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Defining Benefits of Digitalisation in the Mining and Metals Industry

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Companies are currently on their way towards digital transformation or recognising the need for it. The thesis focused on the identifying and describing the benefits of digitalisation for the Metals and mining industry customers. Since the technologies are developing fast, there is a need to explore and demonstrate how these technologies can benefit the customers.

The study followed the applied action research approach. The research design consisted of five steps and the data was collected in three rounds. The first round was gathered for the current state analysis by analyzing internal documents, and conducting meetings and workshops. The second round included internal meetings, interviews and workshops, and was applied for the Proposal building. The third round contained the group interview for validation of the initial proposal.

The current state analysis investigated the company´s existing digital projects in the Metals and mining industry, and also used the Paper and pulp industry as the benchmark of digitalisation. The findings from the current state analysis guided the literature and best practice search that resulted in building the theoretical framework. Both inputs, from the current state analysis and existing knowledge, helped the proposal building in the next stage.

The proposal was developed in five steps. First, there were discussed the visions of potential digital solutions, tools and benefits in the Metals and mining industry. Second, the competitor's vision about digital solutions, tools and benefits were gathered and analyzed. Third, the role or digital twin in sustainability was revised. Fourth, the competitor's analysis of digital twin features was accomplished, together with other digital solutions among 25 leading technology organisations. Fifth, the actual initial proposal was formulated based on these inputs.

As the outcome, the thesis demonstrated that the main benefits of digitalisation relate to efficiency increase, reduction of operational costs, data storage and analysis. Indeed, there are many other benefits of digitalisation, such as better manufacturing processes, faster delivery of services and products, short reaction time to client's feedback, lower production costs, new client acquisition channels, improved innovation processes, but they take a secondary role compared to the identified three main benefits.

Keywords	Digitalisation, Digital twins, Big Data, Industry 4.0, Artificial Intelligence, Internet of Things, Virtual Reality

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Glossary

Digitalisation	The use of digital technologies and data to create value, revenue, improve business, transform business processes and create the environment for digital business models.
IoT	Internet of Things. Object-relational mapping. The set of rules for mapping objects in a programming language to records in a relational database, and vice versa. It is a network of the connected objects in the Internet that is able to collect and exchange data.
AI	Artificial Intelligence. Database management system. Software for maintaining, querying and updating data and metadata in a database.
KRTI 4.0™	Pöyry's, Nokia's and Infosys's operational excellence AI platform that provides real-time knowledge in predictive and prescriptive analytics on the most cost-effective options with acceptable risk level. It is an artificial intelligence application for maintenance optimisation.
Digital Twin	A virtual model, replica, of a product, process or service which enables to build, test and apply different versions in the virtual environment.
VR	Virtual Reality. The use of computer technology to create a simulated environment.
AR	Augmented Reality. The use of technology to add to the reality different objects.
VR Designer™	Virtual Reality Site Designer. A unique interactive Virtual Reality tool for plant's design, operation and maintenance. It is an application to illustrate content created by the

	combination of laser scanning, aerial photogrammetry and 3D engineering model.
AFRY Smart Site™	ARFY's framework, digital platform for helping industries to leverage Industry 4.0 principles to maximize the benefits of digitalisation.
OPEX	Operating expense, operating expenditure
CAPEX	Capital expense, capital expenditure
Industry 4.0	The fourth industrial revolution that utilizes smart technologies and digitalisation.
Big Data	Large diverse set of information, that comes from multiple sources, which is used for predictive analytics and advanced analytics and other global analytical processes.
ET-OT-IT	Engineering Technology, Operational Technology, Information Technology. Usually collaboration and analysis of these three sources of data create a Single Source of Truth.
RAMS	Reliability, Availability, Maintainability, Safety
SSOT	Single Source of Truth
ERP	Enterprise Resource Planning

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1 Introduction

Digitalisation is one of the megatrends in the 2020-s. However, what does it mean "digital", and why is it so transformational? In simple words, going digital means to convert the data of an enterprise into a digital format in order to improve business operations. But it means more, namely "a utilization of digital technologies in order to change a business model and deliver more revenue and value creation opportunities". (Gartner 2019.) In other words, digitalisation is currently gaining ground as it enables enterprises to revise their strategic approaches and work methods in order to achieve greater benefits and value by implementing new digital technologies.

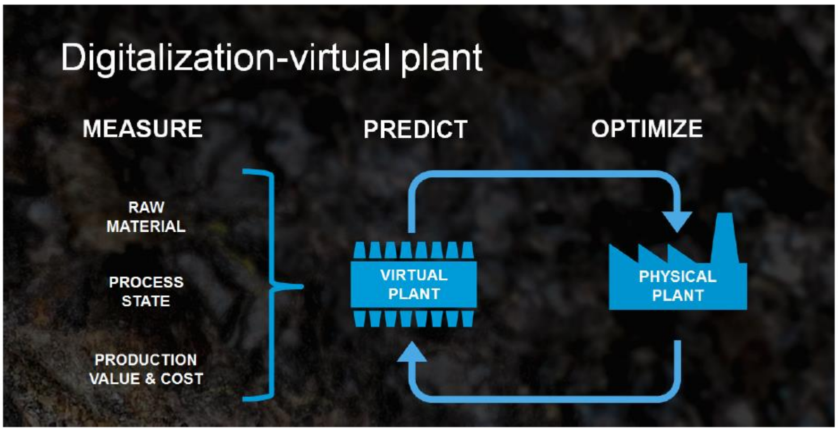

Figure 1. Digitalisation in the industry: vision of a virtual plant (Ghosh 2017: p.43).

Figure 1 shows one vision of digitalisation for the industry. It implies that the main benefits of digitalization are measuring, predicting and optimizing. This is absolutely true in essence. The real challenge, however, is how to convince the customers that a digitalised plant will help them to improve processes, value and cost.

There is multiple convincing numerical evidence gathered on a global scale using various analytical tools. For example, Figure 2 illustrates the ongoing industrial revolution globally and the forecast for the next several years. European market increases the use of industrial revolution tools equally every year. The estimate reflects the expected improvement by 2026 comparing to 2020.

As seen from Figure 2, the use of digital tools is expected to double over 6 coming years, from 2020 till 2026. It makes digitalisation a priority topic for companies.

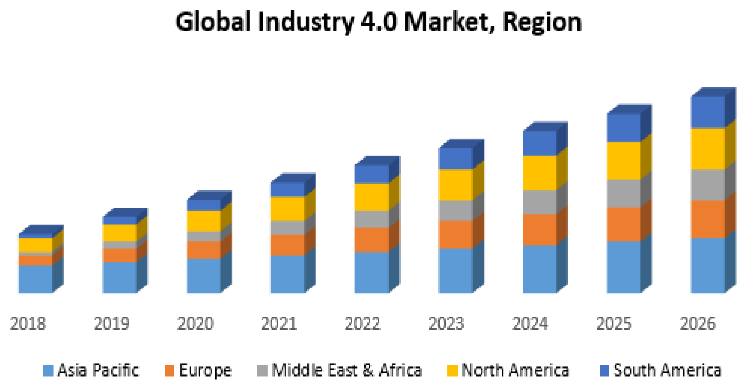

Figure 2. Global Industry 4.0 market by regions (Maximize Market Research 2019).

Furthermore, Figure 3 shows the market scenario for the years 2017-2023 concerning global Industry 4.0 market.

Figure 3. Global Industry 4.0 Market Size 2017-2023 (IoT Analytics 2017).

As seen in Figure 3, the global industry market size will more than double by year 2023, from the current $119B up to the estimated $310B. Industry 4.0 technologies will seem to influence the growth almost exponentially, as the overall market for Industry 4.0 to global spending is based on 6 connected industry blocks – hardware, cloud platform and analytics, connectivity, applications, cybersecurity, system integration.

All these facts point to the critical role of digitalisation for the industry in the very near future. Yet, industries and companies need to make a decision to invest into digital. Massive investment is needed for digitalisation, as well as there are various risks related to the untrodden path to digitalization. These factors at the moment are often overweighting the important evidence in favour of digitalisation. As a result, *industrial customers have a need to recognize the benefits of digitalisation more clearly.* This thesis makes an effort of the road to reveal and define the benefits of digitalisation to industrial customers.

1.1 Business Context

The case organisation of this thesis is AFRY, an international consulting and engineering company that delivers smart solutions globally across the energy, industry and infrastructure sectors. The company's ambition is to become one of the most digitally advanced consulting and engineering companies, enabled by #AFRYDigital solutions. Pioneered by leading industry experts, #AFRYDigital helps its clients to take advantage of Industry 4.0, Big Data and the Internet of Things (IoT), as well as the Automation of Engineering in order to increase their competitive advantage.

Figure 4 below represents the use of Industry 4.0 concepts in the survey done in 2015 versus 2020 years, gathered by Infosys and RWTH Aachen University.

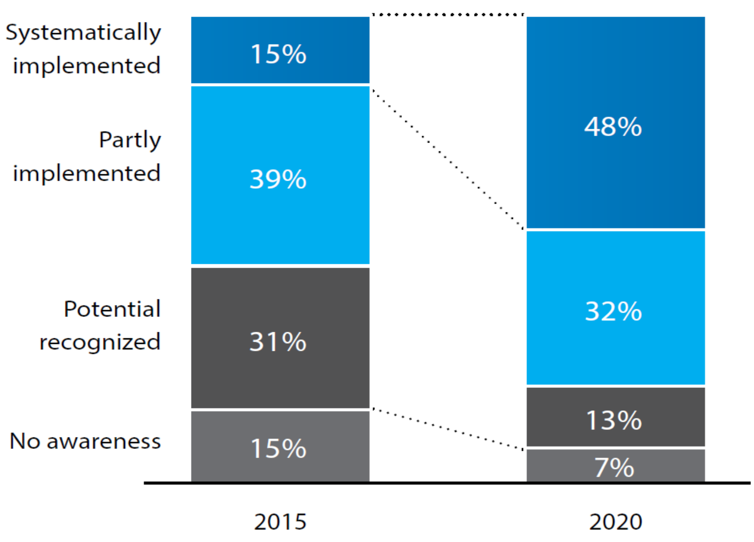

Figure 4. The ongoing revolution 4.0 (Infosys 2015: Smart Site concept 2019, slide 9).

As seen from Figure 4, vast majority (85%) of the companies are aware of the high potential in implementing Industry 4.0 concepts. However, currently only 15% of the companies have started to systematically implement Industry 4.0. According to AFRY, 48% of the companies want to implement Industry 4.0 solutions systematically by the end of 2020. It also means that the rest of the customers' needs support to recognize the benefits of digitalisation.

The department that commissioned this thesis is Industry Business Group Finland (IBG Finland), Process Industries division. This division is searching and developing diverse solutions in the Pulp and paper, Forest, Chemical industries, as well as Mining and metals, Food and beverages, and Biobased solutions. Also, Smart Site platform was created in this division, and hence the department is struggling in forming unique selling points of digital products and services for the process industries.

1.2 Business Challenge, Objective and Outcome

Many organisations in the Metals & mining industry are currently on their way to developing digitalisation, or at the stage of recognizing the need for it, and identifying the level of its attractiveness for the clients.

Since technologies are created constantly, there is a necessity to find out whether these technologies are really in high need, and whether they are valuable for the customers. AFRY´s customers are no exception, and they need to scrutinize, identify and recognize the true needs and benefits of digitalisation for their businesses, before they can make any decisions to invest into this new technology. Any new technology should create value for the customer, because without a proper task, it is just a technology. Thus, the goal for AFRY is to ensure benefits of digital solutions for the customers, and prove and demonstrate them accordingly to the customers, as the existing and potential benefits are many, and customers need help to recognize and make good sense of them.

The objective of the study is *to identify and describe concrete benefits of digitalisation for the Industry customers in the Metals and mining industry (possible via AFRY Smart Site).* One of the steps will be to clearly understand the digital solutions that would benefit the industry customers, and the outputs from these digital solutions. The scope of the thesis will cover mostly Smart Site tools (and within this toolbox platform Digital Twin as the prerogative tool).

The outcome of the study is the identification and description of the benefits of digitalisation for the Metals and mining industry.

1.3 Thesis Outline

The scope of the thesis is limited to the Process Industries in Scandinavian market, which includes the Pulp and paper (used as a benchmark) and the Metals and mining segments mostly. The thesis applies to the identifying and describing concrete benefits of digitalisation for the Industry customers in the Metals and mining industry (AFRY Smart Site). The scope of the thesis also will cover mostly Smart Site tools (and within this toolbox platform Digital Twin as the privilege tool).

This thesis is written in seven sections. The first section introduces the case company and its business challenges. Then the next section continues to setting the objective and presenting the intended outcome, as well as describing the research design. The third section is the current state analysis, and the fourth section focuses searching for the relevant existing knowledge and creating the conceptual framework. The fifth section focuses on the development of the initial proposal for the company. The last two sections contain the validation of the initial proposal and the building of the final proposal.

The thesis uses an Applied Action research approach and qualitative research methods, which are aimed on improving the knowledge concerning a certain problem. Process Industries clients are willing to identify the benefits of digitalisation more accurately. Thus, this thesis focuses on finding and defining the benefits of digitalisation to industrial clients.

2 Method and Material

This section describes the research approach and the materials used in this thesis. Firstly, it provides an overview of the research method that was selected for the thesis work. Then, it presents a research design and data collection that were used for this work.

2.1 Research Approach

According to Krishnaswamy (2010), research is a process of searching for facts that answer to questions and solve problems. Generally, research is classified as descriptive or analytical, applied or fundamental, conceptual or empirical (Kothari 2004: 2-4). *Descriptive* research means that the researcher does not have any control over the variable, and the research contains only the description of the facts at present. While during *analytical* research, the investigator uses and analyses already available facts to produce a critical assessment. *Applied* research aims at creating a solution of a problem, while *fundamental* research is aimed at improvement of scientific theory and fundamental knowledge. *Conceptual* research is aimed at developing new concepts and ideas. On the opposite, *empirical* research relies on observing or experience only. In this type of research, it is significant to first gather the data and facts and create an objective (hypothesis), and then to prove or disprove it.

There are two basic methods of data collection in research – qualitative and quantitative methods. Referring to Kothari (2004), *qualitative* research relates to subjective evaluation of attitudes, thoughts and behavior. The main goal of qualitative research is to describe and comprehend a problem and give it a reasonable interpretation (Kananen 2013: 26-40). Qualitative research is usually applied for not well-known phenomena or different innovations, based on non-numerical data that is difficult to measure. The methods for qualitative research can vary, but mostly used are interviews, workshops, observations, textual documents, presentations and meetings. *Quantitative* approach, unlike qualitative, requires gathering numerical data and applying diverse statistical and mathematical methods of analysis. The results of this research are generally numbers that can be utilized for drawing statistically valid conclusions. Sometimes, it is important to apply both qualitative and quantitative approaches in the research, which is called a *mixed* approach.

This study utilizes applied research approach, because the goal of it is to solve a certain problem and find an answer to concrete questions. The research approach includes the analysis based on observing, exploring and analyzing the present situation concerning the study's problem. Furthermore, Action research – and more specifically, Applied action research (Kananen 2013: 20-23) – is selected as the type of research approach due to the fact that the study aims to improve the knowledge about a certain problem and does not have the goal to implement this knowledge.

Therefore, this study uses an Applied Action research approach and mostly uses qualitative research methods. However, the study also illustrates some important facts with numbers and calculations, i.e. it also utilizes some elements of numerical calculations.

2.2 Research Design

This study follows the Applied action research approach. As illustrated in Figure 5, the research design contains five phases. The first phase is setting the objective. The second phase is the current state analysis, according to the collected internal data (internal documents and interview). The current state analysis focuses on exploring the existing solutions in the Pulp and paper industry which is used as a benchmark for the Metals and mining industry. These are the solutions and ideas that already exist. It also presents the analysis of existing visions for future solutions in the Metals and mining industry. The current state analysis identifies the existing benefits and solutions for the Pulp and paper industry.

Next, in the third phase, based on the result of the current state analysis, the study focused on exploring the literature and best practice related to digitalisation in the Metals and mining industry.

Figure 5 below presents the research design for this study.

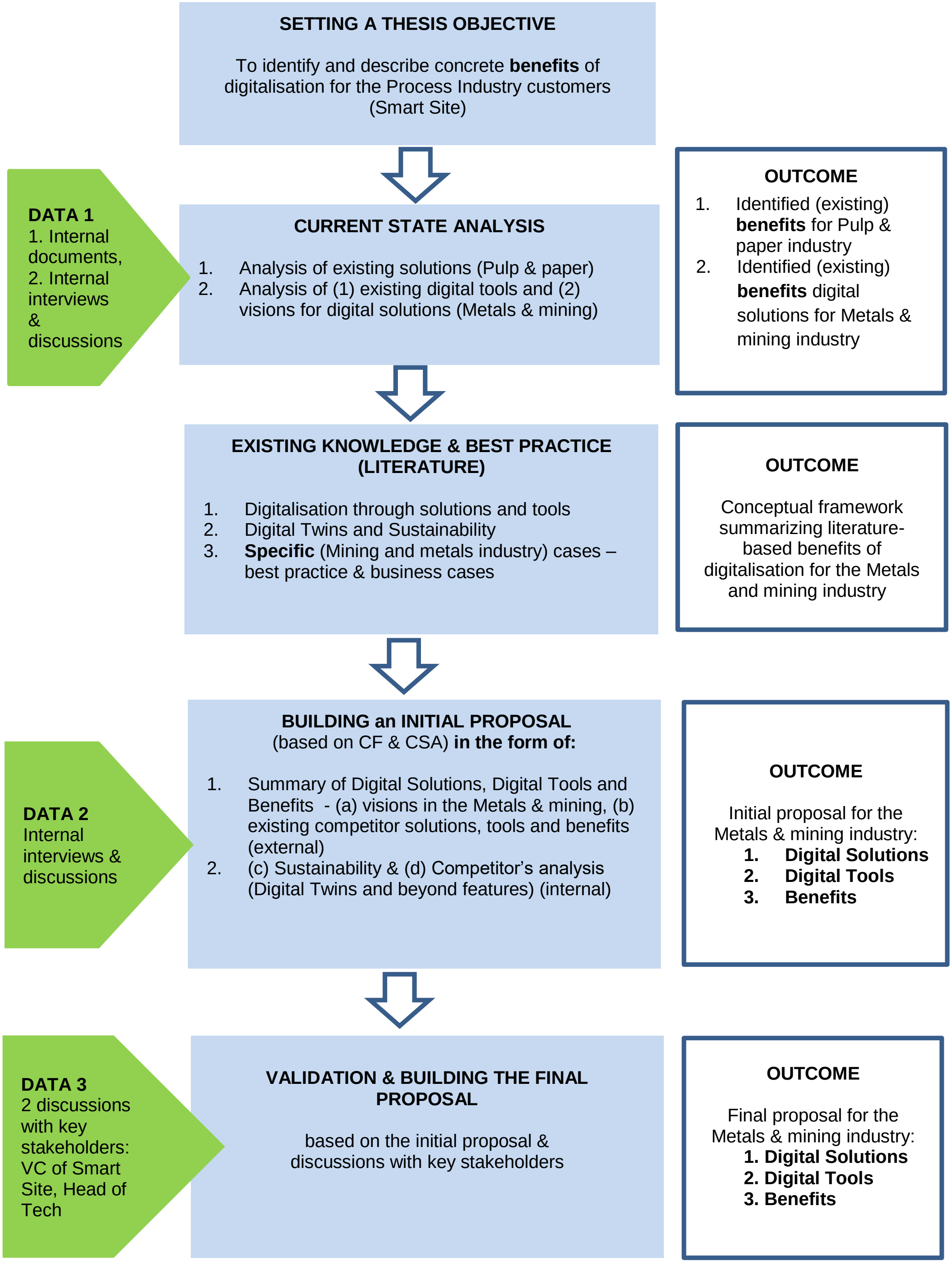

Figure 5. Research design of this study.

As seen from Figure 5, the next phase in the research design is the initial proposal building. In this phase, the proposal was build based on internal interviews and discussions, as well as the results from current state analysis and conceptual framework (from the fourth phase). The final phase focuses on the validation of the initial proposal and the building the final proposal for the company.

2.3 Data Collection and Analysis

This study draws from a variety of data sources, and the data was collected in three data collection rounds. Table 1 shows details of Data collections 1-3 used in this study.

Table 1. Details of Data collections 1-3 used in this study.

	Participants / role	**Data type**	**Topic, description**	**Date, length**	**Documented as**
	Data 1, for the Current state analysis (Section 3 or 4)				
1	Respondent 1: Internal experts: Vice President Process Industry Division Finland; Head of Asset Management, Thermal and Renewable Energy; Digital Leader, Industry 4.0;	Face-to-face meeting	Smart Site introduction and detailed technical approach, Smart Site solutions, Virtual Reality, Virtual Site Designer, Krti 4.0, Cyber security	Decembe r. 17 2019, 7 hours	Field notes, presentation slides
2	Respondent 2: Virtual Site Designer creator Technology Manager	Workshop	Virtual reality workshop and the use of glasses (3D scan laser)	Decembe r. 17 2019, 1 hour	Presentation slides
3	Respondent 3: Metals and mining department experts Head of Competence Line, Mining and Metals; Process Manager Mining and Metals	Workshop	Metals and mining industry overview and the actual workshop	January. 22 2020, 2 hours	Field notes, presentation slides
4	Respondent 4: Vice President, Process Industry Division Finland	Face-to-face meeting	Cyber security	January. 22 2020, 1 hour	Field notes, presentation slides
	Data 2, for Proposal building (Section 5)				
5	Respondent 5: Vice President, Process Industries	Skype meeting	Digital twin insights	June. 18, 2020, 1 hour	Field notes
6	Respondent 6: Sustainable Director, Process Engineering	Interview	Sustainability in Mining and metal sector	May. 25 2020, 1 hour	Field notes

7	Respondent 7: Creator of the tool, IT Global department, Program Manager Infosys	Workshop	EDM Sandbox, connection to Digital Twin	June. 24 2020, 30 minutes	Field notes, presentation slides
8	Respondent 8: Vice President Process Industry Division Finland	Skype meeting	Competitor's analysis	September. 8 2020, 30 min	Field notes
9	Respondent 9: Vice President Process Industry Division Finland	Skype meeting	Competitor's analysis insights, digital twin	September. 18 2020, 1 hour	Field notes
	Data 3, from Validation (Section 6)				
10	Respondent 10: Vice President Process Industry Division Finland	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 10 2020, 1 hour	Field notes
11	Respondent 11: Subconsultant Process Industries Division	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 10 2020, 1 hour	Field notes
12	Respondent 12: Sustainable Director of Process Engineering	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 19 2020, 1 hour	Field notes
13	Respondent 13: Vice president of Technology and Smart Solutions	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 19 2020, 1 hour	Field notes
14	Respondent 14: Director of Smart Site	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 19 2020, 1 hour	Field notes
15	Respondent 15: Director in Chemicals and Biorefining, and Metals and Mining Technology	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 19 2020, 1 hour	Field notes
16	Respondent 16: Technology Specialist in Metals and Mining	Group interview/ Final presentation	Validation, evaluation of the Proposal	November. 19 2020, 1 hour	Field notes

As seen from Table 1, Data 1 was gathered and analyzed in the current state analysis phase. The primary data consisted of personal interviews with internal stakeholders and workshops. The secondary data included internal data and documents, as well as public data and industry reports.

In the second round, Data 2 was collected by interviewing the key stakeholders to gather suggestions from the case unit for developing the proposal. This data included workshops, online meetings and interview.

In the third round, Data 3 was collected when conducting validation of the initial proposal. Data 3 included feedback for the proposal from the case company and the unit.

The interviews were conducted as semi-structured, face-to-face interviews, held on the company premises, with questions created in advance. The interviews were recorded and the field notes taken. The questionnaire for the interview with the Respondent 6 can be found in Appendix 2.

The textual data was analyzed using Thematic/ content analysis.

Table 2. Internal documents used in the current state analysis, Data 1.

	Name of the document	**Number of pages/other content**	**Description**
1	Smart Site Introduction internal document	28 pages	Overview of the digital platform and innovation process in the company
2	Smart Site Detailed Training internal document	58 pages	Innovative processes and further information about the digital platform
3	KRTI 4.0 and RAMS internal document	76 pages	Document about reliability, availability, maintainability and safety analysis framework
4	Digital Twin Technical Proposal internal document	19 pages	Specific engineering information about digital twin
5	Digitalisation at Kemi Mine Outokumpu internal document	7 pages	Client’s case study
6	Services for the Mining and Metal Industry internal document	9 pages	Diverse facilities for the metals and mining industry
7	Virtual Site Designer internal document	9 pages	Technical information about AFRY Smart Site tool
8	Virtual Site Designer as a part of Digital Twin internal document	8 pages	Technical information about AFRY Smart Site tool

9	Smart Site concept 2019	31 pages	Concept development
10	EDM Sandbox	21 pages	Technical data about the Sandbox Engineering Environment
11	Smart Site Integrated Engineering	52 pages	Facilitating to establish a Smart Site based foundation for a case client
12	Smart Site Sales presentation	38 pages	Detained information about the smart platform including case examples
13	Kappa number prediction and digester optimisation	11 pages	Cooking processes and kappa number explanation

As seen from Table 2, this study also analyzed a number of internal documents. The main documents included Smart Site presentations and digital twin technical proposals. The documents were analyzed for Data collection 1 round, the current state analysis, to get a clear understanding of the existing nowadays situation in the company concerning digitalisation, innovation technologies, digital products and their current benefits. Data 1 consisted of the primary data, including interviews and workshops with internal experts and interviewees; and secondary data, such as internal documentation and presentations on the topic of the study. Data 1 allowed to collect and analyze the current state of digitalisation in the case company, and define the gaps for the further proposal building.

The biggest part of data was analyzed for the current state analysis, to establish the current state of digital solutions in the company. The findings from the current state analysis are discussed in Section 3 below.

3 Current State Analysis of the Company´s Existing Digital Solutions and Their Benefits

This section describes and analyzes the current state of the existing digital solutions in the Pulp and paper industry. Then, it is followed by the analysis of visions for various existing digital solutions in the Mining and metals industry, and the ideas that already exist. The outcome of the current state analysis is the identified existing benefits for both the Pulp and paper (as a benchmark) and the Mining and metals industries.

3.1 Overview of the Current State Analysis

This current state analysis starts with the description and analysis of the present situation in the Pulp and paper industry solutions in the company concerning digitalisation and available digital solutions. The current state analysis is conducted the following way.

First, it contains an overview of digitalisation and the digital solutions provided by AFRY. This part gives the definition to the term “digitalisation” and describes how digital applications are utilized by the company in order to improve the daily business operations in the company projects. It also describes AFRY Smart Site and digital tools and the basic benefits for the enterprises from applying these tools.

Second, current state analysis explores and analyzes the digital solutions in the Pulp and paper industry. This part includes two elements. One analyzes the existing benefits of digitalisation as viewed by the case company, and another shows the concrete examples of digital benefits in the Pulp and paper industry. These examples consider different tools, for instance, digital twin tool, and virtual reality. This part ends with the summary of digitalisation benefits evident from the Pulp and paper industry.

Third, there is an analysis of digital solutions in the Mining and metals industry. This part includes 5 elements. One focuses on the current situation and context in the mining sector in Finland. Another explains the potential digital products in the Mining and metals sector that the clients might benefit from – these are the current visions. This part includes the overview of KRTI 4.0 analysis and digital twin. It also investigates the examples of digital solutions in the Mining and metals sector to prove the advantages of digitalisation. Two examples from mining sector illustrate the digital tools utilization.

The current state analysis ends with the summary of AFRY's current digital solutions in the Metals and mining industry, visions of digital solutions in the Metals and mining industry, competitors' visions analysis (benefits in the Metals and mining industry), summary of the key benefits findings in the Metals and mining industry, compared to the summary of the key benefits findings in the Pulp and paper industry. Moreover, the final part of the current state analysis shows the missing points that cause the main problem of the study – to define the benefits of digitalisation in the Metals and mining industry.

To reasonably limit the scope of the analyzed projects and products, this study covers only the most advanced digitalisation applications shown in Table 3 below. The study will focus on the tools and solutions that are offered in the Scandinavian market, and especially in Finland. Since the chosen industries of this study are Metals and mining, while Pulp and paper is a benchmarking industry, only the solutions used in these industries will be considered.

3.2 AFRY Smart Site and Existing Digitalisation Solutions: Overview

AFRY's ambition is to become the first-choice digital transformational partner for the Nordic clients. The company sees digitalisation as the process of using digital technologies in order to decrease costs and to change the core business model by means of creating new sources of revenue. In addition, the company provides the "smart solutions" – future technologies integration into the modern life. One of such future scenarios is the digitalisation with AFRY Smart Site™.

AFRY has developed a unique toolbox for developing and supporting digital solutions. AFRY Smart Site is the Industry 4.0 solution toolbox that enhances industrial plant processes and operations in terms of efficiency, safety and quality, sustainability by utilizing digitalisation. This service uses the latest technologies, such as Big Data, AI, machine learning, virtual reality, augmented reality, digital twins. AFRY Smart Site helps the company to leverage the principles of the fourth Industrial revolution and extend the services for industrial operations in order to maximize the benefits of digitalisation.

The Smart Site gathers data from diverse sources ET-IT-OT (Engineering Technology-Information Technology-Operation Technology) and combines into a single source of truth in one place, that can be then used by means of different applications. The key benefits of the Smart Site are the maintenance efficiency, performance efficiency and energy efficiency. The examples of possible future outcomes from using AFRY Smart Site are dark factories, real-time decisions, predictive operations and sustainable production.

Figure 6 below illustrates the contents of AFRY Smart Site and its tools.

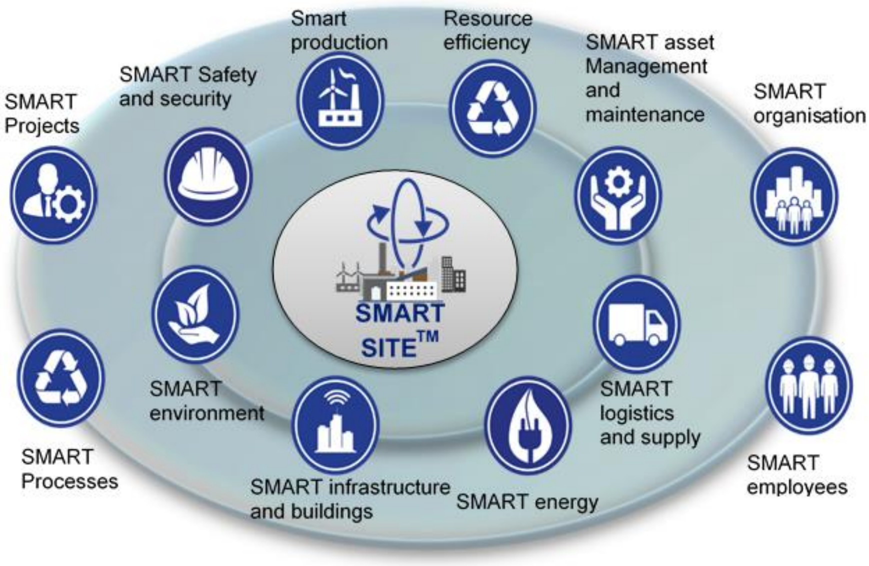

Figure 6. AFRY Smart Site (Smart Site Introduction, slide 7).

As seen from Figure 6, the case organisation provides the full cover digital solutions for the clients through introducing AFRY Smart Site platform.

> *"Digitalisation is a part of the solution… but it is not about technology, it is about the values we create." (AFRY, afry.com 2020)*

As seen from Figure 6, AFRY Smart Site is a toolbox for industrial plants digital solutions using Industry 4.0 technologies and associated principles to maximize the benefits of digitalisation. For example, with AFRY Smart Site services, owners of industrial plants can effectively aggregate smart data from many different systems to optimize their entire site. By integrating the latest technologies, AFRY Smart Site increases plant efficiency and safety, while decreasing energy consumption and the use of raw materials.

Table 3 below illustrates the platform's digital applications and solutions.

Table 3. AFRY Smart Site Digital Applications and Solutions

Smart Site Digital Applications and Solutions	
Engineering Solutions and Analytics	AFRY MES (Pulse)
	KRTI 4.0 AI Framework
	Tall-oil optimization
Consulting Solutions	Smart Site (full scope)
	Industry 4.0 Maturity Assessment
	Cybersecurity
Augmented and Virtual Reality	Holobuilder
	Digital Twin
	Virtual Site Designer
	Virtual Site

As seen in Table 3, the case organisation offers diverse options for the enterprises to improve their digital state. The applications represented in Table 3 will let the customers utilize digital technologies and leverage Industry's 4.0 principles to create value, revenue, benefits. Let us consider each application separately in details.

First, AFRY Virtual Site is a professional solution to create, store, maintain and access technical data of an industrial plant. Instant access to the current information brings benefits to the client and improves competitive edge. Virtual Site contains 3D model, digital documentation and a database. The result from this cooperation creates a plant's information management system between ET-OT-IT.

Second, AFRY MES is the abbreviation from Manufacturing Execution System, a platform that connects systems and allows to respond to the demands of competitive industries that aim at Industry 4.0. In other words, this platform allows to improve production efficiency in an easy and competitive way. AFRY MES solution can be utilized in most kinds of industries enhancing the experience in integration of processes, systems and equipment. Part of the MES platform is AFRY Pulse, a production support system, which enables to boost availability of the industrial processes by means of smart functions. These functions include inspections rounds, fault reports, visual key figures, standardized dashboards and reports, which help to promote digital solutions for more sustainable industrial activities.

Third, KRTI 4.0™ is an artificial intelligence framework that enables to advance and manage the organization's assets by providing value, leadership and assurance through lifecycle management approach, risk-based, information driven, planning and decision-making process, increased employee awareness, and enables processes that connect performance and objectives. Krti 4.0 combines in an innovative way a model-based (RAMS, Reliability, Availability, Maintainability, Safety) and data-driven (AI) models together. This is an AI platform for operational excellence. The platform utilizes predictive and prescriptive analytics with optimal risk level.

Fourth, Tall-oil optimisation is a solution that brings real-time visibility and optimizes the tall oil production by analyzing real-time data leveraging process expertise. This solution allows to foresee and influence on the changes in processes. By collecting data and supplementing additional needed measurements process data can be turned to knowledge using non-linear modelling. That knowledge brings visibility to process and guides the operation. Additionally, by testing operational parameters without any incidents, the solution helps in operational parameters setting. The major output values - production rate and product density indicating product quality - are estimated based on the new mathematical models. Simulation either from database or with online data gives predictions to operators of the direction of the current operation.

Fifth, Smart Site is a platform, application, that provides a single source of truth, establishes data architecture, enable data utilization, implement business processes harmonized and collaborated. This solution improves industrial plant operations and processes, by means of making them more efficient, safe and qualitative, and sustainable. AFRY Smart Site combines information from different sources ET-IT-OT (Engineering Technology-Information Technology-Operation Technology) and reveals a single source of truth, that can be then used by different applications.

Sixth, Industry 4.0 Maturity Assessment. It is a multi-dimensional framework that delivers a complete approach to develop digital transformation roadmap, which is aimed on improving key business outcomes towards achieving vision of future state. This consultation project is usually offered to existing mills or plants, i.e. for already running projects. In other words, this framework is targeted on boosting digitalisation to enhance efficiency and productivity of the enterprise.

Seventh, Cybersecurity. Nowadays industrial network with cyber physical systems is very special environment. It is essential to have expertise on both Operational Technology (OT) and Information Technology (IT) to be able to reach maximum level of Industrial Control System (ICS) security. AFRY provides a unique combination of knowledge to minimize the attack surface of any industrial site. AFRY brings in the customer business knowledge combined with understanding of OT networks and equipment.

Eighth, Holobuilder is a 360º capture of site reality (software license) cloud-based application, that is mostly applied in the construction sites. AFRY provides this solution to help engineers and builders to manage the real-world counterparts easily from everywhere in the virtual reality. AFRY buys license for using this software from the creator of this tool HoloBuilder.com, and then combining it with own production solutions.

Ninth, Digital Twin is a virtual model, replica, of a product, process or service which enables to build, test and utilize different versions in the virtual environment. One of the purposes to apply AFRY Digital Twin is to predict when the equipment or the physical product needs maintenance. Respectively, unexpected production downtime can be avoided, which saves costs and lets the production flow continue without interruptions. In modern design, a plant's simulation model is applied and called a Digital Twin. Adding process modelling as a part of the digital twin concept will help to achieve more accurate results, optimize processes and keep changes under control at different project stages.

Finally, Virtual Site Designer or Virtual Reality Site Designer is a unique interactive Virtual Reality tool for plant's design, operation and maintenance. This application helps to illustrate the content created by the combination of laser scanning, aerial photogrammetry and 3D engineering model.

Table 3 illustrated the tools and solutions that are utilized in the process industries: the Pulp and paper, Forest, Chemical, Mining and metals, Food and beverages, Biorefining.

The advances of the Paper and pulp industry are analyzed below.

3.3 Pulp and Paper Industry: Analysis of Existing Digital Solutions

Pulp and paper industry is one of the biggest industries in the world. For more than 50 years the case company has been successfully managing diverse projects in the pulp and paper industry. The company is the world leader in this field (ENR Engineering News-Record ranking 2016). AFRY has been involved in 90% of the world's biggest pulp mill designs. The most recent project concerns Finnish sawmill customer, which will become the most modern and efficient sawmill in the world, utilizing digital technologies.

Innovative fiber-based products are substituting plastics and creating new prospects. AFRY´s goal is to help to take advantage from these opportunities. The company's key competencies are paper mill technology, pulp mill technology, design and logistics, power plants and additional operations (buildings, infrastructure, water), recycled pulp, tissues and many other. For this end, the company provides consultancy and solutions through the whole value chain of the mill, helping to increase the return on investments on time, budget and exceed expectations.

3.3.1 Description of Existing Digital Solutions in the Pulp and Paper Industry

Despite the diversity of problems that occur in the paper and pulp mills, a certain approach can be recognized in most of the cases, which – in my opinion – enables a defined and straight way in value realization. Typically, AFRY applies a certain outline, which includes several steps, to achieve the solutions in the pulp and paper industry projects. The first step is *data extraction*, which enables to reach open connectivity and establish the architecture. Then, the second step is *data harmonization*, where the IT-OT-ET integration is done. The third step is *data visualization*, which allows to set real-time visibility. It is followed by the *data analysis*, which implies engineering analytics. Finally, the last step is *optimisation of operations* and further *continual improvement*. This approach is not officialized, but it is visible when analyzing the cases of digitalisation.

The case company also successfully utilizes *advanced control products and applications*, which include *platform solutions* (digester Kappa, tall oil optimisation, KRTI 4.0 AI, AFRY Pulse production optimisation – operational excellence dashboard), *plant data analytics* (simulations, machine learning, artificial intelligence), *cyber security*. These digital solutions allow to help the Pulp and paper industry customers in achieving their goals. For instance, *KRTI 4.0 AI framework* in comparison to competitors' AI platforms is focusing on enterprise learning to provide failure forecast in the mill, as well as concentrating firstly on critical data parts of the plant, and then gathering the whole picture.

3D plant models and virtual reality is also one of the existing solutions in the paper and pulp industry. These tools cover photogrammetric aerial photography and more accurate laser scanned model, which are then transformed into virtual reality resource. The solution contributes the plant's efficiency in maintenance purposes, pre-planning, and safety trainings. The virtual reality modelling and site designer benefit from improved maintenance engineering, hazardous scenario modelling and induction programs. Later all planned versions can be then placed into a real mill environment, to simplify the understanding of the actual environment overall. Generally, 3D plant model and VR do increase the effectiveness of the mill and use of it in the digital form and significantly improve safety issues. The most common way AFRY suggests to the pulp and paper client is the scan, gathering and analyzing the material and creating a content; The 3D glasses and the supporting virtual equipment can be purchased from the partner supplier. Figure 7 illustrates the virtual mill environment.

Figure 7. AFRY's demonstration virtual mill (internal document).

Also, AFRY provides *the assessment for existing mills*, or *pre-engineering* for new mills. AFRY sells not just the tools, but also the design based on the enterprise's data and plan for the digital twin.

IT- OT- ET integration needs to be done first as the core part of the digitalisation (foundation). The biggest mistake the client can do, is first to choose the tools. Then it turns out that the client needs the sources of information and data integration; and that causes problems in the future, - it should be done vice versa. The platform allows to get all data from one source. Smart Site converts data in a way the tools and applications can utilize. So, the first step naturally is always assessment (pre-engineering, basic engineering). The client needs value and short payback time. But the proof of concept will not lead to anything, - this is a long-term vision. The Smart Site platform has a value, but it is difficult to communicate it, mostly on ET (engineering) level. Usually the assessment lasts for 8-10 weeks, then the detailed planning is 8-10 weeks, and implementation is 6-24 months (depends from client wishes) and ET- OT- IT integration, to get and generate data(sometimes engineering data might be on paper in the old mills, which creates some obstacles to gather it fast).

The most recent projects concerning digitalisation and Smart Site in the Pulp and paper industry are the following: *pre-engineering digitalisation* of paper mill in Europe (2019-2020), *pre-engineering and basic engineering digitalisation* of a new pulp mill in South America (2019-2020), *Industry 4.0 maturity assessment* of existing paper mill in Europe (2019), *process improvement and MES/ERP implementation support* in North America (2018-2019), *Industry 4.0 pre-engineering* of new pulp mill in Europe (2018). Therefore, there is a wide variety of already existing solutions of digital applications in the pulp and paper sector.

The next sub-section will illustrate the examples of the successful utilization of digital tools.

3.3.2 Analysis of Existing Digital Solutions, Tools and Their Benefits in the Pulp and Paper Industry

This subsection analyzes the benefits of digitalisation on the example of three cases, where AFRY successfully utilized digital tools in order to solve customers' problems. The first example tells about tall oil optimisation in the pulp and paper sector. The second case shows an effective Kappa number prediction and digester optimization. Finally, the third case illustrates the application of 3D plant modelling and virtual reality in the mill in Scandinavia. The benefits are identified after each case.

Case 1.

Tall oil optimisation is one the examples in the pulp and paper sector. Tall oil is a liquid extracted from the wood during the kraft pulping process. Tall oil is usually utilized as a component of drilling fluids or adhesives, rubber, inks, paints, fuel. The demand for tall oil is increasing because of European Union's vision to get 10% of the transport fuel coming from renewable sources by the end of 2020.

Problem:

Case company X has suffered from inefficient production processes, which significantly impact overall yield, product quality and quantity. The case company had many challenges, such as lack of visibility to production data, no optimal process model for tall oil acidulation and production, high impurities content reducing the yield.

Solution:

AFRY has solved the problem that Case company X suffered from by utilizing the digital solutions in its project for the company (namely, by introducing risk assessment, AI, and data analysis application to the pulp mill).

As the outcome, AFRY's optimisation solution (digital) brought about the following improvements: (a) visibility to the processes for case company X; (b) it optimised the production process by analysing the data in the real time.

The client, Case company X has benefited from the following: 1.better visibility, 2.precise production forecast, 3.improved control of the material usage, 4.simulation option to evaluate scenarios, and finally 5.optimisation of the cleaning schedules. Table 4 below shows the benefits from the tall oil optimisation for the mill provided by AFRY.

Table 4. Benefits of tall oil optimisation in the paper mill.

Number	Benefits
1.	Better visibility
2.	Precise production forecast
3.	Improved control of the material usage
4.	Simulation option to evaluate scenarios
5.	Optimisation of cleaning schedules

Case 2.

The second example of digital solution in the paper and pulp industry in Kappa number prediction and digester optimisation. Kappa number is the most significant index for measuring the residual lignin in pulp. In the digester wood chips are treated with cooking liquors in order to remove lignin from the wood.

Problem:

Typical concerns for operation include the variation of digester output Kappa number caused by changing or raw material characteristics and conditions, such as wood chip moisture. The variation in Kappa number leads to lower pulp yield and higher production costs.

Solution:

AFRY provides the forecast in the Kappa number variation using predictive models from process data, as well as kraft pulping modelling utilising AI algorithms for overall process optimisation in the pulp mill. Better accuracy in Kappa number control yields uniform platform, maintains quality and stability in fibre line steps, saves chemical costs. The following Table 5 reflects the benefits from the Kappa number prediction solution.

Table 5. Benefits of Kappa number prediction and digester optimisation.

Benefits	**Solution Outcomes**
Kappa number prediction and control	Increased pulp yield
Reduction in digester blow kappa variations	Better control over variability
Improved quality consistency	Increased visibility
Automatic change control	Competitive advantage
Early detection of digester failures	Production costs reduction and increased sales

AFRY applied data analytics for the process optimisation operation efficiency, as this enables to save twice more over the investment with the payback time 6-12 months.

Case 3.

The third example is maintenance of forest industry company from 3D plant model and Virtual Reality.

Problem:

The company started to manufacture fully recyclable non-plastic consumer packaging boards, which does not have any harmful fluorochemicals or waxes. AFRY (at that time former Pöyry) was involved into implementation of this new product from the very beginning.

Solution:

The provided service consisted from engineering support, 3D modelling, laser scanning and aerial photogrammetry. The 3D model allowed to create digital data and intelligent information about the equipment and its connection to the whole site. Then the intelligence was gradually increased by laser scanning and new 3D models. The Table 6 below demonstrates the major benefits from utilizing AFRY's solutions.

Table 6. Benefits of 3D plant model and virtual reality.

Number	**Benefits**
1.	Preventive maintenance of the plant
2.	Development of operational safety functions
3.	Digital equipment information availability
4.	Maintenance of equipment

Therefore, Pulp and paper industry uses lots of different solution in the digital approach, that enhances efficiency, reduces operational and production costs, improves the company's overall processes.

Future Case "The dark factory".

This example illustrates the future solution for the factory dark utilizing the Smart Site. Figure 8 demonstrates the outcomes from the digital applications by a pulp and paper plant. By utilizing new technologies, an enterprise can keep the factory dark (without lights and lamps), due to fully automation processes, thus the energy is optimized accordingly.

The operations and maintenance are done in a predictive way by utilizing artificial intelligence tools. The production overall becomes more sustainable and cost-efficient with improved quality.

Operations efficiency in the paper plant includes the following parameters: connected factory, real-time planning and scheduling, productivity modelling, statistical quality control and production optimization. All these parameters can be applied or improved by means of digital solutions provided by AFRY Smart Site.

Maintenance efficiency can also be developed by monitoring the condition, applying the predictive maintenance tools, keeping maintenance planning and scheduling, and analyzing the root cause.

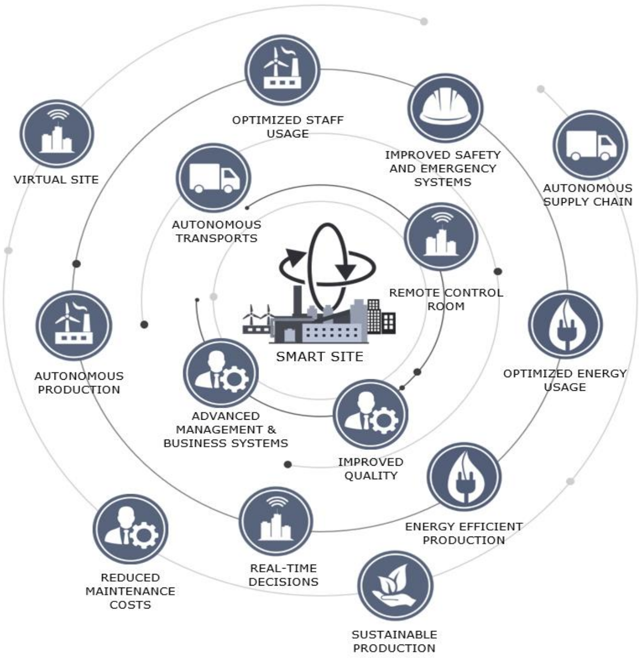

Figure 8. Smart Site future outcomes (Smart Site sales presentation, page 11).

Service efficiency has the following parameters: remote management and remote services, tracking and traceability, materials management of spare parts and service parts, service lifecycle management, and supply chain analytics. Digital improvement allows to keep service efficiency on a high level.

Information efficiency consists of the next parameters: intelligent dashboards, data quality framework, asset lifecycle information model (digital twin), machine-born data analytics, knowledge management and modelling.

Energy efficiency has the next parameters: energy management, recourse efficiency, asset sustainability index, safety performance management, regulatory standards and compliances.

Importantly, *process simulation and modelling* improve productivity and provides clients with added value. However, the technologies are innovative and expensive, thus the task of the study is to find a solution between the customer and the company. A simulation model can save thousands of tons of material, megawatts of energy and millions of euros in cost and lost income. Using a simulation model, the safety of a new process can be improved by focusing on the physical and chemical properties of the process. Indicative benefits of implementing the digitalisation, especially digital twin, are the conclusions of the current study.

Summing up, there are multiple already *existing* benefits of digital application and soon-to-be-utilized (dark factory case) in the pulp and paper sector. Based on the results from analysis of the internal documents and interviews, the major digital beneficial outcomes and improvements of five types of efficiency are: 1. operations efficiency, 2. maintenance efficiency, 3. service efficiency, 4. information efficiency and 5. energy efficiency. The next subsection will summarize the benefits of successful utilization of digitalization in this industry.

3.3.3 Summary of the Existing Benefits in the Pulp and Paper Industry

This subsection summarizes the benefits of digitalisation on the example of three implemented cases and one example of "dark factory". In these cases, AFRY successfully utilized digital solutions and tools in order to solve customers' problems. The first example analyzed the benefits of tall oil optimization; the second case demonstrated the benefits via an effective Kappa number prediction and digester optimisation; the third case illustrated the application of 3D plant modelling and virtual reality. The benefits of digitalisation in the pulp and paper industry are summarized and revised below.

According to the information gathered from the multiple rounds of internal interviews and internal materials (especially Smart Site internal documents), the digitalisation in the Pulp and paper operations can increase efficiency of the enterprise in the following directions: decision making, enhanced efficiency, safety and quality, and general profitability.

Table 7 sums up the digital solutions, tools and benefits from the 4 cases that were illustrated in the previous sub-section.

Table 7. Digital solutions, tools and benefits from the previous 4 cases.

	Digital solutions	Digital tools	Benefits
1	Tall oil optimisation	Risk assessment, AI, data analysis	• Better visibility

			• Precise production forecast • Improved control of the material use • Simulation options to evaluate scenarios • Optimisation of cleaning schedules
2	Kappa number variation forecast	Predictive model from process data	• Better control over variability • Reduction in digester blow Kappa variations
3	Kraft pulping modelling	AI algorithm	• Increased pulp yield • Increased visibility • Production costs reduction • Increased sales
4	Digital data creation	3D modelling	Digital equipment data availability
5	Increase of data intelligence	Laser scanning	Development of operational safety functions
6	Increase of data intelligence	Aerial photogrammetry	• Plant preventive maintenance • Equipment maintenance
7	Smart Site (full scope)	AI	• Sustainable production • Cost-effective production • Improved quality

Next, Table 8 sums up the main existing benefits in the Pulp and paper industry in AFRY nowadays.

Table 8. Summary of key findings (Benefits in the Pulp and paper industry).

	Benefits	**Including**
1	Collection and Control	• Data monitoring • Analysis and prediction of operation efficiency • Production optimisation
2	Interoperability	• Real-time planning and scheduling • Information efficiency (saving in total business expenditure) • “Single source of truth” (improved data utilisation)

		• Cost-effective maintenance planning
3	Visibility/ Real-time monitoring	• Real-time monitoring • Improved process control • Control over raw material use
4	Transparency/ Root cause analysis	• Tracking and traceability of data flows • Cybersecurity as a cyberattack solution • Intelligent dashboards • Machine-born data analytics • Productive online design reviews
5	Predictive Maintenance	• Simulation option provides scenarios for different production models • Maintenance efficiency (increase in equipment lifetime) • Impressive visualization of the plant design • Continuous internal quality monitoring
6	Autonomy	• Information visualization • Self-optimising (fully implemented autonomous production (long-term)) • Safe and high-quality environment training
7	Efficiency	• Performance efficiency • Maintenance efficiency • Information efficiency • Service efficiency • Energy efficiency and sustainability

Based on this summary, the following benefits of digitalization can be formulated for the customers of the Pulp and paper industry. First of all, better and faster decisions will let the company increase the visibility and real-time decision making. Better process predictions will improve the productivity. The applying of a digital twin will improve overall different production processes in the company.

Second, enhanced efficiency means that the enterprise will increase the level of the intelligent process automation, as well as highly efficient and optimized production. In addition, improved efficiency can create highly inter-connected systems and seamless interoperability, which benefit for the enterprises.

Third, digitalisation will bring visible improvements in safety and quality issues. From my point of view, considerable adoption of advanced technologies for the environment, health and safety management can enhance protection and increase the image of the company, that utilizes digital tools.

Fourth, autonomy implementation will increase safety and decrease environmental impact. In my opinion, in the long-term data visualization and self-optimisation will save investments and lower costs.

Fifth, data gathering, its further analysis and monitoring will let the company optimize production and improve process control.

Sixth, utilization of a “Single Source of Truth” will enhance the data utilization and, hence, create an efficient data for its further application.

Seventh, transparency will create a competitive advantage for the company. Also, this will ensure the protection form the cyber-attacks and thieves. Root-cause analysis will enhance the traceability of information flows and will leverage intelligent dashboards.

Therefore, the customers can benefit by increasing in overall profitability: digital leaders outperform their peers, innovate more easily, work more efficiently, and thus rise in operational agility.

Before proceeding to the next section, it is important to remember that the average lifetime of a pulp and paper plant is 50 years, and the costs are more oriented on operating expenses. Therefore, when the digital solution is utilized by a plant, it is in most cases a long-term relationship. Mine’s average lifetime is 15 years; the costs are more capital oriented. Thus, the digital tools’ utilization should be fast and easy, including promptly increasing learning curve and visible benefits and advantages.

3.4 Mining and Metals Industry: Analysis of Visions for Future Solutions

This section describes and analyzes *potential* (future) solutions and their benefits from the digital point of view in the mining and metal sector. Firstly, there is an overview of the current situation in the Metals and mining sector in Finland. Then, the section discusses the exiting and later potential digital solutions, and the examples on the real case companies. Also, the section considers the competitor’s digital solutions and the case example. The section reflects the visions of the potential digital products in the mining industry as well. Finally, it summarizes the existing and potential (future) digital benefits in the Mining and metals industry in AFRY.

3.4.1 Current State and Context of the Mining and Metal Industry in Finland

Finland is located on the Fennoscandian shield, which has a strong mineral potential. This area is still largely unexplored (MiningFinland 2020). The average lifetime of a mine in Finland is 15 years, yet it might expand up to 30 years. Comparing to the Pulp and paper industry, which is more OPEX oriented, Mining and metals industry is fully CAPEX oriented.

Figure 9 illustrates the map that shows the mineral deposits, mines and drilling sites in Finland. The white boxes reflect the active mines and the orange boxes reflect the current mine development projects in Finland.

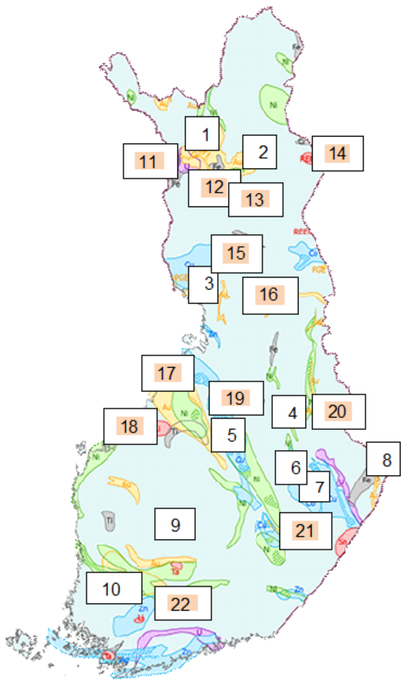

Figure 9. Mine ores in Finland 2020 (source: miningfinland.com).

As seen from Figure 9, Finland has a great potential as 11 mines are nowadays under construction. The ground contains base metals, diamonds, high tech metals, precious metals and other commodities. The main and additional commodities are represented in

Tables 9 and 10. Further on, Table 9 shows the acronyms and the explanation of different ore commodities.

Table 9 presents the active mines in Finland (number in the white box).

Table 9. Active mines in Finland (source : miningfinland.com).

Number	Mine's name	Main commodities	Other commodities
1	Suurikuusikko	Au	Ag
2	Kevitsa	Ni, Cu	Pd, Co, PGE, Au, Pt, Ru, Os, Ir, Rh
3	Kemi	Cr203	-
4	Sotkamon kaivos	Ni, Cu, Zn	Co, U, Mn, Ag, Mo, Pd
5	Pyhäsalmi	Zn, S, Cu	Ag, Au, Fe
6	Siilinjärvi	Phos, Apat	Cal, Mica
7	Kylylahti	Cu, Zn	Au, Ag, Ni, Co
8	Pampalo	Au	-
9	Orivesi	Au	-
10	Jokisivu	Au	-

Table 10 shows the list of the current mine development projects in Finland (numbers in the orange box).

Table 10. Current mine development projects in Finland (source: miningfinland.com).

Number	Mine's name	Main commodities
11	Kolari	Fe, Cu, Au
12	Pahtavaara	Au
13	Sakatti	Ni, Cu, PGM
14	Sokli	P, Fe (REE, Nb)
15	Suhanko	PGM, Ni, Cu, Au

16	Mustavaara	V, Fe, Ti
17	Laiva	Au
18	Kaustinen	Li, Ta
19	Otanmäki	V, Ti, Fe
20	Taivaljärvi	Ag, Au, Pb, Zn
21	Hautalampi	Au
22	Kaapelinkulma	Au

(source: miningfinland.com)

Tables 9 and 10 show the mine's name and location on the Finnish map (see Figure 10) and the main commodities that the mine possesses. According to the geological investigation, the mineral potential is very high, the amount of gold prospectivity is high as well. Base metals, such as nickel and copper, and precious metals, like gold and silver have a big part in the Finnish cluster, and together with outstanding infrastructure and possible future digital solutions Finland attracts more and more investments and clients into mine industry.

Table 11 below lists the names of the main commodities that are under exploration in the Finnish mines.

Table 11. Acronyms and their meaning in the mining and metal sector.

Acronym	Meaning	Acronym	Meaning	Acronym	Meaning
Au	aurum, gold	Ru	ruthenium	Mn	manganum, manganese
Ag	argentum, silver	Os	osmium	S	sulphur
Ni	nickel	Ir	iridium	Fe	ferrum, iron
Cu	cuprum, copper	Rh	rhodium	Phos	phosphophyllite
Pd	palladium	Cr203	chromium oxide powder	Apat	apatite
Co	cobalt	Zn	zinc	Cal	calcium

PGE	platinum group elements	U	uranium	Mica	mica group of sheet silicate (phyllosilicate) minerals
Pt	platinum	Mo	molybdenum	PGM	platinum group metals
P	phosphorus	Nb	niobium	Ti	titanium
REE	rare -earth elements	V	vanadium	Li	lithium
Ta	tantalum	Pb	plumbum, lead		

Moreover, in addition to the commodities themselves, another important component for the investment and development of the metal and mining industry is *the business and economic context.* In this sense, Finland makes a very attractive destination for CAPEX investments. Finland is ranked as politically and socially stable country with one of the lowest risk levels. The new entrant gets support from the mining cooperation group, which includes geological modelling and clarification, united exploration and measuring methods, environmental and geotechnical support. Consequently, the market is attractive, and an increasing number of technological innovations should attract the investors and new market entrants. Such an environment should enhance the demand for digital development and create a competition amongst the solution providers. (miningfinland.com 2020).

Investment into CAPEX projects such as metals and mining projects is always a shorter-term investment (compared to investments into pulp and paper plants). The average lifetime of a mine in Finland is 15 years, yet it might expand up to 30 years. Mine's lifecycle consists of the several stages: exploration, pre-feasibility, feasibility, implementation, operation, decommissioning, closure, and post closure. At the exploration stage, the main consulting and investigation is usually done by the solution provider. It is common to check cartography, to set the targets, to get geological and geophysical consulting, to explore services and to estimate the resources at this first stage. During the pre-feasibility and feasibility stages, there are typically investigations related to such fields as topography, geology, climate and hydrology, water and waste management, health and safety, access infrastructure, process engineering. The Implementation stage focuses on the basic and detailed engineering, mine engineering, and environmental monitoring. At the operation stage, there is supervision and audit of the services related to operations, mineral exploration services, and health and safety engineering. The last three stages include after-mine landscaping, closure procedure, and further environmental monitoring.

Thus, one of the trickiest points in the digitalisation in the Mining and metals industry is that the benefits from the digitalisation process must be *straightforward*, that is to say, they should be *visible immediately*, since the lifetime of mine is relatively short. This puts a specific demand to the solution provider to be able to articulate and demonstrate these immediate, short term benefits in a clear and, ideally, quantifiable way.

Next subsection looks into the example of the already *existing* digital solutions and tools in the Metals and mining industry, analyzed from this prospective of immediate visibility and straightforwardness.

3.4.2 Existing Digital Solutions in the Metals and Mining Industry

Currently, the competition between the digital service providers in the mining industry is developing every single day and increases constantly. All these factors force to create new solutions and values from digital tools for the customers.

> *“Credibility is the key to get the social acceptance and the basis for future sustainable business.” (Director, Process Industries, AFRY)*

Presently, there are several digital technology applications in the Finnish mines that allow to improve work conditions. These are, first, *3D-layouts* that help to do engineering move effectively; second, *engineering templates* that help in time management, and finally, *process balance calculations* that positively affect the process development.

The content of *3D-layouts* usually varies from different projects, but typically includes overall infrastructure, for example, general layout of the site, pipeline’s modelling, diverse water- and heating system’s maquettes. Due to 3D visualization it is easier to comprehend the actual plan.

Engineering templates simplify the work by decreasing the time and effort of data repetition. There is plenty of various engineering templates, available from the web, as well, as the company's personal created engineering templates.

Process balance calculations allow the customer to lower the investment costs and to improve the progress of mining processes.

As it can be seen, there are not many digital tools, which are currently utilized in. Thus, I would like to emphasize again, that the little number of current digital solutions in the Mining and metals industry proves the need of this study in defining more benefits for this industry.

3.4.3 Analysis of the Existing Digital Solutions, Tools and Benefits in the Mining and Metals Industry

The fist example case in the Mining and metals sector is Outokumpu mine in Kemi. The second case is Outokumpu mine in Tornio, and the third case is Yara Siilinjärvi mine.

Case 1. Outokumpu mine in Kemi

Kemi mine produces over 50 million tons of processed chromite ore. The production is over 50 years as well.

Problem:

Digitalisation focus areas at Kemi mine are the following: enabling well-timed decision making and forecasting *by visualizing mine operations and conditions in real time;* and decreasing exposures to risks and optimizing operations efficiency *by increasing automation* where feasible.

Figure 11 below shows the levels of mine in Kemi.

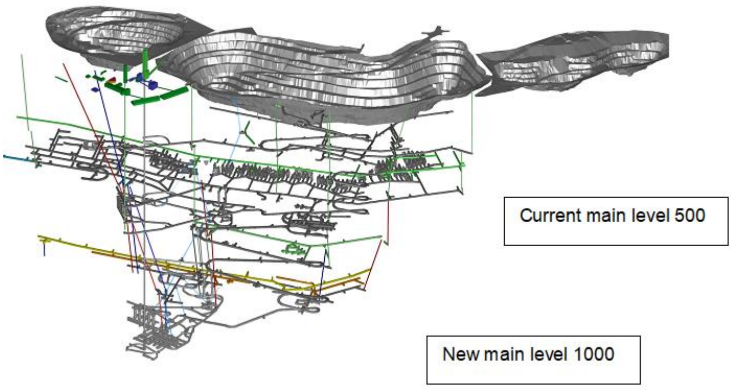

Figure 10. Kemi Mine: Deep Mine Project (source: Outokumpu).

Solution:

AFRY's digital contribution into the Kemi mine was done in the following steps: *network capability – efficient connections covering the whole mine*. Operations efficiency – *improving situational picture* and *optimization of planning and control*, *extending automation in production*. Maintenance efficiency – *improving utilizing of data in mining machines predictive maintenance*. Optimizing E2E yield over time – *improving utilization of ore data through production*. Non-digital solutions: underground logistical efficiency – *upgrading and improving fleet positioning and navigation* (source: Outokumpu 2018).

Case 2. Outokumpu mine in Tornio

Problem:

The goal of the project was to expand the production of ferrochrome. AFRY's role in the project was help in the several fields: underground mine, project management support, concentrating plant, ferrochrome (FeCr) plant.

Solution:

Underground mine project included structural engineering (digital tools were applied), mechanical engineering, electrification, automation, instrumentation, and mine ventilation system. The project management support conducted project engineers, procurement and supervision actions. Concentrating plant support was most held by structural engineering. Ferrochrome plant was supported by collaboration with Outotec in piping engineering (AFRY), scope mechanical engineering (Outotec), scope electrical engineering (Outotec).

As a result, the goals were achieved. Nowadays, due to new technologies, it would be possible to create more value and to increase productivity and safety as well.

Case 3. Yara Siilinjärvi mine.

Problem:

The order contained the engineering solutions, production expansions, mechanical engineering.

Solution:

Several small works for the following areas were completed: concentrating plant (grinding, cyclones updates), Sulphur acid plant (engineering for roaster, converter replacement, enrichment plant, gas scrubber project, piping), fertilizer plant (ammonium nitrate reactors, granulation, storage house, material handling). Larger projects were achieved: concentrating plant production expansion, which included diverse digital solutions (chemical/flocculant systems update, ventilation engineering site supervision), belt filters / mine and phosphoric acid plant (Larox filter update, apatite drying, all detail engineering works, excluding filters), wetting and granulation drums / fertilizer plant (washing system improvement, engineering for drives, mechanical engineering). AFRY (at that time Pöyry) continued to support services for the following design disciplines: EIA, process, mechanical, ATEX, civil, environmental, geological services, HVAC and building electrification.

Table 12 summarizes the benefits from the company’s existing digital solutions in the Metal and mining industry.

Table 12. Benefits: AFRY's current digital solutions in the Metal and mining industry, according to three cases.

	Digital solutions	Digital tools	Benefits
1	Effective engineering	3D layouts	Simplification of the plan development
2	Time management	Engineering templates	• Cost reduction • Time reduction
3	Process development	Process balance calculations	Improvement of business processes
4	Visualization of mine operations and conditions in real time	Network capability	• Forecasting • Well-time decision making
5	Automation increase	N/A	• Operation efficiency optimization • Risk exposure decrease •

As seen from the mine's examples, AFRY participates in many stages of a mine's lifecycle. The current digital solutions include increase of automation, visualization of mine operations, process development, time management and effective engineering (3D layouts). Thus, the company has huge influence on the ongoing processes, and the utilization of digital technologies will be an inevitable positive consequence in the nearest future. Thus, it is important to define benefits, values in order to improve the mines business operations as fast as possible.

3.5 Summary of Existing Digital Solutions, Tools and Their Benefits in Two Industries

This section compares the current digitalisation benefits in the Metals and mining industry to a more digitally developed Pulp and paper industry.

Metals and Mining			
	Digital solutions	Digital tools	Benefits
1	Effective engineering	3D layouts	Simplification of the plan development
2	Time management	Engineering templates	Cost reduction; Time reduction
3	Process development	Process balance calculations	Improvement of business processes
4	Visualization of mine operations and conditions in real time	Network capability	Forecasting; Well-time decision making
5	Automation increase	N/A	Operation efficiency optimization; Risk exposure decrease

Pulp and Paper			
	Digital solutions	Digital tools	Benefits
1	Tall oil optimisation	Risk assessment, AI, data analysis	Precise production forecast; Improved control of the material use and better visibility; Simulation options to evaluate scenarios; Optimisation of cleaning schedules
2	Kappa number variation forecast	Predictive model from process data	Better control over variability; Reduction in digester blow Kappa variations
3	Kraft pulping modelling	AI algorithm	Increased pulp yield and visibility; Production costs reduction; Increased sales
4	Digital data creation	3D modelling	Digital equipment data availability
5	Increase of data intelligence	Laser scanning	Development of operational safety functions
6	Increase of data intelligence	Aerial photogramm etry	Plant preventive maintenance; Equipment maintenance;
7	Smart Site (full scope)	AI	Sustainable production; Cost-effective production; Improved quality

Unfortunately, as the CSA demonstrated, nowadays the case company has some gaps in digitalisation of the Metals and mining sector, - the only current solutions for mines and metals are *engineering, time management and process development*. The Pulp and paper industry currently utilizes a big number of digital applications - bigger than, so far, the Mining and metals industry does. This fact challenges the mining sector. Therefore, due to AFRY’s long experience in this industry and the utilization of plenty successful digital tools in the paper plants and pulp mills, the Pulp and paper industry was a useful benchmark for the Metals and mining industry.

As the goal of the thesis is to define the benefits in the Metals and mining sector from the digitalisation point of view, I suppose, the next step should be to revise and re-think the current benefits provided by AFRY´s digital solutions, and to utilize the insights from benchmarking, as well as also to analyze the competitor offerings, and to compare them and to identify and possibly suggest remedies for the missing points.

To conclude, this is what the current state analysis of the digitalisation benefits in AFRY revealed. In the next Section 4, I will consider and illustrate the best practice and cases from the Metals and mining industry cover the digital solutions and unique beneficial points for the customers.

4 Existing Knowledge and Best Practice on Digitalisation through Solutions and Tools, and Its Benefits in the Metals and Mining Industry

This section discusses the results from the available literature, case studies, articles and white papers. The previous Section 3 focused on the current state analysis of the case company. This Section 4 seeks for insights from literature on digitalisation, digital twins and the Metals and mining outlooks.

First, this section overviews digitalisation, where digitalisation in general through solutions and tools is discussed. The literature chosen for this sub-section focuses on best practice of going digital, as well, as proving the trends for the year 2020. Second, the most interesting digital twin cases and their influence on sustainability are discussed. Third, digitalisation in the Metals and mining industry also includes the best practice in robotics, automation and operational hardware; digitally empowered workforce; platforms, ecosystems and platforms; decision maintenance and next-generation analytics. Additionally, two cases from the available reviews illustrate the current digital solutions in the Metals and mining industry. Finally, the conceptual framework points to the key elements picked up from the existing literature and available knowledge to guide the proposal building in the subsequent sections.

Table 13 summarizes the key sources utilized in Section 4. They only include the selected “diamonds” utilized as key sources in this thesis. They were selected among two dozens of less relevant sources. Importantly, a lot of insights were gathered from 25 leading technology companies’ web-sites that were cherry-picked and analyzed for Section 4 (see the full overview in Appendix 1). Finally, this section also includes a few most interesting cases in the digitalisation, as well as sustainable perspective to digital twins and competitors’ own digital solutions.

Table 13. Key sources used as main input for the backbone of Section 4.

Digitalisation	**Digital twins and Sustainability**	**Metals and mining, digital cases**
Hitachi Consulting 2019, The Secrets to Scaling Digital - Leveraging the Experience of Digital Front-runners.	Weber, U., Grosser, H., Detecon Consulting 2018, How Companies Benefit from a Digital Twin.	McKinsey&Company 2018, Behind the Mining Productivity Upswing: Technology-enabled Transformation.

Cearley, D., Jones, N. et al. 2019, Gartner, Top 10 Strategic Technology Trends for 2020.	Tech Trends 2020, Leveraging Next-generation Digital Twin Capabilities to Design, Optimize, and Transform the Enterprise.	Oracle 2004, Oracle Customers in the Metals and Mining Industries. Towards a Sustainable Industry.
	Malakuti, S., Schlake, J., et al. 2019, ABB Digital Twin: an Enabler for New Business Models.	Mori, L., Saleh, T., McKinsey&Company 2018, Unlocking the Digital Opportunity in Metals. Metals and Mining Practice.
		World Economic Forum 2017, Digital Transformation Initiative, Mining and Metals Industry.
		Siemens 2018, SIMINE Solutions for the Mining Industry.
Additionally, 25 leading technology companies' web-sites were analyzed, see Appendix 1.		

4.1 Digitalisation through Solutions and Tools

Digitalisation, a general term of digital transformation, is the incorporation of digital technologies into all parts of business, fully shifting the way organisations function and bring value to the clients. (The Enterprisers Project 2020.)

Digitalisation implies a use of a wide range of technologies, innovative and disruptive. Digital technologies enable to companies to use possibilities for reaching efficiency and creating customer value. However, the critical word here is *possibilities* – it does not necessarily mean success for a company. The company should be able to focus on the fundamentals first, by changing the mindset of the employees and the company's culture as a whole, ensuring the digital spirit within the organisation. As a result, the adoption of digital technologies is currently considered as a must. (Harvard Business Review 2020.)

Also, digitalisation enables to use digital data to simplify the way people work. By digitally analyzing tones of information, collecting relevant data and choosing the appropriate one, organisations can change the way to do business, in order it to become more effective, more valuable and more applicable. (Salesforce 2020, PwC & Microsoft 2017.)

The main features or characteristics of digitalisation are focusing on *customer experience, efficient operational process, integration between process and data,* and *value delivery* (Tedder 2016).

First, the new era of digital technologies enforces the organisations to search for new ways and opportunities to deliver value to the clients. In order to succeed in this step, the companies should think in a different way, looking for innovative decisions perhaps through new business models. Second, the integration between process and data needs to be clear and rational. In the digitally transformed companies, the decisions supposed to be made based on the facts, i.e. the data which is produced from the processes. This will enable a competitive advantage. Third, transparent and precise operational processes are inevitable for companies, that want to achieve digital transformation. These processes create clear information flows within the company, as well as produces a certain data needed for making decisions. Fourth, continuous development of customer experience plays a crucial role in digitalisation of the company. It is wise to reconsider the customers' understanding by, for instance, building analytics capabilities for more detailed client's comprehension. (Tedder 2016.)

An example of digitalisation is by Hitachi Corporation that illustrates the points discussed above.

Case 1. Hitachi

Hitachi is a worldwide company which is focused on innovation business in terms of information technology, operational technology and products. This organisation provides digital solutions using Lumada data platform in different areas to improve the clients' economic, social and environmental value. Hitachi suggests to create a competence to scale digital innovations for deeper engagement with new and existing customers, and assessment of new tools and capabilities. (Hitachi Consulting 2019: 24.)

For Hitachi digital means concentrating on business outcomes, values and innovations, as well as improvements in IT systems, leaderships skills and business models. It is a challenge nowadays to predict and scale digital results, however, the actual measurement of the business outcomes is necessary for the digital transformation to succeed in the long run. Important to note, that 60% of the companies are working on the digital strategies, but only 10% are trying to embody or implement them. The inability to coherently scale the digital solutions challenges many organisations presently. Applying innovative technologies is not enough for transformational differentiation in the business. (Hitachi Consulting 2019: 3-5.)

According to Hitachi (2019), digital development can enhance to value the products. The company offers to take steps towards “a proof of value” when trying to scale digital solutions. It is wise to validate not only the technology area, but also the customer and business models, and actual operations, before the measurement’s consideration. Therefore, the company illustrates three major areas to focus on when scaling digital initiatives:

1. To improve products, or operational systems and optimize business models by utilizing data insights. This means to aggregate and sufficiently use data, that is not yet properly utilized. Such approach will help to concentrate and deliver the outcome, not a product; and to provide better service.

2. To move from product to service attitude with clients. Here the main as-a-service models can be applied, for instance, paying price per asset, skipping purchasing the product.

3. To reinforce ecosystems. This implies to connect products and services into other organisation’s solutions or ecosystems (Hitachi Consulting 2019: 10-11).

As seen from the above example, today, many organisations are utilizing diverse digital technologies to become more mature than the rivals, to improve operational efficiency, to transform disruptive innovations to own advantage. Still, simply to have digitalisation process in the company is not enough, it is wise to understand the value behind the digitalisation. Thus, the ability to scale digital solutions becomes inevitable nowadays.

Summing up, typical benefits from digital solutions can be pulled together are shown in Table 14 below.

Table 14. Indicative outcomes of digitalisation (Infosys FIR 2015).

1.Performance Efficiency	Increase in Operational Efficiency	20-25%
2.Maintenance Efficiency	Increase in Equipment Lifetime	20-40%

3.Information Efficiency	Increase in Savings in Total Business Expenditure	5-10%
4.Service Efficiency	Increase in Service Margin	30-40%
5.Energy Efficiency and Sustainability	Reduction in Energy Consumption	25%

As show in Table 14, the tangible business outcomes from digital solutions bring the efficiency improvements and increase value for potential customers. However, some of the digital solutions – such as digital twins – can exemplify and illustrate the fruits of digitalisation for customers in a much more vivid way and demonstrate the benefits of digitalisation even stronger.

4.2 Digital Twins and Sustainability

Digital twin can be defined as a digital prototype of an asset, product, process, or a complete unit. Digital twin is needed because it provides visibility with regard to the functioning of a remotely located product, process or system. According to Gartner (2019), digital twins add value to traditional analytical approaches by improving situational awareness, and enabling better responses to changing conditions, particularly for asset optimisation and predictive maintenance.

From the circular economy perspective, digital twins can extend the life of the object they represent and optimize the performance of the asset it runs, and thus lower operating expenses and potentially capital expenses to. Also, digital twin helps the company to gather data and utilise it for driving certain business outcomes.

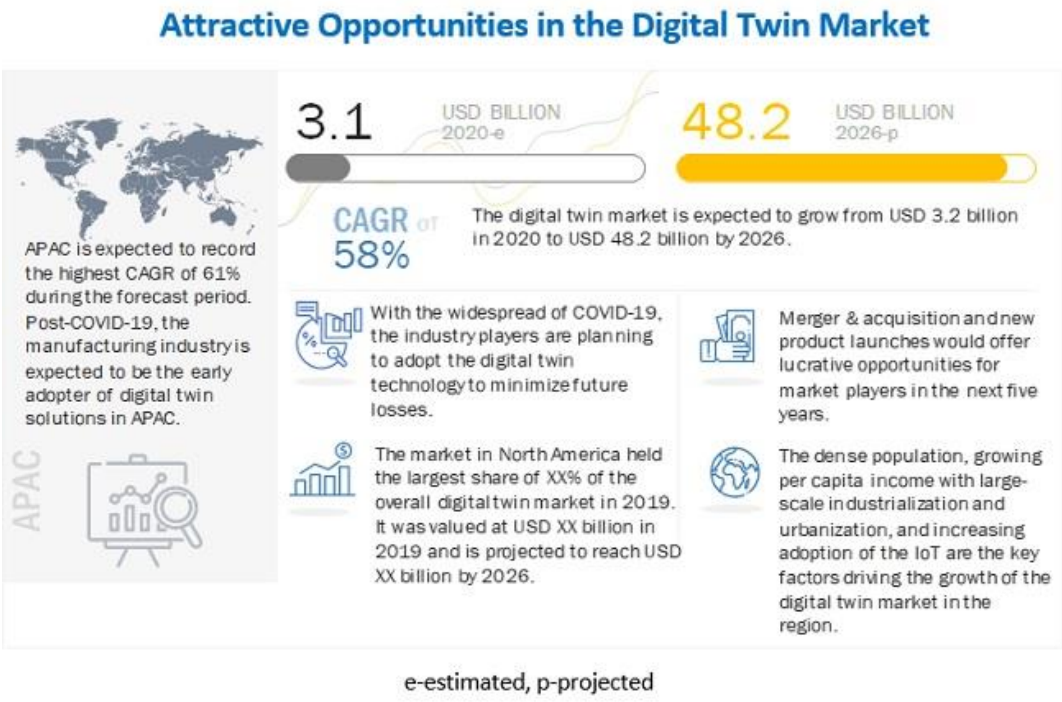

Figure 11. Attractive opportunities in the Digital twin market (Source: Marketsandmarkets 2020).

Figure 11 provides one illustration of the attractiveness of the digital twin market which is expected to grow from the current 3,1 billion USD in 2020 to 48,2 billion USD by 2026.

According to Detecon Consulting (2019), the benefits from using digital twins are reflected in the production and product development, and in planning products reviews after sales. Also, one of most significant features of digital twin is its granularity. This means that not all details should be replicated to digital twin, but only the relevant ones. Therefore, only the most important data has to be processed. (Weber et al. 2019:3.)

Another benefit from how companies can use a digital twin is the real-time evaluation. For example, at Porsche, all production steps are usually linked and compared to the digital twin through information technologies systems in real time. This allows to find out the fluctuations in quality before clients notice (Weber, Grosser, Detecon Consulting, 2019:3).

Detecon (2019) has launched a survey among the 170 organisations from 10 industries, with the biggest industries in terms of number of respondents being automotive, telecommunications, public, transportations, logistics, pharmaceutical and health care.

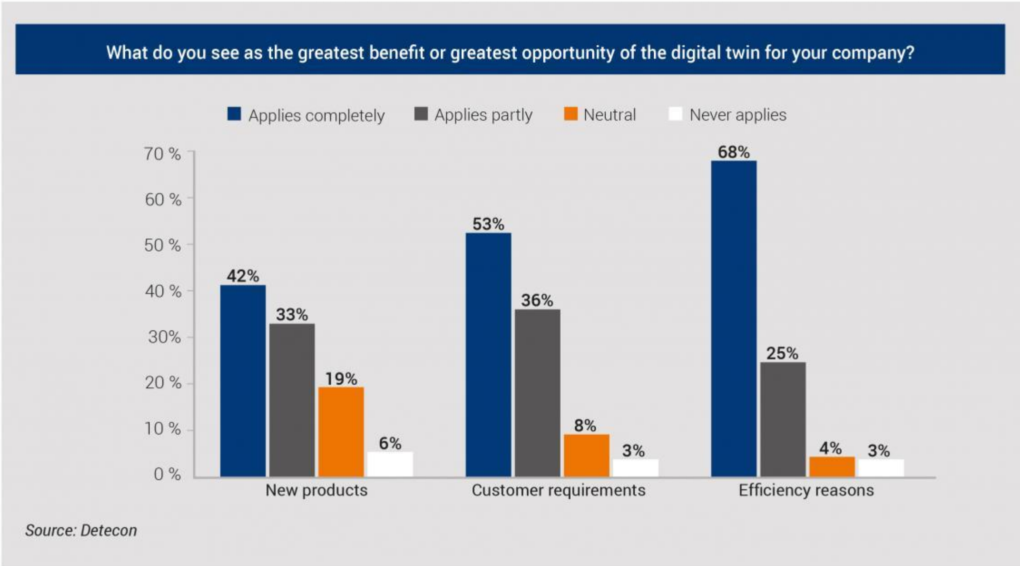

Figure 12. Benefits and opportunities of digital twins, survey (source: Detecon, 2019: 22).

Figure 12 above illustrates the results from the survey, investigating the best opportunities and benefits from applying digital twin for the companies. 68% of respondents stated that efficiency is the greatest benefit, followed by customer requirements (53%), and new product lines (42%).

Referring to TechTrends (2020), the digital twin trend has become popular and gained attraction due to the fast evolving modelling and simulation capabilities, improving interoperability and IoT, as well as developing computing architecture. Digital twins enable engineers to recognize potential technology upgrades, quality and durability concerns before the actual design is finished. Therefore, the time spent on the prototyping speeds up and the production becomes more efficient and at lower costs. Digital twin as a trend accelerates recently, hence, more companies enable digital twins to optimize the processes, to make real-time decisions and to do predictive analytics and maintenance issues.

Referring to ABB, the concept of digital twin includes collection, maintenance, aggregation, processing, and provision of the data about an asset, product, or anything else. Most of the companies offer their digital twins as a separate, isolated solution, which in turn, does not benefit because of lack of data exchange, interoperability and synchronization of information and actions. Thus, compatibility or interoperability become an important output of digital twin. Another value that is brought by digital twin is improved quality. Outdated of wrong data causes mistakes in production and different delays. Digital twin enables companies to have full access to present data in the real time. (Malakuti et al. 2019: 2-3, 11.)

As for the sustainability issues, digital twin lets the user to simulate and discover possible scenarios, then to choose the most suitable one and embody it in the real world (Cearley, Jones, 2019: 12). In this sense, twin creates the best currently available opportunity to test the sustainability and check the environmental impact of technology.

Sustainable solutions are becoming the major issue in the industry's value chain – from materials planning to contractors, manufacturers and product performance. Efficiency of the raw materials and usage of renewable resources are increasingly becoming an obligation in the product development, letting the companies with expertise in sustainability to have a strong competitive edge. Presently, it is as important as ever to transfer from the linear economy towards the circular economy, with circular materials flows, where the products are consumed with least possible material extraction and possible waste. As the utilization method for different metals is different, thus the overall environmental impact can be huge, especially in relation to:

- High consumption of energy due to industrial processing of steel and aluminum,
- Ecological and health toxic issues due to lead and cadmium utilization,
- Waste appearance during the metal's extraction and production. (Sillanpää, Ncibi, 2019: 140-146.)

The whole lifecycle of metals is very important for economic and environmental points of view. Nowadays situation in the ores, starting from extraction process, harms the surrounding area, as well as creates big amount of waste stream, which in turn causes water pollution and landscape destruction.

Innovative technologies allow the metals and mining industry to utilize an eco-friendly exploration and extraction processes. For the metals and mining industry, digital twin is *the main* solution from the sustainability and circular economy points of view (Sillanpää, Ncibi, 2019: 142). Digital twin focuses on ecological exploration and extraction of a mine, and can offer a spectacular virtual environment and simulation to try all what-if scenarios, and thus, to predict and prevent failures to achieve greater performance. (Sillanpää, Ncibi, 2019: 140-146.)

Therefore, for the circular economy and sustainability digital twin plays a vital role, enhancing performance optimisation. The ability of digital twin to collect the data and use it for achieving certain business goals makes it a relevant and effective digital tool for the organisations from the sustainability and circular perspectives.

4.3 Digitalisation in the Metals and Mining Industry

Heavy metals and ore sector are among the slowest in adapting new digital technologies in comparison to financial or media spheres. In the past years the main driver of the rivalry and value creation for the mining and metal company was its structural location on the cost curve. Nowadays data become the major driver beyond the actual physical product, and the mature organisations will win by how efficiently they gather and leverage data. (Mori, Saleh, McKinsey&Company, 2018: 3.)

According to World Economic Forum (2017), in the metal and mining industry health and safety issues, as well as environmental sustainability appear to be the major issues currently. Digital solutions, and especially digital twins may positively influence of the above points. Digital solutions enable to improve environmental impact by decreasing emissions and waste, and rising sustainability and transparency; also, to improve health and safety sector by saving lives and reducing work injuries. (World Economic Forum, 2017: 3.)

Overall there are four major topics that will become fundamental to digitalisation in the metals and mining industry for next decade:

1. Robotics, automation and operational hardware

2. Digitally empowered workforce

3. Integrated enterprise, ecosystems and platforms

4. Next-generation analytics and decision maintenance. (World Economic Forum, 2017: 9.)

Why Metals and mining industry is considered to have lower levels of utilizing digital than others? According to Accenture analysis together with World Economic Forum (2017), there are numerous factors, that influence on low digital application: geographical spreading of main operations, capital availability, big varieties in control technologies and base equipment, complexity of some operations, and managerial conservatism. (World Economic Forum, 2017: 9.)

Table 15 below represents the four major digital topic and their initiatives for the metals and mining sector.

Table 15. Digital topics and initiatives in the metals and mining industry (World Economic Forum, 2017: 10).

Topics	**Initiatives**
1.Robotics, automation and operational hardware	Autonomous operations and robotics
	3D printing
	Smart sensors
2.Digitally empowered workforce	Connected worker
	Remote operation center
3.Integrated enterprise, ecosystems and platforms	IT/OT convergence
	Asset cybersecurity
	Integrated sourcing, exchange of data, commerce
4.Next-generation analytics and decision maintenance	Advanced analytics and modelling simulation
	Artificial Intelligence

Let us consider these topics separately and more precisely.

4.3.1 Robotics, automation and operational hardware

The main themes included into this topic relate to autonomous operations and robots, 3D printing, and smart sensors. Analytics and robotics enable monitoring of condition, predictive estimations and maintenances. (Mori, Saleh, McKinsey&Company, 2018: 4.) 3D printing for the mining organisations can help to source plastic and metal parts, providing fast access to diverse spare parts and machinery in remote places. However, this digital solution should become more economical, effective and accessible in order to create an opportunity to utilize it in operations and production in the mining and metals industry. Smart sensors gather chemical, physical, biological data and change into digital format for further processing of the data. It is beneficial for the companies to utilize smart sensors to get real time insights and adjustments to the performance thanks to data (big data analytics), collected by these smart sensors. (World Economic Forum, 2017: 12-13.)

4.3.2 Digitally empowered workforce

According to World Economic Forum (2017), the digitally empowered workforce implies two actors: a connected worker and a remote operation center. In the context of metal and mining industry, virtual and augmented reality together with connected mobility are able to empower and monitor mine employees. Such digital solutions provide the benefits of real-time data, seamless communication, instant remote support, and critical gathered data from the mine in the real time. Remote operation centers mean a certain type or control room for mines and ores that provide the offsite area for the workers to manage the operations without travelling to the actual mine locations. These rooms allow to monitor and control the operations despite external conditions, which in turn positively influence on the health and safety issues. (World Economic Forum, 2017: 15-17.)

4.3.3 Integrated enterprise, ecosystems and platforms

The main challenges that are tackled by this topic are information and operational technologies convergence, assets cybersecurity and integrated sourcing, data exchange, commerce. Metals and mining industry is able to create bigger value by combining IT and OT and then exchanging information through the whole supply chain. IT and OT integration enable the connection of the operations of a mine on different levels, as well as leveraging the digital mine ecosystem. The major booster for partnerships and collaborations is data integration or data exchange. By utilizing digital technologies, platforms can share the information between the client and the supplier concerning forecasts or delivery timetable, for instance, which empowers the relations and creates the trust and transparency, hence, succeeding in competition.

Common cybersecurity objectives include integrity, confidentiality and availability. In the Mining and metals industry, diverse networks are usually connected with hardware and sensors of the MES (Manufacturing Execution Systems), which should be protected. Asset cybersecurity protects digital cyber mining environment, by safeguarding different connected computing devices, infrastructure equipment, tools and applications, data and internal storage servers. (World Economic Forum, 2017: 18-20.)

4.3.4 Next-generation analytics and decision maintenance

For the Metals and mining industry, AI, modelling simulation and advanced analytics are very significant initiatives. Utilization of advanced analytics enables optimization of materials sourcing, boost predictive maintenance to increase equipment uptime, forecast the demand, gather data for digital twins simulation (Mori, Saleh, McKinsey&Company, 2018:4-9), Mine simulation allows the companies to estimate operational performance by utilizing what-if scenarios, and thereby, to decrease the investments , waste and environmental impact. Artificial intelligence can attract disparate data sources to establish a holistic view of future, actual and past operations, as well as manage a network of sensors and robotics in a mine. (World Economic Forum, 2017: 21-22.)

Therefore, sensors and advanced analytics enable mining companies to decrease maintenance costs downtime costs; robotics and autonomous machinery allow to reduce risk and costs by taking workers out of the actual mine. Utilisation of Artificial Intelligence and machine learning enables to diminish environmental footprint. (Metals and Mining Practice, McKinsey&Company, 2018: 2-3.)

4.3.5 Cases and best practice

Case 1: Oracle solutions for Solid Energy

Solid Energy is a New Zealand company, doing business in mining, and distributing coal. The company wanted to improve ERP systems in order to develop. Solid Energy hired Oracle to solve the problems.

Problem:

Lack of integration caused inconvenience and costs for utilising software. Difficulties with interconnection and communication systems in asset management, accounting and purchasing roles.

Solution:

Oracle established a platform, that collected needed management data. Oracle applications gathered, analysed and provided the support for the financial team and sales team by using advanced analytics. Also, another set of Oracle digital solutions allowed the case company to make better preventive maintenance practices, increase the productivity of equipment.

Table 16. Benefits of ERP integration and advanced analytics.

Number	Benefits
1.	Equipment maintenance
2.	Preventive maintenance
3.	Advanced analytics support
4.	Process improvement by advancing ERP system

(From: Oracle Solutions for the Metals and Mining Industries, 2004: 25-26)

Case 2. Siemens solutions for Inner Mongolia Yitai Group

Inner Mongolia Yitai Group Co. Ltd. wanted to get benefits from the work.

Problem:

Inner Mongolia Yitai Group Co. Ltd., China has ordered from Siemens the complete automation control and monitoring systems, as well as engineering and commissioning.

Solution:

Siemens developed effective hoisting system for health and safety issues. Also, the company designed al the machines from a unite source. Siemens utilized SIMINE solutions (own digital applications and tools) to achieve the goals. Consequently, the client benefited from lowering the investment costs, decreasing the carbon footprint and getting the worldwide highest output per shaft.

Table 17. Benefits from utilizing SIMINE solutions by Siemens.

Number	Benefits
1.	Highest output per shaft
2.	Reduction of investment costs
3.	Decrease of carbon footprint

(From: SIMINE, Siemens digital solutions for metals and mining, 2018: 17)

The Oracle example shows the benefits from ERP integration and advanced analytics. The digital solution was to create a platform to gather the data. Oracle digital applications enabled to do that, as well as to analyse the data and to provide the further support. Also, the company utilised predictive maintenance digital tools to improve equipment maintenance.

The Siemens example illustrates the utilization of SIMINE, a well-known set of digital solutions for the mining and metals clients. The applied solutions allowed Siemens customer to decrease investment costs and improve sustainability issues.

These two cases are very important for this study because they illustrate the real examples of successful digital solutions applications as well as benefits from these solutions.

4.4 Conceptual Framework of This Thesis

This sub-section contains the Conceptual framework of this study. It includes the key elements that were discussed earlier in Section 4.

The first element of the Conceptual framework is digitalisation. It considers the tangible business outcomes from utilizing digital solutions, that are able to bring the productivity improvements and therefore rise the value for the potential clients. Then, the case review from Hitachi Consulting tells the main focus areas to scale digital initiatives. This should be done to better understand the value behind the digitalisation.

The second element of the Conceptual framework is sustainability and digital twin cases. This subsection shows the benefits from how other organisations utilize digital twins in their practice. Also, the subsection illustrates that the digital twin can become a solution for circular economy and sustainable future.

The third element of the Conceptual framework is the digitalisation in the Mining and metals industry. This sub-section explains what kind of digital solutions can be applied in the mine ores and metals and how they benefit for the potential customers.

Figure 13 presents the Conceptual framework of this study.

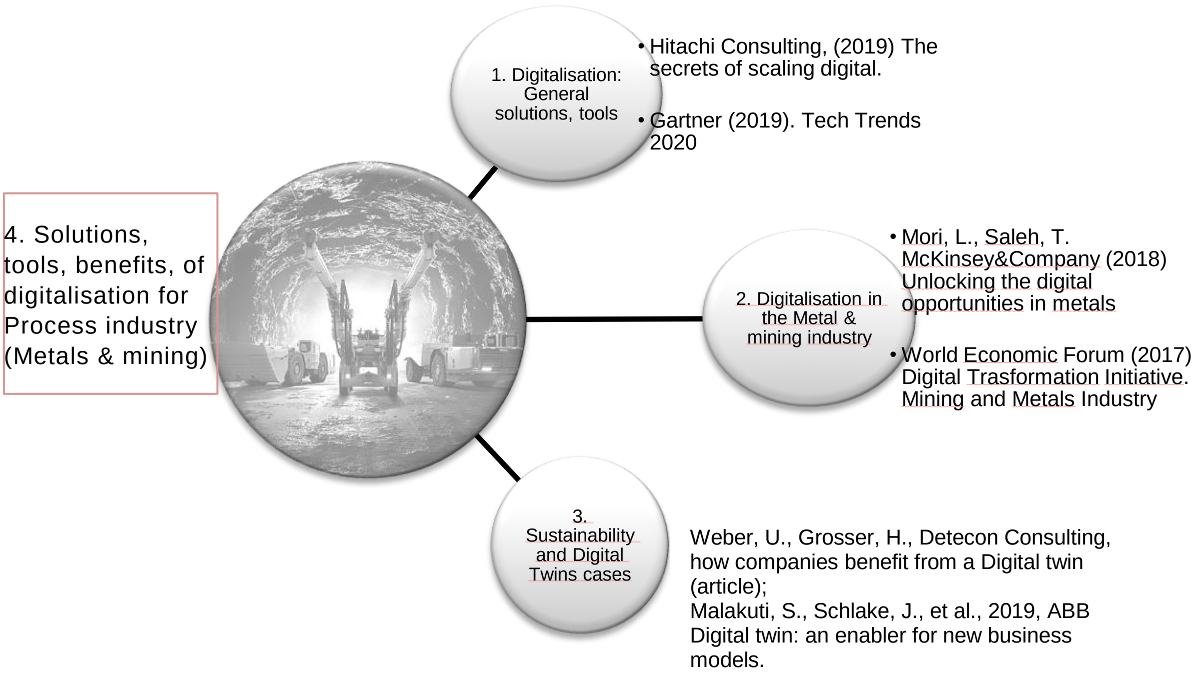

Figure 13. Conceptual framework-1 of this thesis.

Figure 14 illustrates the summary of Table 14, which shows the indicative outcomes of digitalisation in accordance with Infosys (2015), as well as Table 15, which shows the Digital topics and initiatives in the metals and mining industry in accordance with World Economic Forum (2017), and Table 16 and Table 17 as the representation of best practice from Oracle and Siemens.

1.Performance Efficiency	Increase in Operational Efficiency	20-25%
2.Maintenance Efficiency	Increase in Equipment Lifetime	20-40%
3.Information Efficiency	Increase in Savings in Total Business Expenditure	5-10%
4.Service Efficiency	Increase in Service Margin	30-40%
5.Energy Efficiency and Sustainability	Reduction in Energy Consumption	25%

Benefits	**Outcomes**
Performance efficiency	Increase in operational efficiency
Maintenance efficiency	Increase in equipment lifetime
Information efficiency	Increase in savings in total business expenditure
Service efficiency	Increase in service margin
Energy efficiency and sustainability	Reduction in energy consumption
Robotics, automation and operational hardware	Autonomous operations and robotics
Robotics, automation and operational hardware	3D printing
Robotics, automation and operational hardware	Smart sensors
Digitally empowered workforce	Connected worker
Digitally empowered workforce	Remote operation center
Integrated enterprise, ecosystems and platforms	IT/OT convergence
Integrated enterprise, ecosystems and platforms	Asset cybersecurity
Integrated enterprise, ecosystems and platforms	Integrated sourcing, exchange of data, commerce
Next-generation analytics and decision maintenance	Advanced analytics and modeling simulation
Next-generation analytics and decision maintenance	Artificial Intelligence
Equipment maintenance	
Preventive maintenance	
Advanced analytics support	
Process improvement by advancing ERP system	
Highest output per shaft	
Reduction of investment costs	
Decrease of carbon footprint	

Topics	**Initiatives**
1.Robotics, automation and operational hardware	Autonomous operations and robotics
	3D printing
	Smart sensors
2.Digitally empowered workforce	Connected worker
	Remote operation center
3.Integrated enterprise, ecosystems and platforms	IT/OT convergence
	Asset cybersecurity
	Integrated sourcing, exchange of data, commerce
4.Next-generation analytics and decision maintenance	Advanced analytics and modelling simulation
	Artificial Intelligence

Number	**Benefits**
1.	Equipment maintenance
2.	Preventive maintenance
3.	Advanced analytics support
4.	Process improvement by advancing ERP system

Number	**Benefits**
1.	Highest output per shaft
2.	Reduction of investment costs
3.	Decrease of carbon footprint

Figure 14. Conceptual framework-2 of this thesis.

The conceptual framework together with the results of current state analysis leads to the building of the proposal for AFRY concerning the topic of the study: defining the benefits of digitalisation in the Mining and metals industry.

Next, Section 5 presents the proposal building process.

5 Building Proposal for Digitalisation Benefits in the Metals and Mining Industry for the Company

This section defines and describes the benefits of digitalisation for the Metals and mining customers for AFRY. The findings from the current state analysis in Section 3 and the conceptual framework with the best practice in Section 4 reflect the results of the Section 5.

5.1 Overview of the Proposal Building Stage

Before the actual proposal building, the previous results were considered again. The results of the Section 3, showing the current state analysis of AFRY, summarized the existing digital solutions, tools and benefits in two industries: Metals and mining, and Pulp and paper as a benchmark. Also, the visions of potential benefits in the Metals and mining industry are discussed. The current state analysis revealed that the company has the gaps in the digital solutions, tools and benefits for the Metals and mining customers.

Therefore, further in Section 4 I tried to search for best practice, literature and case studies in order to find potential ideas focused on defining the benefits of digitalisation. Section 4 reflected the most relevant best practice cases such as digitalisation in Hitachi Corporation, Siemens solutions for the Metals and mining, and Oracle solutions towards sustainable future.

After revising the previous results, the proposal was conducted in several steps. First, the visions of potential digital solutions, tools and benefits for the Metals and mining industry were analyzed as Element 1 of the Proposal. Second, the rival's visions towards digital solutions and benefits were identified and analyzed in Element 2 of the Proposal. Third, sustainability and digital twin as a solution were discussed as Element 3 of the Proposal. Fourth, there was a competitor's analysis done of digital twin features and other digital solutions with 25 leading technology companies (see the results in Appendix 1).

Finally, the initial proposal illustrates the combination of all elements pulled together. The key stakeholders were involved into the process of proposal building. They came up with the suggestions for the proposal, which is discussed in Section 5.2 below.

5.2 Element 1 of Proposal - Metals and Mining Industry: Visions of Potential Digital Solutions, Tools and Their Benefits

According to the interview results, the general need for all potential digital tools should be *the ease and simplicity to use*. The training also should be not difficult, but fast, due to short lifetime of the mine, comparing to the plant's lifetime (15 years average lifetime of a mine, 50 years average lifetime of a plant).

Based on the interview results, one of the potential digital products that can be successfully utilized in the mining industry is the Virtual Site Designer for *the predictive maintenance*. This tool will let to evaluate the condition of equipment by constant virtual monitoring. Due to this tool, the level of dangerous accidents will be decreased accordingly. There is plenty of examples published by Finnish safety and Chemical Agency (Tukes) such as falling of excavator with the driver in underground mine in Kittilä mine (yle.fi, 2016). That collapse could have been predicted and avoided by utilizing new technologies. Thus, amongst digital solutions safety and predictiveness are most obvious benefits for the mining sector.

Another possible digital tool for the mining sector, as pointed out be the stakeholders, is *an improved data collection.* For instance, AFRY Smart Site platform allows to make integrated information management; in other words, to gather and analyze engineering technology, operations technology and information technology. This digital tool can provide a single source of truth, establish utilization of data and implement processes harmonization and collaboration. Within AFRY Smart Site platform there is an artificial intelligence (AI) tool, which can analyze data much more effective than the human.

Also, based on the discussions with the stakeholders, there is a probability to use KRTI 4.0, an artificial intelligence application for *the maintenance optimization*. The focus is held on the availability and the risk assessment of all plant systems and, therefore KRTI 4.0 (which combines RAMS model-based approach (Reliability, Availability, Maintainability, Safety) and data-driven approach AI (Artificial Intelligence)) provides proactive insights and prescriptive maintenance (source: AFRY Smart Site presentation). Risk analysis tool AFRY KRTI 4.0 can also be considered as an attractive solution for the ore mines. AFRY has had a successful project for the company SSAB where the deep risk analysis was done by means of AFRY KRTI 4.0 tool for one of the mines in Scandinavia.

Moreover, KRTI 4.0 AI has a variety of options that the mining and metal client could choose from: *incident root cause analysis, process standardization, asset maintenance, service automation, predictive analytics, prescriptive analytics, correlation of failure with operational data and design, advanced visualization, minimization of restoration time*.

Additionally, in order to implement a project successfully, there can be used *a site supervision and construction management,* for instance. This solution was discussed as a vision by the stakeholders. This is possible since AFRY provides services and consulting during all stages of a mine business life. In order to support the operations, AFRY offers a range of solutions for maintenance. Figure 15 illustrates the services for the client's entire business lifecycle.

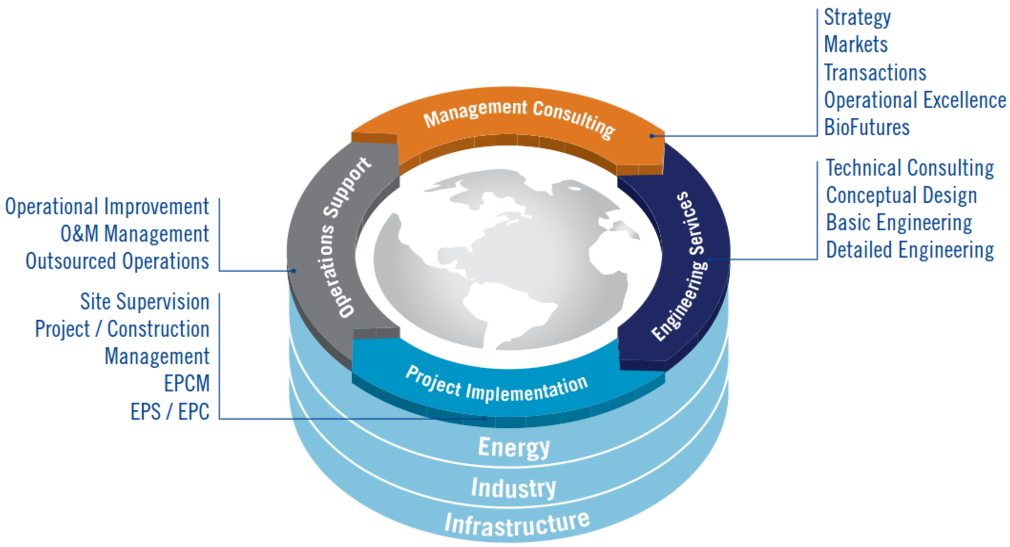

Figure 15. AFRY´s services for the client's entire business lifecycle.

As seen from Figure 15, during the management and engineering stages, there is consulting provided by AFRY in strategy, markets, transactions, conceptual design, basic and detailed engineering. Consequently, AFRY participates in all the stages of a mine's life, this fact allows to utilize a plenty of new technologies, especially based on AFRY Smart Site platform.

Another potential development is the use of a framework utilized in AFRY for the customers ordering a development project for the ore mines. Figure 16 below shows the example of the gate approach as checkpoints in the mining industry.

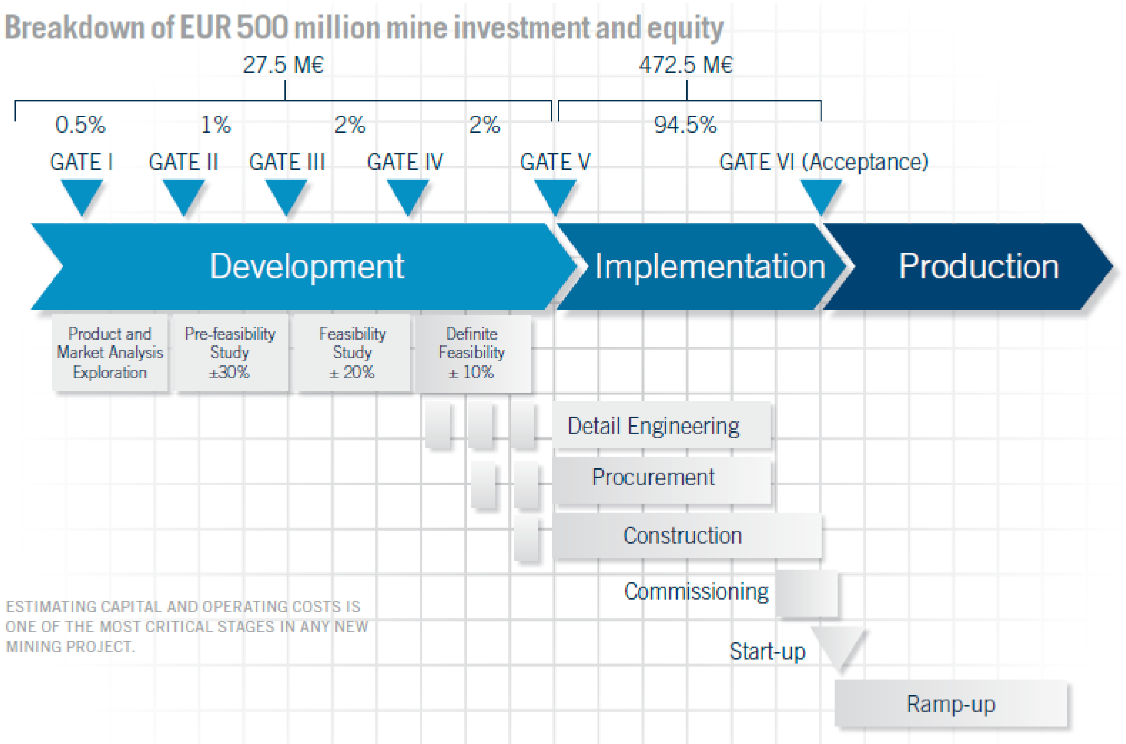

Figure 16. Gate approach to the main checkpoints to construct a mine.

As shown in Figure 16, the whole lifecycle is divided into 5-6 gates. The gate approach method works like a security check at every step of the project to make sure that all aspects of a phase are completed properly and in the correct order before any additional work, time or money are committed. It is easy to add digital tools at different gate stages, and thus to show to the client the simplicity and speed of the utilization of digital tools. Table 18 summarizes the potential digital solutions, tools and their benefits proposed based on the discussions with the stakeholders.

Table 18. Summary of the potential digital solutions, tools and their benefits.

	Digital solutions	Digital tools	Benefits
1	Preparation for maintenance	Virtual Site Designer	• Safety • Predictiveness

2	Improved data collection	AFRY Smart Site platform	• Integrated information management • SSOT • Process harmonization and collaboration
3	Advanced analytics	AI	Effective data analysis
4	Maintenance optimisation	KRTI 4.0 and RAMS+AI	• Proactive insights • Prescriptive maintenance • Incident root cause analysis • Process standardization • Asset maintenance • Service automation • Predictive analytics • Correlation of failure with operational data and design • Advanced visualization • Minimization of restoration time
5	AFRY management consulting	Site supervision and construction management	• Consulting during all stages of a mine business life • Operations support • Successful project implementation

Table 18 above summarized the digital tools, solutions and benefits for the Mining and metals industry with the most potential for the case company, based on the input form the stakeholders.

5.3 Element 2 of Proposal - Competitor's Visions Analysis in the Metals and Mining Industry – Solutions, Tools and Benefits

This element focuses on the analysis of the competitors´ visons for the Metals and mining industries. These visions were collected based on open published materials as well as materials from participating in the events, fair trades and conferences. For instance, one of the most significant inputs came from the cooperation project of 5 companies – LKAB, ABB, Combitech, Volvo Group, Epiroc. They developed a project in Sweden, called "*Sustainable Underground Mining SUM*". ABB plans to create virtual reality simulation for the deep mine in Sweden, Kiruna (2020 -2030) (Sustainable Underground Mining 2020).

[Internal materials. Access restricted]. Based on the materials related to this project, the following visions were analyzed which are summarized in Table 19 below.

Table 19. Competitor's vision on digital solutions in the metal and mining industry.

Benefits	**Explanation**
Sustainability	Carbon dioxide-free production, that reduces environmental impact
Autonomy	Fully self-governing mine or remove monitoring, despite environmental conditions and pandemic
Safety	Virtual simulation in 4D beforehand
Virtual mine	Virtual mine and simulator, coordination of activities, elimination of possible mistakes, costs reduction, increased productivity

Table 19 illustrates the rivals' vision of digital benefits in the Mining and metals industry.

> *"It is estimated that mine digitalization could save $373 billion by 2025 raising productivity, reducing waste and keeping our mines safe." (ABB)*

This evidence from the ABB presenter points to the expected benefits of digitalisation based on the relevant visons in the cooperation project by 5 digital leaders in the project in Sweden.

5.4 Element 3 of Proposal – Sustainability & Digital Twins as a Solution

Sustainability as a trend aims at achieving the circular economy. Nowadays most of the materials are used only once. In order to decrease the pollutions and waste of material it is necessary to become more sustainable. Circular economy is the future of the material production industry. However, it is a challenge today to implement. Waste and pollution, especially from the mining, causes huge problems in the current situation. In order to solve these issues, there should be applied innovations and new strategies across the whole value chain. The investments that are required to bring circularity start from education, achieving a radical reduction in waste production, further collection and logistics of the waste, and finally, its recycling. This requires enormous capitals, innovative technologies, engineering capacity – these factors are challenging AFRY in the current world situation. A short lifecycle of a mine should bring much more improvements and increase efficiency than nowadays.

> *“Managing emissions into water and how to reconstruct the landscape afterwards are essential as well as all safety measures during the operations, and in each of these areas AFRY can support the Metals and mining industry to become more sustainable.” (Director, Process Industries, AFRY)*

The extraction of such metals as gold, copper and nickel is usually followed by large volumes of waste streams, polluting water and destructing landscape. By utilizing digital simulations and replica, and via life cycle and emission calculations, it should be possible to somewhat decrease the amount of waste materials. As one of the goals of digital twin is to extend the life-cycle of an asset (metal), and therefore to protect the raw material input, and also reduce the extraction, which causes negative environmental issues.

The investments that are required to bring circularity start from education of employees, further collection and logistics of the waste, and finally, the recycle. A short lifecycle of a mine should bring much more improvements and increase efficiency than nowadays (Sillanpää, Ncibi, 2019: 140-146). Hence, the circular economy concept of 3Rs, Reduce-Reus-Recycle, can be applied to the Metals and mining industry, where digital twin can help to utilize these three principles.

The Reduce principle in the mining industry implies to minimize or eliminate the number of hazardous components. At this stage, a digital twin analyses all possible situations, where the minimization done better. Digital twin creates a prototype model or situation, and it is wise to try all the possible solutions at this stage.

Then, at *the Reuse principle* digital twin collects the data and analyses how better and productively to reprocess or reapply the mine and metals components. The utilization methods are developed continuously, still, it is important to minimize the waste generation by optimising processes, where digital twin can be used.

Finally, *the Recycle principle* means the recovery of usable resources or energy from waste or by-products. Here digital twin enables to reutilize the metals components back to the circular loop

5.5 Competitors' analysis of Digital Twin Features

Additionally, the researcher (myself) conducted the competitors´ analysis, based on the materials gathered from 25 companies, including IBM, Siemens, Microsoft, Etteplan, ABB, and Ramboll and suchlike in summer 2020. The goal of this competitors' analysis was to identify and compare the competitors´ and AFRY's existing digital solutions, tools and benefits, and thus find any missing points. It should provide chances to identify and improve the features of digital twins as a solution for the metal and mining clients, as well as to help create a unique selling point for the company.

The table with the competitor analysis results illustrates the main AFRY's rivals from the digitalisation point of view generally, and in digital twins in particular. In this analysis, I have considered the main digital twin features, such as *predictive maintenance, optimisation of process, simulation, product development and open interface*, and how other companies describe these features in the open sources.

Also, I have checked the other digital applications and solutions amongst rivals, and the major solutions were *the engineering technology (ET) solutions, device management, cybersecurity, virtual reality or augmented reality (VR/AR), partnerships with different enterprises, data management and advanced analytics, enterprise resource planning (ERP) integration,* and *3D visualisation*. [Internal materials. Access restricted].

5.6 Initial Proposal

The initial proposal was pulled together from the elements describes above, namely from*:*

- the results of the current state analysis (comparison of the current digitalization benefits in the Metals and mining industry to a more digitally developed Pulp and paper industry),
- *Element 1* - Metals and mining industry: visions of potential digital solutions, tools and their benefits,
- *Element 2* - Competitor's Visions Analysis in the Metal and Mining Industry – Solutions, Tools and Benefits,
- *Element 3* – Sustainability & digital twins as a solution,
- additionally, the competitor´s analysis, based on the materials gathered from 25 companies from the digitalisation point of view generally, and in digital twins in particular
- all of these elements merged together and guided by the Conceptual framework of this study.

Based on these inputs, Table 20 shows the comparison of the current state of the case company and the probable gaps in digital offerings for the Metals & mining industry. AFRY can offer very many solutions, such as autonomy, predictive maintenance and many other, but this is difficult to do in the mining and metals sector. After that, I will try to define the main benefits and help to create exceptional selling points for the mining and metals clients.

Table 20. Proposal for benefits in the metals and mining industry.

	Digital Solutions	Digital Tools	Benefits
AFRY's current benefits	Effective engineering	3D layouts	Simplification of the plan development
	Time management	Engineering templates	• Cost reduction • Time reduction
	Process development	Process balance calculations	Improvement of business processes
	Visualization of mine operations and conditions in real time	Network capability	• Forecasting • Well-time decision making
	Automation increase	N/A	• Operation efficiency optimisation • Risk exposure decrease
Competitors' benefits	Carbon dioxide-free production, that reduces environmental impact, reduction of injuries	N/A	Sustainability
	Fully self-governing mine or remove monitoring	N/A	Autonomy
	Virtual simulation in 4D beforehand	Simulation	Safety
	Virtual mine and simulator, coordination of activities, elimination of possible mistakes, costs reduction, increased productivity	VR	Virtual mine
Potential benefits	Predictive maintenance	Virtual Site Designer	• Safety • Predictiveness
	Improved data collection	AFRY Smart Site platform	• Integrated information management • SSOT • Process harmonization and collaboration
	Advanced analytics	AI	Effective data analysis
	Maintenance optimisation	KRTI 4.0	• Proactive insights and Prescriptive maintenance • Incident root cause analysis and Process standardization • Asset maintenance and Service automation • Predictive analytics • Correlation of failure with operational data and design • Advanced visualization and Minimization of restoration time
	AFRY management consulting	Site supervision and construction management	• Consulting during all stages of a mine business life • Operations support • Successful project implementation
Literature suggestions	Decrease of carbon footprint	Digital twin	Sustainability
	Digitally empowered workforce	Remote operation center	Improved health and safety issues
	Connected worker	VR/AR, connected mobility	• Seamless communication • Real-time insights

			• Instant remote support
	Robotics, automation and operational hardware	3D printing	Efficient metal parts utilisation
	Big Data analytics	Smart sensors	Real time insights
	Mine simulation	Modeling simulation	• Improvement of operational performance • Investment decrease • Waste reduction
	Next-generation analytics	AI	Holistic view and management of mine operations

This initial proposal pulls together and creates a list of *all of the identified digitalisation benefits* derived from various sources and comparisons, such as the analysis of own solutions, the analysis of competitors´ benefits as discussed by these competitors, the potential digitalisation benefits, as well as suggestions from best practice and literature identified from the published materials and cases. In more detail, the following benefits were identified:

As seen from Table 20, **AFRY´s current benefits** (identified from the current state analysis) include simplification of the plan development by utilizing 3D layouts, cost and time reduction due to engineering templates, and improvement of business processes owing to process balance calculations. Besides, due to network capability, visualization of mine operations and conditions in real-time enhance forecasting and well-time decision making, Also, automation increase boosts operation efficiency optimisation , as well as decreases risk exposure.

Apart from current benefits, **rival's viewpoint** on the Metals and mining should be taken into consideration. Virtual mine simulation enables to *reduce environmental impact* and *decrease number of possible injuries*, as well as tend to reach *carbon dioxide-free production*. The ability to utilise *virtual mine simulation in 4D* beforehand makes AFRY competitor more emulating and allows to apply *safety* as a benefit.

Next, **potential benefits** include safety, predictiveness, integrated information management, SSOT, process harmonization and collaboration, effective data analysis, proactive insights and prescriptive maintenance, incident root cause analysis and process standardisation, asset maintenance and service automation, predictive analytics, correlation of failure with operational data and design, advanced visualization and minimization of restoration time, operations support, successful project implementation.

In concordance with visions of potential benefits, I recommend to apply *artificial intelligence* and *KRTI 4.0 RAMS digital tools* to benefit from effective *data analysis, proactive insights* and *prescriptive maintenance, advanced visualization, asset maintenance, service automation, connection of failures with operational data* and *design.* Moreover, use of Smart Site platform will create *a single source of truth* and *process harmonization and collaboration*, and *integrated information management*.

Virtual Site Designer allows to do preparations for further maintenance to enable safety and predictiveness in the mine. Site supervision will enhance successful project implementation.

Finally, according to **literature suggestions**, it is recommended to use *the data analytics* by means of *smart sensors* in order to get *the real-time insights*, to utilise *artificial intelligence, 3D printing* and *modelling simulation* for more *effective metal utilisation*, holistic view and efficient management of *mine operation*s, improvement of *operational performance*, *reduction of costs* and *waste*. Besides that, I would like to suggest to use *digital twin* and *VR/AR, as well as remote operation center* to improve *health and safety issues*, achieve the *seamless mine communication*, provide *instant remote support* and enhance *circularity* in the Metals and mining industry.

As it can be seen from the Initial proposal, plenty of digital solutions, tools and benefits are defined from the analysis of the current AFRY´s digital solutions, tools and benefits, as well as from best practice and literature, competitors' viewpoint and visions of potential benefits of AFRY.

The goal of this proposal was to make a full inventory" for the case organization so that to have a complete view of the benefits provided by digitalisation for the Metals & mining industry. Such an inventory should help the case organisation (a) help the customers to recognize the benefits of digitalisation, as well as (b) for the decision-makers, to recognize the gaps in the current AFRY´s digital benefits, solutions and tools, and thus help decide on the direction for further actions to develop digitalisation.

Next, Section 6 continues the discussions on the proposed elements and validates them into the Final proposal.

6 Validation of the Proposal

This section presents the results of the validation stage and the recommendations for further improvements to the initial Proposal. First, the sections describe how validation was conducted. Next, it discusses the developments to the Initial proposal. Last, the Final proposal and the recommendations are presented at the end of this section.

6.1 Overview of the Validation Stage

The goal of this stage was to validate the Initial proposal, which is developed in Section 5. For this end, the key stakeholders provided their expert judgement on the Initial proposal created in Section 5. The recommendations from the expert stakeholders provided the basis for improvements of the Initial proposal.

There were two validation meetings in AFRY. The first validation meeting consisted from the Vice President of Process Industries and Subconsultant of Process Industries. The study's overview, key sections' points and the initial proposal were presented in the first validation meeting. The first validation meeting was conducted virtually, because of the current world circumstances. The data (recommendations) from the first meeting were documented via filed notes, and then later processed into the final proposal. This meeting was very important for this study, because it provided the professional view on the thesis objective and outcome.

The second validation meeting included Sustainable Director of Process Engineering, Vice President of Technology and Smart Solutions, Director of Smart Site, Director in Chemicals and Biorefining, and Metals and Mining Technology, Technology Specialist in Metals and Mining. The meeting was conducted virtually as well as the first validation meeting. The shown material contained the presentation of study's overview, main sections' points and the initial proposal. The result of the second meeting was the opinion and comments concerning the study. The results were gathered as the field notes. Ekaterina, tell that there were 2 validation meetings. who participated? what was presented? what you asked them for? what insights were gained, generally? how data was documented?

Based on these inputs, the Final proposal is created. The Final proposal includes the revised and updated information about the topic of the study.

6.2 Developments to the Proposal

This sub-section reflects on the improvements of the Initial proposal gathered at the validation stage (Data 3). This Data was gathered from the key stakeholders in the form of opinions, validation comments, and recommendations to the Initial proposal and concentrated on identifying development points proposed by the experts.

6.2.1 Developments to Element 1 of the Initial Proposal

According to the expert input and comments, it was recommended to do the adjustments in *Element 1,* Metals and Mining Industry: Visions of Potential Digital Solutions, Tools and Their Benefits, described in the Initial proposal.

The first recommendation was to correct the information about KRTI 4.0 digital tool. It is important to add that KRTI 4.0 includes RAMS modeling and AI framework. Since KRTI 4.0 is an artificial intelligence application, *the AI framework approach* needs to be mentioned in the discussion. Furthermore, it was stressed that it was significant to emphasize that KRTI 4.0 utilizes *RAMS model-based approach* as well (Reliability, Availability, Maintainability and Safety) in order to get the full picture of this digital application.

The second recommendation related to the need for an adjustment in the Virtual Site Designer digital tool. This digital tool enables to prepare for the future maintenance cases. It is not a predictive maintenance tool, but instead *a preparation for the further predictive maintenance case.* Therefore, firstly, Virtual Site Designer provides the groundwork for maintenance cases; and then, surely, it connects to the actual predictive maintenance benefit.

As a result, Element 1 was refined to reflect these suggestions for improvements to the Initial proposal by the key stakeholders.

6.2.2 Developments to Other Elements of the Initial Proposal

Overall, the key stakeholders were uniformly satisfied to learn about the findings, which were reflected in the initial proposal. The major comments performed were that it is important that now the focus on Metals and mining industry comes also from the business context.

Besides that, the analysis of competitors' visions was praised as up-to-date (summer 2020) report on the market situation. The reflection of the rivals' description of their solutions, tools and benefits was very significant for the case company AFRY as it was recognized by the experts.

The next sub-section below illustrates the Final proposal on this study.

6.3 Final Proposal

This sub-section illustrates the Final proposal, which is produced from the combination of Section 5 Initial proposal and Section 6 Recommendations for improvements. The Table 21 below shows the result of the revised Initial proposal of this study.

As was mentioned earlier, key stakeholders suggested to improve only Element 1 of the Initial proposal – Metals and Mining Industry: Visions of Potential Digital Solutions, Tools and Their Benefits. Consequently, KRTI 4.0 and Virtual Site Designer were revised and improved in the Final proposal, as can be seen in Table 21 below.

The Final proposal is important finding for the case organisation due to its wish to be the one the most digitally developed company and enable digital transformation for its clients. As was mentioned before, the case company has the gaps in the digitalisation of the Metals and mining industry. Basically, the only current solutions for are process development, time management and engineering. In comparison to the Pulp and paper industry, which uses much more bigger number of digital solutions, Metals and mining industry is lacking these digital solutions.

According to the key stakeholders' reaction, the business point of view to the problem contributes the case company in a way, that before there was no business context of the digitalisation in the Metals and mining industry. Besides, the demonstration and explanation of the possible digital solutions, tools and benefits shows the value for the potential customers and creates awareness of various digital solutions for the Industry.

The company can utilize the study's material, the theoretical knowledge and the final proposal for the future development of digital solutions and tools in the Process Industries overall and in the Metals and mining industries more specifically.

In my opinion, it is wise to further develop the risk analysis from applying certain digital solutions. The risk analysis could involve the investigation how the outcomes and the objectives can change because of the impact of risk possibility. After identifying the risks, they need to be analysed in order to successfully create steps to mitigate these risks.

Also, the financial part of the final proposal could be developed. Certainly, due to confidentiality issues, it is impossible to show the numbers and figures in the study, however, internally in AFRY such ability needs to be considered. When choosing a particular digital solution, the customer desires to understand not only the digital value, but also the financial value from utilizing the tool.

Therefore, the further development of the Final proposal will enhance the case organisation's chances to find more potential customers and identify all aspects of the digital solutions, which the client then benefits from.

Next, Section 7 presents the executive summary of this study and the evaluation of the thesis.

Table 21. Final Proposal for benefits in the Metals and mining industry.

	Digital Solutions	Digital Tools	Benefits
AFRY's current benefits	Effective engineering	3D layouts	Simplification of the plan development
	Time management	Engineering templates	• Cost reduction • Time reduction
	Process development	Process balance calculations	Improvement of business processes
	Visualization of mine operations and conditions in real time	Network capability	• Forecasting • Well-time decision making
	Automation increase	N/A	• Operation efficiency optimisation • Risk exposure decrease
Competitors' benefits	Carbon dioxide-free production, that reduces environmental impact, reduction of injuries	N/A	Sustainability
	Fully self-governing mine or remove monitoring	N/A	Autonomy
	Virtual simulation in 4D beforehand	Simulation	Safety
	Virtual mine and simulator, coordination of activities, elimination of possible mistakes, costs reduction, increased productivity	VR	Virtual mine
Potential benefits	Preparation for maintenance	Virtual Site Designer	• Safety • Predictiveness
	Improved data collection	AFRY Smart Site platform	• Integrated information management • SSOT • Process harmonization and collaboration
	Advanced analytics	AI	Effective data analysis
	Maintenance optimisation	KRTI 4.0 and RAMS+AI	• Proactive insights and Prescriptive maintenance • Incident root cause analysis and Process standardization • Asset maintenance and Service automation • Predictive analytics • Correlation of failure with operational data and design • Advanced visualization and Minimization of restoration time
	AFRY management consulting	Site supervision and construction management	• Consulting during all stages of a mine business life • Operations support • Successful project implementation
Literature suggestions	Decrease of carbon footprint	Digital twin	Sustainability
	Digitally empowered workforce	Remote operation center	Improved health and safety issues
	Connected worker	VR/AR, connected mobility	• Seamless communication • Real-time insights

			• Instant remote support
	Robotics, automation and operational hardware	3D printing	Efficient metal parts utilisation
	Big Data analytics	Smart sensors	Real time insights
	Mine simulation	Modeling simulation	• Improvement of operational performance • Investment decrease • Waste reduction
	Next-generation analytics	AI	Holistic view and management of mine operations

7 Conclusion

This section contains the summary of this study. The executive summary describes the main steps and results of the study. Then, there are proposed next steps towards implementation. Finally, the research quality and thesis evaluation are discussed.

7.1 Executive Summary

Digitalisation is not anymore the future, it is the present. A lot of work is nowadays automated, converted into digital mode and analyzed by different applications that utilize artificial intelligence. Digitalisation makes the work processes more efficient and creates opportunities for business. Digitalisation also enhances safety and health issues, increases profitability and regulates the emissions. It is a use of digital technologies to transform a business model and bring more income and value creation opportunities.

The objective of the study was to identify and describe concrete benefits of digitalisation for the Process Industry customers in the Metals and mining industry. One of the issues was to understand the digital solutions that would benefit the Process industry customers, and the outcomes from these digital solutions. The scope of this study was limited to AFRY Smart Site tools. The outcome was the identification and description of the benefits of digitalisation for the Process Industry customers in the Metals and mining industry.

The study followed the Applied action research approach. The data was collected in three rounds. The first round, Data 1, was gathered for the current state analysis by exploring internal documents and conducting meetings and workshops. Data 2 was gathered from internal co-creation meetings, interviews and workshops, and was applied in the Proposal building. Data 3 was gathered from the group interviews for validation of the Initial proposal.

The current state analysis focused on investigating the existing digital solutions in the Pulp and paper industry (as a benchmark), existing solutions and visions in the Metals and mining industry, which is currently lagging behind the benchmarked Pulp and paper industry. The outcome of the current state analysis contained the summary of the identified current digital solutions, tools and benefits in the Pulp and paper industry, compared to the Metals and mining industry. The results pointed to the presence of missing points or gaps from digital point of view in the Metals and mining industry. The only current solutions for the mines and metals were time management, engineering and process development. Thereby, it was significant for this study to find out other available digital tools and solutions and the benefits from utilising them, to strengthen AFRY’s position on the market.

In support to the insights from the current state analysis, the study explored available literature, best practice, case studies and industry white papers to create an overview of digitalisation, identify digital twin cases, as well as to define the role of digital twin in sustainability and circular economy. The main focus was on the identification of digitalisation benefits in the Metals and mining industry. Ideas and relevant suggestions from these materials were selected and merged into the conceptual framework, a summary of four tables, reflecting the indicative results of digitalisation benefits based on digital themes and initiatives in the Metals and mining industry according to World Economic Forum, the case examples from Siemens and Oracle, and other latest industry materials.

Both, the insights from the current state analysis together with ideas from literature and best practice paved the way for building the proposal. The proposal was merged out of several elements. First, Element 1 analyzed and derived ideas from the visions of potential digital solutions, tools and benefits in the Metals and mining industry. Second, Element 1 analysed and derived ideas from the competitors´ visions of digital solutions, tools and benefits. Third, Element 3 revised the role of digital twin in sustainability. Additionally, the researcher also zoomed into the competitor’s analysis of digital twin features and other digital solutions among 25 leading digital organisations. Based on these input, and supported by the co-creation discussions with the stakeholders, the initial proposal was built.

The Proposal suggested to use the data analytics by means of smart sensors in order to get the real-time insights, to exploit artificial intelligence, 3D printing and modelling simulation for more operative metal utilisation, holistic view and efficient management of mine operation, improvement of operational performance, reduction of waste and cost. Besides that, it was recommended to use digital twin and VR/AR, as well as remote operation center to advance health and safety issues, get the seamless mine communication, deliver instant remote support and boost circular economy in the Metals and mining industry. Also, it was proposed to use artificial intelligence and KRTI 4.0 RAMS digital tools to benefit from efficient data analysis, proactive insights and prescriptive maintenance, advanced visualization, asset maintenance, service automation, connection of failures with operational data and design. Moreover, utilization of Smart Site platform would generate a single source of truth and process harmonization and collaboration, and integrated information management. Virtual Site Designer would let to prepare for further maintenance to enable safety and predictiveness in the mine. Site supervision would boost successful project implementation. Virtual mine simulation would enable to decrease environmental impact and cut number of probable injuries.

This initial proposal was validated in two sessions with the key stakeholders where further ideas and recommendations were gathered how to improve this proposal. The expert judgement was provided in a professional and constructive way that enabled further developments in the proposal. In the final proposal, the thesis demonstrates that the main benefits of digitalisation relate to an efficiency increase, reduction of operational costs, data storage and analysis. Indeed, there are many other benefits of digitalisation, such as better manufacturing processes, faster delivery of services and products, short reaction time to client's feedback, lower production costs, new client acquisition channels, improved innovation processes.

7.2 Next Steps Towards Implementation

The case company's ambition is to become one of the most digitally advanced consulting and engineering companies. Therefore, by pioneering and leading this industry, the company can enable its clients to take advantage of Industry 4.0, Big Data and the Internet of Things (IoT), to rise their competitive advantage and achieve greater value.

Further steps towards the final proposal implementation can be considered as follows.

First, the suggested benefits, digital solutions and tools can be introduced to the potential Metals and mining industry customers. It is important to demonstrate and explain the benefits of digitalisation to the clients, so that the potential clients become better aware of the value of various digital solutions and tools, as well as their provided benefits.

Second, I would recommend to create a risk analysis based on the digital solutions, tools and benefits represented in the Final proposal. The risk analysis might involve the examination how the outcomes and the objectives may change because of the impact of risk possibility. Risk identification allows the case company to analyze them in order to effectively create steps to mitigate these risks.

Third, the financial aspect of the final proposal could be developed in my opinion. Indeed, because of confidentiality issues, it is impossible to display the numbers and figures in the study, however, internally in AFRY such ability should be considered. When choosing a particular digital solution, the client wants to comprehend not only the digital value, but also the financial value from utilizing the tool.

Fourth, the digital scaling can be applied as the roadmap to next steps towards implementation. Nowadays many companies are utilizing diverse digital technologies to become more mature than the rivals, to improve operational efficiency, to transform disruptive innovations to own advantage. Surely, just to have digitalisation process in the company is not enough, it is wise to understand the value behind the digitalisation. Thus, the ability to scale digital solutions becomes the next step to AFRY. I would suggest to produce a capability to scale digital innovations for profounder engagement with new and existing customers, and valuation of new digital tools and solutions. Thus, there can be identifies several main areas to concentrate on, when scaling digital initiatives. They are the following. Collection and sufficient use of data, that is not yet properly used, - this will help to deliver the outcome, not a product, and therefore provide better service. As-a-service model's application can boost the move of AFRY from product to service attitude with customers. And the reinforcement of ecosystems will help to connect products and services into other AFRY's solutions and ecosystems.

7.3 Thesis Evaluation and Research Quality of This Thesis

The study was significant for the case organisation, because there was a need to fill in the gaps in digitalisation in the Metals and mining industry. Since the case organisation tends to be among the most digitally advanced companies in the market, it is important to improve the digital solutions and tools and show the potential customers the benefits from utilizing these solutions and tools.

The objective of the study was to identify and describe concrete benefits of digitalisation for the Industry customers in the Metals and mining industry (possible via AFRY Smart Site). The study outcome meets the above objective and therefore identifies and describes the benefits of digitalisation for the Industry customers in Metal and mining industry. Besides that, the outcome also shows the digital solutions and tools, that enhance the benefits for the Metals and mining customers.

This sub-section illustrates the Final proposal, which is produced from the combination of Section 5 Initial proposal and Section 6 Recommendations for improvements. The Table 21 below shows the result of the revised Initial proposal of this study.

As was mentioned earlier, key stakeholders suggested to improve only Element 1 of the Initial proposal – Metals and Mining Industry: Visions of Potential Digital Solutions, Tools and Their Benefits. Consequently, KRTI 4.0 and Virtual Site Designer were revised and improved in the Final proposal, as can be seen in Table 21 below.

Since the study followed the Applied action research approach and used qualitative research methods, the research quality can be discussed following the criteria of credibility, validity and transferability as the popular criteria of research quality.

7.3.1 Validity

Validity in Action research typically relates to the quality of instruments and processes for data collection. Validity can be evaluated for example by scrutinizing how well the knowledge or data was generated (Herr, Anderson, 2005: 50-52). There are four types of validity: internal, construct, external, and reliability (Quinton, Smallbone 2006: 125).

In this study, the validity was ensured by the following steps. Internal validity implies that the actual results from the gathered data is what was intended to be got, during the research design stage (Quinton, Smallbone 2006: 126-127). In this study, the collected data was gathered in accordance with the established research procedures, and came from the most relevant stakeholders via interviews and discussions in order to collect the best available data and document and analyse it correctly. *Construct* validity confirms the significant of the research (Quinton, Smallbone 2006: 129). Therefore, in this study, it was ensured that the case company´s needs would guide the study, thus, proving the basis for construct validity.

External validity is the estimation if the outcomes can be used in other situations (Quinton, Smallbone 2006: 129). The topic of this study does not imply utilization of the outcomes to a different area; however, it can be utilized as a benchmark when solving similar challenges related to identifying the benefits of digitalization. External validity comes close to *Transferability,* which means the opportunity to apply the research findings in the similar situations. Usually the results from the action research are unique and not directly transferable (Nielsen, 2007: 365). But such studies can be utilised as good examples of approaching similar challenges in other industry, for example, for this study, probably in automotive or chemical.

Finally, *reliability* means that the results are trustworthy and compatible (Quinton, Smallbone 2006: 130-131). In this study, reliability was strengthened by utilising diverse data sources and data collect tools, such as interviews, discussions, workshops, internal documents. Reliability resembles *Credibility*, which means that the outcome of the study is believable and trustworthy. It usually depends on the richness of gathered data, its quality and depth (Statistics Solutions 2020). In this study, reliability/credibility is ensured by applying the triangulation of sources. The triangulation includes here Data 1, Data 2 and Data 3, which in turn contain important key stakeholders' interviews, workshops, discussions. Also, there were utilized multiple internal and external documents, as well as best available literature and most recent cases concerning the topic of the study.

7.4 Closing Words

Digitalisation is restructuring all industries nowadays. Many processes are automated and transformed into digital mode. Diverse application and digital tools analyze these processes thanks to artificial intelligence. Digitalisation boosts health, sustainability and safety matters. Digitalisation makes daily working life more effective and generates prospects for business. This study proposes to utilize the digital solutions, tools and benefits in the Metals and mining industry. Because the use of digital technologies enhances the digital transformation, thus, it generates more value, boosted profitability and greater opportunities for the companies applying it.

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Appendix 1: Competitors' Analysis of Digital Twin Features

	Kongsberg	DNV-GL	Iotics	GE Digital	Dassault Systemes	Siemens	Microsoft	Oracle	PTC	Ansys	IBM	SAP
Platform	Kognifai		Event-Data	Predix	3DExperience	Mindshere, Comos, Simine	Azure	IoT production Monitoring Cloud	ThingWorx	TwinBuilder	Watson	Leonardo IoT
Industry	Energy, maritime, utilities (power grid)	Maritime, oil and gas, power and renewables, automotive and aerospace, food and beverages, healthcare	Manufacturing, construction, health care, transport, insurance	Aviation, healthcare, manufacturing, oil and gas, power generation, transportation, mining	Aerospace and defense, business services, construction, retail, high-tech, life sciences, transportation, industrial equipment, marine and offshore, energy and	Aerospace, automotive, battery manufacturing, chemicals, cement, cranes, data centers, fiber, food and bevarages, glass, machinery and plant construction, marine, mining, oil and gas, pharma, power utilities, tire, transportation, water, wind energy, pulp and paper	Automotive, discrete manufacturing, energy, healthcare, process manufacturing, retail, transportation and logistics	Banking and insurance, communications, engineering and construction, food and beverages, healthcare, hospitality, life sciences, public sector, retail, utilities	Aerospace and defense, automotive, electronics and high-tech, industrial machinery, life sciences, oil and gas, retail and consumer	Automotive, aerospace, construction, consumer goods, energy, healthcare, high-tech, industrial equipment ans rotating machinery, materials and chemical processing	Aerospace and defense, automotive, banking and finance, education, electronics, energy and utilities, government, healthcare, insurance, life sciences	Energy and natural resources, service industries, consumer, discrete, financial, public services
Digital Twin features												
Predictive maintenance	x	x	x	x	x	x	x	x	x	x	x	x
Process optimisation	x	x	x	x	x	x	x	x	x	x	x	x
Simulation	x			x	x	x	x	x	x	x	x	x
Product development			x	x	x	x	x	x	x	x	x	x
Open interface				x		x						
Digital twin Plus (other digital apps and solutions)												
ET solutions	x	x	x (partly: ET appro	x	x	x				x		x
Device management			x	x	x	x	x	x	x	x		
Cybersecurity	x	x		x		x	x	x			x	
VR/AR	x			x		x	x		x	x		
Partnership	x	x	x	x		x	x		x	x	x	x
Data management and advanced analytics	x	x		x	x	x	x	x	x	x	x	x
ERP integration				x		x						
3D visualisation	x	x		x	x	x	x	x	x	x	x	x

	AkerSolutions	ABB	Etteplan	Equinor	Ramboll	Bosch	(Alstom) Anylogic	Infosys	Nokia	Hitachi Vantara	Andritz	Valmet	Bentley
Platform	Integral	Ability				IoT Suite	Cloud Anylogic	Nia	Warp 6, SI Suite	Pentaho	Metris	VII - Valmet Industrial Internet	iTwins
Industry	Oil and gas, maritime, wind offshore, energy	Automotive, buildings, data centers, EV charging, food and beverages, manifacturing, marine and ports, mining and metal, oil and gas, chemicals, power, pulp and paper, renewables, transportation, water	Aerospace and defense, automotive, consumer products, energy and power transmission, forest, pulp and paper	Oil and gas, transportation, energy, renewables,	Building, transport, water, health, energy, telecom, management consulting	Agliculture, building, cross-industry, energy, retail	Transportation and mobility	Aerospace and defense, agriculture, automotive, communication services, consumer package	Utility, transport and logistics, electricity, gas, renewable, manufacturing, shippers, public	Manuacturing, energy, healthcare, life sciences, government, retail, communications, financial services	m, architecture, automotive, carbon steel, chemicals, desalination, environment, feed, food and	Biofuels and biomaterials, chemical, fiberboard, filtration, food, marine, minerals and metals, oil and gas, paper, wastewate	Building and facilities, communications, discrete manufacturing, electric and gas utilities, government, mapping and
Digital Twin features													
Predictive maintenance	x	x	x	x	x	x	x	x	x	x	x (not dig.twin)	x (not dig.twin)	x
Process optimisation	x	x	x	x	x	x	x		x	x	x (not dig.twin)	x (not dig.twin)	x
Simulation	x	x	x	x	x	x	x		x	x			x
Product development	x	x	x	x	x	x			x	x	x (not dig.twin)		x
Open interface							x						
Digital twin Plus (other digital apps and solutions)													
ET solutions	x	x	x							x	x	x	x
Device management						x			x	x			
Cybersecurity			x							x		x	
VR/AR		x	x		x		x		x	x	x		x
Partnership	x			x		x	x	x	x	x	x		x
Data management and advanced analytics			x			x		x	x	x	x		x
ERP integration													x
3D visualisation	x	x	x	x	x	x	x	x		x			x

Appendix 2: Interview Sustainability in Mining and Metals Industry, Questionnaire

Sustainability in the Mining and metal industry

1. What are the main pitfalls?
2. How to decrease pollution?
3. How to create sustainable recycle from the waste production?
4. Can circular economy be applied?
5. Is it possible to achieve carbon-dioxide ($C0_2$) free mining?