the connect capability. The path from energy efficiency capability returns to the starting point of controlled process capability. To come back to the theoretical findings, challenges related to the development of energy efficiency capability seem to stem mostly from the upper managements' awareness in regards to RESC initiatives. The organization in general should comply with multiple energy efficiency regulating requirements. It might be speculated, that the capability doesn't seem to fall under the most popular development process since the implementation returns are harder to track. Also, the introduction of the capability requires company-wide R&D resource reallocation.

After the energy efficiency capability the theory suggests that the next capability to develop is industrial robots capability. And this seems to be the case in the model as well. Industrial robots capability if coming back to the theoretical findings is considered to be the most complex capability to implement in the technological sense. Therefore, the number of paths here is also way lower than in a case of analytics capability. The number of paths is only 45 which is again two times lower than the analytics capability had. The development of the capability requires advanced technological awareness and re-design of the whole SCM practices. However, it also gives an opportunity to optimize separate business areas and save workforce resources in a sense of time and energy. Therefore, it still falls into the most popular pattern.

And the last capability in the theoretical approach is 3D printing capability which reflects in the Fluxicon Disco model as well. Only the path number – 18 is again twice lower than the industrial robots capability had – 45. This can be read as a confirmation to the theory where it was mentioned that 3D printing capability lags behind in mass-scale implementation because of the lack of common integration practices and also unregulated legal aspects of its usage and implementation.

Looking at the overall frequencies of the capabilities from the Table 35.0 *Frequencies per capabilities* the theoretical part of the thesis also gets confirmed in a way since the frequency scores match with the outline of the capabilities suggested from the theoretical perspective. Controlled process capability had relative frequency of 21,38%, software augmentation capability – 19,14%, connect capability – 18,71%, analytics capability – 15,34%, energy efficiency capability – 10,63%, industrial robots capability – 10,16% and last one 3D printing capability – 4.63% to the data set excluding the cases without any variable (capabilities) values in them.

Table 35.0 Frequencies per capabilities

Activity	Frequency	Relative frequency
Controlled process capability	545	21.38%
Software augmentation capability	488	19.14%
Connect capability	477	18.71%
Analytics capability	391	15.34%
Energy efficiency capability	271	10.63%
Industrial robots capability	259	10.16%
3D printing capability	118	4.63%

As the most common path was already discussed the less popular processes of the development of digitalization capabilities might also be mentioned. For example, the process starts with controlled process capability (273), then travels to analytics capability (113), industrial robots capability (45), 3D printing capability (18), software augmentation capability (12), connect capability (176) and energy efficiency capability (62), finally goes back to controlled process capability (48). However, from the theoretical and statistical point of view this path makes less sense in practical implementation, unless the company has an unique value proposition that requires heavy technical advancement from the early stages of its development. On the other hand, the mentioned sequence includes all 7 capabilities into its set.

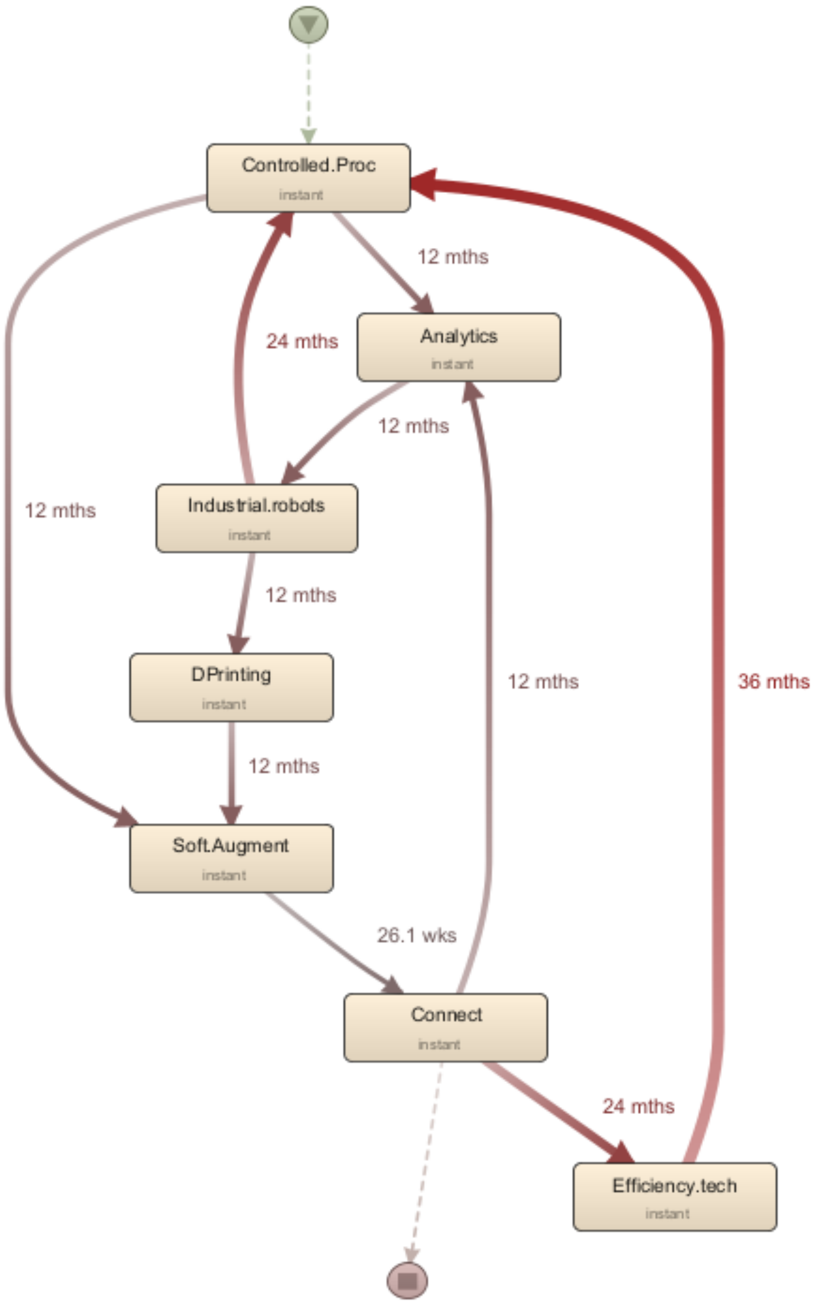
It is also worth mentioning that the model presented in the Table 34.0 *The process of the development of digitalization capabilities through frequencies* displays values with 100% reduced spread of frequencies/paths. If the frequency spread would be reduced 50% the model would show way more smaller paths that the process of the development could follow. Yet, for the purpose of answering the main question of thesis the 100% reduced model serves the approach to the answer.

To sum this sub-section with, the model corresponds with the theory almost identically. And the motivation and the challenges that were uncovered in the theoretical part seems to explain the number of outcomes in the process. Therefore, a common path was described in a great detail. The next step, is to check the process against their average timeframes to get a full picture into the process of the development of digitalization capabilities and give an understanding in what period of time the full set of currently desirable digitalization capabilities expected to be deployed.

4.2.2 Process of the development of digitalization capabilities through timeframes

The following sub-section is devoted to looking through the process of development of digitalization capabilities through their average implementation timeframes. The timeframes are going to be followed using the most popular process path discussed in the previous sub-section.

Table 36.0 The Process of the Development of Digitalization Capabilities through Timeframes



Looking at the Table 36.0 *The Process of the Development of Digitalization Capabilities through Timeframes* the average time to implement software augmentation capability after already having controlled process capability implemented is 12 months. Regarding software augmentation capability, theoretical part revealed that it is one of the capabilities that relies heavily on the redistribution of financial resources and it takes the preparation in regards to implementation and requires prior testing. Therefore, a year timespan seems appropriate from the theoretical as well as practical side.

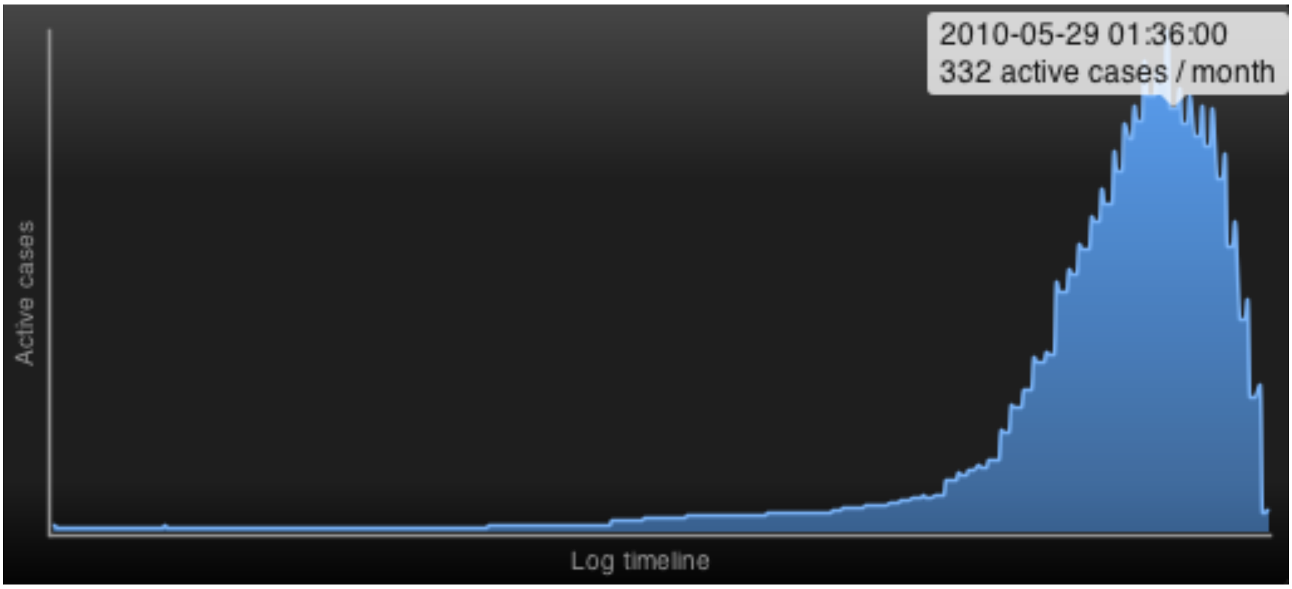
As follows, connect capability is developed after 26,1 weeks which is a bit above 6 months. Which is the shortest path timeframe of all other capabilities. As this capability is closely connected to software augmentation, meaning already pre-made software augmentation capability preparations. The connect capabilities' main challenges come from the managements' side such as strategy revision and willingness to develop the organization further. In this sense, the short introduction time is also theoretically backed-up. Between all the rest capabilities: analytics, industrial robots and 3D printing the development path takes on average 12 months. These capabilities, have more complex technical requirements therefore the one year timespan is corresponding to theoretical findings.

If given a closer look to other paths besides the most popular one, the path from connect to efficiency capability takes 24 months. As energy efficiency capability has very specific requirements to be developed the extension of the timeframe for this path seems understandable. Another path that takes 24 months is from industrial robots to controlled process. Here, only a presumption could be made that after already having more specified instead of the high-level capabilities it is harder and takes longer to develop and introduce control of the smaller capabilities. Rather, when the process is conducted from a different side. This presumption could be partially validated by the path leading from energy efficiency to controlled process capability as this process takes in total 36 months.

4.2.3 Additional note on the process of the development of digitalization capabilities

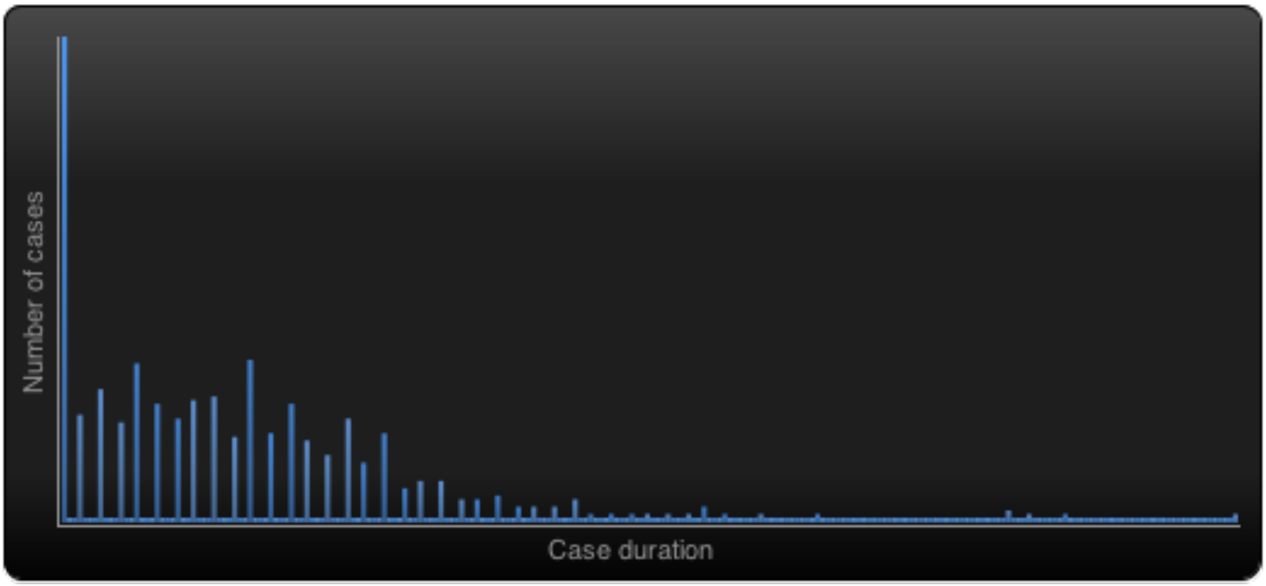
Additional insights could be made by peeking into how the cases spread throughout overall time. To look briefly at the Table 37. *Active Cases over Time* it can be noticed that first introductions of digitalization capabilities start around 1990, pick up a steep pace in 2000 and the vast majority of cases is happening from 2005, reaching its peak in 2010 and further – slowly declining. According to CHM, this could be explained by common breakthroughs in digital solutions. For example, supercomputers and hard drives started to shrink and get optimized in the 90s. In 2000s network systems were being established, in 2005s automated robotics picked up the pace and in 2010 3D started to spread. Which means that software improvements get adopted by wide variety of industries in order to stay relevant in the market pretty quickly as the data from the set seems to validate that.

Table 37.0 Active Cases over Time



Further additional notes could be extracted by looking at the Table 38.0 *Case Duration* from the left to right. Looking at the right side of the graph it shows that the amount of cases with shorter development timeframes is slightly higher than the amount of cases with extended development timeframes. Shortest implementation timeframe takes only up to 24 days with 131 cases and the longest implementation timeframe is 62 years and 37 days. As it was mentioned before the average implementation time is 10 years. However, most of the cases could be seen to gather over the right side of the graph meaning that capabilities are being introduced in shorter rather than lengthy timeframes.

Table 38.0 Case Duration



4.3 Summary of the results of empirical research of the analysis of process of development of digitalization capabilities

To summarize the chapter IV with, it overlooked how the most popular process of the development of digitalization capabilities looks from the perspective of frequencies. The empirical findings were matched against theoretical approach. Together with that, alternative paths were considered and again checked-back through the theoretical lenses. In a similar manner, the process of the development of digitalization capabilities was overlooked through their timeframes and considered together with the theory. Some additional insights in regards to active cases overtime and case durations were also reviewed briefly. All in all, the results from the empirical analysis proved to be confirming the resource-based theory that was used as an explanatory back-bone of the thesis. Therefore, the most common path and timeframe of the development of digitalization capabilities was discovered and is going to be repeated and overlooked in the last part of the thesis – conclusions.

Conclusions

To conclude with, the thesis started with the introduction and brief description of relevance and importance to analyze the subject of the process of the development of digitalization capabilities. To back-up, current global market demanded the international organizations to expand their ways of operating towards digitalized model. Therefore, modern organizations faced the need to have appropriate tools at hand to navigate through the digitalization development process. Digital transformation in turns raised not only managerial, strategical or operational challenges but also procedural questions when and what capabilities to develop. Therefore, in the introduction the research question was raised: what is the process of the development of digitalization capabilities. Also, an aim was set to reveal the mentioned process using process mining approach. Next, the objectives were set: conduct literature review revealing the dimensions of digitalization, background the thesis with resource-based theoretical approach, lay down the methodological viewpoint of descriptive statistics and process mining algorithm, conduct empirical research and present its results.

Therefore, the following part of the thesis was focused on reviewing current approach towards digitalization practices which appeared to be through the readiness for the Industry 4.0. The Impuls, WMG and Maturity models were reviewed with a goal to uncover in which dimensions the process of the development of digitalization capabilities currently is desirable for the market and is happening in practice. The literature review provided insights that the core focus of the Industry 4.0 revolves around areas such as products and services, manufacturing and operations, strategy and organization, supply chain, business model and legal considerations. For further research smart factory, smart operations and smart products as focus areas were selected since these dimensions of the development of digitalization capabilities proved to be of the most importance for digital process enhancements.

The subsequent part of the thesis was dedicated to reviewing the recourse-based theory as the grounds for further empirical research. Resource-based theory pre-suggested that dynamic capabilities are the source of competitive advantage for modern organizations. However, researches themselves appeared to question whether this approach is not conditional in terms of timeframes and sequences of the digitalization development. Meaning, when and what changes need to be adopted. Therefore, the scholarly questioning of the theory also gave good grounds to see in what timeframes these capabilities are being introduced in practice and in what particular order. The theoretical part further focused on the definitions of the most prominent digitalization capabilities, the challenges that each of them bears and the opportunities they provide. This further provided a ground for interpretations of the empirical findings.

The next part of the thesis was focused on the methodological approach, therefore, presenting the data collection procedures, following the steps of how the raw data was prepared through SPSS (conducting factor analysis, statistical validity and reliability test, re-computing new variables, transposing and ranking in excel). In this part, some of the initial findings from the raw data set were already provided. The most relevant observation to repeat-back comes from the computation of average years variables. Computing the total average year from the variables of first years use of the capabilities it appeared that the ‘earliest’ capability to be developed in the organizations was controlled process capability. Then the rest went as follows: energy efficiency, software augmentation, analytics, industrial robots and latest 3D printing capability. Which in the following part of the thesis – the interpretation of empirical findings appeared not to be the most common path of the process. This outcome also allows to connect the average years of the introduction with market trends and adoption as well as with dispersion with newest technologies. An area here for further research would be to follow the trends in historical perspective and match them with the given data. Yet, for now, the mentioned analysis does not fall into the scope of the thesis.

Further, and the last part of the thesis covered the descriptive analysis of dispersion of digitalization capabilities per set of events in frequencies, per cases throughout time and per countries. An interesting detection was made when looking through organizations who develop 2 to 5 capabilities. The most popular capabilities to introduce in these cases were software augmentation, controlled process and connect capability. In addition, the process of the development of digitalization capabilities was interpreted through frequencies and through timeframes. The frequency analysis revealed that the most common process consists of these capabilities: controlled process, software augmentation, connect, analytics, industrial robots and 3D printing capabilities. Here, the energy efficiency capability was left out of the path. And in their timeframes almost all capabilities took on average a year to be developed and only connect capability took 26 weeks to be implemented. Which in total substitutes to 5 years and 6 months for the development process.

Depending on the empirical findings the common pattern of the process of the development of digitalization capabilities was detected. The following question might be, how and what other capabilities from the digitalization dimensions discussed in the chapter I are being developed. Further research could also be made by including company and country contexts where an in-depth analysis might reveal if the dispersion of certain capabilities is different throughout the industries or countries depending on their main export vertical. In addition, following research could be conducted to find correlations between digitalization of the companies and their performance in terms of financial gains or market shares. All in all, the topic of the development of digitalization capabilities remains relevant both to the organizations and scholars as the global market is still ongoing the digital transformation.

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