Master's thesis

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A suggested framework for measuring digital maturity in construction projects in Norway

Master's thesis in Project Management
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June 2019

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6/10/2019

Preface

This is a written Master Thesis in the course TPK4920 Project and Quality Management Master's Thesis, during spring 2019 at the Norwegian University of Science and Technology (NTNU). I would like to take the opportunity to express my gratitude to everyone who has been a part of this master's thesis.

I would like to thank my supervisor Associate professor Jan Alexander Langlo for his supervisions, guidance, and feedbacks. I would like to thank my co-supervisor professor Bjørn Sørskot Andersen for his constructive feedbacks and suggestions. I would like to thank Per Morten Schiefloe for sharing his working paper and providing valuable inputs. I would like to thank Sjur Stumo for all the valuable inputs to the thesis. I would like to thank my friend Bahdor Hafezi for his discussions and valuable hints during the master thesis.

Summary

Digitalization has become an important trend in many industries with a fast-paced market. But the construction industry is behind digitalization in comparison with other industries. The reason for the lack of development is different. Many companies are not aware of the benefits of digitalization. Some are aware of but are risk-averse companies. Some are preoccupied with projects and cannot find time to act. There are some commercial tools for measuring digital maturity. The main challenge is developing a framework which can measure better than existing ones. The characteristic and process of such a framework were unclear at the beginning of this research effort.

For attaining the research purpose, the deductive approach applied in the thesis as well as inductive. Analysis of data was qualitative, and the strategy was innovative exploratory. Literature review contributes to identifying some digital maturity tools in manufacturing and construction. With the evaluation of tools, research gaps identified. The initial process of measuring digital maturity suggested. This model is inspired by performance measurement systems. The second and main step of the thesis was developing a holistic digital maturity framework using Pentagon model. The process progressed until making a framework. The current research shows the building blocks of digital maturity framework (DMF). This framework is a useful guide for companies and researchers toward the main components of digital maturity framework. In addition, it is a familiarity with less considered criteria which are friendship, informal power, trust, etc. The thesis suggests the researchers implement the framework in the real world with expert's contribution.

Abbreviations

BIM	Building Information Modeling
PMS	Performance Measurement System
DMF	Digital Maturity Framework
WA	Work Area
SRaN	Social Relation and Network
CDML	Construction Digital Maturity Ladder

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Chapter 1

Introduction

This thesis is an effort to provide a framework for measuring digital maturity in construction projects organizations. In this path, the process of developing a tool presented. For making framework the thesis benefits the organizational model. The candidate organizational model is the Pentagon for the purpose of this project.

In the first section of this Chapter, the background of the research will be presented. The second section pertains to the reasons for commencing this research project as well as a description of the problem and research questions. Next section focuses on the main objective and the scope of the research. Final section elaborates on the thesis structure.

1.1 Background and Motivation

The necessity of having a tool for measuring digital maturity triggered by the impact of digitalization on human life. Digitalization can influence different industries and causes different changes in economic, social, political and scientific aspects. Despite the advances, the construction industry has gained less from the potential of digitalization in comparison with other industries. Some researches reflect this issue in their work (Schober et al., 2015),(Ustundag and Cevikcan, 2018).

The reasons for moving toward digitalization in the construction industry is different. Some of them are declared in this section:

- Productivity improvement of companies in their operations is a driving force for a change (Malleson, 2019a).
- Life cycle perspective which stimulates companies to change their business model and move toward more engagement (Malleson, 2019a).
- Nowadays client expectation has been changed. The reason for this change is the comparisons they make with other industries and services they receive. For example, they receive very fast products and individualized services form banking, shopping or other

services. They want to perceive these changes in their buildings, products, as well as their communication with the project side in construction (Oliver Wyman, 2018).

- Governments, especially in Nordic countries, are interested to make rules for reducing the level of CO2 by industries. Digitalization can contribute to this purpose in construction processes (Oliver Wyman, 2018).
- Technological advances are making much progress in cost and timesaving. The range of existing technologies in the market such as augmented reality, virtual reality, drones, etc. provide the opportunity for exploitation (Oliver Wyman, 2018).
- Young graduates are more technology interested than before which provide the opportunity for using new technologies (Oliver Wyman, 2018).

Norway faced a significant increase in the level of digitalization and the government puts emphasis on building a digital society (OECD, 2017). The speed of digitalization in the construction industry in Norway is slow and many companies have less desire for digitalization. Some of the companies are even unaware of this change. Some are aware and are in the route for digitalization.

There are different reasons for less desire of digitalization in Norway companies. The probable reasons for this problem can be a preoccupation in daily projects. Daily project and occupation with these projects obstruct them for having time to think about digitalization. Some companies are unaware of digitalization benefits. Some perceive digitalization as a risky effort, and some perceive it as a heavy financial investment.

Having a framework for measuring digital maturity is a useful guide for companies to measure their digital level. First, this framework gives structure, based on their real capabilities and performance level. For example, some online tools ignore the real structure and context of companies. In addition, they evaluate areas which measurement of them may be not important for some companies. Second, make the companies acquaintance with a step by step approach for measuring their digital level. Third, it contributes to companies being independent of expensive tools which are offered as commercial products. Some tools are designed based on predefined questions and ignore the pace of changes in the digital world. Fourth, the holistic structure contributes to companies observing some important dimensions in digital maturity which is noticed less in previous studies.

The purpose of the thesis is to provide a framework for measuring digital maturity in project-based organizations in the construction industry. This framework aids the companies in the route of digital transformation. Report by MIT Sloan shows the digital transformation path clearly (Unruh and Kiron, 2017). Companies start with digitization which is the simple transformation of analog information to digital as illustrated in Figure 1. The second process is digitalization which is changes in business model and processes and using opportunities. Many companies in construction in Norway have not arrived at this level. The final level is the digital transformation of the business (Unruh and Kiron, 2017). Digital maturity in this path demonstrate to the companies where they are? What degree of improvement is necessary for their approach toward digital transformation?

Figure 1[1]*:* Framework for understanding digitalization *(Unruh and Kiron, 2017)*

There are different tools for measuring digital maturity in various industries. There have been fewer considerations regarding construction. The main reasons for measuring digital maturity with the existence of the several tools in the market is to concentrate on aspects which have been considered less in the literature and to undertake the endeavor of developing a better framework.

Making this framework is a helpful guide for companies which are in the path for digital transformation. This study contributes to researchers and practitioners about the various criteria which exist in the literature of digital maturity. In addition, this thesis gives perspective to the researcher about the application of organization models for measuring digital maturity.

[1] Source: https://sloanreview.mit.edu/article/digital-transformation-on-purpose/(Unruh and Kiron, 2017)

1.2. Problem Description and Research Questions

There are different maturity tools in the market. The process of measuring digital maturity is a step by step approach. This step by step approach is a project for each company. But many research projects conceal the process of developing a digital maturity tool. They just show the final product, important dimensions of measurement, and some sample measurements for different sectors. The main reasons can be the confidentiality of the information, competition among companies, etc. In order to fill this gap in the literature, this thesis tries to design a step by step framework for measuring digital maturity. Hence, the question that arises here is as follow:

Q1: What is a suitable process for developing a framework for measuring digital maturity?

After knowing the step by step approach, the focus will be on choosing important aspects in digitalization. There are different dimensions for measuring digital maturity. Many previous types of research explained these dimensions.

The main argument in the thesis is:" Organizational analysis model can give a better answer to the problem of measuring digital maturity". The probable answer to this argument based on a preliminary analysis which creates the interest for doing the research include:

First, Companies are a combination of people and culture in the framework of the organization. Digitalization shape in the context of the organization. Hence measuring maturity in this framework can have a structure compatible with this frame. Organizational models proved their usefulness in the analysis of organizational problems and issues (Rolstadås *et al.*, 2014).

Second, digitalization, as stated by many scholars, is not a simple technology application (Westerman et al.,2014). For measuring the maturity of digitalization, the suitable tool measures the maturity of different dimensions involved in digitalization. It progresses more than this and measures the interconnection of different effective elements in maturity. For instance, the connection of different cultural dimensions with technological dimensions. This does not mean that other models do not notice these aspects but, it means they may highlight technical and structural aspects more than social and cultural issues. In our assumption, these issues are as important as technological and structural issues in measuring digital maturity.

Third, having a framework or model, contribute companies to measure maturity in a structured format. The necessity of structured format is to contribute them to observe many aspects of maturity in the company, and interconnections of different parts in a holistic view. Organizational models are a type of structured format. Models are suitable tools for showing the reality of phenomena. There is no complete model which can show all the components and complexity of real systems. Although, models are not exact representatives of the reality, are very helpful in the demonstration of important aspects.

Based on three reasons which are explained, the second question of the research will be as follow:

Q2: What is a suitable framework for measuring digital maturity?

This thesis is an endeavor to answer the above questions. Answer to these questions will be the contribution of the thesis:

- Helps to construction companies to know the process for digital measurement
- Offer a holistic framework for measuring digital maturity
- Are able to know the innovative approach for making maturity ladders
- To help the researchers to identify the uncovered criteria of maturity

1.3. Objectives and Scope

The purpose of the research is to develop a framework for measuring digital maturity from a holistic perspective. For having a holistic perspective organizational model uses for analysis. This thesis focuses on the construction industry as an industry which has a low degree of digital progress in Norway in comparison with other industries. In addition, the focus of the thesis will be on measuring digital maturity in the path for digital transformation. This path starts from digitization which is converting from analog to digital. In the second step is digitalization which is beyond digitization and covers many aspects. The end of this path is digital transformation. The assumption of the thesis is based on that many construction companies are in the first step. Some are in the second step. The objective of measuring digital maturity shows its potential and position in this path.

1.4. Thesis Structure

The second chapter of the thesis explains some theoretical background about maturity, digital maturity, performance measurement systems, and organizational models. The third chapter demonstrates how research has been conducted. It shows the research process form data collection to the development of the tool. The methods for data collection and analysis explained in this chapter. Finally, the limitations of the research explained. Chapter four introduces a step by step approach for measuring digital maturity. Chapter five describes the building blocks of maturity. Chapter six introduces digital maturity framework. Chapter seven covers analysis and discussion of the suggested framework. Final chapter concludes the thesis.

It is noteworthy to say that each chapter has its own target readers. Chapter two gives a perspective to student and researchers to the concept of maturity and digital maturity. Chapter three contribute to new master students with drawing the path of the research from data collection to the final framework. Chapter four can be an inspiration for experts in the industry about the process of measurement and introduction for performance measurement of digital maturity. Chapter five is a guide with blocks of digital maturity for experts not only in construction but also the experts active in other industries. Chapter six is for practitioners and industry experts which suggest a framework for measuring digital maturity. Chapter seven is an analysis of the results that gives direction to the researchers for further research.

Chapter 2

The Theoretical background for assessing digital maturity

This Chapter provides information about the meaning and application of maturity as well as familiarity with the concept of maturity. Knowing the characteristics of digital maturity is necessary for measuring digital maturity. The measurement can be aimless and wasteful without familiarity with the concept of measurement. Based on the literature review, some reports were elected to derive a common definition for maturity characteristics.

Some companies developed tools for measuring digital maturity. Selected ones deemed to be important is explained in this Chapter. These models are compared with each other. Evaluation of these models contributes to finding uncovered dimensions of digital maturity tools. These uncovered dimensions help to develop a holistic tool which is the aim of this thesis. The remaining part of the chapter introduces organizational models, especially the Pentagon model. The reasons for choosing organizational models, especially the Pentagon, for measuring digital maturity is explained in the following parts of this Chapter.

2.1. Maturity

Having a small introduction about maturity is interesting at the starting point. Philip Crosby (Crosby, 1979) presented maturity model first time in the quality management (van Looy, de Backer and Poels, 2011) (Tarhan, Turetken and Reijers, 2016) and maturity models developed in software and system engineering. Previous researches showed that maturity models have been applied in different fields such as product development, human resource, project management, e-government, IT (Buglione, 2006) and digitalization (Schuh et al., 2017), (Anderson and William, 2018).

Based on the research by Khoshgoftar and Osman (2009) maturity models were used pervasively with the purpose of performance improvement. There are various maturity models. It became obvious that there is no standard model for measuring maturity, after some investigation. Different models of maturity are introduced in previous researches by Buglione (2006), Khoshgoftar and Osman (2009),.The important ones are OPM3, P3M3, Prince, Kerzner, Berkeley, Anderson, which are introduced in project management and CMMI in software, BPMM in business, and

FAA-CMM is not recognized. Khoshgoftar and Osman (2009) categorized these models based on twenty-seven variables. Some of the variables are: the reliability of publisher, the cover area of the model, the number of maturity level, consisting of the maturity levels, the considered dimensions, the date of release, etc. The following characteristics are identified by Khoshgoftar and Osman (2009) for maturity models:

- The proposed subject maturity is confined to maturity levels from four to six level.
- Each level has the specific qualification and the measured entity should fulfill these requirements to be at the specified level.
- Levels are designed consecutively, and the last level is the perfect level.

After knowing a short of background about maturity models, applications and their characteristics, maturity concept will be explained. Cambridge dictionary defines maturity as a "very advanced or developed form or state"(Cambridge University Press, 2015). The other dictionaries such as Merriam-Webster and Oxford have a similar definition: "the quality or state of being mature" (Webster, 2006) (Oxford, 2016). According to these definitions, maturity is a kind of completeness with different stages. Maturity means physical or mental development, but this definition is more about human characteristics and there is a need to know the definition related to systems.

In this thesis, the systems we evaluate, are organizations and projects which are social systems. Hence, knowing maturity from this perspective can contribute to the thesis' aim. Maturity in social systems presented in the paper by (Mettler, 2011) contains three dimensions: First, people (culture) that notice the improvement of skills and knowledge of people. Second, processes (structure) is related to the degree the processes are well-defined, well-managed, and effective, and third, objects (technology) which concentrate on the growth of technologies to the expected level of completion.

Knowing the concept of maturity contributes to knowing the definition and application of maturity. For the purpose of developing a digital maturity framework, this definition gives an understanding of this concept that maturity has 1. stages and 2. is an evolutionary process. In addition, helps to know maturity can have different dimensions.

Next part defines digital maturity and the characteristics for digitally mature companies. For the purpose of the thesis which is developing a framework for measuring digital maturity, knowing digital maturity models gives a better understanding of the process, dimensions, and functions of digital maturity.

2.2. Digital maturity

After the introduction to the concept of maturity and maturity models, the main concept of the thesis will be evaluated. The pace of changes in IT and changes in the environment of companies cause companies to face different challenges in their market and finding a mature company in digitalization seems to be an impossible task. But there exist some companies who act better than others in digital transformation. These companies show more flexibility and adaptability in their practices. Digital maturity is not achieved merely by the entrance of technology or advanced systems. It starts inside companies, from organizational structure, culture, interactions as well as adaptability to new technology with the aim of reaching to reasonable performance level based on organizational objectives. Therefore, it needs holistic coordination among different organizational dimensions.

Digital maturity and maturity can be defined differently. In defining digital mature companies, the initial step is to know the characteristics of these companies. In the research by MIT SMR and Deloitte, which is our first report, it was found that digitally mature companies have the following characteristics (Kane et al., 2017):

- Mostly organized around teams which have different functional expertise
- Motivate innovation in the work environment
- Nurture digital culture in the company and recruiting a digitally competent workforce
- Connect digital strategy to core processes and technology
- Having a broad horizon for strategic planning
- Focus on organizational change and flexibility which result in high adaptability to digital changes
- Have more tendency to invest in digital solutions in comparison with other companies which are less digitally mature

- In digital companies, small innovations and practices lead to big innovations in comparison with other companies
- Having a culture which is agile, exploratory, risk taker, less hierarchical, and collaborative.

TM Forum, which is our second report, defines digital maturity noticing five dimensions. This tool was the result of contribution and test of several international companies (Anderson and William, 2018):

a. Customers see the company as a partner and the company dedicated private channels for them to shape their expected future.
b. The strategy concentrates on the process of boosting competitive advantage with the help of digital technology and the strategy is aligned with the business strategy of the company.
c. Management of data is done through technology to satisfy customer needs efficiently.
d. The operations are performed using digital tools to fulfill strategic goals and enhance work efficiency and effectiveness.
e. Culture, people, and organization: Having a culture concentrating on skillful workforce development and structured governance with the aim of moving towards digital maturity path and having agile practices towards innovative goals.

Deloitte, our third report, mentioned that technology is an enabler and not the main purpose. They tried to demonstrate eight characteristics of digital enterprises in another report (Mazor and Knowles, 2019). These characteristics are:

a. Aim to set brave goals and try to "Scale the edge"[2] .
b. Fostering agility in operations, for instance, developing new ideas and testing them in a qualified team with short repetitive cycles.
c. Obtain a skillful workforce to provide innovative ideas in digital thinking to increase abilities of the company.
d. Provide adequate freedom to the workforce for innovativeness and agility.
e. Customer experience has high priority and provide value to the customer.
f. For solving customer problems new ideas applied

[2] Means low investment on opportunities with the high possibility of growth and different practices which have the capability to change the core of the business (Wong and Scharf, 2012).

g. The design makes difference and cross-functional teams when having design thinking can be impressive.
h. Concentrate on creating value and important items for creating profit.

Evaluation of these three reports shows, as illustrated in Table 1, some common point and some differences among them. The culture of supporting innovation and developing a competent workforce in companies started by the above-mentioned reports. These reports focus on innovation in their practices. The first and third report mentioned it directly and the second one considers it as the result of agility. Both reports, (Kane et al., 2017) and (Mazor and Knowles, 2019), put emphasis on cross-functional teams. The governance is mentioned implicitly in three reports. Risk acceptance culture is not mentioned directly in the third report, but having the brave goals is a synonym for accepting the risk. Contrary to the second and third report, the first one did not mention the customer as the center of attention. The third report gives much value to the customer as declare that customer satisfaction has the main priority. In the second report, customers see the company as a partner which implies on a high level of trust.

However, other aspects of organizations such as trust, cooperation, friendship, informal power, and other social factors are noticed less in these reports. If we accept that digital maturity is a kind of completeness and development, these aspects can affect its maturity. For instance, consider two companies with the same performance level, it is hard to find such companies which are comparable, but it is an assumption. In company A, customers have a high level of trust to digital application and in company B customers have medium level trust. It is clear that the score of the company A is higher than company B in digital maturity level.

The learning environment is not mentioned by any study directly, but we assumed it as an important dimension, because the performance of many companies may depend on this dimension. Companies which are better at learning can be successful in digital business (Westerman, Bonnet and McAfee, 2014). In addition, based on the thesis assumption, this dimension is complementary for other dimensions such as risk-taking culture.

	Support innovation	Cross-functional teams	Governance	Agility in culture	Customer centric	Learning environment	Digital strategy alignment	Risk taker	Competency of workforce
(Kane *et al.*, 2017)	✓	✓	Implicitly	✓			✓	✓	✓
(Anderson and William, 2018)			✓	✓	✓		✓		✓
(Mazor and Knowles, 2019)	✓	In company with a design thinking can be effective	Implicitly	Agility in operations	✓		Not stated directly	Having brave goals	✓
✓	✓ = This sign shows the criteria are stated in the report directly								

Table 1: Comparison of reports

Through the evaluation of all these definitions and criteria for digital maturity, the following important aspects make a basis for the description of digital maturity in this thesis:

1- Support of innovation by leaders
2- Learning environment
3- Customer-centric
4- Agile processes
5- The technology uses for Efficient management of data
6- Concentration on the competency of the workforce
7- The digital strategy supports strategic goals and main processes
8- Response on-time to digital changes in the environment

After reviewing these criteria one question emerges: What is the boundary of mature and digitally mature companies?

Some of these criteria can be the characteristics of successful companies. Although these traits observed in digital mature companies, these can be the basic needs for companies which perform better than other companies. The research can divide these characteristics into two groups: a. the preconditions for digitally mature companies, and b. main characteristics of digitally mature companies. Therefore, the category of important characteristics will be as follow:

a. Preconditions for digital maturity
    - Support of innovation by leaders
    - Learning environment
    - Agile processes
    - Customer-centric
    - Concentration on the competency of the workforce

b. Digital mature characteristics
    - The technology uses for efficient management of data
    - Dedication of communication channels for customers
    - Concentration on the competency of the workforce (digital competency)
    - The digital strategy supports strategic goals and main processes
    - Response on-time to digital changes in the environment

The scope of the thesis is to measure digital maturity in construction projects. Therefore, to make this definition more consistent with the structure of the construction project organizations in Norway, some adaptations in the description seems necessary. For this purpose, two criteria added, stakeholder requirements and environment-aware solutions. Stakeholder requirement encompasses the customer. Although customers are as one of the important stakeholders in projects, the criteria related to customer removed for simplicity and avoiding redundancy. The environment-aware solutions refer to solutions which contribute more to the preservation of nature. For example, purchasing expensive servers and using the cloud are two digital solutions. But, using cloud computing capability has a more environmentally aware solution than buying expensive servers. In the first solution, the company pay the cost of service and in second solution company dedicates space for servers, consumes more energy, requires more workforce, etc. In essence, digitalization in construction can improve these issues through avoiding waste of material, resources, and better design of the building. The modified criteria for the construction industry are as follow:

a. Preconditions for digital maturity
    - Support of innovation by leaders
    - Learning environment
    - Agile processes
    - Increasing efficiency in response to stakeholder requirement
    - Concentration on the competency of the workforce

b. Digital mature characteristics
    - The technology usage for efficient management of data
    - Dedication of communication channels for stakeholders
    - Concentration on the competency of the workforce (digital competency)
    - The digital strategy supports strategic goals and main processes
    - Response to digital changes in the environment quickly
    - Providing environment-aware digital solutions

What is the next step for measuring digital maturity in the company after grasping the definition of digitally mature companies?

There are different approaches to measure digital maturity. Some of them in manufacturing and construction companies explained in the background for digital maturity tools.

2.3. Background for maturity tools

Identification of the necessary elements of digital maturity tool needs an examination of previous tools and their frameworks. For the sake of this aim, this part is dedicated to familiarity and analysis of previous tools. Main reasons for evaluation of these models are as follow:

1) The methodology or process these tools applied for measuring digital maturity.
2) To know which criteria are ignored or less attention has been paid to in comparison with other criteria.
3) To realize the common characteristics of these tools.

It consists of two main sections. First section presents some digital maturity tools. The second section introduces a digital maturity tool in the construction industry conform to the scope of the

thesis. This tool called Construction Digital Maturity Ladder. The contribution of this model is to evaluate important aspects of digital maturity of construction project organizations.

2.3.1. Previous digital maturity tools

With the start of digital transformation efforts, some digital consulting companies tried to find methods for measuring digital maturity. They developed different tools with different capabilities. This part explains existing tools in the literature for measuring digital maturity and their characteristics. Identifying these tools gives an overall view of different dimensions of maturity as well as the discovery of the uncovered parts. The approach of the thesis in this part is to focus on the introduction of the digital maturity tools which include the dimensions and processes of maturity. In addition, identification of different processes of measuring maturity aid to compare the approaches with the proposed approach in this thesis.

The first report by, McKinsey conducted a survey of 150 companies from different parts of the world. They tried to develop a maturity framework which is called digital quotient (DQ) with a focus on digital strategy, capabilities, and culture. The company determined four main areas based on this survey, as illustrated in Figure 2. Companies will be placed in one of these areas based on their score. These areas are called: below average, above average, emerging leaders, and established leaders (Catlin, Scanlan and Willmott, 2015). The main findings of these survey can be summarized as follow:

- Companies which create outstanding result and made differentiation had a right and clear digital strategy.
- Having the right investment in digital abilities which is in coordination with the digital strategy of the company.
- Culture can play a more outstanding role than technology.
- The alignment of digital strategy with organizational structure, skills, financing, and key performance indicators.

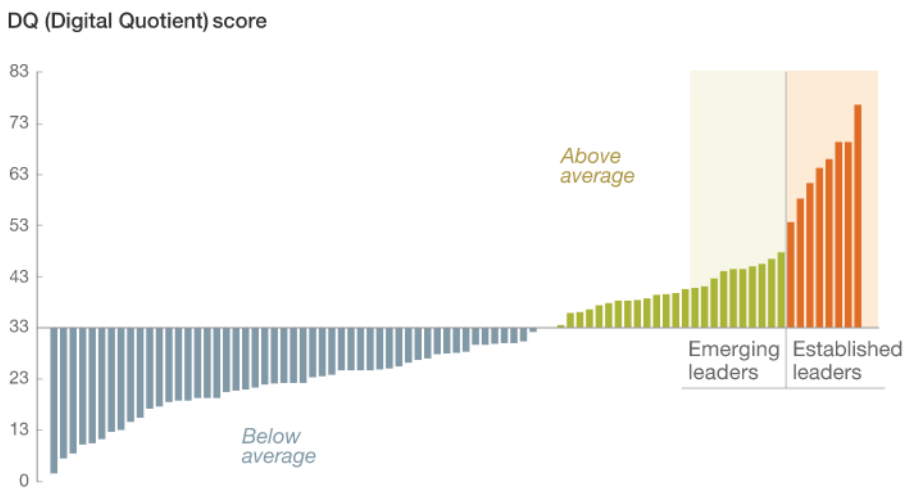


Figure 2: Assessment of digital maturity of companies3 (Catlin, Scanlan and Willmott, 2015)

This report concentrates on the digital strategy, digital capabilities such as modular IT and agile technology against customers and having an agile and flexible culture (Catlin et al.,2015). The focus is on a digital strategy which is an important issue in the transformation process. The process of work is based on a survey and four levels for digital maturity. But, the steps of the process are not proposed.

The second report by Acatech (Schuh et al., 2017) presents the industry 4.0 maturity index model which part of it related to measuring maturity demonstrated in Figure 3. Although Acatech model is not with the name of digitalization maturity, it covers the digital maturity and goes beyond it to cover industry 4.0 maturity. The closeness of evaluated dimensions to the thesis approach and semi-holistic perspective to maturity motivate us to present this maturity model in this section.

[3] Source:2-014-15 McKinsey company survey

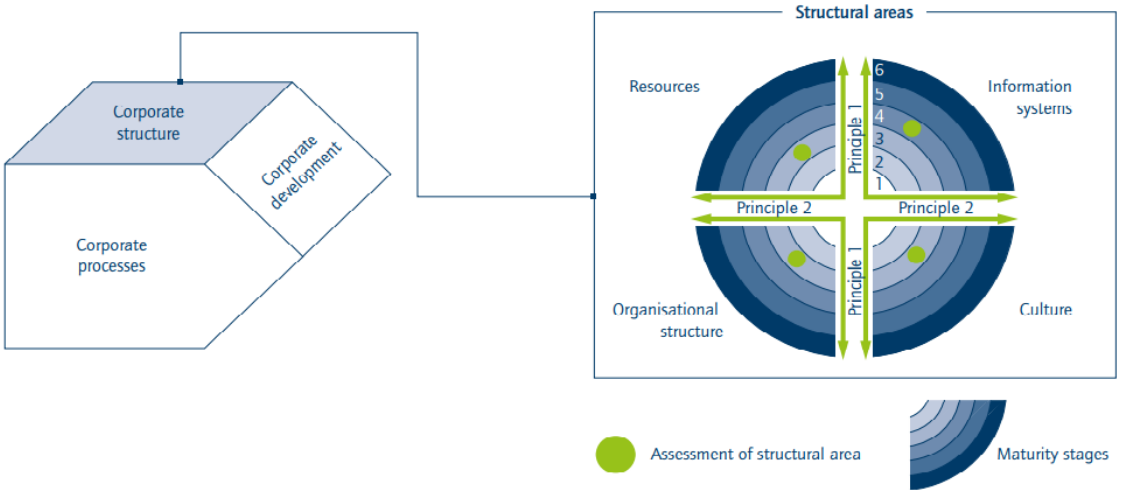


Figure 3: Structural areas of Maturity index[4](Schuh et al., 2017)

Acatech's industry 4.0 maturity index has three main dimensions which are corporate structure, corporate processes, and corporate development. In this model corporate structure includes four structural areas:

- Resources,
- Information systems,
- Organizational structure,
- Culture.

Each structural area has two principles as depicted in Figure 3 in the model for development. These principles should be performed based on the six-stage of digital maturity. Elaboration is made regarding them in the following:

Resources: covers two main principles, structured communication and digital capability. Structured communication includes efficient communication and task-based interface design. Digital competence includes providing digital competencies and automated data acquisition through decentralized (pre-) processing of sensor data (Schuh et al., 2017).

Information system: This area has two principles that are information processing and integration. Information processing covers data analysis, information customized for decision making, user

[4] Source: From Acatech Industry 4.0 maturity index (Schuh *et al.*, 2017)

interface related to the task, and flexible IT infrastructure. Integration includes horizontal and vertical integrity, data control, standardized data interface, and IT security (Schuh et al., 2017).

Organizational structure: Has two principles, organic internal organization and dynamic collaboration in value networks. Organic internal organization includes flexible communities, decision right management, motivational goal system, agile management. Dynamic collaboration in a value network covers customer benefits and cooperation in relations (Schuh *et al.*, 2017).

Culture: This area entails a willingness to change and social collaboration. Willingness to change relates to data-based learning, knowing the importance of mistakes, continuous improvement, and forming the change. The social collaboration focuses on possessing a democratized style of leadership, being open to communication, and having enough confidence in systems and processes (Schuh et al., 2017).

This report defines digitalization as computerization and connectivity with the aim to create value. This digital maturity tool has three main stages for measuring digital maturity which is: First, identification of current maturity level of the company based on the score of each functional area which is Production, development, logistic, and …, second: to know the capabilities which we can put emphasis on them for improvement. The areas are suitable which has the close or same maturity degree in all four structural areas, third: identifying solid measures for areas which need necessary action for improvement.

The third report which proposed a tool is Deloitte and TM Forum (Anderson and William, 2018). These two companies cooperated with each other to develop a tool for measuring digital maturity which is illustrated in Figure 4. This tool was a guideline in the path for digital transformation and evaluate digital maturity from five main dimensions. Namely: customer, technology, strategy, operations, and organization and culture.

Figure 4: Digital maturity model by Deloitte and TM Forum[5]

- Customer dimension is an effort to make a close relation with customers. The customer has a partnership relation with the company and has their personal channels for communication with the company as well as monitor their expected outcome from the company. This dimension gives a broad view of customers (Anderson and William, 2018).
- Technology dimension seeks to meet customer expectation with minimum cost and with efficient data management. This dimension includes applications, connected things, data and analytics, delivery governance and network (Anderson and William, 2018).
- Strategy targets the competitive advantage with the contribution of "digital initiatives"[6] .It also helps to understand that digital strategy is synced with business strategy. This dimension includes brand management, ecosystem management, financial issues, market, portfolio and innovation, stakeholder and strategic management (Anderson and William, 2018).
- Operations are viewed strategically with the exploitation of digital tools and focusing on efficiency and effectiveness aspects of the business. This dimension includes change management with agility, automation in resource management, integration of service management, concurrent insights and analytics, having flexibility and smartness in process

[5] Source: Report by Deloitte and TM Forum (Anderson and William, 2018)

[6] Digital initiatives: Based on the report by deloitte digital initiatives are:" digital strategy", "digital customer segmentation", "customer life cycle journey", "digital operating model", "agile transformation", "digitization of processes", "mobile and omni-channel", "cyber security", "FinTech", and "analytics".

management, having automation in governance and standards (Anderson and William, 2018).

- Organization and culture concentrate on making culture in digital transformation route through utilizing “talent processes” and governance in the organization with the purpose of growth and innovation achievement. This dimension includes culture to understand digital transformation, leadership, and governance for better management of digital transformation, organizational design and talent management, and workforce (Anderson and William, 2018).

They used a survey to develop a tool with 28 sub-dimensions and these sub-dimensions divided into 179 criteria. Some companies use this tool to measure their digital maturity degree in three steps of digital transformation which are imagine, deliver, and run. First, by identifying the now state of the digital maturity and recognizing opportunities and defined vision (imagine). Second, the categorization of capabilities to improve based on the objectives of the company. Conducting an assessment to know the effects of digital initiatives in the transformation route (deliver). Third, conducting an assessment to know: the effect of digital initiative on digital maturity, enhancement of processes, and efficiency related to processes (run) (Anderson and William, 2018).

Fourth research by Westerman et al. (2014) evaluates digital mastery with two aspects of digital capability and digital leadership. Digital capability revolves around the reason and the impact of the technology choice for investment. Leadership capabilities refer to directing digital progress in the right way. Considering these two aspects, companies can be put in one of these categories: Beginner, Fashionista, Conservative, and Master as can be seen in Figure 5. Digital mastery is not precisely the same as digital maturity but the ability of tool in measuring digital progress of companies motivate us to choose it as a digital maturity framework.

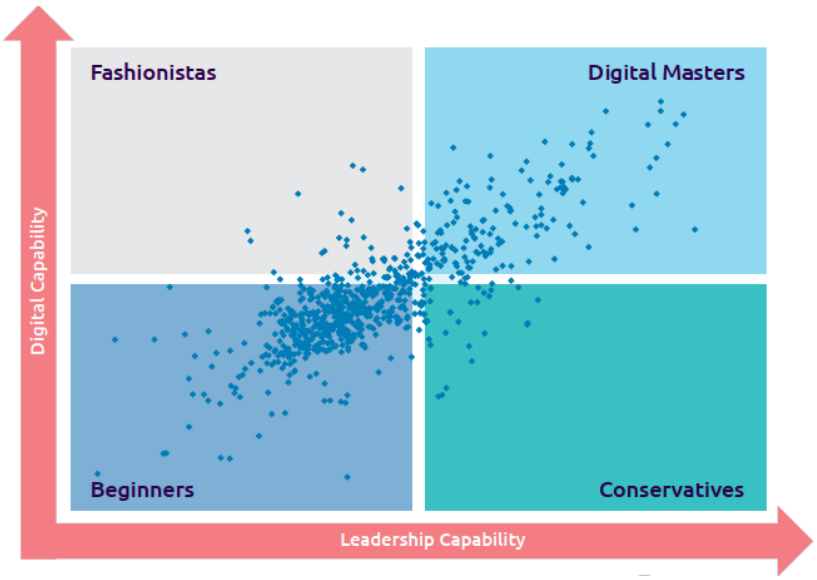


Figure 5 :The four groups of digital mastery[7]

According to Westerman et al. (2014) digital beginners are cautious about their steps. They have very limited digital capabilities. They are not risk takers for opportunities or have weak leadership to act. Digital fashionista invests in digital technologies, but they lack the digital leadership and governance to exploit their investment. Digital conservatives have good leadership capability, but they suffer from excessive cautiousness. This cautiousness is an obstacle for making digital business and finally lead to extreme control in the work environment (Westerman et al., 2014). Digital masters are strong in both:

A. Digital capability shows the quality and direction of investment in digital opportunity.
B. Leadership capability illustrates direction to digital changes in the right path.

Digital capabilities encompass the relation with customers, internal process operations, and business model definition. Leadership capabilities embrace technology and business relation, empowering workforce, vision and purpose, governance, culture. The report declares that the business strategy should align with the vision. The culture in this report includes agility and flexibility, collaboration, customer centricity, data-driven decision making, digital-first mindset, innovation, and open culture (Buvat et al., 2018).

[7] **Source:** Capgemini Digital Transformation Institute, Digital Mastery Survey; April–May 2018, N=1,338 respondents, 757 organizations(Buvat *et al.*, 2018)

These maturity tools all have been applied in manufacturing companies in different countries. It would be interesting to find and assess digital maturity tool(s) in Norway or Nordic countries. The shortage of such tools emphasized by some companies and experts. Close contact with construction companies guided us to find digital maturity tool in Norway that is called Construction Digital Maturity Ladder (CDML).

2.3.2. The Construction Digital Maturity Ladder (CDML)

Having a digital tool in the construction project-based organizations has different advantages. First, it contributes to knowing the main process of measuring digital maturity. Second, it determines which areas of projects are important for evaluation. In addition, it provides an opportunity to know which areas of work are not covered.

CDML is an online assessment tool to show the digital maturity of the company in comparison with other companies (Geniebelt, 2019)[8]. Note that the Beta version of the tool was considered. The aims of introducing this tool are:

- To represent the top mature companies' characteristics that is useful for finding the gap between companies,
- To learn from failures of companies in digital transformation path,
- To create profiles of similar companies for learning.

The report recognized eight important areas for digitalization based on the report of the McKinsey:

a. Design management,

b. Scheduling,

c. Material management,

d. Crew tracking,

e. Quality control,

[8] This reference is online questionaire for measuring digital maturity accessible through this link: https://geniebelt.com/cdml, the result is the report.

f. Contract management,

g. Performance management,

h. Document management,

The thesis assumes these areas as important Work Areas (WA). Later in chapter 5 and 6, these areas will be used as high potential areas for digital improvement in the thesis. Familiarity with these areas gives a clear guideline to areas which needs more evaluation in comparison with other areas.

The CDML (Geniebelt, 2019) performs benchmarking in the country level, between countries in Europe and at an international level. After evaluation in the target company and knowing the score, the company will be located in one of the maturity levels. This model has seven levels in maturity ladder which are depicted in Table 2.

Maturity levels	Characteristics of each level
Guiding star	In this level, all the produced data from different sources (cost, people, safety …) are used for improvement. The company exploit the power of machine learning and artificial intelligence
Innovative and adaptive	The data produced through different sources (cost, people, safety, quality and …) used in decision making
Converged	Learning in the project emphasized and digital strategy, digital chain, and learning loops are integrated which contribute the learning from other projects or programs in order to perform modifications
Strategic	The project strategy covers to great extent the strategic aim of the external project players. The digital strategy of the projects based upon data collection and integration strategy and alignment exist with the digital strategy of the company
Formalized	The project has a specific digital strategy and pre-determined digital tools. Training exists and CDML is a tool for measurement and amendment
Present and active	The company have a framework for definitions and execution of projects
Business as usual	Project managers choose the tools arbitrarily, a systematic learning and data collection does not exist

Table 2: maturity levels in CDML (Geniebelt, 2019)

As illustrated in Table 2, the maturity level starts from the bottom which is business as usual. The tools selection conducted randomly, and clear digital strategy does not exist. In the second level, the company designs a framework for project execution, and it shows progress in comparison with the previous level. The formalized level is the category of the companies with clear digital strategy. The choice of tools has an advanced plan. The strategic level is the characteristics of the companies which support external parties in the project. Data collection and integration has importance in these companies and there is coordination between digital strategies with business strategy. Converged referred to companies which are a learner and learning from similar projects is the advantage of this level. Data usage has high priority in the company in an innovative and adaptive level. The guiding stars are data-centric companies and use advanced tools for data management and exploitation.

All the criteria declared for digital maturity in section 2.2 are kind of capabilities. Each capability reflects itself in the level of performance in the company. Therefore, we assume that the digital maturity is the level of performance. The method of thesis for measuring digital maturity follows the method of performance measurement. Next part of the report introduces the performance measurement process and using a similar process for measuring digital maturity.

2.4. Performance Measurement System (PMS)

Following the recognition of digital mature characteristics, some digital maturity tools are introduced. Some unseen dimension of the work identified in previous studies. The PMS was chosen as inspiration for the process of measuring digital maturity. The process of performance measurement has origin in quality control with the development of the productivity concept. Then performance measurement used instead of the term productivity. Sink and Tuttle are one of the first researchers who introduced a model for performance measurement (Andersen and Fagerhaug, 2001).

The reasons for choosing the performance measurement for designing the steps of measuring digital maturity are as below:

- Developing a framework for measuring digital maturity itself is a process. There are some steps for developing a framework for measuring digital maturity. The design process of thesis inspired by measuring digital maturity is a step by step approach.
- The steps in the PMS start with recognizing the system (first step) and the process continues with the procedures which have more similarity to the approach of the thesis.
- PMS can provide a suitable approach for measuring digital maturity because the measurement will be more realistic and based on the performance level of the system.

The PMS design based on Andersen and Fagerhaug (2001) has eight steps:

1) Knowing the business and the company structure and processes with an effort to map these processes.
2) It is essential to set a performance priority for business before designing a performance measurement system. It encompasses business strategy priorities and all the performance priorities of stakeholders based on their expectations.
3) Identifying existing performance measurement system of the company. The existing systems are a significant aid for the developers to base their effort on previous works.
4) Determining performance indicators which is one of the main steps. Performance indicators contribute to measure a company's performance and business processes performance.
5) The strategy of data collection is another important step. This step is complementary to the previous step. Data collection is conducted for performance indicators. Required data is gathered based on the performance indicators.
6) This step is related to data presentation and reporting of the PMS.
7) This step focuses on testing the developed system. This stage helps to recognize the main potential problems of the system.
8) The eighth step is the implementation of the system. This step is related to the official usage of the system.

After identifying the inspired process for measuring digital maturity, the main purpose of the thesis will be on developing a tool for measurement. As previously stated, the literature review represents that existing tools may not cover all aspects of maturity. For evaluation of important criteria in

measuring digital maturity having a model can be helpful. As mentioned before, models are used for showing the reality of phenomena. Context of thesis for measuring maturity is organization and projects. Therefore, there is a requirement to a model which can show dimensions of the organizations. The organizational model can be a fair candidate for this aim. Among these organizational models, the aim of the thesis is to find a holistic organizational model.

2.5. Organizational models

The process of measuring digital maturity includes some important steps as stated in the previous part. This process follows the framework of PMS. One of the steps in the process of measuring digital maturity is dedicated to the development of digital maturity framework.

Review of previous digital maturity tools demonstrates that these tools observed some aspects of digital maturity and some aspects are unseen or less considered. There are different reasons for this lack of attention to these aspects. The unseen parts of research are not unimportant parts. Concepts such as trust, informal power, learning environment, friendship, and knowledge can improve digital measurement.

Organizational models can give a framework for considering different dimensions of digital maturity. For example, with the framework, there is a low probability of ignoring some of the dimensions. In addition, it gives a chance to see different dimensions of the problem in a holistic structure. The holistic structure can illustrate the different effective criteria and interconnections simultaneously. The chance of observing different dimensions increase with applying a holistic model. The influence of these dimensions on digital maturity can be seen through the model. For example, culture and technology have a mutual effect on each other and both affect digital maturity. Same rules apply for remaining dimensions. In summary, first, the model aid to show the real-world variables in a simple understandable way. Second, help to demonstrate the relations of these variables in a holistic way.

There are different organizational models in the literature. Some of them are identified in this research which are Levitt (1965)-diamond model, Scott (2003) - modified diamond of Levitt, Hatch and Cunliffe (2012)-organizational model, and Schiefloe (2019)[9]-Pentagon Model. These

[9] This reference is a "working paper" by Per Morten Schiefloe identified in May,2019

models except the Pentagon are presented in Appendix A. These models represent the characteristics of organizations as social systems.

The reasons for choosing Pentagon first, its capability in the analysis of organizational problems have been proved and the validity of the model approved by case studies (Rolstadås *et al.*, 2014) (Rolstadås and Schiefloe, 2017). Second, it is a sample of a successfully implemented model in construction projects in Norway (Rolstadås *et al.*, 2014). Third, the flexibility of this model in the evaluation of problems. This flexibility stems from the structure of this model which can evaluate the problems from different aspects and can analyze the problem in a holistic view (Schiefloe, 2019).

2.5.1. Pentagon model

The model was first developed for risk analysis after the accident in the North Sea in 2004 and then Schiefloe developed it and applied in the analysis of project organizations. The validity of this model approved by different studies in empirical studies in the framework of organizations (Rolstadås and Schiefloe, 2017). This model illustrated in Figure 6 with five dimensions below:

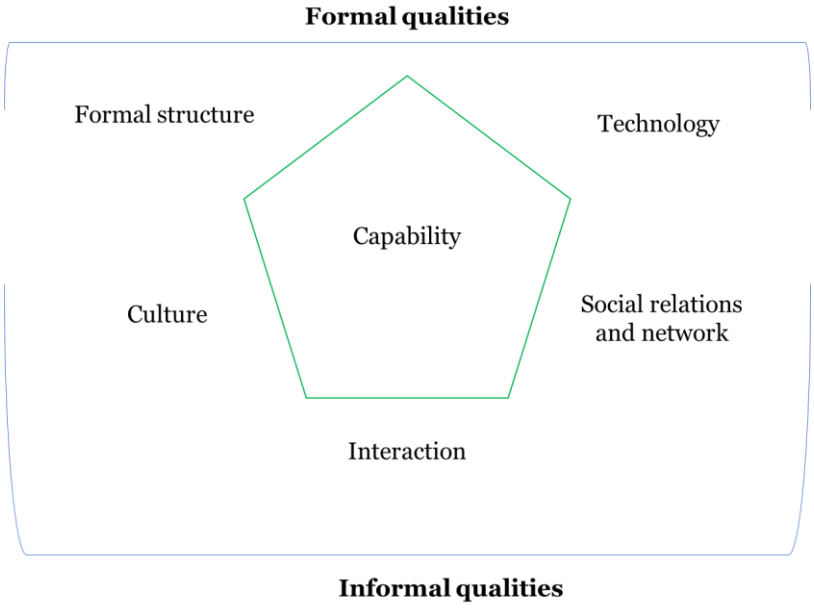


Figure 6: Pentagon model

Structure: this dimension includes “roles, “responsibilities”, “authority”, defined procedures”, “regulations” and working environment”.

Technology: This dimension includes “different tools” and “infrastructure”.

Culture: this dimension includes “language/concepts”, “values, attitudes”, “norms”, “knowledge and established ways of working”.

Interaction: This dimension covers “management”, “leadership styles”, work processes and “information flow connected to communication”, “cooperation”, and “coordination”.

Social relations and networks (SRaN): This dimension focus on the “trust”, “friendship”, “access to knowledge and experiences”, “informal power”, “alliances”, “competition and conflicts” (Rolstadås and Schiefloe, 2017).

Capabilities and performance: dependent variables are performance or capabilities which are placed in the center of the Pentagon model. Other five factors affect the performance of the project.

The creator of the Pentagon believes in the organizations five main dimensions exist which is itself categorized to two formal and informal dimensions. The research declares that these dimensions are closely interconnected and affect each other. The research gives priority to dimensions based on the context of analysis in the organization and the importance of dimension for the researcher to analyze (Schiefloe, 2019).

Previous chapters were an introduction to the concept of digital maturity. The brief explanation of previous works shows the characteristics of digitally mature companies and some gaps in the current literature. For filling this gap and developing a better framework the organizational model introduced which scrutinizes the digital maturity. The research design fulfills the research purpose using the defined concepts and identified tools in the next step.

Chapter 3

Research design

Research design contributes to finding a way to resolve the research problem(s). This thesis adopts a mixture of deductive and inductive approach, with exploratory purpose and qualitative strategy. The research design process of the thesis depicted in Figure 7.

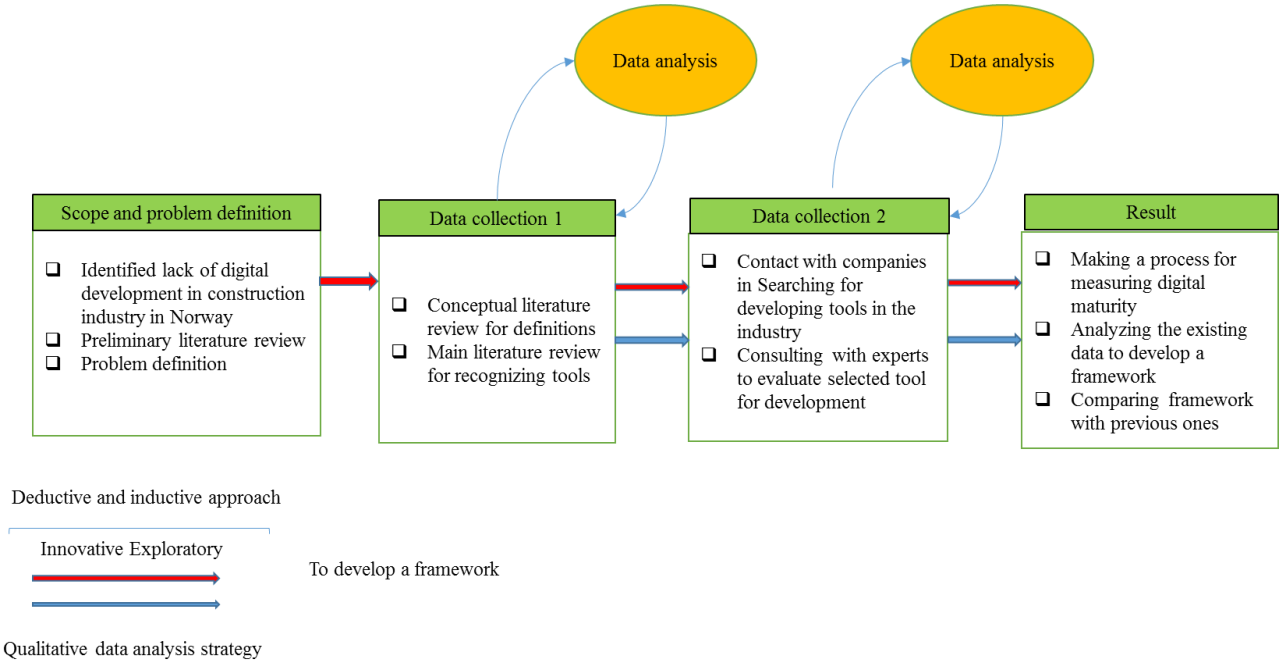


Figure 7: Research design

Figure 7 illustrates the research design of the thesis from the scope and problem definition to framework development for measuring digital maturity. In the next sections, thesis purpose, research approach, research purpose, research strategy, methods for data gathering and analysis, research quality, weaknesses, and research limitations are explained.

3.1. Thesis purpose

With the digital improvement in many sectors, this question might arise: *what is the level of digitalization in the construction industry?* Close contact and probing this industry show that there are different patterns and movements toward digitalization in construction. Some companies are far from any progress and preoccupation with daily projects can be one of the reasons. Some are aware of changes but have concerns about digital progress in projects. These concerns can be about risks or cost of the digitalization of projects. There are companies which are aware of digital transformation and accepted it as a right approach in the way of digital transformation. A number of these companies are in the first steps and some are in the middle way of digital transformation. Proposing digital maturity framework aid companies to realize the level of their projects' digitalization degree.

Developing a process-based framework may contribute to digital transformation route. This framework shows the process of measuring digital maturity. In addition, the process intends to introduce a holistic framework for measuring digital maturity which is the main purpose of the thesis. Further than that, researchers can use the result of the study to realize which aspects of digital maturity has the potential for more research.

3.2. Research approach

There are two types of research approach: inductive and deductive. In the deductive approach, the theory steers the research. Inductive attains a specific theory in the research progress (Bryman, 2012). The thesis is deductive because it exploited the existing theory and literature to make a new framework. The thesis is inductive regarding Work Area and DMF. The detection of WAs is based on a hypothetical model which is suggested by the author. DMF structure uses different components but the whole structure is innovative.

3.3. Research purpose

Kumar (2011) suggests four categories for research purpose:

- Descriptive
- Correlational

- Explanatory
- Exploratory

The descriptive study tries to describe a situation in a systematic way. The correlational study tries to find a relation between two or more aspects of the condition. The explanatory study tries to find an explanation for the relation of two or more aspects (Kumar, 2011). Exploratory research is an endeavor to find unknown or less known areas of research. In addition in some cases use for finding new ways of doing research (Kumar, 2011) (Stebbins, 2012).

"The art of Exploratory research is to find an idea from data" (Stebbins, 2012). This research is under the category of Innovative exploratory researches which tries to find the innovative process of measuring digital maturity, building blocks of the digital maturity, DMF. The validity of the presented framework will not be tested in this thesis and thus, remains as future research. There exist other researches with a similar purpose, but thesis approach in developing the framework is different. It uses Pentagon and the concept of WA. In addition, using PMS for the process of measuring digital maturity makes it different from similar tools and frameworks.

3.4. Research strategy

Research strategy includes two main types of quantitative and qualitative. Quantitative is more related to deductive and testing of the theory and qualitative is related to inductive and creating the theory (Bryman, 2012). The strategy of the current research is qualitative. The reasons for choosing this strategy are the limitations of the work including the exploratory nature of the work and limited time horizon. Hence, the qualitative strategy used for conducting the research.

3.5. Methods of Data Gathering

In this study, a literature review was conducted as illustrated in Figure 7. An analysis of literature review was performed for finding related criteria in the maturity degree of digitalization. The key words for doing literature review were digitalization, maturity, maturity degree of digitalization, digital maturity in construction projects.

For the aim of understanding the concept of maturity some articles were reviewed. There are many definitions for maturity, but the purpose of the research is identifying maturity in the context of social systems. Some references related to the concept of maturity are listed below:

- Crosby (1980)
- Buglione (2006)
- Van Looy, de Backer and Poels (2011)
- Tarhan, Turetken, and Reijers (2016)
- Schuh et al. (2017)
- Anderson and William (2018)

The conceptual review (Kothari, 2004) helped to know the concepts and theories related to the maturity degree of digitalization. In order to identify digital maturity tools, three criteria considered for the election of resources as depicted in Table 3. These criteria are explained in the next paragraph.

First, the resource should be released by well-known companies in IT consulting. The reference for being well known was choosing from the list of best management and consulting companies which is issued by Forbes (Valet, 2018) or well-known institutions. Second, the number of citations. All these papers, book or reports have a high number of citations. This number of citations imply the credibility of these works. Third, the resource should be fresh. For instance, a paper released in 2014 or later. Some articles and reports recognized for further analysis in the literature review to find tools and frameworks. The result is as below:

	Title	Company or institute	Citations	Reference
1	Leading Digital	Capgemini Consulting and MIT	316	Westerman, Bonnet and McAfee, 2014
2	Raising your Digital Quotient	McKinsey Quarterly	53	Catlin, Scanlan and Willmott, 2015
3	Industrie 4.0 Maturity Index	Acatech	86	Schuh et al., 2017
4	Digital Maturity Model - Achieving digital maturity to drive growth	Deloitte &tmforum	-	Anderson and William, 2018
5	Understanding digital mastery today	Capgemini Consulting and MIT	This tool is common with line 1 research	Buvat et al., 2018

Table 3: The list of articles for digital maturity tool

Another literature review conducted to know the characteristics of criteria in the framework of the Pentagon. The concept of each criterion, its applications in construction and its connection with digital maturity were the main purpose of this literature review.

The thesis contains both primary and secondary source of data. Data form experts, email contact with experts at the university and companies are the primary sources of data. A secondary source of data is data from articles and reports.

3.6. Methods for data analysis

Data analysis can be qualitative or qualitative. The data analysis in the thesis is qualitative. The first goal was to conduct research using a questionnaire and use quantitative data analysis. Because of limitations in the process, qualitative data analysis applied in the thesis. Dey (1993) explains qualitative data analysis as a circular process as depicted below:

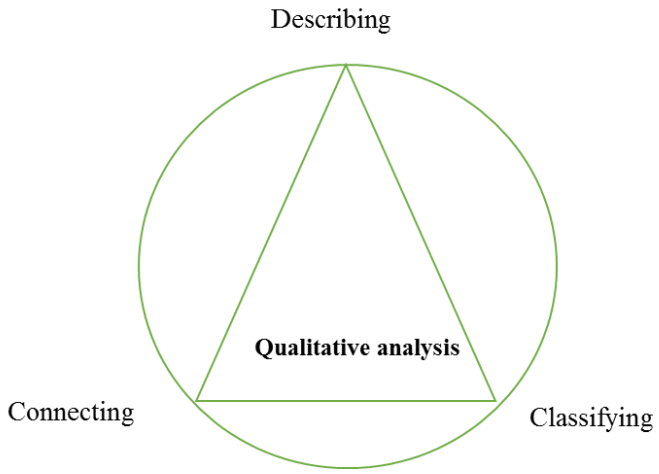


Figure 8[10]: Circular process of qualitative analysis (Dey, 1993)

This approach by Dey (1993) applied to our thesis for qualitative data analysis. As illustrated in Figure 8 this process has four components: describing, classifying, and connecting, and qualitative data analysis. These blocks connected through analysis to make a framework. The circular process repeated until the final framework obtained as illustrated in Figure 7 and Figure 8.

The research starts with a description of concepts in the specified context which is construction. The collected data should be classified to have a meaningful pattern. For example, classifying data of different reports helped us to discover a gap in previous maturity tools. Besides, this classification helps to recognize the process and the building block(s) of digital maturity. This gap is related to the concept of social relation and network. Then this classified information connected to make a framework of the thesis.

In addition, data triangulation applied which is "an approach that uses multiple observers, theoretical perspectives, sources of data, and methodologies, but the emphasis has tended to be on methods of investigation and sources of data" (Bryman, 2012). In the thesis using different models and contacts are equal to triangulation which improves the validity of the final framework.

The analysis in this research has high importance because the outcome of the thesis is a framework. Framework or models are not complete but there are models which can show the reality of the

[10]Source: Figure adopted from book (Dey, 1993)

phenomenon's better. The aim of the thesis at the start was to test the model in the company but the late response from company side and time limitation cause the research to be confined to literature review and consultation with experts through contacts.

3.7. Research Quality

Two criteria of validity and reliability apply for measuring the quality of the current research. The quality in research is related to all phases of the research; however, the significant concern goes to the quality of data collection (Bryman, 2012). Research quality of thesis assessed based on internal validity, external validity, and reliability.

3.7.1. The validity of the research

Two important aspects of validity in qualitative research are internal and external validity. Internal validity means if there is good coordination between researchers' observations and theoretical ideas they develop (Bryman, 2012). The research from data gathering and data analysis viewpoint uses different sources of data or triangulation as explained in section 3.6 which increase the internal validity of the research. The generated model is based on different frameworks which their validity is tested in different studies, but the generated model has some innovative aspects. These innovative parts need assessment.

External validity is the ability to apply to other cases or situation with a generalization of the results without considering the context of the application (Gray, 2014). In this research, external validity is not examined in a real case or by experts and needs improvement from this perspective. If we aim to judge the framework, it is necessary to evaluate its components. The first step in the framework is the choice of WAs. WAs selection is independent of context because it is based on digital benefit and stakeholder priorities. These criteria can be applied in many contexts. The Pentagon has the potential and flexibility for application in different organizational structures. It cannot be confined to construction. The ladders which are designed in this study and methods of designing ladders is applicable in many studies. All these components one by one have some level of generalization. But it does not mean this framework has high external validity. We leave this interpretation to the readers.

3.7.2. Reliability of the research

This concept refers to the issue that how much our study is applicable and replicable to similar domains of the problem. One of the ways for measuring reliability is testing measure and applying it to other samples (Bryman, 2012). Determining the reliability of this work is challenging. Because it is an innovative work. If the same material is given to another researcher, the result can be different. The reason for this difference would be different interpretations and way of thinking. Testing the reliability of the DMF is for example, two people in the same organization assess digital maturity using DMF with the same setting and receive the same result. The thesis did not reach the assessment point and hence there is a room for argument.

3.8. Weaknesses

There is no complete research study and all the researches have some strong and weak points. This research in different phases of research has some weaknesses. The primary source of data suffers from the bias of the authors' viewpoint and attitudes (Gray, 2014). But, using different models and sources of data for making a framework improve the validity of the model. Weaknesses can stem from internal validity, external validity, and reliability. Each of them is described and discussed in the contributing sections.

3.9. Research Limitations

Each research project has some limitation. These limitations show the boundary of the research. Some of the important ones are explained below:

- The research progressed until developing digital maturity tool. The implementation of the tool was the aim in the beginning, but this research progressed until developing a framework and not implementation. This is one of the main limitations of the research.
- This thesis focuses on performance measurement process for designing the process of measuring digital maturity. This process is derived from the research conducted by (Andersen and Fagerhaug, 2001). There are other methods for designing PMS which are not covered in this thesis. This can be one of the limitations of the research.
- The exploratory approach has some advantages and some disadvantages. Power of exploratory is in the essence of this approach in finding a new method based on the previous

methods or discovering a unique way. The drawback for exploratory analysis is in risky exploration. It may fail in finding a new tool or a new approach.

- This thesis focuses on the Pentagon model because of the reasons explained in section 2.5. There are other models in the literature of organizational studies which are mentioned in Appendix A. Using the Pentagon, five main dimensions recognized. It is important to declare that there are other dimensions which are important. For instance, sustainability and environmental concerns. The extent to which digital solutions contribute to these concerns. There are many capabilities in construction for environment and digitalization can play a role. For example, saving material and avoiding waste of resources can decrease the level of pollution and waste of energy. In measuring digital maturity these aspects can be considered and digitally mature companies on construction can have more environmentally friendly solutions.
- Each project has a specific time plan and Master thesis obeys the same rule. This time limit, as one of the reasons, compelled the thesis to choose the qualitative methodology.

Chapter 4

The process of measuring digital maturity

This chapter answers to the first research question *What is a suitable process for developing a framework for measuring digital maturity?* It presents a process for measuring digital maturity. Measuring digital maturity can be measured through a process. This process starts with some preparations, continues with developing a framework. Finally, it is completed with the implementation of the framework in the real world. However, this thesis progressed until developing a framework, and its implementation in a real environment is a future purpose.

It is necessary to introduce a process for measuring digital maturity before developing the framework. This process gives a practical perspective on the process of digital measurement to digital experts and digital managers. The reasons for choosing this process as a suggested process for measuring digital maturity as stated in chapter 2 are:

a) Developing a framework for measuring digital maturity itself is a process.
b) The steps in the Performance Measurement System (PMS) start with recognizing the system (Andersen and Fagerhaug, 2001) (first step) and the process continues with the procedures which have more similarity to the approach of the thesis.
c) PMS can provide a suitable approach for measuring digital maturity based on the real performance level of the system. Besides, digital maturity is a capability and each capability have a performance level.

This process is illustrated in Figure 9. Thesis focuses on step 4 which is highlighted in the Figure 9. All the steps will be explained in the next section in detail.

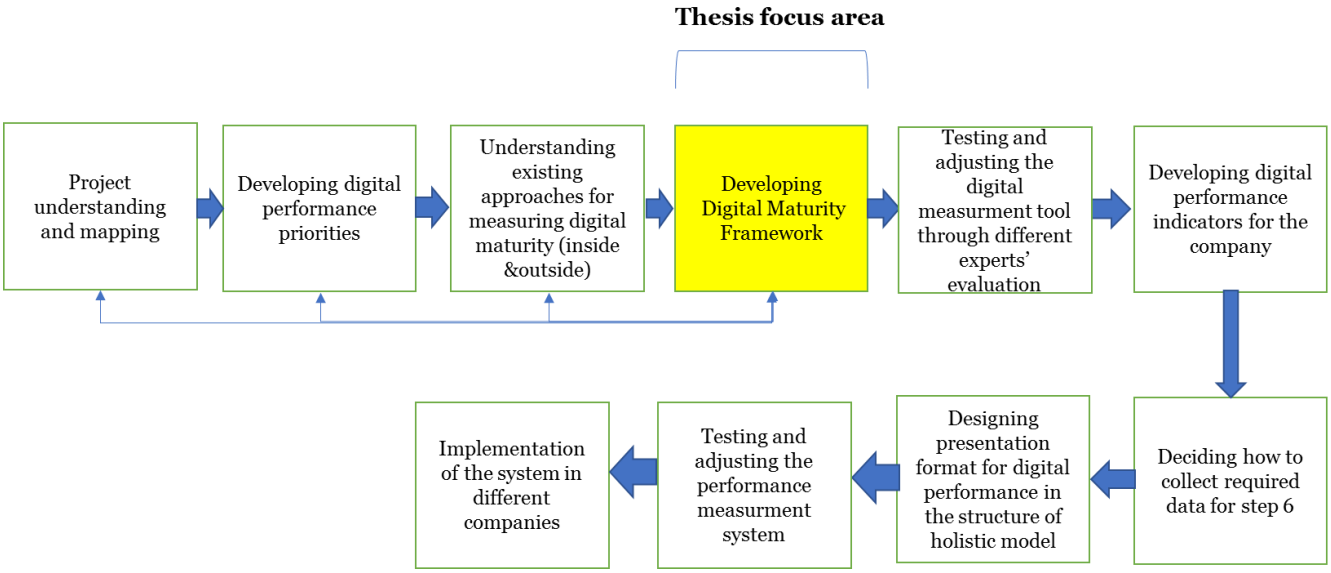


Figure 9: Process for measuring digital maturity (Andersen and Fagerhaug, 2001)

Introduction of the process for measuring digital maturity

This process inspired by the design structure of PMS which is introduced by Andersen & Fagerhaug (2001). Some changes made in the structure of this process and the result illustrated in Table 4. First three steps are approximately the same as the original framework with minor changes. Based on the structure of the original process, the suggested processes for measuring digital maturity will be at the table below.

Original process			Suggested process	
Steps	The performance measurement system (Andersen and Fagerhaug, 2001)		Steps	Framework for measuring digital maturity
Step 1	"Business structure and process understanding and mapping"		Step 1	Business structure and Project's process understanding and mapping
Step 2	"Developing business performance priorities"		Step 2	Developing digital performance priorities for the projects
Step 3	"Understanding the current performance measurement system"		Step 3	Understanding existing approaches for measuring digital maturity (if any)
Step4	"Developing performance indicators"		Step 4	Developing Digital Maturity Framework (Holistic model)
			Step 5	Testing and adjusting the digital measurement tool through different experts' evaluation
Step 5	"Deciding how to collect the required data"		Step 6	Developing digital performance indicators for the company
Step 6	"Designing reporting and data presentation format"		Step 7	Deciding how to collect the required data for step 6
Step 7	"Testing and adjusting the performance measurement system"		Step 8	Designing a presentation format for digital performance in the structure of the holistic model
			Step 9	Testing and adjusting the performance measurement system"
Step 8	"Implementing the performance measurement system"		Step 10	Implementation of the system in different companies

Table 4: Developing a framework for measuring digital maturity

Table 4 shows the eight steps for PMS and ten steps process for measuring digital maturity. The eight steps for performance measurement elaborated in chapter 2. The suggested model has some changes considering the essence of the work. In the following the steps are explained and the differences with the original process are mentioned.

Step 1-Business structure and project's process understanding and mapping: In a simple way, this step tells us what is going on in the project. Knowing and identifying the processes is the first step in every design effort. Without knowing the main processes of the project, the measurement of digital maturity can be impossible. This step is based on Andersen and Fagerhaug (2001) and is an initial step for designing a PMS. It helps managers to know their company well and comprehend some strategic issues of their company. The difference with the original process is that this framework concentrates on construction projects organizations.

Step 2-Developing digital performance priorities: knowing the different expectations of stakeholders in the project is vital to know what is important for the company. There are different stakeholders in every project. Understanding stakeholders' expectations can contribute to knowing the company priorities and performance requirements better. Hence, digital maturity will be measured in the areas which have more benefit for the company through identifying these priorities. For instance, in construction projects, some areas of work such as design management, contract management have high priority.

Step 3-Understanding existing approaches for measuring digital maturity: This step contributes to knowing the existing systems for measuring digital maturity in the company. Every company has a measurement system to some degree (Andersen and Fagerhaug, 2001). Hence, this step aids the company not to start from the scratch for developing a system. The difference of this step with the performance measurement system is that our suggested framework includes searching for other measurement tools in the market in addition to internal systems.

There are different ways of measuring digital maturity, especially for the companies which perceive this measurement is essential for their business. One approach is to use online tools of the consulting companies which are free access. Another way is to request from consulting companies or buy tools from these companies. There is another way which is recommended by this thesis, which is developing a framework by the company itself. Step 4 covers this framework.

Step 4-Developing Digital Maturity Framework (DMF): This step is the focus of the thesis. The Pentagon model was chosen for this aim in this research. The reasons for choosing the Pentagon was because first, its capability in the analysis of organizational problems has been proved. Second, the validity of the model approved by many case studies (Rolstadås et al., 2014) (Rolstadås

and Schiefloe, 2017). Third, it is a sample for a successfully implemented model in Norway (Rolstadås et al., 2014). Fourth, the flexibility of this model in the evaluation of problems. This flexibility arises from the structure of this model which can evaluate the problems from different aspects and can analyze the problem in a holistic view (Schiefloe, 2019).

In the Pentagon, based on Schiefloe (2019), each dimension can be evaluated alone or in connection with other dimensions. Besides, this model provides an opportunity for analysis of the dependent variable which is digitalization in thesis. Pentagon analyzes the digital capability from different aspects which are culture, technology, structure, social relation and networks, and interaction. Chapter 6 of the thesis covers developing DMF in details.

Step 5-In this step DMF will be evaluated by experts in the industry. The experts in the construction will provide feedback about digital dimensions, mature and immature state, rating system, and framework's ability in measuring what is aimed to measure.

Step 6-One of the essential steps in this step-by-step approach is developing digital performance indicators. This approach contributes the company to measure the real performance of digital capability. Choosing a suitable combination of indicators is the main challenge in this step (Andersen and Fagerhaug 2001). Andersen and Fagerhaug (2001), in their framework, stated that business performance indicators should be designed based on business process mapping in step one and business performance priorities in step two.

For example, performance indicators in design management help to measure the digital performance of tools and people. If the company uses one version of Building Information Modeling (BIM) for designing, its output and real performance can be compared with expected performance and target performance. After consulting with experts and managers it becomes clear that the company needs a higher version of BIM which can satisfy the stated performance.

Step 7-After choosing the performance indicators for digital maturity, data related to these indicators should be collected. These data are indicators of the digital performance of the company. There are different methods of data gathering. Data gathering is conducted through survey, interview, online questionnaires, observation, sensors, etc.

Step 8-Showing the digital performance of the company in specified areas in the structure of the holistic model and its maturity ladders. Collected data in step 7 use to put in the structure of DMF which is designed in step 4. This framework with real data shows the digital maturity of the company based on the performance of tools and people. This is an ambitious goal for future research purpose.

Step 9-Testing the PMS and trying to counteract problems of the system. There can be different problems in different areas of the work which needs to be recognized and modified. Problems in data collection for example cause to measure the performance weekly. Choosing the wrong indicators from previous stages can lead to the wrong measurement of digital maturity and impose much cost to the company. It can have other negative consequences such as lack of motivation of personnel, underestimate or overestimate digital tools, etc.

Step 10- This step is related to the practical application of this procedure in some companies. These implementations contribute to improving the validity of this framework.

The steps of measurement in the project-based organization is a guide to know the start and endpoint for measuring digital maturity in the company which was the aim of this chapter. One of these steps, step 4, is developing a DMF. Each framework has some necessary components. Familiarity with these components is the purpose of the next chapter.

Chapter 5

Building blocks for DMF

In Chapter 4, the primary process for measuring digital maturity introduced. One step in this process relates to developing a Digital Maturity Framework (DMF). In this chapter, building blocks of DMF are added. These components include the Work Area concept in construction projects, the criteria in the structure of the Pentagon model, and digital maturity ladder concept. It is necessary to answer these questions for making a suggested framework:

i. Where the measurement happens?
ii. Which aspects to be measured?
iii. What is the maturity level?

Finding an answer to these questions guide the thesis in discovering the main blocks of digital maturity. The first question tries to find an answer to the areas of measurement. The area addresses the important areas of the project which have a high potential for digitalization. The second question concentrates on the aspects of measurement. The measurements consist of several criteria. For example, when a company wants to measure job satisfaction, they set some criteria for measurement such as level of motivation, the performance level of personnel, and absence from work, etc. Hence, defining some criteria for measuring digital maturity seems necessary.

Question three is related to determining the maturity level. One of the main challenges in developing a framework is related to specifying the maturity level. This level helps to design maturity ladder. Although there is no final point for maturity and there it is no precise point, determining this level will be a benchmark for companies which are behind in this dimension. In this chapter, blocks are introduced and explained in general. Then these blocks are used for making the main framework for measuring digital maturity in chapter 6. The first block recognizes work areas. The concept of Work Area (WA) defined in section 2.3.2, as important areas with high potential for digitalization.

5.1. WA in construction projects

One of the suggested works in measuring digital maturity of construction projects is to identify the important WAs. There are different reasons for choosing these areas. The performance of these areas is important for the project because it helps companies and managers to identify essential parts of their work. The works which add value to project or company and as stated before in section 2.3.2, these areas have a high potential for digitalization. They show the priority of the industry. Therefore, these areas are chosen for measuring digital maturity.

This step can be placed in step one of the process for measuring digital maturity as shown in Figure 9. The report by McKinsey introduces eight areas in construction for digital improvement, as mentioned in section 2.3.2. These areas presented here based on the priority in the report of Agarwal et al. (2018). Their importance for construction projects explained as follow:

a) Design management:

In construction, digitalization can help project teams to design the process of the work before the commencement (Agarwal et al., 2018) (Geniebelt, 2019). Nowadays this process progressed more than this and with the aid of the Building Information Modeling (BIM) and design of a building can be conducted before the project starts. Virtual reality has the capability that can help customers to feel the future of building and give their suggestions to the project team. This process has other benefits such as reducing the uncertainty in the work to a great extent (Malleson, 2019a).

Design management has some important tasks (EY, 2018b) (Malleson, 2019b):

- Working with spreadsheets to import relevant data,
- Using standards,
- Writing specifications about quality which makes the future design process easier,
- Create drawings,
- Common data environment, which is available for all members and objects,
- Report and schedule with 3D models,
- Representing models for members and clients,
- Checking models.

There is no specific technology which can work for all these processes. For instance, BIM cannot cover all these processes and other tools are necessary (Malleson, 2019a).

b) Scheduling:

Digital solutions can provide a platform for reporting the actual time of the works in the projects. It assists in reporting changes to members and project teams as well. Furthermore, digital solutions facilitate the connection with subcontractors of the project through mobile tools (Agarwal et al.,2018) (Geniebelt, 2019).

c) Resource management:

One of the important areas of the work in construction project organizations is resource management. The importance of resource management for some projects is the availability of tools and material, and on time, on the right location. Digitalization can affect this process. For instance, by using the power of automation order handling will be conducted readily without any paperwork. Other benefits of this automation are the speed of the work and doing work without any physical effort. In addition, different parties have access to the right information about the material which can improve the efficiency of the orders and avoid redundancy and waste material (Agarwal et al., 2018) (Geniebelt, 2019).

d) Crew tracking:

Crew tracking is important for projects in some aspects. First, contribute to monitoring the workload of the workforce. For example, if the hardship of the work by some workforce is higher than other members project manager or responsible person can balance the workload. Second, In the case of responsibility for doing a specific work and increasing the commitment in the work, it can aid project managers. Third, crew tackling helps managers to calculate the approximate time on the work and off the work which is important for prediction and productivity purposes (Agarwal et al., 2018) (Geniebelt, 2019).

e) Quality control:

Digital solutions can help to preserve the quality of the work through the remote tools which can be used for inspection. These tools are equipped with sensors that generate data. One of the usages of such data is to alarm. These alarms help members to understand problems before accidents and

save time and money for the project. Other facilities such as group applications can provide an opportunity for sharing notes and photos of the problems on sites (Agarwal et al., 2018) (Geniebelt, 2019).

f) Contract management:

A company can have different projects in construction project organizations. Especially in complex projects different contractors can handle parts of the work. This complexity increases the importance of contracting. Digitalization can improve the process of contracting by automation of the work and sharing information among contract parties. For instance, a portal can facilitate the contracting with offering the possibility that different parties can read the contract items on it and can give their feedback about the contract items (Agarwal et al., 2018) (Geniebelt, 2019).

g) Performance management:

Digital tools, as mentioned before, can make a significant contribution to show the real performance in the work through providing data about the operation of the workforce. This can contribute to performance improvement and the success of the projects (Agarwal et al., 2018) (Geniebelt, 2019).

h) Document management:

Digitalization improves document management in projects through tools and automation of the work. Many paper works exist in the projects. Digitalization removes paperwork and saves budget for the companies (Agarwal et al., 2018) (Geniebelt, 2019). This area has a high potential for digitalization in construction projects.

The important WAs are presented. The first step in making a framework can be identifying important WA. It shows the priority of areas for digitalization in the company. These areas can be different from company to company as well as the method for choosing them. However, it can be similar to the McKinsey report in general. It may be chosen by external experts, digital managers or internal experts, committees, project managers in the field, etc. The method can be quantitative or qualitative. Qualitative methods are fast and can be cost-effective in comparison with quantitative methods.

These areas categorized based on several criteria and can be chosen based on the balance benefit for the stakeholders and company. For example, Figure 10 shows the assumed process for choosing work areas in construction projects.

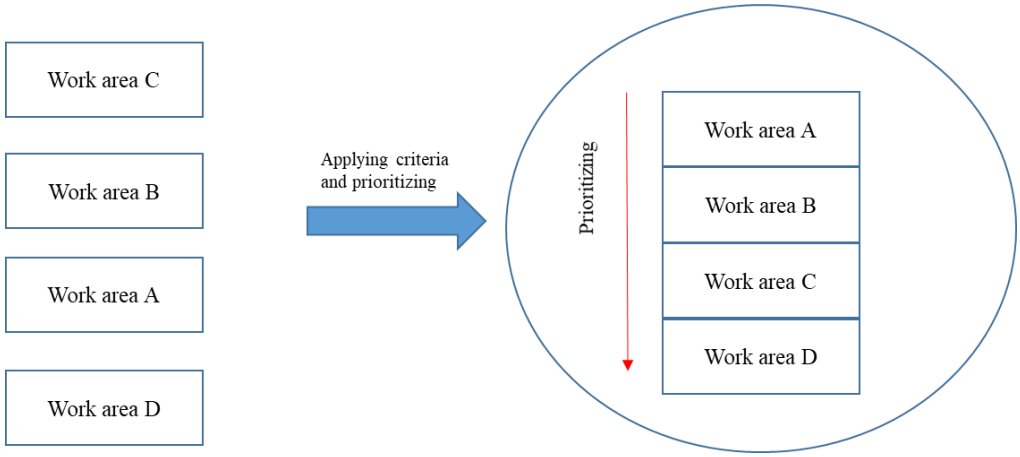


Figure 10: Prioritizing Work Areas

First, some important WAs will be identified. Then prioritized based on company's important criteria. After choosing these areas for digital maturity it is necessary to measure the degree of digital maturity in these areas with using some criteria. The next block covers identifying criteria and prioritizing these criteria for each WA.

5.2. Digital criteria in the framework of the Pentagon model

This section is dedicated to answering the second question asked at the beginning of this chapter, *which aspects to be measured*. The criteria proposed by the Pentagon model (Rolstadås and Schiefloe, 2017) was the basis for the measurement. Some of the important ones, which will be used in the main framework in chapter 6, are introduced and the remaining ones are in Appendix B.

The modified Pentagon model, Figure 11, consist of different parts, formal qualities (technical factor) and informal qualities (human factors). Formal quality includes structure and technology. Several criteria have been defined based on these two formal qualities and will be used for

measurement. Formal qualities are used for decision making and management. Informal qualities consist of interaction, culture, and social relation and network (SRaN). Several criteria have been defined according to informal qualities for measurement as well. Informal qualities complement the formal ones and thus, its criteria influence and improve decision making and management.

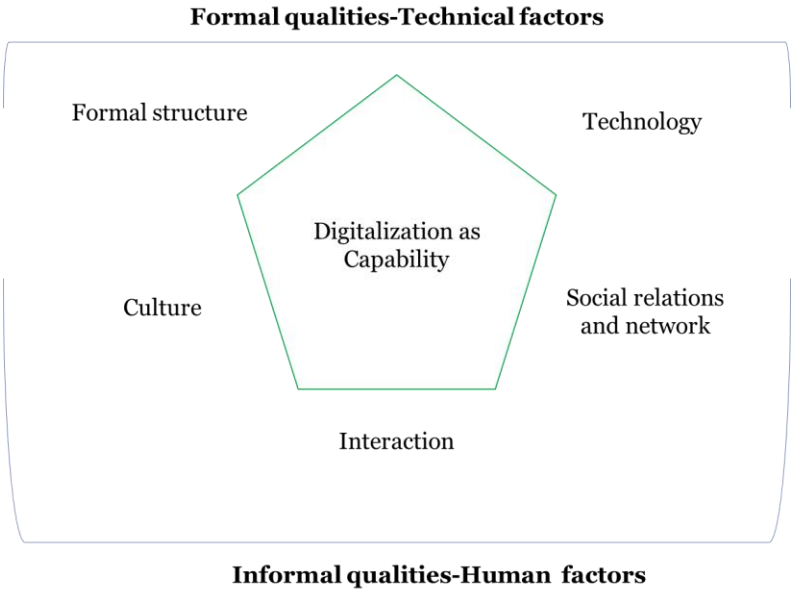


Figure 11: Pentagon adapted model (Rolstadås et al., 2014)

The criteria extracted from (Rolstadås and Schiefloe, 2017) which are defined based on construction projects. For the purpose of measuring digital maturity, some adjustments are necessary between these criteria in (Rolstadås and Schiefloe, 2017) report and thesis' criteria. For example, a defined procedure in the (Rolstadås and Schiefloe, 2017) considered as operations in the thesis. The strategy as an important criterion in digital maturity considered as a sub-dimension of structure. Technology on Pentagon (Rolstadås and Schiefloe, 2017) includes different infrastructure and tools. In this thesis a few dimensions from the report by Anderson & William (2018) exploit for technology. Because this report covers some important criteria for technology which is close to the thesis scope. Adjustment of these criteria in the context of digitalization demonstrated in Table 5.

Dimensions	Structure	Technology	Culture	Interaction	Social relation &network
1	Operations	Applications	Learning	Leadership styles	Trust
2	Business Model	Analytic	Competence	Work processes	Friendship
3	Digital Strategy	Security	Knowledge	Communication	Informal power
4	Defined roles & responsibilities	Delivery governance	Attitude to digitalization	Cooperation	Alliances
5		Network	Leadership & governance	Coordination	Competition
6		Technology architecture			

Table 5: adjusted digital criteria for five dimensions

There are two methods for the analysis of digital maturity based on the Pentagon model. First, analysis of individual criteria in the framework of the organization. This approach gives a preliminary knowledge about each dimension and sub-dimension in a digital environment. Second, analysis of the influence of each dimension on other dimensions. In this thesis these two levels of analysis emphasized. Elements or criteria work in connection and influence each other and are not separate identities in the context of the organization as a complex system.

Two aspects of defining characteristics are considered: digital maturity and construction projects. The characteristics contribute to design digital maturity ladders. These characteristics will be used in questionnaire in chapter 6 as a guideline for experts. These guidelines help experts to have a preliminary understanding of these criteria and levels of ladders. Table 6 sums up the result of these criteria. Some samples are explained after the table to give the reader a better understanding and the rest of the criteria are transferred to Appendix B.

Structure	Technology	Culture	Interaction	SRaN
Operations: Range from manual to automatic operations. Management of subcontractors, suppliers. Providing innovative contracting models, monitor project from cost and time dimensions.	Applications: Freedom in choosing tools against companies with a uniform and similar tool (Geniebelt, 2019).	Learning: In two levels of personal and organizational. Leadership style also influences learning. Digital masters are better learners.	Leadership style: Transformational leadership which supports cooperation, accept change, support innovative ideas. Hierarchical leadership with the characteristics which are opposite of mentioned characteristics.	Trust: Trust to technology is considered for measuring digital maturity. Trust in information sharing and trust to communication channels in the project.
Business model: This criteria from company to company in construction and the operations and perspective of managers can be different (Pekuri et al .,2013).	Analytics: From decision making without using data to decision making. using simple to complex tools (McGirr, 2014).	Competence: companies without specific strategy – companies have the strategy for recruiting skillful workforce- companies with the environment for nurturing competent people.	Work process: The report by Deloitte and TM Forum consider agility in change management, automation and integration in resource management for the characteristics of digital maturity.	Friendship: Quality of friendship in a social network is important which may reduce stress and increase productivity based on thesis assumption.
Digital strategy: Digital strategy support digital goals and main processes. innovative solutions in digitalization and have a Clear vision for moving company to the next performance level.	Security: Companies without a strategy or inactive toward security to companies with a proactive view towards security.	Knowledge: Two levels of knowledge can be assumed. Personal and organizational level. In digital mature companies' high level of knowledge sharing happens.	Communication: The levels of digital maturity include uncontrolled level without any standard for communication, controlled level there are defined processes, innovative level information sharing happens regularly and knowledge acquisition happens completely (Bavunoglu, 2015).	Informal power: The power of the social network as a type of informal power. In digital mature companies' social network and friendship groups may have a significant role in improving social relations in the projects.
Defined roles and responsibilities: From undeveloped structure to the defined and systematic structure of roles.	Delivery governance: Companies without any guidelines for implementing IT development and utilization to companies which are well planned.	Attitude to digitalization: Unaware about digitalization-seeing digitalization as a threat-seeing digitalization as a costly effort-seeing digitalization as an opportunity.	Cooperation: Based on thesis assumption digital maturity of cooperation related to sharing information, joining in friendship groups, and training by digital tools.	Alliance: Digital mature companies have the suitable infrastructure, strategic view, and value creation for an alliance.

Table 6: Characteristics and/or covered range of digital criteria for making ladders

5.2.1. Structure

This dimension refers to the organization and its formal structure. The structure in the Pentagon model consists of roles, "responsibilities," "authority," defined procedures," "regulations" and "working environment" (Rolstadås and Schiefloe, 2017). For each of these criteria in Pentagon, an equivalent in digitalization was found. These criteria are operations, business model, digital strategy, and defined roles and responsibilities. Operations and digital strategy explained in following and remaining are in Appendix B.

Operations

Operations are necessary for doing the business. Technology has a complementary role for operations in this criterion. In construction projects, Operations should improve management of subcontractors and suppliers, providing innovative contracting models, similar framework for project management, monitor project from different aspects of time, cost and scope of the projects (World Economic Forum, 2016). The operations categorized from manual to automatic in maturity ladder, based on the thesis' assumption.

Digital strategy

The digital strategy of the company ought to be coordinated with the business strategy of the company. It is a path to reach the digital vision of the company (Anderson and William, 2018). In construction industry digital strategy should have 1) organizational structure and tools that support collaboration and communication between workforce, company culture and design of work environment 2) a vision which moves the company to the next performance level 3) (an) ambitious goal(s) which is open to innovation 4) a movement towards new digital solutions (EY, 2018a). In addition, as mentioned in chapter 2, the digital strategy supports strategic goals and main processes in digital mature companies (Kane et al., 2017).

5.2.2. Technology

Based on the Pentagon model, the technology consists of different tools and infrastructure (Rolstadås and Schiefloe, 2017). Schiefloe (2019) define technology as all the equipment, tools which people in the company use to conduct their job. Based on this report technology is in close connection with formal structure, culture, interaction, and relation in the organization.

For the aim of digital transformation, companies should accept new technology (Westerman, Bonnet and McAfee, 2014). It is noteworthy to say that technology or digital platforms are not solutions alone. They need the participation of human factors to be effective. Some experiences demonstrate the unsuccessful applications of the technology by ignoring cultural background (Geniebelt, 2019). Integration of technology with processes is an important factor which supports the criterion of analytics with feeding proper data (EY, 2018a). Technology has these sub-dimensions as the main dimension: applications, analytics, security, delivery governance, network, technology architecture (Anderson and William, 2018). Application and analytics explained in following and remaining are in Appendix B.

Applications

There are different applications and software in construction projects. One categorization of these applications are: computer-aided design and visualization (CAD), building enterprise applications, cost estimation using computer, planning and scheduling software, and business and information management (Sun and Howard, 2004). Nowadays with the progress of technology and the introduction of different versions of Building Information Modeling (BIM), many of above-mentioned functions can be conducted through BIM. BIM is one of the common digital technologies in construction (EY, 2018a).

“Independent tool” choice for project management recognized as a poor strategy in construction projects because there will be no strategy for data gathering in the company. Data can create learning and without structured data, the learning will not happen (Geniebelt, 2019). Hence, for measuring digital maturity, the ladder is: from the company without a strategy of using similar applications to companies which have an integrated and uniform approach for choosing applications.

Analytics

The process of finding and communicating meaningful patterns from data with the aim for better decision making. It encompasses a variety of areas such as statistics, data mining, web mining, big data, machine learning, programming tools etc. The level of maturity in this section depends on the ability of the company in using data efficiently (Chen, et al., 2018).

For measuring digital maturity there are different maturity models in the literature (McGirr, 2014). One general model was chosen with different levels of maturity, depicted in Figure 12, for the aim of thesis.

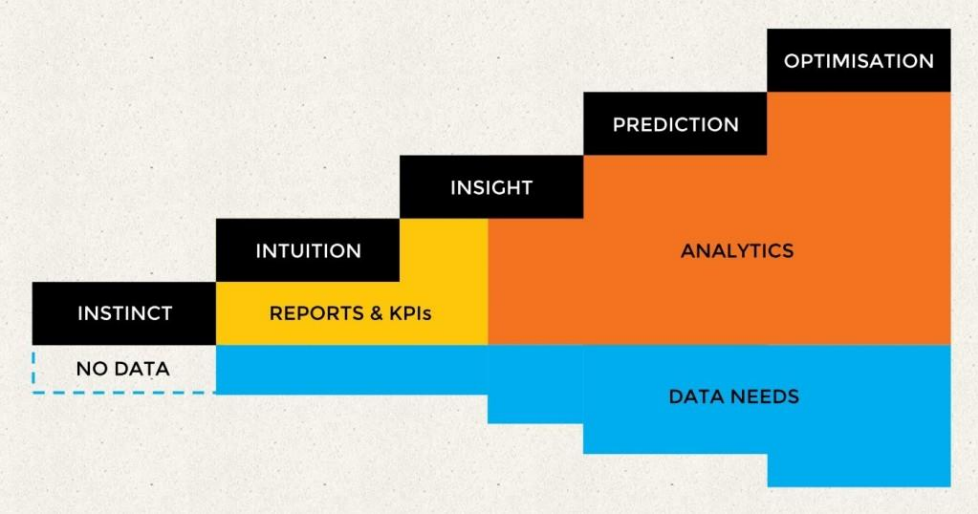


Figure 12[11]*: Digital maturity model for analytics in general (McGirr, 2014)*

The black boxes represent different ways for decision making. The first box shows there is decision making without using data. Then decision making with using reports and key performance indicators. Afterward, it progresses and uses advanced methods for decision making.

5.2.3. Culture

Culture is one of the dimensions of the Pentagon model. This dimension includes "language/concepts", "values", "attitudes", "norms", "knowledge" and "established ways of working" based on (Rolstadås and Schiefloe, 2017). Some changes are applied in this dimension and the derived criteria are Leadership and governance, attitude to digitalization, learning environment, and competence. Like other dimensions culture affects or receives influence from the structure, technology, social relation and network, and interaction (Schiefloe, 2019). Knowledge and attitude to digitalization explained in the following others are explained in Appendix B.

[11] Source: https://optimalbi.com/blog/2014/12/02/orange-paper-what-is-analytics/ (McGirr, 2014)

Attitudes to digitalization

Some companies see technological changes as an opportunity, and some see it as a threat. As stated earlier, digital masters see digital innovations as a change and support it (Westerman et al., 2014). Acceptance of change is not limited to digitalization; the story of some successful companies shows that they see changes in their environment and show suitable behavior against these changes. For ranking digital mature and immature companies it is obvious that mature companies have a better strategy and plan against change. They are more risk taker and accept change as an opportunity.

Knowledge

Knowledge is the capability which empowers people or organization to understand the situation (Schiefloe, 2019). Knowledge has high importance in project-based organizations. It can contribute to the improvement of performance level of the project. Knowledge of similar projects can improve efficiency through prevention from repetitive work and procedures. It can compensate for the lack of competent workforce in some situations. For example, in the areas where a high level of expertise needed, knowledge resources can help the company to teach the procedure to less trained workforce.

Knowledge can be at different levels from individual to company level. For measuring digital mature project-based organizations the research focuses on organizational level. Based on Westerman et al. (2014) digital masters share their knowledge with colleagues. In addition, it can be assumed these companies have a specific process for knowledge management in their company.

5.2.4. Social Relation and Network (SRaN)

SRaN emphasized on informal relations which connect people in the organization. Informal relation has the necessity for the relationship between people, departments, and the whole system. The main sub-criteria of SRaN in the framework of pentagon model is “trust”, “friendship,” “informal power,” “alliances,” “competition,” and “conflicts” (Schiefloe, 2019). The alliance addressed in this section as a sample and Trust, friendship, informal power competition in Appendix B.

Alliance

Schiefloe (2019) connects alliance to power and explains that two forms of power exist in the organization. Alliance can be inside the company as the result of "network-based alliance" among people of the company in an informal way (Schiefloe 2019) or can be the result of making cooperation contract between companies (Kanter et al., 1994). Knowing the different styles of alliance contribute to the thesis in finding a suitable model for measuring maturity in alliance sub-dimension.

The article by Harvard Business Review called alliance as "cooperative arrangement," which has different categories. "Mutual service consortia," between companies when the outcome is hard to get by oneself. They share their resources, and this cooperation is between companies which are active in a similar industry. "Joint ventures", these companies utilize the abilities of each other. For example, one company provides technology, and another company offers its market share. "Value chain partnership" companies are in close collaboration with each other and sample of these relations is the relationship between supplier and customer. This category starts from far and weak relation to close and robust relation (Kanter et al., 1994).

Gartner divides alliances to four main patterns, Figure 13, including "service provider", "business partner", outsider", and "trusted ally". The weakest form of the alliance is a service provider which is limited to interactions and defined format of services, besides outsourcing, and licensing are famous samples of such systems. Outsider and service provider are similar in trust level but from innovative cooperation, outsider located at an advanced level. The third pattern belongs to business partner having the reverse grade in comparison with the service provider. In this model the basis of cooperation is trust, but the level of innovation is low. The trusted ally is representative of complete alliance and advancement in both aspects of trust and innovation (Panetta, 2016).

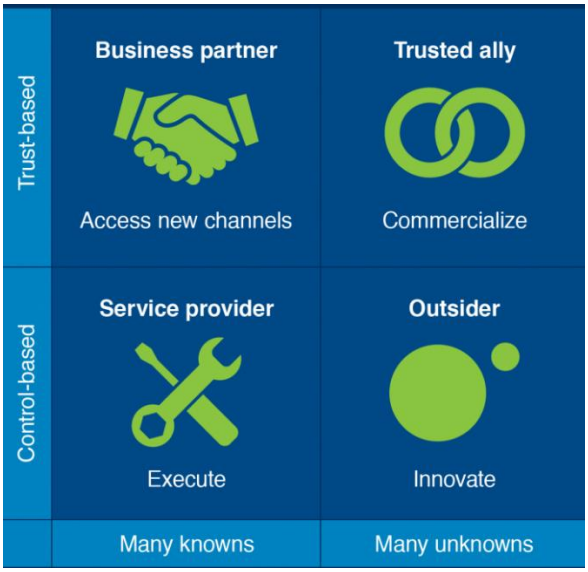


Figure 13: Models of alliance [12](Panetta, 2016)

The three main factors in the business alliance are: first, the parties should obtain benefit from this cooperation, but the main reason beyond these preliminary conditions is the strategic view to opportunities. Second, the alliance should not limit to simple trade-off, and it should create value for both parties. Third, besides formal controls, the alliance should be conducted through internal infrastructure and personal connections with the aim of learning improvement (Kanter et al., 1994). For measuring the digital maturity of the company from an alliance perspective, three main factors from Kanter et al. (1994) selected:

- Having a strategic view towards cooperation,
- Value creation through skills,
- Suitable infrastructure.

In the context of digitalization, these three factors will be strengthened through the right digital capabilities. All these three factors can be applied in one form of alliance which is presented by (Kanter et al., 1994) or (Panetta, 2016). The maturity degree in this sub-dimension is not related to the type of alliance. It depends on the ability of the company to adapt to these forms of alliance

[12] Source: https://www.gartner.com/smarterwithgartner/build-alliances-to-thrive-in-business-ecosystems/ (Panetta, 2016)

and the power of digitalization in facilitating alliance for both parties or internal alliance (among people or teams inside the company).

5.2.5. Interaction

Interaction is an essential factor in making a connection in the company. The Schiefloe (2019) believes this factor creates relationship among the players in the project and is an important factor for work processes. This factor is the basis for social relation and network, which is another dimension of the Pentagon model. Besides, interaction affects the culture and structure of the organization. Hence, it is one of the basic needs in each organizational structure (Schiefloe, 2019). The sub-dimensions related to interaction are as follow: "Leadership styles," "work processes" and "communication," "cooperation," and "coordination." The communication is explained in the following and cooperation, work process, and leadership styles are in Appendix B.

Communication:

Communication is one of the processes in construction projects. This criterion can affect the quality of many measures in the interaction. For example, it can affect cooperation between personnel and between companies. Many works held through communication. For example, different work sessions, reports, work discussions conducted through communication. Project managers spend some of their time in exchanging information with various stakeholders and team members.

Based on the research by Bavunoglu (2015) there are some levels for measuring communication maturity, including uncontrolled level, controlled level, and innovative level. There is no standard for communication in uncontrolled level. There are defined processes in controlled level. In an innovative level, information sharing happens regularly, and knowledge acquisition occurs completely. This is the assumed ladder by the thesis for communication, as stated in Table 6.

5.3. Maturity ladder

This section is dedicated to answering the third question asked at the beginning of this chapter, *what is the maturity level*? One of the important blocks of digital maturity is maturity ladder. The characteristics of maturity in chapter 2 state which is first, it has some stages and second, it is an evolutionary process. This maturity ladder has importance from two dimensions: First, determining the mature level and immature level. Second, it is a scale for determining the digital level of the company in a specific aspect.

High and low level of maturity determined for designing maturity for each important criterion. For instance, for leadership criteria, participative leadership style is the mature level and hierarchical leadership style is the immature level. Maturity ladder can have different stages, for example, some ladders have five stages, some has six stages. Each stage completes the previous stage with adding and/or improving specific characteristic(s).

This section focuses on two effective variables in designing maturity ladders: 1. Context of industry 2. Business priorities. The explanation of these two aspects are as below:

The context of the industry can affect the design of the maturity ladder. As mentioned before, the construction industry is one of the less developed industries (EY, 2018a). Some of these criteria may play a weak role in the structure of digital maturity. For example, construction projects gain less from the power of data mining. Analytic techniques are not applied much in this industry. In another example, many projects in this area are paper-based and are less automated. In comparison with the banking industry which benefits from the power of analytics in discovering risky customers for giving loan or removing physical money transactions. Hence, the maturity ladder for the banking industry will be different from construction project-based organizations.

The business priorities are also important in determining the digital maturity ladder. For example, in the construction industry feeding a report to a client about work progress is important and can lead to customer satisfaction. In the banking industry, safe and fast online transactions are important which can lead to customer satisfaction. As a result, the digital maturity ladder of the construction industry may not be the same as the banking industry or other industries because each industry has its own priorities. The digital maturity ladder for two companies is not necessarily the same because they have different priorities. For one company in construction, the focus is on fast

and safe operations based on a schedule. For another company customer satisfaction at any cost might be a priority. It is obvious that the digital maturity ladder of these two companies will not be the same.

Based on the what has been aforesaid and analysis of previous digital maturity tools in chapter two (Westerman et al., 2014) (Catlin et al., 2015) (Schuh et al., 2017) (Anderson and William, 2018), and (Geniebelt, 2019) the following factors identified for designing digital maturity ladders :

1) They have stages,
2) The stages improve till maturity level is reached,
3) The context and business priorities determine the shape of the ladders (criteria are deciding factors).

Figure 14 shows the sample of the maturity ladder which has the characteristics mentioned above.

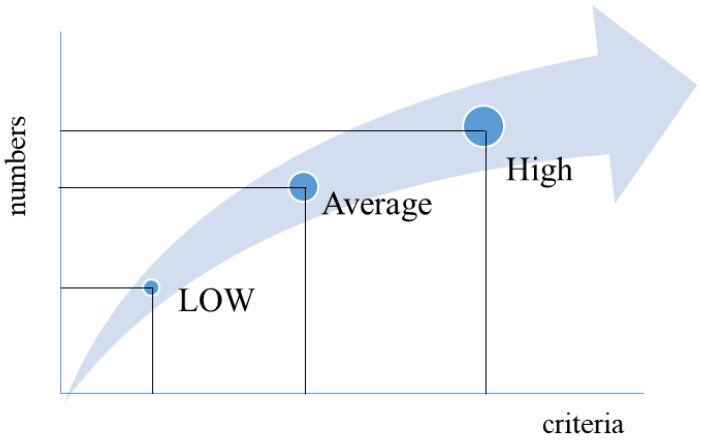


Figure 14: Sample of Ladder

Acquaintance to components of digital maturity makes work easier to make a DMF. All the mentioned components applied in the DMF. Next chapter proposes the DMF and its function.

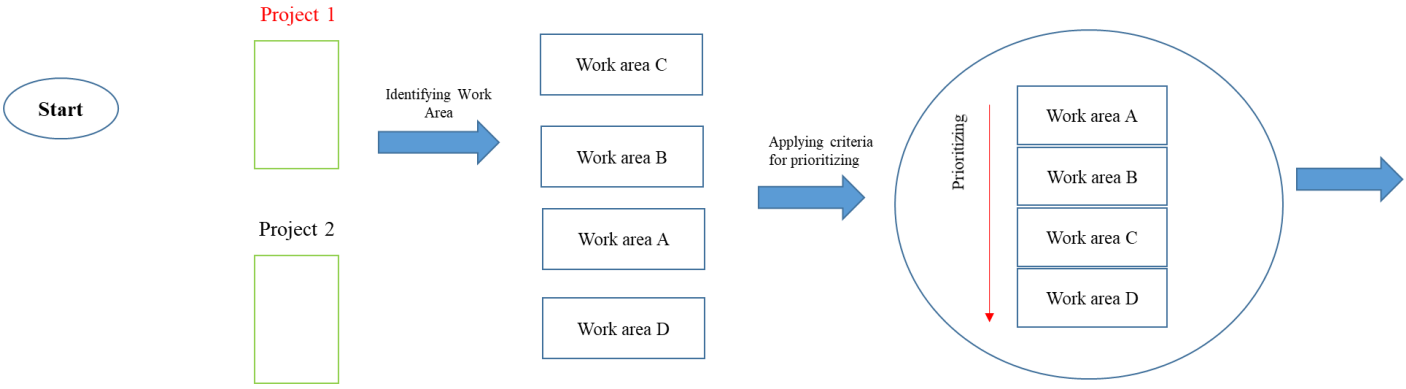
Chapter 6

The Digital Maturity Framework (DMF)

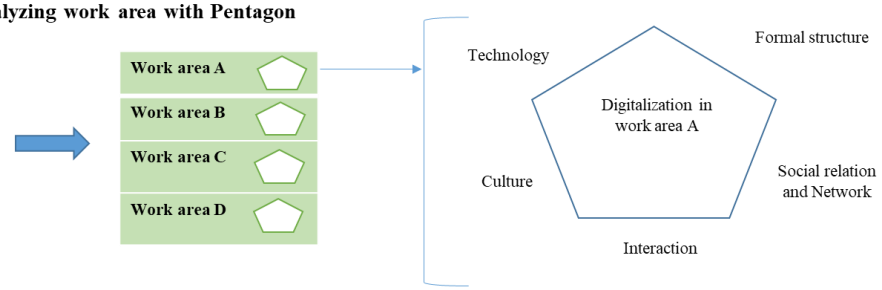
The previous chapter was an introduction to building blocks of digital maturity. This chapter shows the suggested framework, consist of building blocks of digital maturity, and answers the second research question: *What is a suitable framework for measuring digital maturity?* It introduces a holistic framework using an organizational model. Pentagon is the organizational model introduced in chapter 2. This holistic view arises from Pentagon capability in demonstrating different criteria and their interconnections.

Figure 15 illustrates the DMF. This framework has three main stages. First, selection of work areas. Second, analyzing each work area with Pentagon. Third, designing a maturity ladder for each criterion. This framework has a start and finish point. The final point of this framework lead to digital maturity ladder. This framework shows the real application for building blocks of digital maturity. It contributes to have a simple guide for companies doing their measurement. In addition, it helps to understand the function of the framework in measuring digital maturity. A complete description of it is in the following and the framework includes more details than merely building blocks.

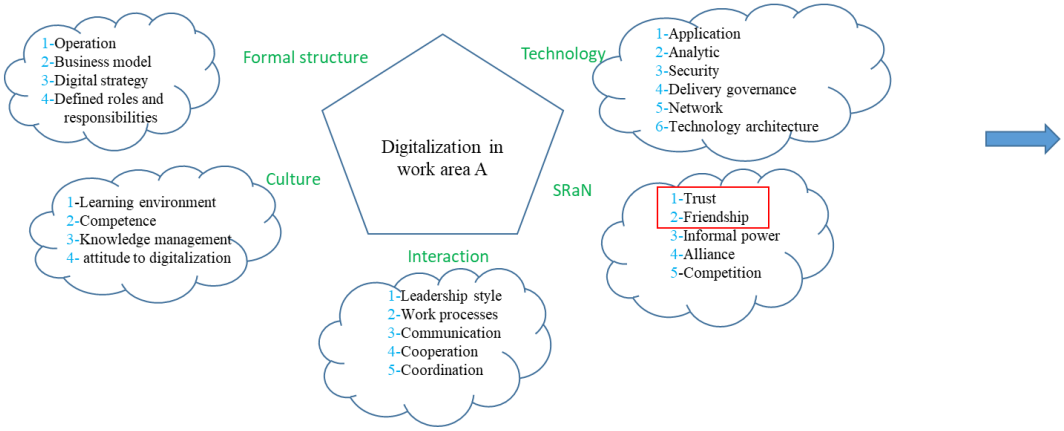
1-Work Area selection



2- Analyzing work area with Pentagon



2-1-Choosing the effective criteria **2-2- prioritizing them**



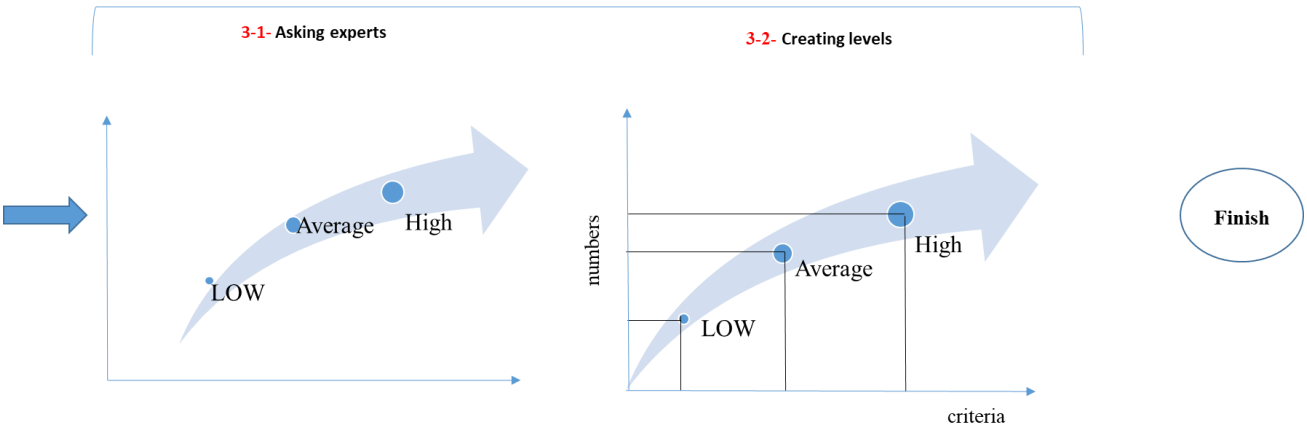


Figure 15: The Digital Maturity Framework (DMF) for measuring digital maturity

6.1. Work Area selection

The first step in this framework concentrates on detecting main work areas. In chapter 2, Work Areas (WA) are introduced as high potential areas for digital maturity. There is no specific way of choosing these areas. This selection in companies can be managed in different ways and strategies. This selection can be managed by managers, experts (internal or external), special committees, etc. The methods of identifying and prioritizing these areas can be various. From qualitative to quantitative methods.

For identification of work areas, the reference of the thesis is the report by McKinsey (Blanco *et al.*, 2017) and, one hypothetical solution designed which will be introduced below. In hypothetical model two criteria considered for prioritizing work areas which are stakeholder priority and digitalization benefit.

6.1.1 Hypothetical model for identification and prioritizing Work Areas

This model seeks to find work areas for measuring digital maturity as depicted in Figure 16. Two dimensions considered for this aim which is stakeholder priority and benefits for digitalization.

Stakeholders priority is important in projects because projects conducted in contact and interaction with stakeholder and there are different stakeholders in projects with different expectations.

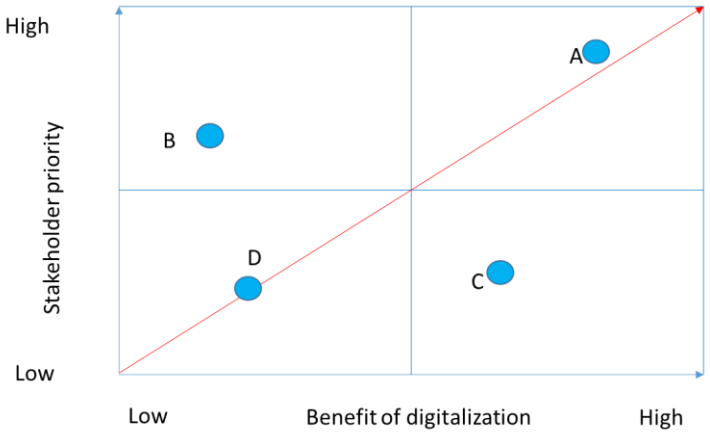


Figure 16: Hypothetical model for Work area detection

Figure 16 represents the two assumed criteria for choosing important work areas. The red line shows the optimal state for choice. When moving in the path of the red line, both benefits for digitalization and stakeholder priority are balanced. Benefiting more means much improvement of work can be seen in these areas which lead to the efficiency of the work. Stakeholder priority shows work areas with higher priority for them. It is necessary to know project stakeholders and their expectations in advance, but the evaluation of stakeholders' expectations is not the purpose of this thesis.

Point A, B, C, and D are showing work areas in Figure 16. Point A has the highest priority from stakeholder's view and provides more digital benefit to the company. Point B has less benefit for digitalization but have a high priority for stakeholders. In a choice among point B, C, D, point D can be a better choice because it fulfills both goals to some degree. Choosing one work area between B and C depends more on the company's priorities. Stakeholder priority has no influence on the benefits of digitalization in the thesis assumption. In real condition, these two variables can influence each other.

After determining work areas, the next step focuses on identifying important criteria related to each work area. Evaluation seems to be awkward without having any scale or criteria. These

criteria chose based on the criteria of the Pentagon model and important criteria in digital literature. Several criteria can be common for all work areas, and some can have different values from area to area. Many criteria introduced in this section but for the aim of the project and the priority of the work areas, a few of them used for measuring digital maturity. Next part covers the work area analysis using Pentagon framework.

6.2. Analyzing each work area with Pentagon

The second step of the DMF analyzes work area using Pentagon model. Pentagon used for two main goals in this section as illustrated in Figure 15. First, choosing effective criteria second, prioritizing them. There are different criteria for measuring digital maturity; some are identified in 5.2, as shown in Table 5.

6.2.1 Choosing effective criteria

Criteria facilitate conducting a measurement. But the main challenge is the choice of effective criteria. Choosing the right criteria helps to perform a better measurement and satisfy the measurement purpose. In the selection of effective criteria, two necessary conditions considered based on thesis assumption as depicted in Figure 15.

A. Effectiveness in the specified work area: effectiveness in the work area determined by experts at the workplace. For instance, design management is the selected work area. Experts concluded that analytics and application are effective criteria for design management from a technology perspective. These criteria for contract management may change based on priority. In contract management, the experts may suggest that security has a higher priority than the analytics because companies have a preference to keep their information safe.
B. The support degree of digital maturity goal (s): The second condition for choosing effective criteria is related to the degree that the criteria support the digital maturity goal(s). In section 2.2, some characteristics (goals) of digitally mature companies were identified:

    - The technology used for efficient management of data,
    - Dedication of communication channels for stakeholders,
    - Concentration on the digital competency of the workforce,

- The digital strategy supports strategic goals and main processes,
- Response to digital changes in the environment quickly,
- Providing environment aware of digital solutions.

The second condition measures the degree of fulfillment of the goals mentioned above. For instance, analytics can contribute to the achievement of the first goal, which is: The technology used for efficient data management. If a criterion does not fulfill the determined goal the choice of criteria will be questioned. Because the final goal is to choose the criteria which are effective in digital maturity.

For example, Design management chose a first work area for measurement. Pentagon helps to know the useful criteria in the design management as illustrated in Figure 17. Trust, friendship, and informal power chose as effective criteria consecutively. Support for goals in Figure 17 is a more qualitative concept. Proving these supports can be conducted by managers, experts or committees in the projects. This process repeats for all the work areas as shown in Figure 17.

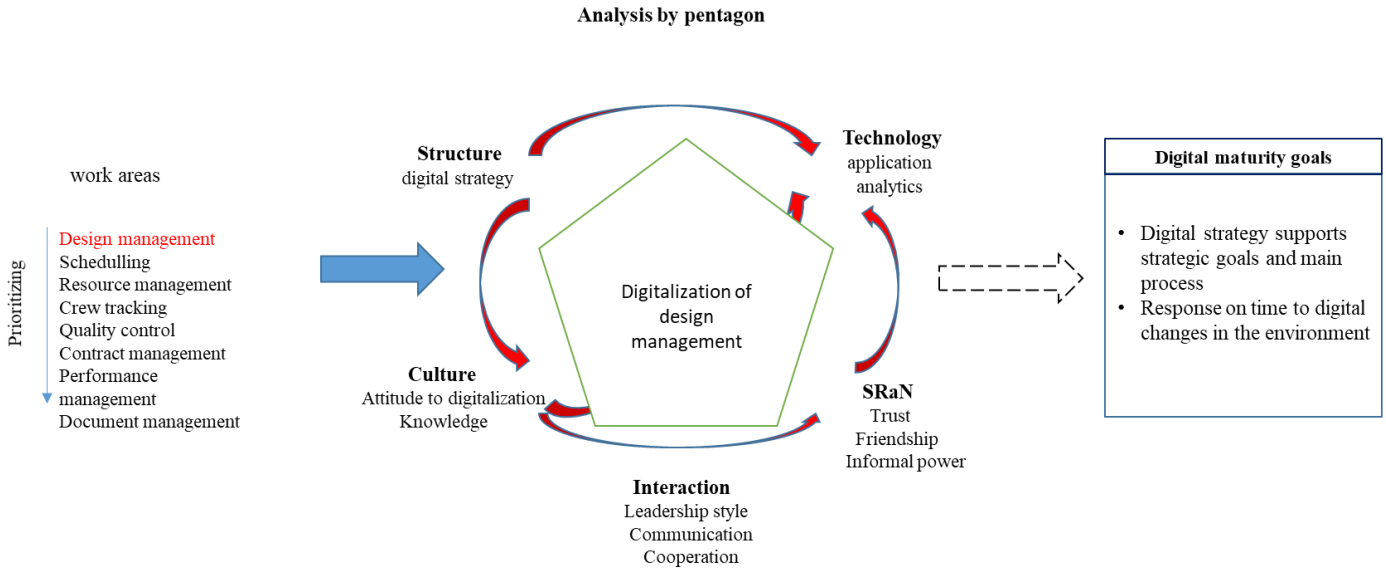


Figure 17: Criteria selection by Pentagon and support of goals

6.2.2 Prioritizing criteria

The second step in analyzing work area is Prioritizing the criteria. There are different methodologies for prioritizing criteria. It can be conducted through a decision in teams, experts in the specified work areas independently, from a literature review, etc. The thesis suggestion is the second approach by experts. In the first methods, a member can be influenced by team decision. The third method can ignore the condition of projects or companies. Hence the second approach is the suggested method of the thesis.

The criteria prioritized based on their importance to the specified work area. For example, one of the Pentagon dimensions is SRaN. In the work area of design management regarding SRaN, two criteria are chosen based on Figure 15 step 2. These two criteria are trust and informal power.

6.3. Designing digital maturity ladder

The previous section in the thesis contributes to recognize the main criteria in the structure of the Pentagon model. For, measuring digital maturity, the next step is to develop maturity ladders. The importance of maturity ladders is to determine the position of the company in the digital maturity ladder. Company or project can adopt some policies for improvement based on the difference with the mature state. It is also a visual aid for managers in some companies which have less time for reading long reports.

Development of digital maturity ladder has two main steps as illustrated in Figure 15. The first step tries to make related questions. The second step seeks to design the ladder by determining stages of maturity, characteristics of each level, and designating the mature and immature level of criteria. There is no exact rule for determining the number of steps and features of each level. The only logic is these stages should be sequential from a lower level to a higher level. In addition, each level should have a new characteristic or improved characteristics plus cover the previous stage(s) capabilities.

6.3.1 Asking experts

The sample questionnaire, Table 7, can apply for collecting information from experts. Their answers provide the following information:

- Determine the priority of the criteria,
- Designate the characteristics of each maturity level,
- Determine the high level of maturity and low level of maturity,
- Determine the weight for each criterion which facilitates the quantification of ladders.

Before asking questions from experts based on the criteria which are identified in section 5.2, Table 6, and Appendix B. Some preliminary characteristics of maturity identified based on a literature review. These initial levels contribute to the experts to some degree and avoid starting from scratch. These levels stated in the questionnaire for expert as a guideline before filling the questionnaire. For instance, for cooperation which is the subcategory of interaction some characteristics identified. According to Appendix B4.3, there is two levels of cooperation. Inside the company or project, and among companies. Cooperation as stated in Appendix B4.3 and Table 6 shape through:

- Sharing information
- Teaching through digital tools (informal way)
- Join friendship groups

This information helps experts to define ladders based on these characteristics. These characteristics stated as guidelines in questionnaires for designing ladders as depicted in Table 7. Then the expert fills the questionnaire. First, they will determine effective criteria and prioritize the selected sub-criteria based on the weight assignment. The criteria with high number have high priority. For instance, in design management, they may give a high weight to trust. This criterion depends on the level of trust of project teams to digital tools for design management. Friendship may locate in the second level and after that other criteria will place. Then based on guidelines and their experience they design ladders. The ladders start from immature to mature state. They determine a lower level of maturity and higher level.

	Questions for SRaN in design management
	From the list which criteria has more weight in determining the digital maturity of design management in projects? Please score from zero to one. Sum of all should not exceed 1. Trust……. Friendship…… Informal power …. Alliance……. Competition…. * In this thesis, design management covers the process of the designing process of construction and using tools for demonstrating building or projects before execution phase.
1	**Trust** **Guideline:** Trust is related to the level of trust on design technology -Trust of stakeholders to digital tools and their accuracy in reports. Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature
2	**Friendship** **Guideline:** Number of friends in friendship circles in social network affects quality of friendship Friendship circles affects the trust level in design team Friendship circles in social media as a social relation can affect the final product of design management Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature
3	**Informal Power** **Guideline:** To what extents social network as an informal power can affects the product of design management. Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature

	Questions for SRaN in design management
4	**Alliance** **Guideline:** The IT infrastructure of the company provide some solutions for cooperation in design management inside the company with other projects and external cooperation The digital solution of the company predicts future possibilities of design management and innovative solutions in the market Alliance in digital framework increase the value of the company in design management. Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature

Table 7: Sample questionnaire for SRaN

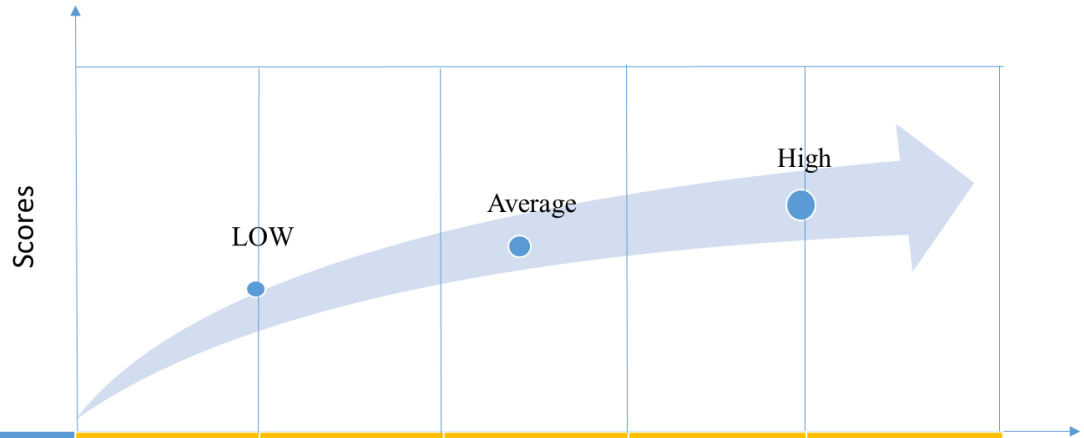
6.3.2. Creating levels

The second steps focus on creating levels. Based on data from questionnaires the levels will be determined, and the ladder will be created. In the thesis, we developed these questionnaires for social relation and network in Table 7 and technology in Appendix D (Table D1). These questionnaires should design for all five criteria of the Pentagon. Evaluation of the criteria based on real performance with experts' score is the future research purpose.

The thesis progress to design the ladders. It is noteworthy to declare that the output from questionnaires will be a maturity ladder as Figure 18. Five level ladders chose as a sample in this Figure. From each questionnaire equal to the number of criteria ladders produced. For example, in Table 7 there are four criteria hence the four maturity ladders will be created. Figure 18 is showing trust as a sample of digital criteria in social relation and network. Same ladders should be designed for other three digital criteria in Table 7.

There are seven columns in Figure 18. First one shows the effective criteria which influence trust. This feature shows the holistic structure of the suggested framework in showing the interconnection of criteria. The second column relates to the weight of criteria which shows the degree of influence of each criterion on trust. These two columns are the aims for future

developments. Thesis progress to design ladders for each criterion. The score of ladders is also the future aim for measuring the real performance of the system by experts. The other five columns are related to the maturity ladder of trust. This ladder starts from immature state (low) and progress to mature level (high).



Effective criteria	Weight	Immature	Beginner	Defined	Integrated	Mature
Governance Leadership style Communication Friendship Security		There is no trust to digital tools and no sign of organizational culture supporting trust in design management	Some training of digital tools and governance guildlines stimulate the workfore to use digital tools for design management and search for new tools in the environement	Training and governance guildlines support trust in a Systematic way for design management Trying to create secure channels for customers in design management (reporting,testing) but it begins in this level	Trust to new technologies and digital tools becomes part of company practices and leadership style support risks in design area accept changes,providing trust for stakeholders through secure design tools (reporting,testing)	Trust to new technologies and digital tools becomes part of company culture and leadership support this culture,Stakeholders trust to digital tools of design management

Figure 18: Sample of Maturity ladder for trust in design management's WA

This chapter gives an overview about the Digital Maturity Framework (DMF). Different components and its implementation introduced. This was the main result of the thesis. However, it is necessary to evaluate the proposed model and framework from different aspects. Next chapter tries to analyses and discuss findings of the thesis.

Chapter 7

Analysis and discussion of results

Step-by-step approach for measuring digital maturity introduced in chapter 4. In chapter 6, the holistic model and main framework of the thesis for measuring digital maturity proposed. It is essential to analyze this process and framework now. For the analysis, the main aspects of the work are considered. These aspects are processes, digital maturity criteria, digital maturity framework, and applicability of result. The reason for the election of these aspects refers to the importance of these aspects as explained in next paragraph.

The process in the development of digital measurement system is essential because the process highlighted the procedure of the work. Criteria are necessary measures which facilitate the measurement. Without choosing the right criteria, the measurement will not reveal the intended result. The main framework of the thesis should be analyzed to understand other aspects of the model and its capabilities. The applicability of finding to other industries is important as well. If measuring digital maturity is important for an industry and no tool or framework is available, it can be an introduction. If such a framework exists, unseen parts of their framework can be evaluated which might lead to improvement.

In summary, these aspects are:

- Process of measurement.
- Digital maturity criteria.
- Digital Maturity Framework.
- Applicability of finding to other industries.

7.1 The process of measurement

The thesis introduced a process for measuring digital maturity. Step 4 of this adjusted process used as the main step, chapter 4 Figure 6. Developing a system of measurement is a process. In order to analyze the thesis process, it is necessary to know the development process of other digital maturity tools. Companies do not share their information regarding the process of tool development. There are some reasons for lack of information such as competition among companies and being busy with main activities. They have less time for being on the edge. There can be different ways for measuring digital maturity, making a tool or purchasing it.

Buying or ordering a tool from software producer companies or consulting companies has its own benefits and drawbacks. Company saves time when buys a solution or tool. In addition, while the development conducted by external experts it helps some experts from impartial view analyze the company. They can give a better view of the company. Looking at negative aspects, it can threaten the privacy of the company. It can reveal the core competencies of the company or projects. Besides, this solution is not cheap necessarily.

Proposing a process for measuring digital maturity, as another way, helps other companies to have a useful guide as inspiration. The proposed process by this thesis may seem time-consuming in comprehension step of the system, or some steps in measuring performance may seem unnecessary. Using a model inspired by Andersen and Fagerhaug (2001) contributes to increasing the validity of process sequence to a great extent.

This process in the research introduced but it is not implemented in real world. This process helps companies to know the implementation of the measurement step by step. They can know where the starting point is for measurement and what information are necessary in the beginning of measurement process. The aim of this process is to measure digital maturity based on real performance.

7.2. Digital maturity criteria

In this section, digital maturity tools which are introduced in 2.3.1 are compared based on Pentagon model's criteria which is considered by the thesis in chapter 5. Table C.1 in Appendix C aims to summarize the analysis of the four reports with the dimensions of the Pentagon model. Pentagon,

as stated before, is an organizational model introduced in section 2.3.3. The Pentagon has five main dimensions: structure, technology, culture, interaction, and social relation and network. In this part, evaluating these reports through the five mentioned dimensions contribute to know which areas of the work are not covered by the previous studies. The result is as follow:

Report 1

The evaluation of maturity dimensions by McKinsey Catlin et al. (2015), through five dimensions of Pentagon model are as follow:

1-Structure: Focus of the report Catlin et al. (2015) is on operations with considering key performance indicators. The report assumed the automation of processes as a necessary function in current businesses. The organizational structure shows the position of the company in the digital transformation effort. Digital strategy is an important factor in the success of the companies in this report. The strategy has an influence on the structure of the organization in the report. There is coordination between the criteria of the thesis and the report.

2-Technology: Technology is a connectivity facilitator between customers and the business in the report. This technology is modular, which contribute to serving customers fast. Besides, decisions are data-centric in mature companies. In this report, culture can compensate for the shortage of technology (Catlin et al., 2015). Technology has various criteria in the assumed model of the Pentagon in comparison with the report.

3-Culture: This digital maturity tool insists on having an agile culture, learning environment, the competency of the workforce, and risk tolerance culture in innovation. The skill of the workforce influences cooperation and collaboration among the competent workforce. The report by Catlin et al. (2015) covers all the aspects of maturity, but knowledge and importance of expertise considered less. Based on thesis assumption knowledge is a subdimension of culture in the modified Pentagon model.

4-Interaction: The Cooperation beyond the company presented in the report with suppliers and customers etc. Communication is a facilitator of real-time monitoring of performance indicators. Leadership style and work processes are not clear in this report (Catlin et al .,2015) as an important criterion for measuring digital maturity. The report refers to investment in digital capabilities of

the company which is close to the concept of work processes which create more value for the company but not in a direct approach.

5-Social relation and network: Trust, informal power, roles, and responsibilities are areas which has received less attention in this report in comparison with adjusted criteria of the thesis.

Report 2

The evaluation of the digital maturity dimensions of Achatech report by (Schuh et al., 2017) through the structure of the Pentagon are as follow:

1-Structure: Organizational structure includes many criteria. One of them is collaboration in Acatech report. In the Pentagon, collaboration pertains to interaction dimension.

2-Technology: This dimension of Pentagon has more similarity with the criteria of information system in the report by Schuh et al. (2017). It covers security, IT technology, analytics, data control which is approximately similar to the criteria of the Pentagon in the thesis. It is necessary to say that Pentagon original model for technology includes tools and infrastructure but in the thesis some changes created in this dimension with borrowing these dimension from the report by Anderson and William (2018). These dimensions are applications, analytics, security, delivery governance, network, and technology architecture.

3-Culture: In the report Schuh et al., (2017), culture encompasses many criteria. Learning and willingness to change are the same with the Pentagon model. Learning from mistakes is an important criterion which is mentioned in the report and in the Pentagon. Same as previous reports knowledge ignored in this report or at least less attention can be seen from the initial analysis of the report.

4-Interaction: This criterion more or less has similar sub criteria however with different categorization.

5-Social relation and network: Trust, friendship and informal power again are criteria which are noticed less in the report (Schuh et al., 2017). Less notice means that these criteria compared with other criteria grab less attention.

Report 3

The main outcome of the third report, Anderson, and William (2018), and comparison with the Pentagon model presented as follow:

1-Structure: Strategy and operations are declared in a report by Anderson and William (2018). The strategic alignment is an important issue which is insisted on the report. If we assume that the organization is equivalent to structure in this report, they propose structure and culture as one dimension. Pentagon assumed culture and structure as two different dimensions. Roles and responsibilities are dimensions with less notice. Roles and responsibilities can be assumed in the subcategory of workforce enablement (Anderson and William, 2018).

2-Technology: Technology has been evaluated form different dimensions. The variety of dimensions in the technology stimulate the thesis to use these dimensions for adjusted criteria of the Pentagon.

3-Culture: Leadership, competency, flexibility, and innovation has been mentioned in the report. Knowledge and learning environment are important dimensions which do not seem to be mentioned directly.

4-Interaction: Cooperation as an important criterion mentioned directly. It can be assumed in stakeholder management. Communication can be assumed in numerous dimensions like ecosystem management, stakeholder management, etc. However, there is no independent criterion for communication within the report (Anderson and William, 2018).

5-Social relation and network: Trust and informal power are areas which have received less attention. Trust over customers declared as a sub-dimension of the customer. (Anderson and William, 2018).

Report 4

Evaluation of fourth report Westerman et al. (2014) with the framework of the Pentagon is as follow:

1-Structure: This dimension approximately has acceptable coordination level with Pentagon model. It covers operations, the business model in the Pentagon. Vision during the report located in the structure and its strategic alignment is insisted. Roles and responsibilities are under the category of governance but in the Pentagon, they are located in the structure category.

2-Technology: Technology is a subset of leadership capabilities in the report by Westerman et al. (2014). In Pentagon, leadership style is a sub-dimension of interaction.

3-Culture: This dimension covers leadership capabilities. It implies that applying the right culture in the organization depends on the leader's abilities, however, culture is the main dimension with different sub-dimensions such as learning, competence, knowledge, etc. in Pentagon. The report by Westerman et al. (2014) assumed collaboration as an important factor in culture.

4-Interaction: The cooperation beyond the company presented in the report with suppliers and customers etc. Communication is a facilitator of real-time monitoring of performance indicators.

5-Social relation and network: Trust, informal power are areas which have received less attention in this report.

The analysis of these reports as illustrated in Appendix C (Table C1) shows that the dimension of social relation and network are less considered in previous studies for measuring digital maturity. Criteria such as trust, friendship, informal power, roles and responsibilities, knowledge, knowledge management, learning environment grabbed less attention in researches mentioned above.

Some may argue that these dimensions are not suitable or relevant for measuring digital maturity. That can be correct, but the Pentagon gives the capability of observing various criteria in the context of projects. Beside digital maturity is a broad concept and covers many aspects. These areas give opportunity for further research.

7.3. Analysis of the main framework

Digital Maturity Framework in this thesis uses features of different tools and models. It uses the options of different tools and methodologies and tries to boost measurement by observing different criteria. It uses literature review to spot the features of ladders. These features become an input to expert's judgment for making ladders. It combines literature and experts' ideas to make a ladder. The thesis adopts a different approach for gathering information as well as designing a framework.

Other frameworks as explained in chapter 2 mostly use surveys and interviews as the source of information. These surveys and interviews conducted in different industries. For example, McKinsey performed 150 diagnostic surveys in different industries to develop a tool for measuring digital maturity Catlin et al. (2015). Each of these methods of data gathering has its own ups and down. For example, it takes a long time from survey distribution until the results are gathered from respondents. The advantage of thesis' framework is that it requires less time from data gathering until the framework developed.

Another aspect to be considered regarding the thesis' framework is flexibility. The framework design gives it more flexibility. This flexibility comes from the fact that experts choose the Work Areas, Pentagon criteria selection, and ladder design. Another flexibility is that each company can adapt and develop this framework according to its own activities.

7.4. Applicability of finding to other industries

The thesis focuses on the construction industry. Some findings of the thesis can be applied to other industries. For example, the criteria of trust, friendship, and informal power can be analyzed in online shopping. Trust can be one important factor for this industry. Social network role as an informal power can be evaluated in many industries. Friendship in the digital area might affect the decision of buyers. These were instances of applicability of the criteria to other industries.

The process of digital measurement can be applied to other measurements such as performance measurement in companies. The performance measurement with the thesis approach can measure the maturity of the process. For instance, if a company wants to measure the performance of its production line, they can measure the performance and at the end, they can have the mature ladder as the intended goal for better performance.

It is noteworthy to say that the construction industry is behind other industries in digital maturity level. As a result, important work areas, effective criteria, and maturity ladder shape can be affected. Thus, some criteria and goals, identified in the thesis, may not be suitable for the other industries. The concept of work areas and important work areas for construction might not be the same for other industries as they depend on the characteristics of the processes. These processes stem from product and/or service offerings, used technologies, industry context, business context, etc. the processes are not the same for all companies and might differ significantly. Thus, not one size fits all and the work areas need to be distinguished and it applies for choosing effective criteria and maturity ladders.

Chapter 8

Conclusion

This thesis was an effort to find a better digital maturity framework. For creating such a framework different maturity tools were studied and analyzed. In an evaluation of previous tools some uncovered areas discovered. The process of the digital measurement inspired by performance measurement system by Andersen and Fagerhaug (2001).This research can be a guideline for the companies which try to make a step towards digitalization and digital transformation. In addition, it is a suitable guide for companies that are not aware of the digitalization trend. The research questions which strived to be answered in the thesis are:

Q1: What is a suitable process for developing a framework for measuring digital maturity?

Q2: What is a suitable framework for measuring digital maturity?

By the introduction of the digital maturity measurement system, *Q1* was answered to some extent. PMS by Andersen and Fagerhaug (2001) has similarity in the process of the thesis approach. This system provides a realistic measurement based on the real performance of digital tools. More explanation has been given in chapter 4.

The proposed framework regarding *Q2* uses the Pentagon for analyzing digital maturity and it constitutes three stages as explained in Figure 15. Stage one encompasses work area detection and prioritizing. Stage two focuses on analysis by the Pentagon model and identifying important criteria. The third stage focuses on designing a maturity ladder for each criterion. These three stages make the main framework of the thesis.

This is important to know to what extent the thesis could satisfy the research purpose. From one view it was able to answer both questions. However, in this step qualitative result has a high value. There are different criteria that can show the fulfillment of the research purpose. The capability of the model can be proved with real data. This research from this aspect which uses different tools and models and tried to cover the gaps was a successful research study. However, our framework such as other frameworks can have weak points. This weak point can be improved with feedbacks

from experts in the construction industry. In addition, some can criticize this framework in its inability to see other tools or frameworks which relate to the limitation of the research.

The outcome of the research is as follow:

- Designing a new process for measuring digital maturity based on performance measurement system,
- Developing a holistic framework based on the Pentagon model,
- Identifying new criteria that grab less attention in other models such as informal power, knowledge etc.
- Finding a new tool, CDML, that is developed for construction project-based organizations,
- Presenting a hypothetical model for work area detection.

Note that the thesis strategy was qualitative, and implementation of the developed framework is not done yet. It can be considered as a limitation to this thesis due to time pressure. This framework does not cover all the aspects of digital maturity because the emphasis was more on construction project-based organizations in Norway.

There are different possibilities for future work. First, this research focuses on the development and designing of a conceptual Framework. This framework can be tested in a real company after some adaptations. Second, the analysis of the thesis is qualitative based on author's idea and perspective. For future work, data gathering in each stage of the work analysis can be conducted by questionnaires from experts in the industry. This can improve the validity and reliability of the framework and the final product.

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Appendix A: Organizational models

A1. Scott's model:

Scott (2003) made his model based on the model of Levitts (1965) diamond model. The model has internal and external area. Internal area is dedicated to the organization and external area to environment of the organization. The internal organization consists of social structure, participants, goals, and technology. Figure A1 depicted the modified structure of the Scott:

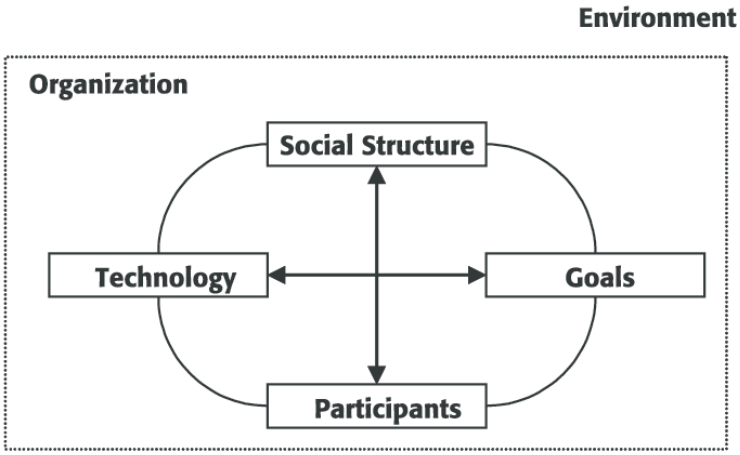


Figure A1: Scott (2003) modified model based on Levitt's original model (Leavitt, 1965)

This model represents the primary dimensions of the organization for analysis. An organization includes people who gathered for the specific aim. Some of these people or participants try to do their work by the technology in the specified framework which is structure. This model describes the components of the organization in a simple way and shows the integrity of components. This integrity represents the real influence of these components on each other. For instance, shows that social structure and technology has a mutual relation. Technology has the same mutual relationship with goals. This integrity represents the holistic structure of the models. This holistic structure facilitates the analysis of problems in organizational context. In addition, it represents the real complexity of the organization.

A2. Hatch model:

The model in Figure A2, introduced the concept of the organization (Hatch and Cunliffe, 2012) (Schiefloe, 2019).

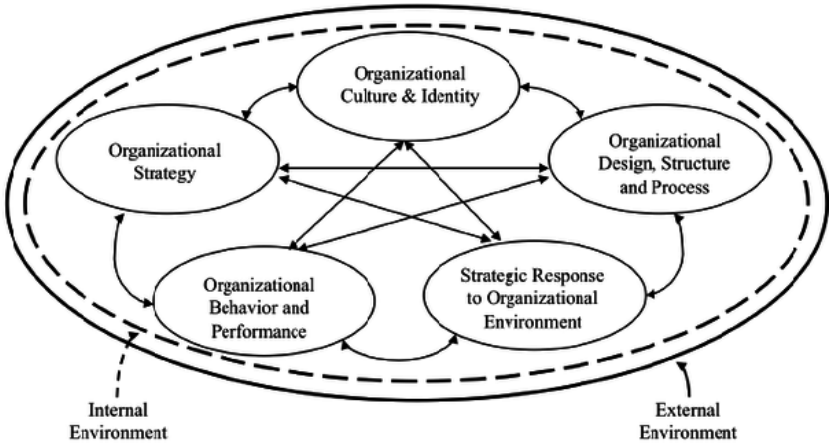


Figure A2: Hatch organizational model (Hatch and Cunliffe, 2012)

This model in comparison with Scott's model has more components. Like Scott's model, this model shows the interconnection of different variables. Hatch considers the power as a variable which affects other variables in this model. Technology is not an independent variable. But this dimension is an important for analysis of the digital maturity. In the process of searching for other models led us towards Pentagon model.

Appendix B: Digital criteria

B1. Structure

B1.1. Business Model: It shows how the company creates value and deliver value to customer. For instance, IKEA which tries to sell with low price with reducing services or by YouTube, in this model many people provide content for free and they have access to other people's content freely.

In construction industry, there are different views toward business model. Operation model of these companies determine their business model and there is no common definition for construction. Hence digital maturity of business model in the context of construction depends to the operation and managers perspective (Pekuri et al .,2013).

B1.2. Defined roles: The Company have different roles and defined structure for digital roles. In some companies the digital roles are defined and this criteria for companies which are behind digitalization can be in less developed shape based on thesis assumption. Hence, there exist some balanced between level of digitalization and digital roles. Digital maturity can be from undeveloped roles or no roles has been specified in the company to the level with classified roles exist for each digital activity.

B2. Technology

B2.1. Security: Security can be considered as one of the factors in accepting digital technologies. Some companies might not follow digital tools in construction because of security concerns. Because they think digital platforms as unsecure environment. Some of these concerns are related to psychological effects form news. Some of security concerns is related to sharing information with suppliers. Sharing information with suppliers can be risky for instance sharing information related to core activities might not be desirable by the company. Hence, security itself has a broad perspective and there exist various reasons for security concerns. The maturity degree can range from companies without any specific strategy toward security to companies which have proactive strategy against security.

B2.2. Delivery Governance: Delivery governance pertains to the presence of guidelines, procedure and rules for implementing IT development and utilization. The maturity ladder can commence with companies weak in governance for technology deployment to companies with having systematic procedures for delivery of technology (Anderson and William, 2018).

B2.3. Network: To assure that the network structure is concentrated on the enhancing issues related to agility, scalability, virtualization, automation, and security. The maturity degree begins with companies without any structure of the network to companies equipped with advanced network structures (Anderson and William, 2018).

B2.4. Technology architecture: This criterion considers future and present changes in the technology structure and its alignment with strategy of the business. The readiness for changes in the shortest time and the capability of technology in communication with other companies through current structure as well as the potential degree of integration with other companies in technology level (Anderson and William, 2018).

B3. Culture

B3.1. Leadership and governance: For the purpose of providing a framework for measuring digital maturity the thesis focusses on leadership style and not on leadership. Leadership is an important factor in managing companies. For measuring digital maturity leadership style has significant role and shows the direction of the company against digital innovations and changes.

Governance structure is an important factor in managing different aspects in the company. It affects the digital strategy and its implementation in the company. It coordinates the movement of different departments and people in the right direction for digital transformation (Westerman, Bonnet and McAfee, 2014).

Many companies have governance structure for their financial and staffing issues. There is a need for digital governance in companies to tackle risks related to digitalization. These risks can be about the unsuccessful application of digital tools, security issues of digital tools, messy professional behavior of personnel in social media (Westerman, Bonnet and McAfee, 2014).

B3.2. Learning: Some companies, support learning in their environment and learning becomes part of their culture. The research by (Westerman, Bonnet and McAfee, 2014) shows that digital masters learn from their failure. For example, in Intel after each failure the personnel report the failure to their mangers. They see failure as an opportunity for learning. Therefore, there can be relation between attitude to change and learning environment. The other factor which affect learning in the company is the leadership style. This item shows to what degree managers support learning in the environment.

There is connection between IT application and business. One of the factors which facilitate the suitable coordination between IT and business is the culture of learning by doing or trial and error (Westerman, Bonnet and McAfee, 2014). When people in specific department want to install specific software or deploy specific technology culture of learning helps. It gives them the opportunity to test a system although the installation might not be successful.

For measuring the level of maturity in digitalization the learning can impact in personal and organizational level. Hence, for measuring digital maturity two criteria considered.

a) The degree of support for learning in individual level

b) The degree of support for learning in organizational level

B3.3. Competence: Based on Schiefloe competence is related to the choice of workforce which have the required skills for conduction the project and considering the team combination. One of the challenges which is mentioned in this report is the integration problem of supplier and contractor .The solution for this problem is to combining these competencies in the framework of teams (Schiefloe, 2019).

Hiring skillful people is one of the challenges in movement toward digital transformation. The culture of the company and leadership style can affect this dimension. Open discussion, declaring ideas in the teams contribute the company in identifying eligible workforce. Cooperative style of leadership support innovation in the work environment and too much extent can enhance the process of talent identification. Company should have the strategy for recruitment of the competent people. The importance of the competent workforce should not be overlooked as one of the main organizational capital.

In order to measure digital maturity, the ladder of digital maturity can start with companies without any specific strategy for talent acquisition. This process progress to companies which have specific strategy to talent acquisition. Finally end in companies which have the culture to spot the competent people. It means the organizational environment, nurture and foster employing skillful people.

B3.4. Competition: Digitalization can bring more competition in the company level or intra company level. Some researches look to competition as positive and some as negative. In this thesis this criterion is not in the focus area.

B4. Interaction

B4.1. Work processes: The term work process first time expressed in the Baldrige Glossary. It refers to processes which produce highest internal value to the business. These processes can be main processes or supportive processes for the company which carry the main workload of the company (Glossary, 2019). In another definition by (Galloway, 1994) the work processes consist

of tasks, activities ,and steps which transforms input to output and add value to input. Identifying these processes in companies have some benefits for the purpose of thesis.

For measuring digital maturity of the work processes, it is vital to know the areas in work process which are important and effective for digitalization. These areas can be extracted from the processes of successful projects organizations which have high performance in digitalization or at least have reasonable performance toward digital transformation. The research by McKinsey (Catlin, Scanlan and Willmott, 2015) as stated previously in section represented that these areas are: design management, scheduling, material management, crew tracking, quality control, contract management, performance management, and document management. Now the main question can be how digital maturity can be defined for these processes? The research by Deloitte and TM Forum shows that for maturity of processes these aspects have importance which are:

a. Agility in change management: Having a strategy for change management which tries to define, design, plan change process with agility. Adopting a right relationship management with stakeholders in the process of change in order to get the better outcome efficiently with the agile-centered approach.

b. Automation in resource management: Automation in identifying the cycle of digital resources which are product, service or are parts of the digital ecosystem of the company.

c. Integration in resource management: Providing a single point of contact with customers from self-service (limited options) to full-service.

d. Real time vison and analytics: Using information and analytics for better management of strategy, customer, organization, people, skill, product and services.

e. Flexible process management: The automatic process management which handle different work issues and adapt to different internal and external needs and expectations (Catlin, Scanlan and Willmott, 2015).

f. Automation of governance and standards: companies who aim in digital transformation trying to conduct risk management intelligently, automated with issuing recommendation and reporting (Catlin, Scanlan and Willmott, 2015).

B4.2. Leadership style

Leadership style is “the underlying need-structure of the individual which motivates his behavior in various leadership situations”. There is a different leadership style in the literature of social science (Hesse, 2018). The leadership style effectiveness depends on condition and situation in the company based on Fiedler contingency theory. The situation manager face brings the power of influence and this influence depends on “task Structure”, “leader position power”, and “leader-member relations”(Fiedler, 1967).

There are different leadership styles such as democratic, participative, relations-oriented, considerate, and autocratic styles. Bass In the paper with the name “Good, better, best” mentioned the “new paradigm” in leadership style from innovative change aspect in the organization. The research categorizes transactional leadership for “low-order changes” and transformational leadership to “high-order changes”. In transactional leadership, leaders try to specify their expectation for the work and subordinate will reward for that expected performance. Transformational leadership tries to create significant changes in followers such as from the need to security to recognition, from the outcome-oriented approach to conscious-oriented to outcomes and being self-interest to work instead of being task-oriented (Bass, 1985). Hesse (2018) in the study found two leadership styles of hierarchical and participative and among respondents to interviews most of them follow the participative approach. It is noteworthy to say, that each of these styles of leadership has their own drawbacks and strengths. Transformational leadership characterized by learning, making an improvement, introducing innovative ideas, motivating members (Zumitzavan and Jonathan, 2015). Contingency theory of Fiedler (1967) again shows can be a satisfactory approach for companies and different condition seeks suitable decisions for leaders.

With the aim of finding the relation between leadership styles and digital maturity, it is necessary to evaluate the outcomes of leadership style and suitable forms of leadership in the path of digital transformation. According to Bass (1985), in modern styles of leadership when the relations between leader and followers is based on participation and cooperation, the output of leadership will increase. It appears that transformational leadership is much closer to this perspective of cooperation and participation of Hesse (2018). Bass (1985) stated that the transformational

leadership is suitable for change in organization. If we assume that digitalization is a kind of change, this approach will be consistent for measuring digital maturity. Despite, there exist different leadership styles, but this transformational leadership for the reasons mentioned earlier and because of its ability in transferring knowledge in the organization can be right style to move toward digital maturity. Although there is another perspective is related to the influence of the digitalization on leadership style, our assumption for measuring digital maturity is on the effect of leadership style on digitalization. Based on our assumption in this thesis, in digital mature companies the style of leadership is strong in transformational aspect. This style has much inclination to accept change, transfer knowledge, support innovative ideas which can be the right cultural characteristics for companies moving toward digital maturity as mentioned in Chapter 2.

B4.3. Cooperation:

The Cambridge dictionary defines cooperation as " act or work together for particular purpose, or to be helpful by doing what someone asks you to do "[13]. Schiefloe believes that cooperation is one type of social interaction in companies and defines cooperation as: people work together to achieve a specific goal in a complementary manner and assumes collaboration as a type of cooperation (Schifloe,2019) (Schalk and Curşeu, 2010) in their research found that the quality of cooperation leads to the success of companies these qualities are: responding to changes in the environment, keeping a good position in inter-organizational network, having flexible production process, doing processes efficiently inside the company and having innovation. This quality of cooperation by (Schalk and Curşeu, 2010) can be an expected outcome for cooperation without considering the context of the study.

In the literature of cooperation, some scientist compares cooperation with competition and look it as two opposite concepts (Deutsch, 1949; Tjosvold Dean, 1984).(Tjosvold Dean, 1984) explain that cooperation has a different meaning for researchers some believe that cooperation can be positive and some believe the reverse. Some correlate cooperation with non-contradiction and competition with challenge and high ambition. In his study Tjosvold define cooperation and competition as "interdependence of goals" and try to clarify it through the study of (Deutsch, 1949) which consider two actions: "effective" and "bungling" . In cooperation, people assist, encourage,

[13] Cambridge Online Dictionary

like each other (effective actions) which facilitate reaching to goal for all members. On the contrary, in competition people suspect, hinder, hate each other (bungling actions) in benefit of their personal achievement (Deutsch, 1949).

For the purpose of measuring digital maturity, we should find the connection between digital maturity and cooperation in the companies. It is better to determine different models of cooperation before making a connection. (Schalk and Curşeu, 2010) in their study recognize three main types of cooperation which is interpersonal cooperation, Inter-group cooperation and, within group cooperation but, for simplicity we assume that cooperation can be in two forms, inside the company and between companies. In the digital mature companies based on our assumption, people have more effective behaviors as proposed by (Deutsch, 1949) assist each other, encourage and like each other more. Assisting each other in digital age can be through sharing information, teaching through digital tools and this can be applying to inter-company relationships. Joining in friendship groups in social networks can be other shape of cooperation which is a form of positive behavior. Encouraging other team members is another shape of effective behaviors which can boost cooperation level in the company, but its connectivity with digitalization is not clear in this stage. When this cooperation in inter-company relationship reduces, it may lead to competition. Therefore, for measuring digital maturity in cooperation level based on thesis assumption three important aspects are:

a) Sharing information
b) Teaching through digital tools (informal way)
c) Joining in friendship groups

These activities can contribute the company to act efficiently, to have more ability to respond to environment changes and encourage innovativeness in the company which is quality of cooperation stated by Schalk and Curşeu, (2010).

After identifying the main criteria in the framework of Pentagon model the next step will focus on

Introduction of the third building block of digital maturity. This building block explains maturity ladder.

B5. Social Relation and Network

B5.1. Trust

Barton et al. (2017) in their research declare that, trust in digital era is not confined to protection of customer data. It includes the ethical standards, preserving trust in cooperation with other companies, data security etc. In the research by Harvard Business Review, four dimensions appointed for digital trust and they evaluated trust in 42 countries. These criteria are perspective of users to digital experience, the user reaction to digital hardships, the process of creating trust, and the user experience in digital environment (Chakravorti, Bhalla and Chaturvedi, 2018).This research receives practical information from users and evaluate the realistic perspectives of digital users about trust. In order to appoint trust to maturity ladder it is necessary to know what is the mature level of trust in digital environment? For the purpose of this thesis ,the second perspective to trust presented by (Chakravorti, Bhalla and Chaturvedi, 2018) is considered for making maturity ladder.

For determining trust level in the context of digital maturity trust can include intercompany relations, with suppliers, other companies or can relate to trust of human to technology or digital devices. In all areas, level of trust depends to different factors. It can relate to previous experience of users or customers, the degree of knowledge of the people, etc. In creating trust in companies or digital mature project organizations trust can be defined in two form:

1. Person to person
2. Person to system or technology

Based on different activities different type of trust presented. For instance, in design management trust of team members to digital tools is important. In contracting, trust can concentrate on the security of the information sharing and privacy of the contracts. In this thesis trust to communication channels, applications, is important which can lead to preserving privacy or accuracy of the result.

B5.2. Friendship

Friendship is one type of informal relation in organizations. Organizations are social systems and the emotional needs of people in the organizations satisfy through informal groups (McBain and

Parkinson, 2017) Researchers believe that friendship is not affected by individual choice and feeling but, the context of creation of friendship affect its shape and content (Graham Allan, 1998). Workplace friendship depends on different factors such as: trust, common interests, linking, lunch time friendship etc. With the increase of workplace friendship, work stress reduces and productivity in work increases (Berman, West and Richter, 2001). Friendship in the context of digital workplace can shape by informal friendship platform such as Facebook, Instagram etc.

Dunbar (2018), defines friendship as "they are the people whom we make an effort to maintain contact with, and to whom we feel an emotional bond". In the paper defines the circles of friendship as illustrated in Figure B1. The 150 people is the optimum size of friends in social networks. Inside layers have the better quality in friendship and with moving to outside the quality of friendship decreases.

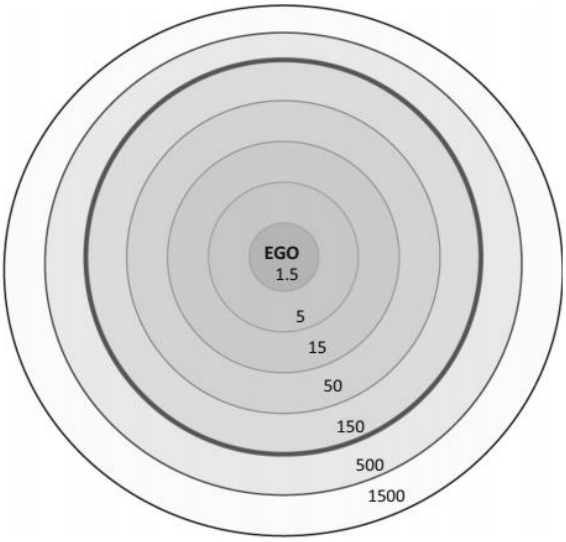


Figure B1: The Circles of Friendship in digital environment , adopted from (Dunbar, 2018)

For measuring digital maturity of this sub-dimension, it is necessary to focus on the effect of digitalization on the quality of friendship in the workplace and teams. The number of people in the circle of friends is an important factor for the quality of friendship in digital era. Therefore, for measuring digital maturity, the quality is an important variable which is affected by the size of

friendship groups. Using (Berman, West and Richter, 2001) approach ,the quality of workplace friendship in the ladder should result in reduction of stress and elevation of productivity.

B5.3. Informal power

Peiró and Meliá (2003) defines" Informal power is based on positive interpersonal relations, involving the exchange of social support, referent relationships, or knowledge, all socially valued unrestricted goods "

This criterion is related to the effect of digitalization on growth of informal power in the company. Digital technology can accelerate the shaping of social groups in companies. These social groups give social support to members, which is one aspect of informal power. People can easily contact and make connection, which can contribute to get information with removing the hardship of physical contacts in the past. Hence, informal power can be one of important criteria in measurement of digital maturity.

Appendix C: Analysis of suggested framework

Dimensions / Reports	Structure	Technology	Culture	Interaction	Social relation and network
(Westerman, Bonnet and McAfee, 2014)	Approximately coordinated with Pentagon. Structure include vison which is aligned with business strategy.	Technology is subset of leadership capabilities But in Pentagon based on our assumption technology covers the criteria of (Anderson and William, 2018) report.	Culture like technology is the subset of the leadership capabilities But in Pentagon culture is main dimension which has different subdimensions.	In comparison with Pentagon interaction in this report does not include leadership style and work processes. Cooperation and coordination are same in both structures.	There is no dimension with the name of social relation and network in this report. subdimensions such as trust, informal power in the structure of Pentagon are noticed less in this report.
(Catlin, Scanlan and Willmott, 2015)	Organizational structure mentioned as important factor which should adapt with the digital strategy of the company. Strategy is one of important dimensions in this report. Roles and responsibilities are uncovered dimension of the report.	Technology is important, but culture can compensate its shortage. Technology has some characteristics in the report such as modularity, connectivity, and analytics for decisions. Based on Pentagon technology is necessary to understand how company works and include all the tools, infrastructures, and ICT system.	It has high importance in this report which can compensate the shortage of the technology. Knowledge is the only area which is not under the subcategory of culture. The knowledge and its importance in the report is not clear.	The report covers cooperation and communication. Leadership style and work process is not clear in this report as an important criterion for measuring digital maturity. Investing in digital capabilities can be equivalent to the concept of work processes in Pentagon model.	Trust, informal power, are areas which has received less attention in this report in comparison with Pentagon model.
(Schuh *et al.*, 2017)	The report of Acatech corporate structure is equivalent to structure in Pentagon but have differences	In this report technology is under the list of corporate structure and resources as a sub dimension encompass the technology	In this report culture is a sub-dimension of corporate structure and do not possess an independent dimension. This subdimension covers willingness to change and social collaboration	Some dimensions of interaction such as communication in Pentagon model here are in corporate structure	This dimension in Acatech report to some degree is inside culture with the title of social collaboration
(Anderson and William, 2018)	In Anderson and William report culture and organization are one dimension. This dimension focus on talent management, and organizational design in the path of digital transformation. Roles and responsibilities are uncovered dimension of the thesis.	In this report technology cover different and various criteria and its purpose is in fulfilling customer expectations and with efficient data management.	This dimension includes culture to understand digital transformation, leadership, and governance for better management of digital transformation, organizational design and talent management, and workforce	Cooperation as an important criterion can be considered in stakeholder management. Communication can be seen in different dimensions such as ecosystem management, stakeholder management, etc. Leadership is under the category of organization and culture but in Pentagon it is under the category of interaction.	Trust, informal power are areas which has received less attention in this report. Trust over customers declared as a subdimension of customer in this report. Other forms of trust are not explained. Roles and responsibilities can be assumed in the subcategory of workforce enablement (Anderson and William, 2018)

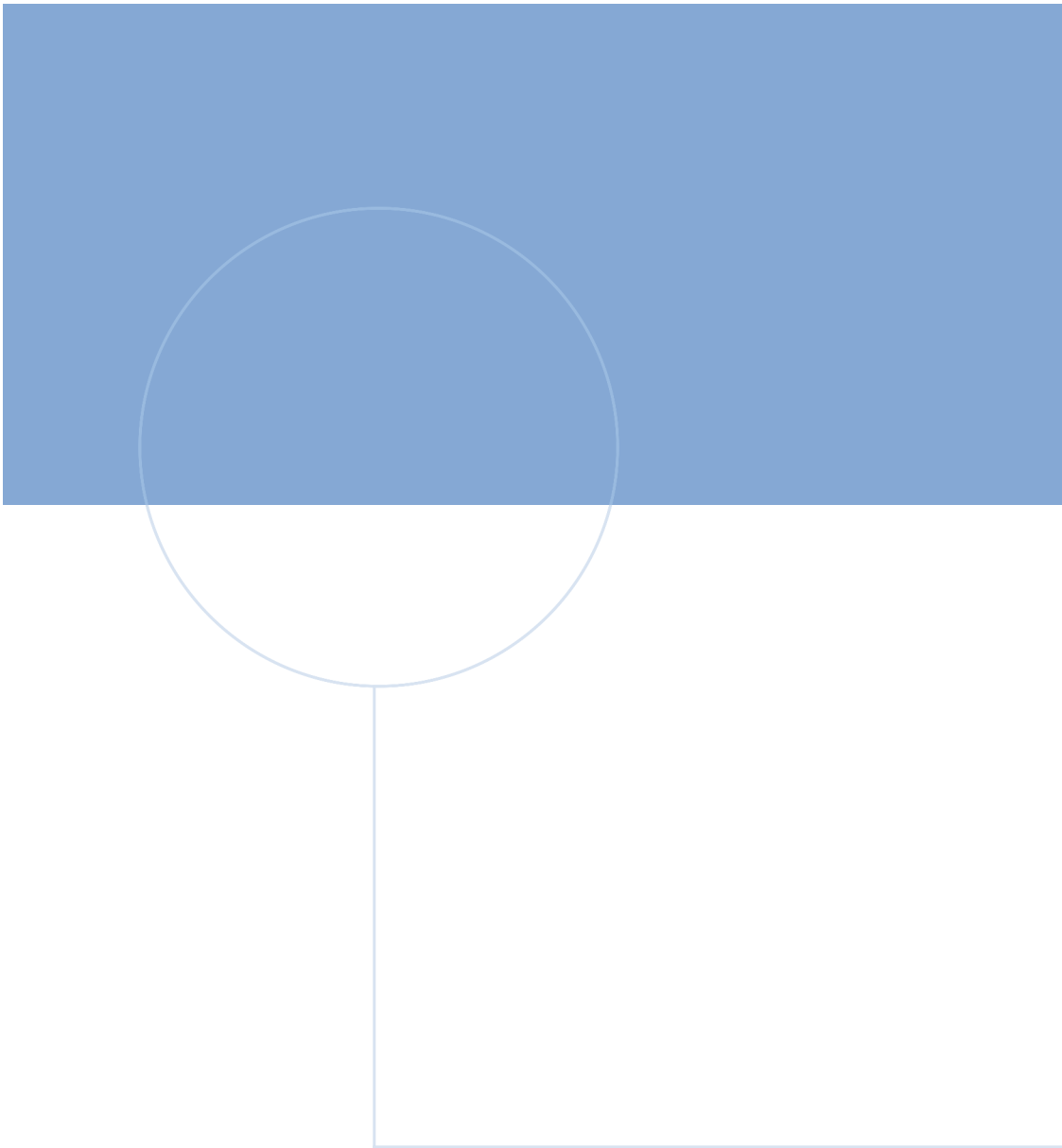
Table C1: Comparison of previous research with Pentagon criteria

Appendix D: Questionnaires for designing the ladders of technology

	Questions for Technology
	From the list which criteria has more weight in determining the digital maturity of design management in projects? Please rate from zero to one. The sum should not exceed 1. Application Analytics …… Security …. Delivery governance ……. Network …. Technology architecture …. * In this thesis, design management cover the process of designing process of construction and using tools for demonstrating building or projects before execution phase.
1	**Application** **Guideline:** Companies without a strategy of using similar applications to companies which have an integrated and uniform approach for choosing applications Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature
2	**Analytics** **Guideline:** Immature companies do decision making without using data. Then decision making with using reports and key performance indicators. The companies using advanced tools for decision making. Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature
3	**Security** **Guideline:** There are different strategies toward security from companies witout specific strategy to companies with proactive strategy toward security Please determine the ladder based on the effective features (characteristics)

	Questions for Technology
	Immature Beginner Defined Integrated Mature
4	**Delivery governance** **Guideline:** The company does not have governance or any policy for technology deployment against companies which have policies for deployment of technologies. Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature
5	**Technology architecture** **Guideline:** The companies with lack of readiness for technology change, integration to companies with a high degree of change and integration with other companies Please determine the ladder based on the effective features (characteristics) Immature Beginner Defined Integrated Mature

Table D1: Sample questionnaire for Technology



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