Aalto University
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A SERVICE VISION FOR A LASER-BASED SCANNING METHOD

Master's Thesis
Emilia Xue
Aalto University School of Business
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Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

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Author Emilia Xue

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Abstract

This master's thesis develops a service vision for a laser-based scanning method targeted to mining industry. The research is a part of Business Finland funded academic innovation commercialization project. Lean Service Creation has not been widely applied as a theoretical framework for a startup service vision creation, therefore this study contributes to the research gap.

This thesis is a single case study, which applies action research for gathering empirical data and analyses the results using qualitative methods. The framework for service vision creation is Lean Service Creation. Besides, the Business Model Canvas is used as a business model framework. The empirical data were collected through semi-structured and contextual interviews as well as prototype testing with fourteen mining industry experts. The interviews were part of the central practice of Lean Service Creation, Build, Measure, Learn feedback loops, which clarify the service and business requirements by testing hypotheses through customer engagement. Based on the aggregated customer insights that derives from the feedback loop, a service vision was created and validated.

The results of this study indicate that the most significant customer needs for geological reporting are increasing the accuracy and speed of retrieving the data in the drill core logging process. The service concept addresses these customer needs through a sample scanner, which will be monetized with a business model that provides analytics-as-a-service. In addition, the final part of the thesis reflects the applicability of the Lean Service Creation method in the startup context, and compares the findings to those of the earlier research. Based on the perceived challenges, this study proposes an alternative business model and market research canvases for startups' to the Lean Service Creation framework.

Keywords Service vision, service concept design, business model design, Lean Service Creation

Aalto-yliopisto
Kauppakorkeakoulu

Aalto-yliopisto, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

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Tiivistelmä

Tässä pro gradu -tutkielmassa kehitetään palveluvisio laserpohjaiselle mittausmenetelmälle kaivosalalla. Tutkielma on osa Business Finlandin rahoittamaa kaupallistamisohjelmaa. Tutkielman tavoitteena on luoda palvelukonsepti sekä liiketoimintamalli, jotka pohjautuvat geologiseen raportointiin liittyviin asiakastarpeisiin. Tämä tutkimus myötävaikuttaa Lean Service Creation -menetelmän soveltamiseen startup-kontekstissa, jossa sitä on tutkittu vain vähän.

Pro-gradu tutkielma on tapaustutkimus, jossa empiirinen tiedon keräämiseen sovelletaan toimintatutkimusta ja tulokset analysoidaan laadullisen tutkimuksen avulla. Palveluvisio kehitetään Lean Service Vision -menetelmää soveltaen. Lisäksi liiketoimintamallin muotoilussa käytetään Business Model Canvas -menetelmää. Empiirinen tieto kerättiin teema- ja kontekstuaalisten haastattelujen sekä prototyyppitestaamisen avulla. Tutkielmaa varten haastateltiin neljäätoista kaivosalan erikoisasiantuntijaa. Haastattelut olivat osa Lean Service Creation -menetelmän keskeistä Build, Measure, Learn -palautesyklillä, jossa palvelu- ja liiketoiminnan vaatimuksia selvennetään hypoteesien testauksen avulla. Palautesyklin kautta kertyvän asiakasymmärryksen pohjalta kehitettiin ja validoitiin palveluvisio.

Tutkimustulokset viittaavat, että suurimmat geologiseen raportointiin liittyvät asiakastarpeet ovat tiedon keräämisen tarkkuuden ja nopeuden parantaminen kairasydänten loggauksessa. Asiakastarpeiden pohjalta palvelumalliksi valittiin näyteskanneri, joka kaupallistetaan tarjoamalla kairasydänanalytiikkaa palveluna. Lisäksi Lean Service Creation -menetelmän soveltamista startup-yrityksen palveluvision kehittämiseen arvioidaan ja vertaillaan aikaisempien tutkimusten tuloksiin. Haasteiden pohjalta tutkimuksessa esitetään Lean Service Creation- menetelmään sovelletut liiketoimintamalli- ja markkinatutkimus työkalut startup-yrityksille

Avainsanat palveluvisio, palvelukonseptin suunnittelu, liiketoimintamallin suunnittelu, Lean Service Creation

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Table of Contents

List of Tables

List of Figures

Abbreviations

GTK *Geologian tutkimuskeskus*, Geological Survey of Finland

LASO-LIBS Large Area Scanning Open-source Laser Induced Breakdown Spectrometer

LSC Lean Service Creation

KPI Key Performance Indicator

MVP Minimum Viable Product

RQD Rock Quality Designation

SVS Service vision sprint

TUTL *Tutkimuksesta uutta liiketoimintaa (*new business from research ideas)

Definitions

Battery metals: The growing number of electric vehicles increases the demand for battery metals. Battery metals include lithium, cobalt, nickel, graphite, manganese, copper, and aluminum.

Diamond core sample: a cylindrical section of a naturally occurring substance, such as rock. The most important source in ore exploration and mining to define the mineralogical and geochemical composition and geophysical properties of an ore deposit.

Feldspar: a mineral that may contain aluminum and potassium

Laser induced breakdown spectroscopy (LIBS): an atomic emission spectroscopy technique, which uses short, highly energetic laser pulses to form a plasma.

Lean Service Creation (LSC): a framework for service creation that encourages rapid prototyping, multidisciplinary teamwork and customer-centric thinking.

Minimum Viable Product (MVP): an early version of a product with minimum number of features to satisfy early customers.

Ore deposit: a natural concentration of one or more minerals within the host rock. The deposit is defined by the quantity in tons and average quality in grades. The deposits have different shapes and may occur for instance as veins, layers or folds.

Oxide: a mineral which may contain chromium, tin, tungsten, tantalum, niobium, and uranium.

Precious Metals: gold, palladium, platinum, rhodium, silver

Rock Quality Designation (RQD): a measure to evaluate the quality of borehole core samples. RQD indicates the degree of jointing or fracture in a rock mass.

Service vision sprint (SVS): The first phase in LSC during which a service concept and a business model are designed.

Sulfide: a mineral which may contain silver, lead, and copper.

1 Introduction

This chapter introduces the background information and motivation for the study, research questions, and scope of the study.

1.1 Background and motivation

We live in an age of unprecedented technological innovation. The advancements in technology are a source of economic growth and improved standards of living, health, and the environment (Albassami & McCoy, 2016). While innovation is vital to sustaining well-being, it is also counted on to solve future challenges, such as combat climate change and help cope with diminishing raw materials (Schaufeld, 2015). Innovation alone is not enough as it needs effective commercialization to survive and make an impact. Despite the importance of commercialization, it remains the least developed area of innovation management (Crossan & Apaydin, 2010).

Commercialization projects' scope varies, yet according to Howard and Guile (2010), most projects have six stages: concept, technical feasibility, development, commercial validation and production, full-scale production, and product support. Although the stages are presented in a linear order, they may overlap and be iterated multiple times to reach the desired outcome. Iteration is particularly common during commercial validation and production. The commercial validation phase comprises of developing an early service vision, that is, the service and business models. Despite finding a market fit for a business idea during the commercial validation stage is a fundamental part of commercialization, it is the most common reason for a new venture failure, according to CB Insights (2019) startup post-mortem inquiry. Furthermore, outstanding 15 out of 20 causes for startup failure were commercial. Several authors suggest that startup failure is more often contributable to business acumen rather than technical prowess (Feinleib, 2011; Bradberry & Slim, 2011).

Even though commercialization can be a challenging process, specific actions increase the probability of success (Schaufeld, 2015). For projects that are on the verge of commercialization, strong market orientation and the use of a human-centered method help to understand the customer needs (Feinleib, 2011; Shah & Shah, 2011; Bradberry & Slim, 2011). The ability to address customer needs and apply adequate technology promptly determine the company's success. The companies that offer higher performance and features that appeal to customers more likely to obtain a competitive advantage (Kamrani et al., 2013). According to Camuffo et al. (2019), startups that use validation, such as ethnographic research and A/B tests, are more likely to result in less false-negative results and address customer needs in contrast to startups that use heuristics. To improve the likelihood of market acceptance for the innovation, Lean Service Creation, a human-centered, iterative method was chosen as the theoretical framework. The objective of this study is to develop a service vision for a LASO-LIBS (Large Area Scanning Open source - Laser Induced Breakdown Spectrometer) scanning method. The method is novel and was invented in the Department of Civil Engineering at Aalto University. This thesis is a part of Business Finland funded TUTL (New business from research ideas) commercialization project that was granted for the innovation.

A LASO-LIBS scanning method can detect mineral and elemental composition, and mechanical properties of a mineral sample in real-time. The depleting high-grade ore deposits and increasing demand for metals, push mining companies to explore and implement more efficient processes. Fast mineral identification can provide better process control and optimize the use of energy and raw materials (Khajehzadeh, 2018). Fennoscandia has a long tradition in mining and is recognized worldwide for the active and innovative mining industry. Therefore, the first customer segment we will explore during the commercialization project is Fennoscandian mining companies.

This thesis contributes to the research gap of studies applying Lean Service Creation for a startup service vision creation. At the same time, this study contributes to a limited number of studies describing commercialization of innovation in the mining industry.

1.2 Problem statement and research questions

The mining industry professionals' needs and challenges regarding geological reporting is not widely researched. In human-centred development methods, such as Lean Service Creation, the process begins with establishing a customer insight. The understanding of the customer needs enables the development to focus on relevant customer problems. The customer focus correlates with likelihood of product success (Varma, 2015). Therefore, the first objective of this research is to establish customer insight for the LASO-LIBS service vision creation. Concurrently, the research will narrow the research gap. The first research question is the following:

Q1: What kind of customer needs in the mining industry can the LASO-LIBS scanning method address?

Due to the novelty of the LASO-LIBS method, and unfamiliarity with the customer challenges and needs, there is no existing data of what kind of LASO-LIBS based service can provide value to the customers. Therefore, the second objective of this research is to develop a service that best addresses customers' needs. The second research question is the following:

Q2: What kind of LASO-LIBS-based service concepts can address these needs?

As will be discussed later, the business models depend on multiple context and time related factors, which makes generalization of business models difficult. Consequently, the available business model development frameworks provide only high-level guidance on what questions should be considered in the development process. The third objective of this research is to explore what kind of business model can be used to monetize the LASO-LIBS method. The third research question is the following:

Q3: What kind of business model could be used to monetize the LASO-LIBS method?

1.3 Scope of the study

The purpose of this study is to develop a service vision for a potential spin-off startup. Other forms of monetization besides establishing a startup will be considered during the Business Finland commercialization project, yet it is beyond the scope of this study. Since the terms and conditions of the funding restrict making revenue, a business model cannot be commercially validated, which limits the scope of validation methods. Therefore, the results of third research question remain hypothetical.

This study concerns the Fennoscandian mining industry, which limits the generalizability of the results in the mining industry. Furthermore, the scope is limited to metal mines because their ore deposits are considerably more challenging than in industrial mineral mines. Furthermore, some of the industrial minerals can be detected by eye, such as clay and sand. Many metallic minerals, on the other hand, are hard to detect as their grades are low (Gandhi & Sarkar, 2016). At the same time, mineral deposits are becoming smaller and more complex, and which increases the demand for analytical instruments (Fischer & Lo, 2012).

1.4 Structure of the thesis

This thesis begins with a literature review that introduces Lean Service Creation and relevant research on business models. The next chapter describes and motivates the chosen research methods for this study. In addition, the research case and context of the study are introduced. The fourth chapter presents the empirical findings of the study, which are discussed and analyzed in the following chapter. The final chapter concludes the thesis by discussing the contributions and proposing further study based on the implications and limitations of the study.

2. Literature review

This chapter discusses Lean Service Creation, which is the theoretical framework used for service development in this study, along with relevant recent topics in business model literature. The review includes Business Model Canvas, which is used as a theoretical framework for business modeling due to its applicability to new business context.

2.1 Lean Service Creation

Lean Service creation (LSC) is a systematic and flexible method that enables a multidisciplinary team to create new services. The impetus for LSC came from a client that asked Futurice, a digital consultancy company, to help them to create a way of working that fosters innovative thinking and promotes collaboration. The LSC tools and handbook are open source, which has made LSC among the most validated open source service creation processes in the world (Nevanlinna et al., 2018). In the following chapters key aspects of the method will be discussed.

Lean Service Creation was chosen as a theoretical framework for the study because one of the key objectives for the commercialization project is to acquire a customer insight of the Fennoscandian mining industry, and apply to insight to a business and service design. Therefore, the team selected a human-centered method for the study as the aim. Compared to similar methods that will be described below, Lean Service Creation appeared as the most practical and approachable due to the largest number of design tools, which support the service vision creation. Lean Service Creation also has a particular emphasis on team building and communication, which was considered critical for the project as the multidisciplinary team

2.1.1 Lean Service Creation definition

LSC is an open-source service development framework with a dual objective. The first objective is to foster innovative mindset and collaborative culture in multidisciplinary teams while the other one is to create human-centred services that address unmet customer needs (Nevanlinna et al., 2018).

The LSC framework consists of a curated set of canvases. The purpose of the canvases is to address all relevant aspects of service creation. This is approached by drawing attention to the problems in a structured manner and asking the right questions. The canvases can be divided into operational and managerial categories based on the thematic focus. Operational canvases consist of tools for teamwork and service development while managerial canvases focus on measuring the strategic impact of the work. Jointly the canvases form a dynamic process in which hypotheses are created and replaced through generative learning.

2.1.2 Lean Service Creation origins

LSC originates from Lean Startup (Ries, 2011), Design Thinking (Brown, 2009), and Agile (Beck et al., 2001) methods. Lean Startup is best known as a new business creation framework, Design Thinking as a mindset to approach product or service development, and Agile as an effective project management tool.

The key practices in Lean Startup and Design Thinking include building a minimum viable product by iteratively validating hypotheses with customers through prototyping. The practice creates a feedback loop that helps the team to ensure they are creating meaningful and customer-centric outcomes (Ries, 2011; Brown, 2009). In Agile the key practices are dividing the project into small tasks that take less than a day to complete, and minimum viable prototype thinking through frequent and prioritized release of features (Beck et al., 2001).

The common aspects among the methods is visual project tools, such as boards and canvases that help perceiving the project holistically while paying attention to details. Furthermore, all the methods promote eliminating waste by continuously testing and validating the product or service. At the same time all methods are human-centered and encourage continuous interaction with customers.

2.1.3 Lean Service Creation principles and practices

Alike its origins, LSC has principles and practices that are integral part of working and service development. In the book, Open Source Tools for Change Agents, Nevanlinna et al. (2018) present the principles and practices as LSC manifesto. LSC has five core principles that reflect the mindset and collaboration that helps multidisciplinary teams succeed in service creation.

The first guiding principle for service development is *"all for the team, team for all"* (Nevanlinna et al., 2018). Since creativity requires trust and openness to flourish, team building, and culture of trust are at the center of the LSC manifesto. The practices advocate teamwork and innovative culture include six teamwork canvases that facilitate project management to giving feedback. For example, Weekly LSC Board, promotes openness by reminding the team of the importance of transparency and prompting the team to discuss on weekly bases any concerns and goals they have work the project.

The second principle is to *“love the problem, not the solution"* (Nevanlinna et al., 2018). The purpose of the principle is to avoid creating solutions that does not address relevant customer needs. LSC encourages to find a problem that is worth solving. Nevanlinna et al. (2018) define worthy problem as “a substantial and scalable business opportunity.” The principle is implemented with a Build, Measure, Learn feedback loop (BML) practice that is depicted in Figure 1.

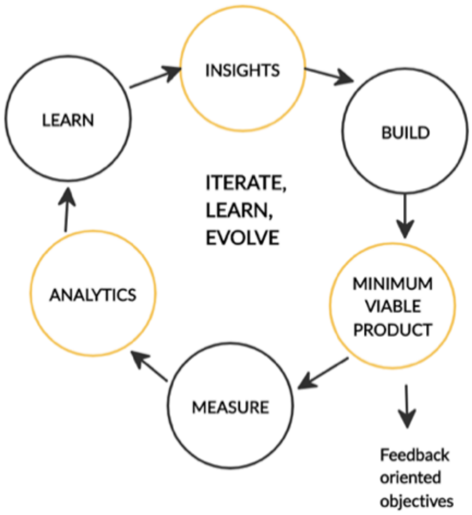

Figure 1. Build, Measure, Learn –feedback loop (Adopted based on Nevanlinna et al., 2018)

BML begins by setting a hypothesis of an assumed customer need. The hypothesis is measures by building a prototype and testing it with clients. The customer interaction with the prototype and feedback provides an insight to whether the prototype addresses a relevant customer need. Through the analysis, teams learn whether the hypothesis was accurate, and to what degree if so. Based on this insight, the team can begin a new BML. The insights are prototyped with falsifiable hypotheses iteratively until the team has reached a minimum viable product.

The third principle is *“no matter what you do, be transparent about it"* (Nevanlinna et al., 2018). As discussed earlier, transparency fosters teamwork. Moreover, traceable processes enable effective project management. In LSC transparency is implemented through recording key activities, visualizing complex dependencies, explaining rationale for decisions, and facilitating open discussions. All LSC canvases reflect this principle by prompting the team to record the process and visualize aspects of the work where suitable.

The fourth principle is *“never stop iterating, never stop learning"* (Nevanlinna et al., 2018). This principle is closely aligned with the second principle. Iteration refines the problem that is worth solving and deepens the understanding of customer needs. Consequently, iteration provides constant customer insight, which yields learning. The principle is reflected in BML practice depicted above.

The fifth principle is *"see the forest, see the trees, spot the squirrel"* (Nevanlinna et al., 2018). In other words, LSC guides the team to view the project at hand holistically. Understanding both macro and micro level of the project, enables the team to strategize and create a detailed implementation plan. The supporting practices come in form of tasks that ask to zoom in and out in the problem space and propose questions that promote both practical and strategic thinking. For instance, the concept and value proposition canvas, asks how does the concept work and what differentiates it from the other solutions solving the same problem.

2.1.4 Lean Service Creation phases

The development process divides into three interconnected development phases, as illustrated in Figure 2. Each phase consists of thematic, gradually advancing service development tasks. Each phase contains as many BML feedback loops that are required to meet insight that allows the team to move on the next phase.

Figure 2. LSC development phases (Adopted based on Nevanlinna et al., 2018)

The development process begins with service vision sprint, which lays the groundwork for the later phases. The next phase defining and building the MVP (Minimum Viable Product) a synthesis, consists most critical testing during the entire process. Finally, once an MVP is validated by the customers, it can be scaled in growing it huge phase. Each of the phases will be discussed below. The visual canvas templates are available in Appendix C.

Service vision sprint

Service vision sprint (SVS) is the first and most extensive phase in the LSC. The objective of SVS is to lay fundamentals for the service development. It contains tools ranging from understanding the customer needs to business model validation. Upon completion of the phase, team will have a validated service vision (Nevanlinna et al., 2018). A validation requires often more than two rounds of iteration to gain confidence in the insight. Furthermore, as SVS is the first phase, it may require extra efforts to align teamwork and develop a culture. Table 1 contains description of the purpose and key findings from each canvas.

Table 1: Canvases in service vision sprint phase (Nevanlinna et al., 2018)

Canvas	Purpose	Key findings
1.Business objective and context	To discover what is the business objective and why it matters	People that are needed for the project, KPIs to measure success, competitive advantages for success, risks and limiting factors
2. Immersion	To make an educated guess of a customer problem	An overview of how the customers and other companies solve the problem currently, what does the public opinion state about the problem
3. Customer groups	To know who your customer segments are	A categorization and prioritization of customers, a description of the customer and an assumption of the customer's problem
4. Insight	To understand your customers' needs	A basic insight of the customer's needs, attitudes and opinions
5. Ideation kick off	To ideate solutions to customers' problems with customer's emotions in mind	Multiple solutions that 1) solve the problem 2) remove or reduce negative feelings 3) amplify the positive feelings
6. Concept and value proposition	To select best ideas from ideation and develop them into full concepts	An insight of what value the concept provides for the customer and business, unique features of the concept
7. Profiling the concept	A validation tool for the probable concept	A confirmation if the concept fits the original business objective and is feasible with the company's resources
8. Customer engagement	To discover what makes people use and advocate the service	An insight how the customers are attracted to use the service, how they make purchase decision, and how they use the service
9. Business model & market size	A tool for validating commercial viability of the business model	An overview of the costs, prices, and revenues
10. Validation	To test the business model	An insight if the business model is viable through testing value proposition, customer grouping and customer's willingness to pay

SVS can be divided into three sub-segments. The canvases from one to four form a validated customer insight, five to eight form a service concept, and nine to ten establish a business model.

Defining and building the MVP

Defining and building the MVP deepens the insight of the service concept and turns the abstract concept into a tangible service. The phase approaches building an MVP by first defining what are the most critical features for the service. After validating the features, the team moves on to build an MVP. Table 2 synthesizes the purpose and key findings that result from the canvases.

Table 2: Canvases in Defining and building the MVP phase (Nevanlinna et al., 2018)

Canvas	Purpose	Key findings
11. Minimum viable (lovable) product	To build a minimum viable product that the customers will love	A list of aspects and values that the product must deliver and a minimum implementation plan
12. MVP backlog	A tool for tracking the progress and identifying issues	Identify any technical or commercial issues that may hindrance the progress, ensure that the target customer segment is correct, measure that the project is progressing through a visual backlog tracker
13. What to measure	To give focus to the project through actionable metrics	What are the key value proposition, service, and business metrics

Growing it huge

The last phase of LSC focuses on scaling the business through growth hacking. Growth hacking is a creative, data-driven marketing technique that focuses on creating viral growth through constant learning and innovation development (Troisi et al., 2019). For startups, growth hacking offers a cost-effective means of attracting attention.

Once the startup is launched, it will begin to accumulate hard data from business interactions. The hard data can then be used for growth hacking. According to Nevanlinna et al. (2018), the startup should continue BML workflow after the service is launched. The data gives quantifiable insight into whether the implemented change generated the desired outcome. Depending on the outcome, the startup can either roll back the previous version or develop the current one.

The growth hacking canvas encourages to visualize of the analytics to measure progress. The upside of visualization is that transparency can create trust within the organization. The KPIs include, among others, a conversion rate, number of users, and average usage time. Targets can be measured in the same chart. Finally, the canvas sets the teams to focus on the future by addressing the next critical issue for development.

2.2. Business models

This chapter discusses the key concepts of business model literature and presents a business model canvas that is used for business model design in this study. A business model is intrinsically connected to the service in question, as it describes the company's assumptions of the markets and the choices to monetize the service. Lean Service Creation contains tools for market research and business modeling, however, it is not a focal point of the method. This may be partially explained that most of the Futurice's clients that use Lean Service Creation have an established business, and the objective of using the method is to create an add-on service on top of the existing business infrastructure. As discussed earlier, developing and validating a business model is critical for a startups' success. Therefore, business models are separately discussed in the literature review.

2.1.1 Business model definition

Despite extensive research and attempts to define what business models are, no uniform definition or vocabulary around business models exist (Morris et al., 2005). Teece (2010) remarks that the branch of business model research is still new and consists of multidisciplinary researchers who perceive the concept through the lens of their discipline. The various definitions can be conceptually abstracted to the following four main categories (Andreini & Bettinelli, 2017).

1. Strategic
2. Narrative
3. Process-based
4. Cognitive

Business model research originates from strategy research. Bellman et al. (1957) outlined the business model concept in a business game that mathematically modeled revenue streams. Strategic definitions emphasize that business models are heuristic methods to realize the company's strategy. In other words, what is the practical implementation to create value for the customer and the subsequent revenue for the company (Casadesus-Masanell & Ricart, 2010; Teece, 2010; Chesbrough, 2002; Afuah, 1998).

Narrative definitions present business models as company-specific descriptions of how value is created. Magretta (2002) suggests that business models are *"stories that explain how enterprises work."* According to the Oxford dictionary, one of the definitions of the word story is *"the commercial prospects or circumstances of a particular company."* It is a common practice that business models are explained as case studies. Consequently, business models are to be viewed contextually on case-basis, which hinders their generalization.

Process-based definitions depict business models as practical frameworks to support business logic. Cavalcante et al. (2011) propose that business models are *"an abstraction of the principles supporting the development of a firm's core repeated process."* Cognitive definitions, on the other hand, display business models as reflections of the managerial insights and logic of how business value ought to be created (Aspara et al. 2013; Martins et al. 2015).

Based on the definition review, a business model is an abstract framework that describes how business value is created through strategic activities, decisions, resources, and processes that address the perceived customer needs and market opportunity. The objective of a business model is to create value for the customer while creating revenue for the company and its shareholders.

2.2.2 Business model components

Afuah (2014) proposes that a business model has five components, as illustrated in Figure 3 At the core of each business model are the company's inherent capabilities, which enable it to create and offer competitive products and services. The capabilities consist of both tangible assets, such as machinery and buildings, and intangible assets, such as the skillsets of the employees. Capabilities are an enabling and limiting factor that determines what the company can do. Therefore, it is also the vanguard of strategy. It is to be noted that a business model is part of the strategy. The business model may exist prior to strategy, yet in practice business model requires strategy's guidance (Spencer, 2013).

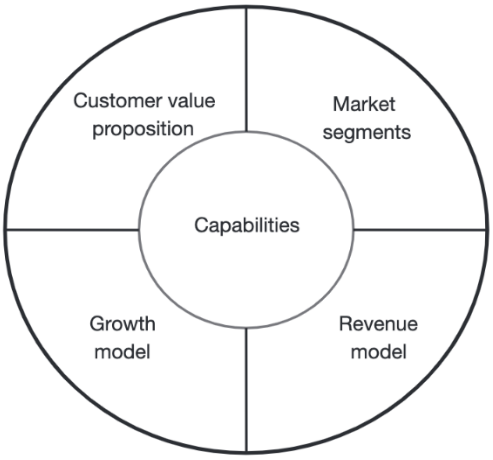

Figure 3. Business model components (Afuah, 2014, pp. 5)

Business model creation begins with an insight into the current market situation. The business opportunity derives from a market gap that is identified during the market research. Market segments are a component of the business model that describes who the customers are, what kind of customer needs they have, how these customers are reached, and what is their willingness to pay. Furthermore, market segment describes a network of external stakeholder, which whom the company will either cooperate or compete with (Afuah, 2014).

A critical success factor for a business model is how well it captures value (Chesbrough, 2007; Afuah, 2014; Bocken et al., 2014) The plan how the company aims to capture value is described in a value proposition. Spencer (2013) describes the value proposition as a value exchange between the firm and the customer as depicted in Figure 4. The steps leading to exchange include collecting customer needs and goals, which are then evaluated by the company's executives. The needs and goals which are deemed as a priority are formulated into a customer value proposition.

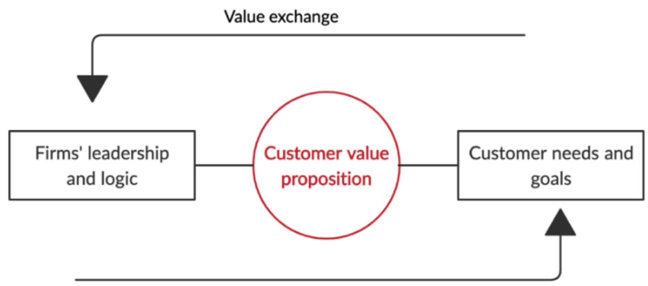

Figure 4. Value exchange relationship (Adopted based on Spencer, 2013).

A revenue model is an in-depth evaluation of the customers' willingness to pay. Revenue model specifies how many customers are willing the pay for each product and service offered, when, and how (Afuah, 2014). The company may have several revenue models that are tailored to each customer segment. Osterwalder et al. (2010) divide revenue models into two categories: single-time and recurring revenues.

The growth model is a description of how the company intends to grow profitably or strategically if feasible. The model contains the plan which the company needs to follow to increase customers' willingness to pay or purchase, or to maintain customer satisfaction while decreasing the cost level. The company should factor in externalities that may affect the plan, such as changes in the competition or macro-economy (Afuah, 2014).

2.2.3 Business Model Canvas

A shared challenge among entrepreneurs is to present their business idea concisely, yet explicitly enough that the audience can capture the essence of the business. Osterwalder et al. (2010) addressed this challenge by introducing the Business Model Canvas. It is a useful communication tool to articulate the business idea and service concept. While the Business Model Canvas is a one-pager, it captures the value proposition and service concept without oversimplifying it.

The Business Model Canvas is a visual, map-like template in which nine central business model components are placed categorically. The visual representation helps the reader to capture the synergies and relationships between the components effectively (Ching & Fauvel, 2013). The left-hand side consists of internal information, which explains how the service is produced and delivered to the customer. The right-hand side, describes who the customers are and how they are reached.

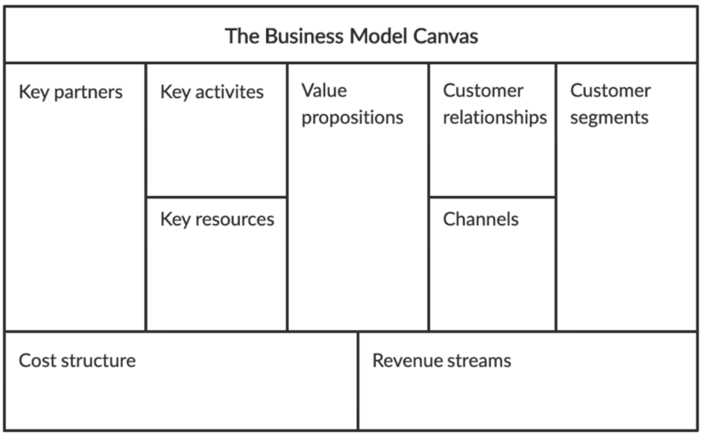

Figure 5. The Business Model Canvas (Adopted based on Osterwalder et al., 2010)

At the center of the canvas, as depicted in Figure 5 is value propositions component which describes what customer need that the product or service solves and how does it differentiate from the competitors. The differentiation points can be either qualitative, such as brand or newness, or quantitative, such as price or performance.

On the left-hand side, customer segments are the specific groups of people or organizations based on whose needs the product or service is created. The customer segments are typically created based on a distinct need. The customer segments are the foundation for designing marketing and sales strategy. Customer relationships, on the other hand, depict what kind of relationship the company plans to have with each customer segment. Furthermore, it can describe how customers are attained and retained, and the possible costs associated with these activities. Channels describe the communication and sales strategy and operations the company has. The main purpose of the channels is promoting the company's offering, providing access to the product or service, and delivering it to the customer.

On the right-hand side, key activities are actions that constitute essential business operations. Key resources are material or immaterial assets that the company obtains. They are critical for running the business and delivering value to the customers. Osterwalder et al. (2010) divide key resources into physical, financial, intellectual, and human resources. Key partners consist of a description of the type of partnerships the company has and a list of suppliers who conjointly orchestrate the service delivery to the customer.

At the bottom, the cost structure is a summary of all the costs that result in the specific business model. Revenue streams, on the other hand, describes what kind of revenue the company makes from a specific customer segment. It gives an overview of cash flow and consequent liquidity the company has as a result.

2.2.4 Business model validation

A common denominator in human-centred approaches to business model design is constant customer validation. The purpose of validation is to discover how the solution is perceived by the customer and reduce risk of introducing a novelty to the market. Since product and service development takes time and effort, discovering early market response can save the company's resources and decrease the risk (Cooper & Vlaskovits, 2016).

The most prominent validation methods are qualitative and involve interaction between the developer and the test users. The validation is thus a result of developers' reflection of what the interactions signify for the development process. The validation process consists of a need-finding stage that seeks to discover what kind of challenges the customers have and an experimentation stage that examines the viability of the developers' solution among the customers. The purpose of the experiments is to test all the critical components before building the business model. Critical components refer to all components that have uncertainty (Cooper & Vlaskovits, 2016; Ries, 2011). Consequently, the testing typically concerns only one or two of the business model components rather than the entire business model at once.

Table 3 describes some of the most common validation experimentation tests and their rationale. The tests have a slightly different focus on what part of the business model they test, yet all contribute to the same goal of validating business viability. Moreover, the degree of complexity, cost, and time vary among the tests. While prototyping can be relatively fast, it requires the most advanced design skills. The crowdfunding test, on the other hand, is the most time-consuming option, and may require investment to branding and marketing material to yield a desirable outcome.

Table 3: List of validation experimentation test Cooper & Vlaskovits, 2016, pp. 131-149)

Experiment	What	How	Why
The Infamous Landing Page	A one-page webpage consisting messaging and call-to-action.	The test measures 1) acquisition method - is the company using the right channel to attract customers to the landing page 2) messaging, positioning and design - the customer behavior on the website indicate how well the company is succeeding in these areas. 3) value proposition - the rate of clicks on the call to action indicate how well value proposition is communicated and perceived by the customers	The test gives insight whether the business idea is competitive, gives you chance to collect customer contact information that you can contact afterwards if the business idea is piloted.

Wizard of Oz Test (also known as Mechanical Turk)	A seemingly finished product to test whether the service has market demand.	The test can be for instance creating an online store that sells electronics. When a customer places an order, the vendor goes to an electronics store, purchases the item and ships it to the customer.	The test allows you to test the business idea without the risk of holding an inventory.
Crowdfunding Test	A funding application for a business idea.	Create a product description and supporting visual materials and apply crowdfunding on websites, such as Kickstarter.	A fast way to validate product ideas with minimal product development.
Prototyping	A simulation of the end-product or an early version of the intended final product.	Build the prototype and present it to the potential customers to receive feedback and discover if it addresses correctly the problems it intends to solve. The improvement-feedback loop continues until the developer is satisfied.	Prototyping can efficiently address if the product development is going to the right direction. It can provide information of the functional, experimental and visual aspects of the product.

Even though the validation experimentation tests can provide clear benefits, as mentioned in the fourth column, the tests also pose certain challenges (Cooper & Vlaskovits, 2016). First, the results can be subject to interpretation bias. The developer can interpret the results, for instance, according to the desired outcome. Second, customers may resist certain forms of solutions despite how sophisticated the solution is. For instance, in some cases, a product may not be accepted as a solution to a service, such as a nursing robot to replace a nurse. Third, the selected validation experimentation method for the test affects the quality of feedback the developer receives. Therefore, being aware of the different types of tests and having clear objectives for the test are important.

3. Research methodology

The research methodology chapter presents the choice of research methods, the collection of empirical data, validity of the research, and the research context.

3.1 Research methods

The study adopts two research methods. The primary research method for the study is qualitative action research. The main objective of action research is either to understand the problem better or to build better ways to address the problem (Willis & Edwards, 2014). Instead of only observing the research context, the practitioners are involved with the studied context to develop scientific knowledge (Willis & Edwards, 2014). Therefore, action research is suitable for service design and business modeling as both involve customer interaction and prototyping.

The qualitative approach was chosen since the central aspects of the study are first to explore and analyze customer needs for the LASO-LIBS scanning methods, and second to analyze the customer insight of the service and business model prototypes. According to Leavy (2014, p. 2), qualitative methods are best for exploring, describing, or explaining a social phenomenon.

Figure 6 illustrates the original action research cycle that founder of the methodology, Lewin (1946), proposed. The cycle begins with collaborative ideation, which is followed by stages that include studying and implementing the idea. The results are then examined, and the idea is revised based on the collected feedback in iterative loops until the objective of the research is reached. The influence of action research is distinguishable in many human-centered design methods, such as Lean Service Creation and Lean Startup methodologies that were previously discussed.

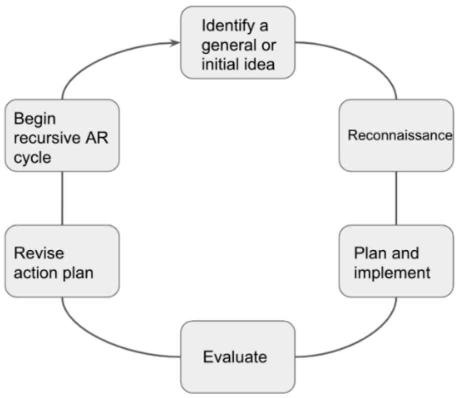

Figure 6. Original action research cycle (Adopted based on Lewin, 1946).

This study adopts LSC as a theoretical framework for developing service concepts and business models. As previously described, the Build, Measure, Learn feedback loop is one of the main practices in the LSC method. The different phases in the loop are allocated below the three main categories, which are depicted in Figure 7. The problem diagnosis is qualitative research, which consists of market research and need-finding interviews. The phase takes place primarily at the beginning of the study, yet when action intervention and reflective learning provide new insight into the customers, the problem will be diagnosed again. Action intervention is the part of this study in which we actively intervene with potential customers by prototyping and presenting service and parts of the business model to the customers. We will also define criteria for the MVP with the users. The last phase of the research cycle is reflective learning, which analyzes and synthesizes the customer insight into learning.

Reflective learning has three potential outcomes. The first outcome is discovering a new problem, which takes the research back to the problem diagnosis phase starting the research cycle from the beginning. The second outcome is going back to the prototyping stage if the outcome does not address the desired results. The third outcome is an insight that the desired goal has been reached.

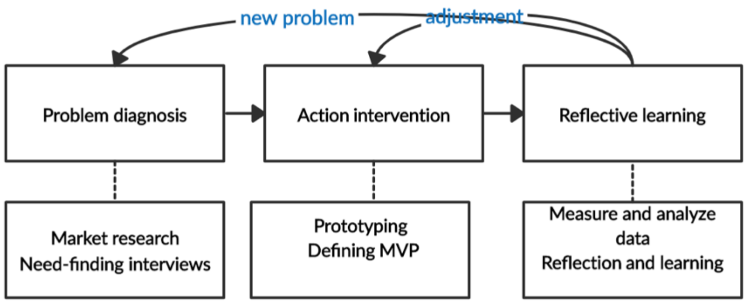

Figure 7. Action research cycle of the study

Secondly, this study is an intrinsic single case study that examines the service vision for the LASO-LIBS method. A case study is an empirical inquiry of a complex unit, such as an event, in its actual context (Yin, 1981, 1984; Stake, 1995). Stake (1995) proposes a classification of case studies into three categories: intrinsic, instrumental, and collective. In an intrinsic study, the case itself is the primary interest of the study. An instrumental case study attempts to collect insight into some other phenomena through the case. A collective study, on the other hand, examines multiple cases to understand a phenomenon. Based on this categorization, this thesis is an intrinsic case study.

3.2 Collection of empirical data

Figure 8 shows that empirical data consists of both primary and secondary sources. The need-finding and subsequent service vision data comes from semi-structured, contextual interviews, and a questionnaire. While semi-structured interviews consist of conversation only, the contextual interview takes place in the interviewees' working environment, which enables observation. Based on the findings from the contextual and semi-structured interviews, a hypothesis of possible services was formulated. The hypothesis was tested and validated with a questionnaire and discussions. Finally, based on validated hypotheses, a fake advertisement and business model were prototyped and tested.

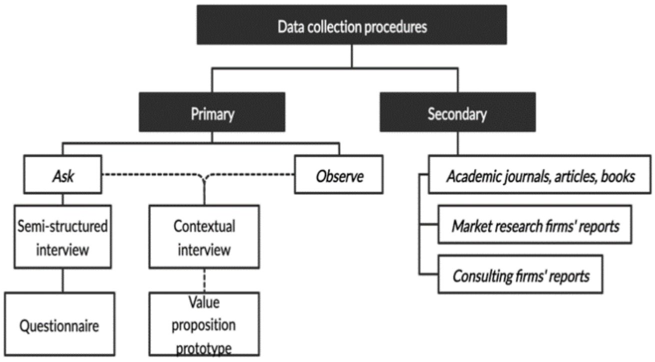

Figure 8. Collected empirical data for the thesis

The literature review data was gathered from external data sources. The data consists primarily of academic journals, articles, and books from Aalto University's databases. Data regarding competitors and recent financial and operational figures in the mining industry were collected from market research firms' reports, such as S&P financial reports on the mining industry, leading consulting firms' publications, such as PwC's annual mining industry report.

3.2.1 Semi-structured and contextual interviews

At the beginning of the research ten semi-structured and three contextual interviews were conducted to identify customer needs, desires, attitudes, and opinions that are related to LASO-LIBS. Based on the analysis and synthesis of the interviews, the research time created four service concepts.

A semi-structured interview is commonly used with a qualitative method. The interview method has a set of structured questions that act as a framework for the interview. The main strength of the method is that when an interesting probe arises, the interviewer has the flexibility to explore the topic beyond the predetermined questions. Hence, the method is often applied in research that explores complex issues as it allows the interviewer to use probes and spontaneous questions to delve deeper into the topic. The objective of semi-structured interviews is to collect systematic information regarding the key questions, while also exploring new issues that are raised in the interview (Wilson, 2013).

A contextual interview is akin to a semi-structured interview. The most distinct difference between these two is that a contextual interview takes place in the environment where the service would take place. The objective of a contextual interview is to create a holistic understanding of the user, which is a combination of the interview and an observation of the social and physical environment (Stickdorn & Schneider, 2011). Consequently, the interviewer can gather more tacit knowledge of the interviewee and the working environment. For this study, the interviews were conducted at two different mine facilities: one two-hour interview at drill core logging facility in a mine, and two interviews at ore exploration core logging and storing facility. The interviews included a demonstration of the key tasks and semi-structured interviews that were done afterward at an office.

3.2.2 Prototypes

To test the customer insight, we developed a service concept and value proposition prototypes. The service concept prototyping takes place after synthesizing customer insight. Its' purpose is to identify how well the service addresses customer needs (Nevanlinna et al., 2018). The service concept was tested with nine interviewees.

The value proposition prototype, or a fake advertisement, is a value proposition prototype that tests primarily whether the concept stands out to the target customers and create a desired emotion when they use the product (Nevanlinna et al., 2018). While the fake advertisement is a way to describe a brand image, it should communicate what key elements are different among its customers. The value proposition prototype was tested with two interviewees due to time restrictions.

3.2.3 Interviewees and interview guide

The interview guide was established based on the literature review on the mining industry and discussion with geological and mining industry experts. Since the interviewees had distinct roles, questions for each profession were tailored. The objective of each interview, however, was the same: to identify customer needs and challenges. The set of questions is attached to Appendices A and B.

Table 4 presents the interviewees, the type of organizations in which they work, and the organizations' main commodity. The interviewees are anonymized to protect their identity. Most of the interviewees are in senior positions and have worked in the mining industry for decades. Consequently, many of the interviewees could broadly reflect and discuss the topics beyond their current positions.

Table 4: List of interviewees

Interviewee	Role	Type of organization	Main commodity
Interviewee A	Senior Mine Geologist	International mining company	Gold
Interviewee B	Exploration Geologist	International mining company	Gold
Interviewee C	Metallurgist	International mining company	Gold
Interviewee D	Senior Exploration Geologist	Finnish ore exploration company	Precious metals, battery metals

Interviewee E	Senior Geotechnician in operations	International mining company	Gold
Interviewee F	Geotechnician in ore exploration	International mining company	Gold
Interviewee G	Director	A major European Geosurvey	Strategic geoinformation and expertise
Interviewee H	Chief Geologist	Fennoscandian mining company	Lithium hydroxide
Interviewee I	Chief Geologist	Fennoscandian mining company	Nickel
Interviewee J	Geologist	Fennoscandian mining company	Iron
Interviewee K	Senior Exploration Geologist	Finnish exploration and product service company	Multiple
Interviewee L	Principal Geoscientist in exploration	International mining company	Copper, nickel, cobalt, lithium
Interviewee M	Geologist in exploration	International mining company	Copper, nickel, cobalt, lithium
Interviewee N	Geologist in exploration	Multinational ore exploration company	Precious metals, battery metals

The data for the the study consists of thirteen semi-structured and three contextual interviews and eight questionnaires. All except for two interviews were face-to-face interviews. The duration of the interviews ranged between half an hour and two hours, which is a recommendation for semi-structured interviews (Robson, 2002).

3.3 Analysis of empirical data

Yin (2011) suggests that an analysis of qualitative research follows a five-step process as depicted in Figure 9. The two-sided arrows refer to the possibility of moving back and forth between the two phases they connect. This approach, combined with thematic analysis, was applied to analyze the findings. In a thematic analysis, the findings are clustered into thematic groups, which makes analysis easier (Corbin & Strauss, 2008). The first phase in an analysis is to compile a database (Yin, 2011). In this study, the notes from the interviews were transcribed and recorded in an Excel file. The second phase is to disassemble the data into small fragments that are labelled according to a theme (Yin, 2011). The interviews were examined to discover themes, patterns, and attitudes. The third phase reassembles the data in a visual format, such as graphs or tables that summarize the findings. In this thesis, the thematic groups with several mentions were created in Excel to discover patterns. The fourth phase includes evaluating the reassembled data and determining which points consist of the main analytical findings in the study (Yin, 2011). Similarly to the previous phases, the reassembly and evaluation of the key points were done in Excel and also by filling in LSC canvases that evaluate findings and customer insights. The fifth phase, as the name suggests, concludes the interpretation that was formed during the fourth phase (Yin, 2011).

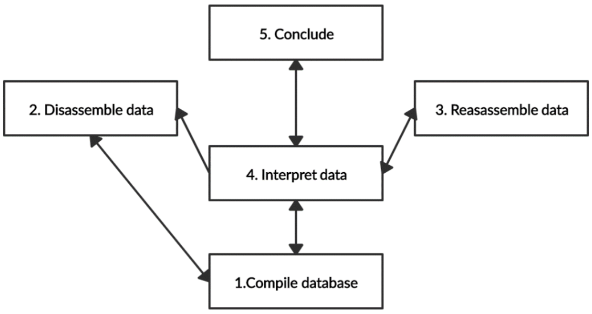

Figure 9. Qualitative data analysis process (Adapted based on Yin, 2011)

3.4 Validity of the study

Objectivity is essential for good research. According to Kirk and Miller (1986), *"objectivity is the simultaneous realization of as much reliability and validity as possible."* Reliability refers to the independence of the findings from the context of empirical research. Validity, on the other hand, refers to the correctness of the interpretation. A uniform definition of valid interpretation of data does not exist since validity is an adjective associated with claims. In research, validity concerns whether the empirical findings and the logical arguments support the theoretical claims (Taylor, 2013; Yin, 2011; Keller & Casadevall-Keller, 2010; Seale, 1999). Despite the lack of consensus over what validity is, certain criteria can be used for the evaluation. Yin (2011) suggests the following five criteria:

1. Completeness
2. Fairness
3. Empirical accuracy
4. Value-added
5. Credibility

Completeness stands for having different stages in the interpretation. In this study, the data collection followed the five-phase empirical analysis process described in the previous chapter. Fairness refers to the interpretation method, and if other researchers would conclude the findings in the same manner. Empirical accuracy, on the other hand, refers to the degree that the interpretation represents the data. In an attempt to have empirical accuracy, findings were discussed with the research group and industry experts. Similarly, the findings and analysis were presented to some of the interviewees and project steering board for validation. The value-added criterion concerns if the interpretation is novel or repeats the previous literature. Due to the unique commercialization project that this project concerns, there is no previous literature that the results can be benchmarked. Finally, credibility implies whether other researchers would accept the interpretation. In order to validate this criterion, an opinion of a wider public is required.

In action research, the researcher participates in the research with the objective of creating a change instead of objectively observing it. Macintosh et al. (2007) claim that the interpretation of the empirical research is unlikely to be heterogeneous despite the participants may agree with each other over the findings. Rather, the interpretation is a result of a concept Wittgenstein (1958) referred to as language games. A simple definition of a language game is an actual or possible way of using language (Hunter, 1980). The concept aims to explain how the usage of language is contextual and normative. At the same time, the concept highlights that certain words have ambiguous meaning, such as time, and that a singular reference to the word does not exist. Thus, the meaning is created on a case-by-case basis by the participants in the language games. In the light of language games, the challenges in action research are that the researchers may have different epistemological stances. For instance, some researchers are realist seeking to establish causation while some are interpretivist seeking to establish multiple explanations of the phenomenon. Therefore, the validity results may be interpreted differently by different researchers (Macintosh et al., 2007).

3.5 Research context

This chapter introduces the LASO-LIBS scanning method and Fennoscandian mining industry, which is the context for this study.

3.5.1 The case: LASO-LIBS scanning method

The innovation underpinning the commercialization project is LASO-LIBS (Large Area Scanning Open source - Laser Induced Breakdown Spectrometer) scanning method. Lasse Kangas invented the method in Aalto University School of Civil Engineering. The novelty of the innovation lies in the fast and efficient way to analyze elemental composition and mechanical properties of samples.

The LASO-LIBS method detects elemental, mineral, and mechanical properties based on atomic emission spectroscopy of plasma by sending high-powered laser pulses on the surface of the material. Since LIBS analysis is based on laser, the method requires minimal sample preparation. Once the data is collected from the sample, it is processed and analyzed with machine learning neural network algorithms. The result is an accurate description of both chemical and mechanical features. Figure 10 depicts an analysis result from a sample.

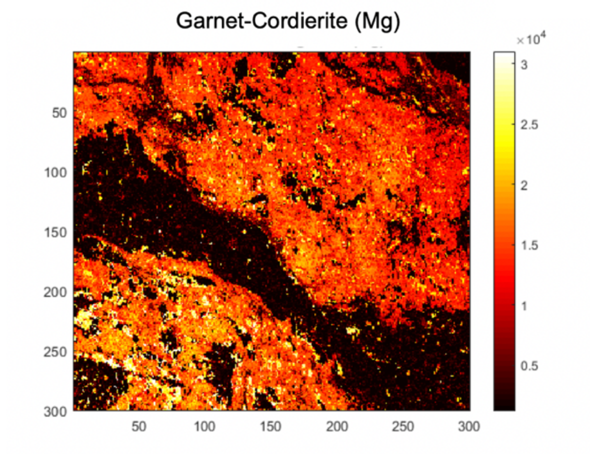

Figure 10. An elemental heatmap of a Garnet-Cordierite Gneiss sample

At first the scanning method will be tested in the Fennoscandian mining industry. Due to the scalability and simplicity of LASO-LIBS method, it can be later scaled to other industries, such as construction.

3.5.2 Fennoscandian mining industry

Fennoscandia is among the top regions globally for the mining industry according to Fraser Institute Investment Attractiveness Index in 2018. Some of the factors leading to the attractiveness besides the geology are good infrastructure, political stability, quality of geological database, and highly skilled labor (Fraser Institute, 2019).

Fennoscandia has over a thousand years of mining history and a strong tradition in ore mining and metal production (Maier et al., 2015). Finland, Sweden, and Norway are part of the Fennoscandian Shield, in which geology and metallogeny resemble the ancient shields in Australia, Brazil, Canada, and South Africa. These countries are the most mineralized regions in the world (Poulsen, 2012; Maier et al., 2015). Although the mining output in the region does not compare to these countries, Finnish and Swedish mining industries are the largest in Europe when measured by the output value (Federal Ministry for Sustainability and Tourism, 2020). The raw materials in the region include gold, silver, nickel, lithium, and rare earth elements.

In recent years, Fennoscandian countries have had traction in both mining and exploration. The Finnish mining industry boomed during the 2010s with, reaching all-time high mineral extraction in 2018. The new production focuses mainly on the precious metals, such as gold and battery metals, such as nickel and lithium (Hernesniemi et al., 2011; Vasara, 2019; Tuusjärvi et al., 2014; Nurmi & Rasilainen, 2015).

Mineral extraction and metal production are part of a broader industrial value chain in both Finland's and Sweden (Vasara, 2019; Olsson et al., 2019). In 2018, Finland had 11 metal and 35 industrial mineral mines, generating approximately EUR 2 billion revenue (Vasara, 2019). In comparison to Finland, the production is more concentrated in Sweden. In 2018, there were 15 metal mines and one industrial mineral mine accounting for approximately EUR 4 billion in revenue (SGU, 2018; Statista, 2020). Norwegian mining industry consists of mostly industrial mineral mines and has only three metal mines (NGU, 2015). In 2013 the revenue was approximately EUR 1.3 billion (Hojem, 2015).

The region is renowned for advanced research and innovations in geology and mining. The local Geological Surveys host an extensive library of geological data that can be accessed freely for the most part. Finland and Sweden are also renowned for technologically advanced mining companies. For example, a Swedish mining and smelting company, Boliden, was the first company in the world to implement a 5G network in Kankberg mine in Northern Sweden (Kajatie, 2019). Furthermore, the mining equipment companies, such as Epiroc and Sandvik, and processing technology and services, such as Outotec and Metso, are industry leaders in their respective categories.

4. Findings from the service vision development

This chapter presents the findings that emerged from the service vision sprint in successive order from the need finding to a formation of a service concept and business model. The presentation of the findings follows the iterative a Build, Measure, Learn feedback loop, which is a central aspect of the LSC framework. The feedback loop is a dynamic process in which the hypotheses are developed and updated based on customer insight. The presentation of the finding follows the loop, which shows how generative learning affected the service and business model development.

4.1 Business objective and context

As mentioned in the literature review, the service vision sprint is the first development phase in LSC. The development phase begins with a business object and context canvas which examines the internal objective, enabling and limiting factors for a new product or service development. These aspects are discussed next.

The primary business objective for the TUTL commercialization project is to identify monetization options for the LASO-LIBS scanning method and develop service concepts and business models for the most promising options.

The enabling factors are both internal and external. On a macro level, megatrends, such as digitalization, and transition to a low-carbon economy, increase the demand for raw materials (PwC, 2019). At the same time, mining companies need to respond to the resource depletion by adopting processes and technology that increase productivity (Humphreys, 2019). The internal enablers include the accumulated intellectual property and experience from previous projects and a secured TUTL funding for 18 months.

Even though the TUTL funding is an enabling factor, it also restricts the project. The terms and conditions prohibit generating income during the project. Because of a restricted budget, recruiting new personnel during the funding will be difficult. All the intellectual property generated during the commercialization project belongs to Aalto University, including trademarks.

4.2 Immersion

After setting a business objective, the LSC proceeds with immersion into the customers' context. The objective of immersion canvas is to formulate an initial hypothesis of what the customer need might be. Simultaneously, it acts also as preliminary market research by prompting the team to consider the competition and the current way of solving the customer problem. The following subchapters present the initial customer problem hypothesis and provide an overview of the competing technology.

Educated guess of the customer problem

The first step in the immersion is to create an educated guess of the customer problem. It is also one of the requirements in the Business Finland TUTL. Therefore, the research team had conducted a brief customer need-finding survey already during the application period by interviewing few mining industry experts and reviewing what academic literature and news state about the mining industry challenges. Based on the existing knowledge, the commercialization team formulated the following hypothesis.

Hypothesis 1. Drill core logging is slow, expensive, and imprecise. Besides direct logging expenses, the mines experience mining process chain productivity loss due to inaccurate logging.

The assumption underlying the first hypothesis is that geologists struggle with the current drill core logging process. Drill core logging is a process of systematically recording drill cores. A drill core is a cylindrical sample from the bedrock. Due to the quantity and quality of information they provide, drill cores are the most important geological samples in the mining industry. Hence, geological reporting, such as resource modeling, is based on geochemical drill core analysis. Resource model describes, among other the resource estimates and the mineralization of the ore deposit (Blackbourn, 2012). Consequently, resource modeling determines the subsequent phases in a mining process chain. The hypothesis supposes that inaccurate ore deposit modeling results in ineffective processes. Eventually, the end product may result in a lower grade than if accurate resource modeling was available.

Competitors within the business domain

After a customer problem hypothesis formulation, immersion focuses on understanding the competition within the business domain on a high level. This chapter reviews first the competing technologies. Next, it introduces a synthesis of competitors' technology. The competitors' business models will be discussed in more detail in later development phases.

Multiple technologies can provide geochemical and geomechanical properties of geological samples. The comparison focuses on other methods that conduct surface analysis to delimit the scope of the study. Based on the market research, X-ray fluorescence (XRF) spectrometer, is the most common surface analysis technology. The method works on wavelength-dispersive spectroscopic principles. When atoms in a material are excited with x-rays, they become ionized. Each elements' atoms have distinct behavior, which can be measured and analyzed (Wirth, n.d.). Hyperspectral imaging (HSI) combines spectroscopic and imaging techniques to capture and analyze wavelengths. HSI works by first capturing an image and then translating it into a precise characterization of color (Sun, 2010). The technique works best in mineral detection (Sun, 2010; Kohli, 2018).

The measured quantities between the technologies vary, as depicted in Table 5. High definition XRF can detect all elements that have an atomic number that is higher than 12 (Garrison, 2003). Therefore, it cannot be used to detect, for instance, beryllium and lithium. A portable XRF, which is a common analytical instrument in ore exploration, is less effective in elemental detection in comparison to high definition XRF. Yet it is convenient for in-situ bulk chemical screening (Declercq et al., 2019). HSI, on the other hand, can detect most minerals. The minerals HSI cannot detect include feldspar, sulfide, and oxide minerals (Meyers et al., 2019). The strength of the HSI method lies in identifying mineralization zones and minerals that indicate the proximity of an ore deposit in ore exploration (Kohli, 2018).

Table 5: Comparison between competing technologies

Technology	Estimated price in EUR	Measured quantities	Size	Speed
LASO-LIBS	20,000-30,000	All elements, strength properties	20-30 kg	1000 points/second
XRF	200,000-600,000	Elements Z>12-14	1300kg	1-10 points/second

HSI	500,000-1,000,000	Minerals that have characteristic properties	500kg	15-60s/drill core box

HSI method is fastest as it takes between 15 to 60 seconds to analyze a drill core box (Dubay, 2012). Depending on the measurement point grid, LASO-LIBS can analyze a drill core box ranges between one to five minutes. XRF analysis time resembles LASO-LIBS, yet the number of measured points is at a minimum 100 times fewer than with the LASO-LIBS method. The price range for the HSI and XRF analysis instruments is between EUR 200,000 and EUR 1 million, as depicted in Table 5. Thus, the LASO-LIBS method is considerably more affordable than the competing methods. In terms of weight, LASO-LIBS is the only portable analytical instrument as the other methods are bound to a fixed space, such as a logging facility or a van.

The market has tens of companies and startups offering technical solutions for on site geochemical analysis. This thesis examines eight industry-leading companies and startups (Appendix D). Based on the review, most of the competitors use the XRF method, while HSI is also popular. The companies emphasize on their websites that they can provide fast or real-time geochemical analysis for drill core logging. Due to weight and design, six out of eight analytical instruments are fixed. The two other analytical instruments are integrated into a van, and thus suitable for most of the field conditions. Based on the competitors' technology review, the team analyzed what the competitive advantage for the LASO-LIBS method in the customers' view might be. The analysis resulted in the following two hypotheses.

Hypothesis 2. Identifying geomechanical properties is likely to provide a competitive advantage for the LASO-LIBS method in both ore exploration and mining operations.

Hypothesis 3. Due to the challenging field conditions, the ore exploration companies, are likely to perceive the portability of the sample scanner as a competitive advantage.

Since the current competing methods cannot provide geomechanical analysis, we hypothesized that geologists may value it. Geomechanical information gives clues about the crushability and grindability of the ore, which affects the economic feasibility of a mine. Through the competitor analysis, we observed that most of the competing analytical instruments weigh over 1000 kg, and due to design, are bound to a fixed location. Since ore exploration sites are often situated in remote locations, geologists may not have access to these analytical instruments when needed. Therefore, we premised that a mobility aspect is particularly crucial for ore exploration companies.

4.3 Data

The third LSC canvas guides the development team to do market research about the central concepts around the customer problem hypothesis. In this study, the market research concerns existing logging process and the market value of drill cores in the mining industry.

Current process of obtaining and analyzing drill cores

Figure 11 describes the drill core logging process. Diamond drilling is a high-precision core drilling that creates accurate boreholes. As a non-percussive technique, it maintains the structural identity of the bedrock. Extracting drill cores is the most expensive, yet the most reliable way to study rocks for mining purposes (Blackbourn, 2012). Therefore, drill core data is used for determining the shape of the ore body and ore grades, which are the key information in resource modeling (Martínez-Vargas, 2017). Three key factors that affect the quality of drill core data include borehole depth, pattern, and the horizontal spacing of the boreholes (Hartman, 2008). Defining optimal spacing is a widely researched challenge as errors result in inaccurate resource models and increased drilling costs (Li et al., 2010; Bertoli et al., 2013; Nowak & Leuangthong, 2019).

The density of the drill hole spacing grid and thus, the number of drill cores increase in the ore exploration as the geological confidence increase During the general exploration stage, which is the second last exploration stage before establishing a mine, the drill hole spacing grid varies between 100 to 400 meters. Once exploration enters the final exploration, a detail exploration stage, the spacing grid becomes as dense as 50 times 50 meters (Haldar, 2018, pp. 9-10; Lappalainen et al., 2015, pp. 40). During the mining stage, the drill hole spacing grid varies based on the mine type and commodity. Commodities that have high value and low grams of ore per tonne tend to have a denser drill hole spacing grid (Hartman, 2008; Pohl, 2011). Based on these findings, the following hypothesis is established.

Hypothesis 4. We hypothesize that companies that have a dense drill hole spacing grid are most interested in optimizing their drilling programs.

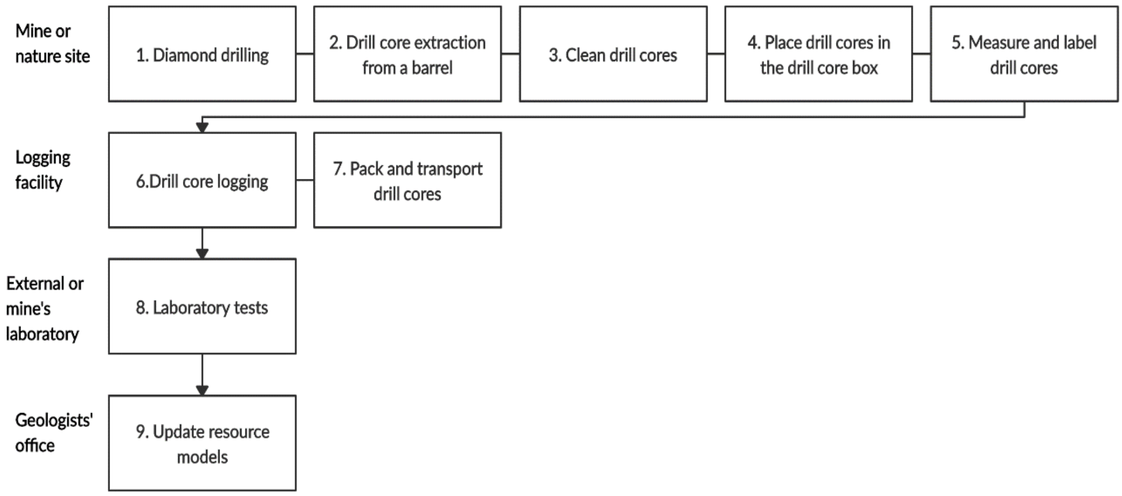

Figure 11. Drill core logging phases (created based on Blackbourn, 2012)

After extraction, drill cores are cleaned and placed in drill core boxes. Next before transportation to the logging facility, either geologists or the person in charge of drilling measures and labels the drill cores. The logging facility may be at an exploration camp or mining site. In an exploration camp the facilities are often tents and at a mining site the facilities are typically large, garage-like, halls that are dedicated to logging and geological analysis. The facility is divided into aisles with long tables on which the drill core boxes are laid.

Drill core logging is a systematic manual process in which geologists record drill core details and analyze them. The objective of a core log is to determine the lithology, the general physical characteristic of the rock, mineralogy, structure, and alteration zones among others. The core log is a primary method of determining grade, size, and mining conditions of a mineral deposit. Core logging often begins with the top of a core and moves downwards, which follows the drilling sequence. Table 6 describes the most common logging tasks and their objective in an order they typically occur in a logging process.

Table 6: Common drill core logging tasks (Blackbourn, 2012; Ganhdi & Sarkar, 2016)

Task	**Purpose**
Photograph drill cores	To leave a permanent visual record of the drill cores' condition. Drill cores are commonly destroyed upon the completion of use.
Drilling method and size	To inform of the method drill cores were extracted
Location	To inform of the prefecture, subprefecture, municipality, district, block, and possible landslide in which the drilling took place.
Elevation	To understand the shape and size of the deposit

Orientation	To understand the shape and size of the deposit
Geological classification	A description of the rock class and type
Color tones	A description of color gives insight among other of minerals, possible weathering, and indication of the potential nature and composition of the bedrock.
Degree of weathering	A strenght measure that describes engineering properties of the rock material and rock mass.
Rock Quality Designation (RQD) percentage	A commonly used rock quality measure that is calculated based on sound rock pieces that are 10 centimeter or longer. A percentage above 75 percent signifies good quality, and anything below 50 percent poor quality.
Fracture frequency	A measure that indicates number of fractures within a unit of length. Fractures impact the strength, deformation, and permeability characteristics of rock mass.

According to Marjoribanks (2010, pp. 104) the difficulty of the visual analysis in logging is that the appearance and the larger structures of the rock are hard to recognize on a small cylindrical surface. The literature supports the part of hypothesis 1 that suggests that drill core logging is error prone.

Based on the logging results, geologists select the most promising and representable samples for laboratory tests. Drill core sampling is among the most critical tasks within the mining process chain because the quality of selected samples will affect geological, geoenvironmental and geometallurgical decision making and planning (Demetriades, 2013; Dominy et al., 2018a; Dominy et al., 2018b). The challenge of sampling errors is that they are difficult to trace (Demetriades, 2013). After sampling, the drill cores are halved, packed, and sent to laboratory tests. Based on the challenges that the review of current drill core logging process revealed, we set the following hypothesis.

Hypothesis 5. We hypothesize that the mining companies will value information that can help them select best samples for the laboratory.

Estimate of market size and value of drill cores

Estimating the market size and value of drill cores in the mining industry is challenging since the price data is scarce, and the mining companies do not publish their drill core records publicly. This analysis includes exploratory drill core prices from Finland and Sweden. Also, the market share of global diamond drilling contractors is estimated.

The price of diamond drilling ranges between EUR 100 and 200 per meter, depending on the depth of the borehole (Malminetsintä, n.d). With a geochemical analysis, the price per meter increases to approximately EUR 250 (Toivonen, 2018). According to SveMin report, the price is slightly lower in Sweden as it is between EUR 50 to 150 per meter. Based on Finnish pricing, a medium-sized borehole (200 meters) with a geochemical analysis costs between EUR 40,000 to 50,000. Therefore, the price of drilling programs can add up to millions of euros. To illustrate, an annual drilling budget for Anglo-American, a multinational mining company, is approximately EUR 10 million in Finland, even though they are still at the early prospecting phase (Toivonen, 2018).

In 2017 the exploratory drilling in Finland increased by 53 percent from the previous year. The drilling distance was in total of 273 kilometers (Tukes, 2018). The distance equals to approximately EUR 40 million in cost. According to Melamies (2018), the drilling quantity could have been higher if there were more drill rigs available. Since drill rigs are capital-intense investments, it is a common practice to rent them. The total revenue of the twelve largest ore exploration diamond drilling contractors was EUR 1.14 billion, with 55 percent market share in 2017 (Samarova, 2018). Hence, the global diamond drilling contractor industry can be estimated to be approximately EUR 2 billion.

Defining the value of drill core logging is challenging because it is not reported separately from the rest of the mining processes. According to Marjoribanks (2010, pp.100), the speed of manual drill core logging is 5 meters per hour. Hence, logging a medium-sized borehole takes on average five days for a geologist who works 8 hours a day. An average monthly salary for a geologist in Finland is EUR 4500 (Ranta, 2017). Thus, the cost of logging one medium-sized borehole is approximately EUR 1250 in wages.

4.4 Customer grouping

Before conducting customer interviews, a preliminary customer groups are formed. In customer segmentation, customers are divided into homogenous subgroups. Each group has distinct characteristics and needs. Knowing distinct customer needs allows the company to build differentiation strategies, and targeted marketing campaigns and sales efforts (Tsiptsis & Chorianopoulos, 2010). Furthermore, segmentation helps to distinguish who are likely to be the early adopters (Eastin et al., 2001). In this study, we created three customer segments based on the findings from immersion and data canvases. The common aspects among the customer segments are that all have high geological expertise and do active diamond drilling.

Primary customer segment hypothesis: We hypothesize mining companies to be our primary customer segment as they have multifaceted geological challenges along the mining value chain.

Secondary customer segment hypothesis: We hypothesize ore exploration companies to be our secondary customer segment because they need real-time analysis in the field conditions.

Tertiary customer segment hypothesis: We hypothesize ore exploration service providers to be our tertiary customer segment as providing real-time analysis provides added value for their clients.

We selected mining companies as our primary customer group because the market research from the data canvas showed that mining companies conduct most diamond drilling. Furthermore, they require geological data at all stages in the mining value chain. Therefore, we suppose that real-time geochemical and geomechanical analysis could support other processes besides logging. For instance, achieve better control of the concentration process. The common characteristics of mining companies are that they exploit mineral deposits in a fixed location. Besides, since establishing mining infrastructure is expensive, the companies strive to improve productivity for maximizing revenue and ensure continuity of the operations. From the potential spin-off startups' perspective, mining companies provide an opportunity for establishing long-term partnerships as well as internationalization as several mining companies in Fennoscandia operate globally.

The secondary customer segment consists of ore exploration companies. The shared characteristics among ore exploration companies include that they actively seek opportunities to make ore exploration reservations. Ore exploration companies are typically small and can be operated by a sole entrepreneur with an educational background in geology. As noted in the previous chapter, ore exploration activities can be expensive. Therefore, ore exploration companies often seek investment in return for a share of the potential ore body discovery. A common goal for ore exploration companies is to sell their discovery to mining companies. Thus, the ore exploration operations are more temporary than in mining. In our hypothesis, ore exploration companies form an attractive customer segment since they require real-time analysis of the drill cores in the field conditions. We suppose that faster and detailed information could help optimize drilling programs.

The tertiary customer segment is ore exploration service providers. Their clientele consists primarily of ore exploration companies and mining companies. In terms of operations, ore exploration service providers and ore exploration companies are akin. They conduct, for instance, target identification or executing drill programs. Also, ore exploration service providers may sell analytical instruments or other supporting tools. As with ore exploration companies, we suppose that faster and detailed information could help ore exploration service providers to optimize drilling programs. Moreover, the ore exploration service providers could be a potential sales channel for the scanning method solution. The rationale for ranking this customer segment third is due to the limited number of ore exploration service providers.

4.5 Customer insight

The customer insight canvas is the first canvas that facilitates customer interaction. The objective of the canvas is both to facilitate interviews with the selected customer segments and synthesize the results. This chapter reviews the findings from the so-called problem interviews, which were conducted first to discover needs and expand the problem space. The needs and challenges are discussed in descending order based on a number of mentions.

A need for accessible and reliable geological data

The most frequent challenge that emerged from the empirical data is a lack of access to high-quality geological information at different phases of the mining process chain. The findings suggest that the requirements for the data vary among the processes, and to some extent among customer segments. The common characteristic of the needs is that the data should be real-time to bring optimal results. The needs are discussed next in successive order as they appear in the mining process chain.

A challenge of optimizing drilling programs

The interviews suggest that lack of reliable data results in a challenge to optimize diamond drilling programs, which is the highest operating expense in ore exploration. The finding is aligned with the earlier market research that suggest it to be a universal challenging for the ore exploration projects. According to the ore exploration geologists, the current analytical instruments suitable for the field conditions cannot provide enough reliable, detailed information. Many geologists used a portable XRF analytical tool, which can indicate elements in a specific point yet cannot measure the whole drill core. Some geologists also used a magnetometer to measure magnetic variations at a surface to analyze lithology distribution. The customer insight did not support our hypothesis that the drilling quantity would translate into the likelihood of adopting an analytical tool to optimize the drilling programs or logging process. Instead, the data proposes that the uncertainty regarding the ore body and ore grade are better indicators. Therefore, the hypothesis 4 was revised as follows.

Hypothesis 4. We hypothesize that optimizing diamond drill grid is most interesting for ore exploration projects since they have highest uncertainty of ore grade and ore body.

The geological data that both ore exploration and mining companies indicated as most important was mineral and elemental composition of the ore. Some of the mining companies wanted also geomechanical information already during ore exploration. The finding is contrary to our hypothesis 2, which assumes that identifying geomechanical properties is as beneficial in both ore exploration and mining. The empirical study suggests that both the mining phase and the type of organization seem to impact the geological data requirements. The literature also suggests that ore exploration is primarily focused on detecting minable grades and economically significant elements (Marjoribanks, 2010). Geomechanical properties become increasingly critical after the ore body has been confirmed economically feasible. The rock quality and hardness determine the mine design and multiple aspects of production, such as blasting and concentration methods (Peng & Zhang, 2007; Muwanguzi et al., 2012). Based on this finding the hypothesis 2 is revised as follows.

Hypothesis 2. Mining companies are likely to perceive identifying geomechanical properties as a competitive advantage.

During ore exploration mobility of the analytical instrument is more critical than during the other mining phases. A typical ore exploration project is situated in challenging conditions, such as in the middle of the forest or peatlands. A distance to the closest drill core facility or laboratory can be hundreds of kilometers. Simultaneously, the projects are intense and follow a strict schedule, which is partially due to the scarcity of drill rig rentals and service during the high season. Therefore, the exploration companies rather diamond drill with uncertain geological information than let the drill rigs sit. Due to the conditions, the ore exploration experts, require analytical instruments that can accommodate easily to basic conditions and are mobile. The findings suggest that the mobility aspect was critical for both ore exploration and the mining companies, even in production drill core logging. Our earlier hypothesis did not consider that mining companies may find mobility as a competitive advantage. Therefore, the hypothesis 3 is updated to be inclusive of all mining industry company types in the ore exploration.

Hypothesis 3. Mining industry companies are likely to perceive the portability of the sample scanner as a competitive advantage.

A challenge to homogenize core log

The reliability of the core log was a shared concern among most mining companies. According to the interviews, the fluctuating drill core recording practices cause challenges for mine. For instance, inaccurate ore grade estimates result in inefficient excavation and concentration process. The findings suggest that logging is dependable on multiple factors. The interviewees shared a view that geologists have a subjective interpretation of geology, which aligns with literature (Marjoribanks, 2010; Sterling, 2011). At the same time, individuals pay attention to different aspects of the samples. Interviewee E mentioned that despite the unified reporting standards, their organization had a fluctuating reporting quality. The interviewee doubted that the core log data was homogenous due to the individual differences.

Besides the subjectivity of geological interpretation, interviewee I attributed geologists' personality, mood, and energy levels to affect the quality of the reporting. Moreover, the logging process is demanding, as it requires continuously careful attention to detail. The challenge appears to be more general as plenty of literature echo similar challenges and attempt to overcome it by automating logging (Blackbourn, 2012; Fresia et al., 2017; Tappert et al., 2011; Harraden et al., 2017). Even though the market research revealed some data quality challenges in core logging, the scale and impact of the challenge were bigger than expected. The findings indicate that especially chief geologists who are responsible for the geological modeling consider the reduction of logging data variation as a key priority.

Although, the desire to homogenize the core log was widely discussed the interviews did not indicate that mining companies experience challenges with selecting the drill core samples for geochemical laboratory tests. The literature, however, remarks that detecting sampling errors is hard (Demetriades, 2013). Therefore, the challenge may be imperceptible. Since the customer insight did not support hypothesis 5 that assumes mining companies would value sampling optimization, we retract it.

A challenge to control dilution

The interviews indicate that dilution, or loss of ore, occurs in a milling process because the quality of the ore mixture in production differs from the order. The interviewees attributed the difference primarily to either insufficient or inaccurate geomechanical and geochemical data of the stockpiles. The ore is stored after in stockpiles after excavation and before concentration. The ore mixture is selected based on the desired cut-off grade, an ore grade in which ore production is economically feasible. The cut-off grade fluctuates primarily based on the commodity market price and production cost (Rendu, 2014).

Milling is the first phase in the concentration process. The objective of milling is to grind and crush the rock into smaller pieces. Grinding is both cost- and energy-intense process accounts for nearly 70 percent of mine's energy cost, which comprises the highest single operating cost in a mine (Curry et al., 2014; Ballantyne et al., 2012). According to the interviews, the lack of accurate information causes challenges to manage the milling process optimally. The milling process can be adjusted, for instance, based on the strength, grindability, and abrasivity of the ore. Suboptimal mill settings result in wasteful energy consumption, lower throughput rate, and the faster wearing of mill linings. Consequently, the right ore mixture and concentration process management affect the profitability of a mine.

Based on the findings, timely geological information helps milling process optimization. According to interviewee C, the concentration plant he works for implemented a rock quality designation, RQD, analysis for sample tests before the ore mixture enters the milling process. The RQD results that were measured a month ago positively correlate with the current feed tonnage. According to him, even a minute improvement in the feed throughput, such a 0.5% increase, can improve the mine's profitability significantly. The findings support the hypothesis 2 that assumes that mining companies will value geomechanical information. In addition, the concentration process depends on the data about mineral concentration. Therefore, we created the following hypothesis.

Hypothesis 6. Real-time geochemical and geomechanical information before the milling process can help mines to optimize the mill settings.

A need for expediating geological data analysis

The second most common theme in the interviews was the need to expediate current data analysis processes. The factors limiting the speed is related to available technology and internal processes. The challenges result in backlog and loss of geological data.

A challenge to speed up core logging

Many of the interviewed mines and ore exploration companies expressed the need to log faster and more reliably. The finding aligns with the earlier market research that suggested the process to be both a time-consuming and error-prone process. The interviewees indicated that logging constitutes the most significant part of geotechnicians and geologists work in the sample preparation and analysis department. One of the interviewees described the working environment as “well-managed chaos”. According to him, due to the constant, although manageable backlog in the logging process, there is not enough time to develop or finetune processes. Many other interviewed organizations also agreed that the logging process cannot keep up with the speed of the drilling programs.

The speed of logging varies among the geologists. According to senior geologists, the speed accelerates with experience. It was also associated with multiple other factors, such as mood and energy level. Some of the interviewees also suggested that the number and type of logging tasks affected the speed. The more mundane the tasks were, the faster the process would be. Since ore exploration requires more attention to detail, the speed of logging might be slower than in operational logging. According to interview B in greenfield ore exploration, the quantity of annual drilling might be only 10 kilometers yet logging and analyzing it may take up to half a year. Due to the lack of mobile solutions, the mining companies cannot expediate logging in the field conditions. The findings support the second hypothesis that assumes mining companies value portability of the solution.

A challenge to record all geological data

For mines, achieving economies of scale is crucial for profitability. Hence, in most mines, the operations run around the clock. In some of the mines, however, geologists and geotechnicians work only in one or two shifts. Concurrently, many geological recording processes are not automated. Therefore, some of the geological information cannot be recorded. This finding supports the customer segmentation

At an iron ore mine where interviewee J works, geologists work in one shift while tunnels are excavated in two shifts. The tunnel excavation process takes only 2 hours from the inception to completion. While the geologists are at work, they map the mine walls to do a geotechnical and geological assessment. Currently, 40 percent of all the mine walls are mapped. Thus, most of the data is not recorded. In addition to an enhanced reporting process, recording mine walls could help mining companies understand the mineral concentration and mineralization zones in a block. While wall recording may automate the recording process, it may also optimize the excavation process. Interviewee G explained that a geochemical test averages the mineral and elemental properties in a block. However, the ore might situate only in a specific location. If mining companies could excavate the ore more precisely, they could improve their productivity. This may help mining companies to separate ore from the waste rock, also called gangue, more effectively and improve stockpiling. As mentioned earlier, the lack of geological data before milling causes the suboptimal milling process.

4.6 Service concepts

The customer insight indicated that the most significant needs for geological data are in drill core logging, mine wall and stockpile recording, as well as concentration ore mixture analysis. Based on these insights, we developed three service concept prototypes as depicted in Figure 12. The concepts are presented in successive order from left to right as they would appear in the mining process chain. The service concept prototypes and customer insight will be presented concurrently.

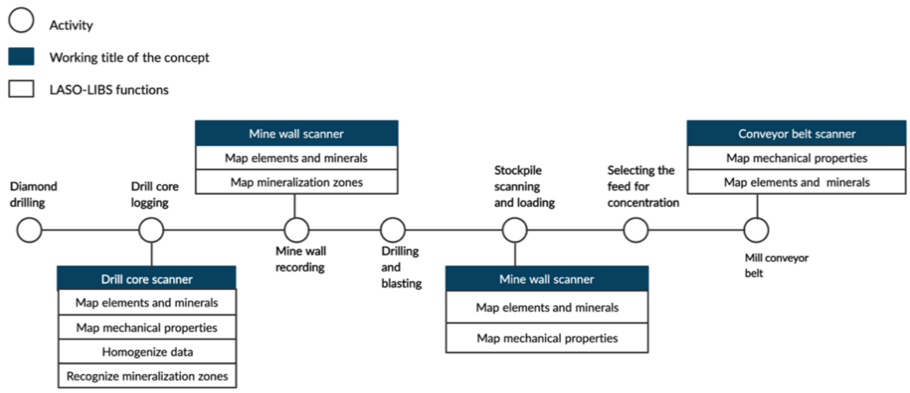

Figure 12. LASO-LIBS service concepts

Drill core scanner

The first service concept is a drill core scanner that can optimize drill core logging, which is depicted in Figure 13. The scanner can map drill cores in real-time both in field and mining conditions. The scanner consists of the scanning head, and a light aluminum frame, which has the same measurements as a standard drill core box. Because the frame weighs only 20 kilograms, it is portable. Depending on the use case, it can be either of similar design as depicted or, for instance, an integrated part of a logging table. The interface will be minimalistic and intuitive, so the geologists' will be able to use it independently from the beginning.

Figure 13. A prototype for drill core scanner

The service concept attempts to address the need to log faster and more reliably. The primary component of the service for all prototypes is the analytics software that provides geochemical and geomechanical information. The user interface will be co-designed with geologists at a later stage of the project once the service vision and commercial potential are validated. The objective is to create a dashboard from where the geologists can select how they want the data to be displayed and visualized. The data will allow the geologists to quickly perceive the mineralization zones, detailed concentrations, anomalies, and other interesting details.

Out of all the service concepts, the drill core scanner received the most interest. The interest was expressed as a desire to test and co-design the device. Both ore exploration and mining geologists showed interest in the prototype. However, the mining geologists that showed the most considerable interest towards the drill core scanner did exploratory logging. A generalizable characteristic between the interested mining companies was that their main commodity has a clear orebody, which is relatively easy to perceive from the surface of the drill cores. The interested ore exploration companies, on the other hand, have a wide scale of commodities from basic to precious metals.

The testing revealed that the ore exploration geologists would like to use the scanner besides drill cores to soil and rock samples. That way, the scanner can be used in all exploration phases, not only at the later stages where diamond drilling takes place. The testing also deepened the teams' understanding of what kind of elements and minerals the geologists require. In addition to ore minerals and elements, the geologists want to know if the orebody contains any minerals that make the ore concentration process unprofitable. The geologists also indicated that they would like to map out lithology, structures, and anomalies to understand the orebody. A potential challenge for sample scanner geologists addressed is sample preparation.

As described before, due to basic field conditions, running water may not be available, so the drill cores cannot be washed after extraction.

Geologists work with operational logging showed the least interest in the service concept. According to some of the geologists' geochemical analysis during drill core logging may not provide significant benefit as the resource model data needs follow official reporting standards, for instance, in Finland the Mining Act 2011/621 decrees mining companies to carry out standardized geochemical tests for resource modeling. Therefore, drill cores are tested in accredited laboratories. At the same time, the geologists evaluated their current logging process to be efficient.

Finally, the testing revealed that geologists perceived core logging automation with reservation. Both ore exploration and mining geologists voiced that automating the entire logging process is unlikely as the geologists' interpretation is an essential part of the process. They believed, however, that technology can assist geologists to focus on critical geological features and reduce mundane work. The interviews indicated that the solution should be collaborative and provide a sense of control and expertise to the geologist.

Mine wall scanner

The second service concept is a mine wall scanner. The solution can be applied to both mine wall, and stockpile scanning as the principle of scanning both is the same. The service concept addresses the challenge to record all mine walls manually and dilution. Figure 14. depicts the mine wall scanner prototype. The scanner consists of laser, optics, spectrometer, and a rotating frame. Similarly, to the drill core scanner, the frame is portable. Depending on the use case, it can be placed on a suited platform, such as the back of a van.

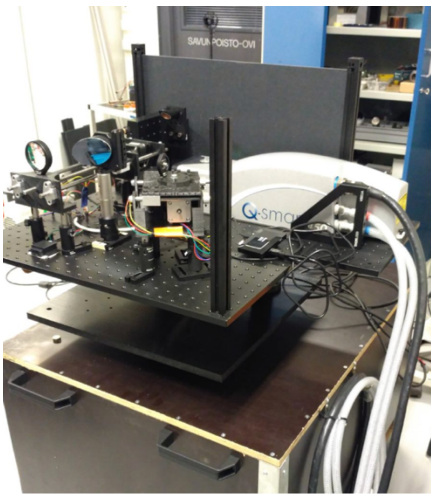

Figure 14. A prototype of mine wall canner

The geologists who showed interest in the concept said that they were primarily interested in improving the geological reporting and recognizing the mineralization zones. In all the mines that showed interest, mine wall mapping was a manual process, and they were interested in automating the process, which is a predictable outcome. The interested mines said that they had experience using XRF to scan the stockpiles. The previous experience of analytical instruments seemed to correlate with the openness and interest of the mine wall scanner positively.

According to the geologists, the possible challenges of adopting the method include the operational environment. Mines are often dusty, and the mine walls are dirty. To reduce dustiness, mine-workers water the mine walls before drilling and blasting. Consequently, the geologists were concerned that dusty or wet walls might affect the analysis results. A distinct finding from the empirical data was that whereas the shape of the deposit and commodity seemed to impact the interest in the sample scanner, it did not matter for the mine wall scanner.

Conveyor belt scanner

In the third service concept, conveyor belt scanner, LASO-LIBS scanning parts are integrated into the conveyor belt before the mill, as depicted in Figure 15. In the concept, the sensors measure all the incoming feed and send information about the mechanical and geochemical properties to the mill so that the settings can be adjusted accordingly. The need that this solution addresses is minimizing dilution.

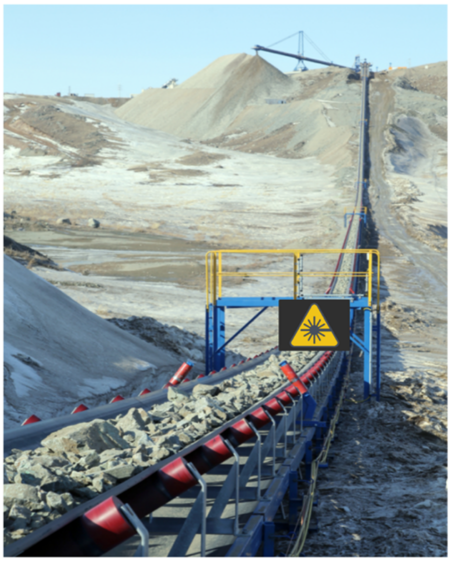

Figure 15. A visualization of the intended prototype (Kuzmichev, n.d)

Due to a time limitation and invasiveness, we could not build and test the prototype in the mining conditions. The market has many conveyor belt scanning solutions. Therefore, the concept was familiar to the interviewees. Based on the feedback, the most suitable concentration process for the service concept is scanning the feed before the mill. As discussed earlier, the milling process is among the highest operating expenses in the mine. Therefore, optimizing the process can yield considerable savings. Furthermore, the concentration plant has the most uncertainty and information about the ore properties before the milling process. The service testing revealed that besides to geochemical and geomechanical properties, information of feed size and RQD are critical. Hence, hypothesis 6 was revised as follows.

Hypothesis 6. We hypothesize that a minimum viable product for the conveyor belt scanner includes besides geochemical and geomechanical properties, information on RQD and feed size.

Revised service concepts

After testing the prototypes, the service concepts were revised based on the feedback. Followed by the revision, both the requirements and the indicated customer demand were analyzed to decide the first service concept. Figure 16 displays the minimum viable service concepts that should be obtained to fulfill customer needs.

The results indicate that the drill core scanner is promising for also analyzing other geological samples, making the scanner usable at all exploration stages. Hence, the concepts' working title was altered to a sample scanner. The testing showed that mapping lithology, structures, and anomaly detection are central tasks in exploratory logging. Therefore, these activities were included in the list.

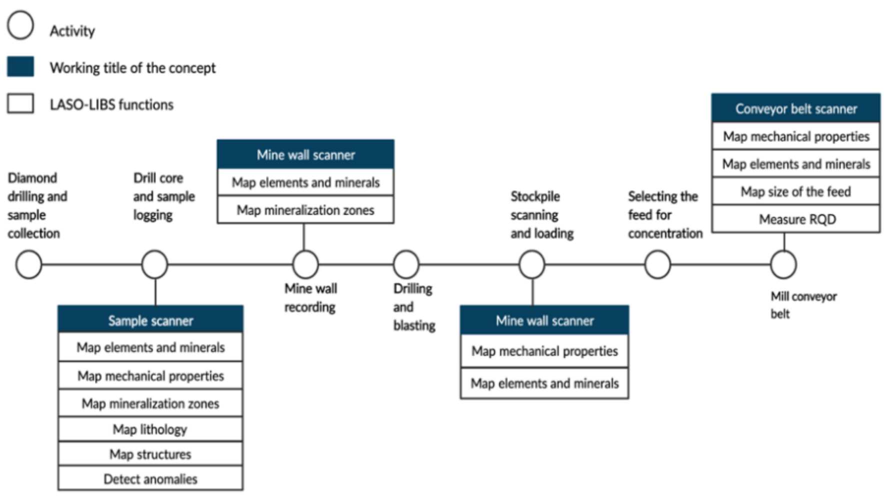

Figure 16. Revised LASO-LIBS service concepts

The mine wall scanners' activities remained the same through the testing. The service testing helped to identify that the primary need that the customers want to solve with the scanner is automating the geological reporting process, which is currently manual and dependable on the geologist. Between the two application areas, mine wall scanning was more appealing to the customers. Even though the concept received interest, the results suggest that the first geological reporting area that mining geologists would like to optimize is the logging process.

Testing the conveyor belt scanner concept helped to identify that the mills' conveyor belt is most likely the optimal place for LASO-LIBS. In addition to geochemical and geomechanical properties, the metallurgists would like to know the feed size and RQD. Measuring the feed size and RQD requires a visual analysis that is not feasible with current hardware and analytics. In comparison to the sample and mine wall scanner, the conveyor belt scanner requires more extensive research and development. Therefore, we decided to postpone the development of the concept to a later stage.

On the ground of the current analytical capability and the customer requirements, both sample scanner and mine wall scanner are fastest to develop into a minimum viable product. Out of these two concepts, the sample scanner attained more interest. Moreover, the aggregated customer insight suggests that the primary concern that mining geologists have along the mining process chain is the quality and accuracy of the resource model. Therefore, the sample scanner is chosen as the first concept since it can most effectively address the need for accurate resource modeling. Simultaneously, the sample scanner can serve ore exploration service providers and companies.

4.7 Business model

The next phase after concept selection in LSC is business model design. The first step in the design is to create and validate value proposition, which is the core component of a business model. Based on the value proposition, rest of the business model is composed and evaluated.

4.7.1 Value proposition prototype

After selecting the sample scanner as the service concept, we created a value proposition prototype also known as fake advertisement. Besides testing the value proposition, the fake advertisement measures how the users feel about the service and the brand personality (Nevanlinna et al., 2018). As the most significant customer need that emerged from empirical data is to improve the geological modeling, we integrated it as the central aspect of the value proposition as follows.

"We support geologist in geological modeling by enhancing the uniformity and quality of a drill core log by augmenting the logging process with a real-time surface analysis that provides an overview of the geological characteristics and interesting details."

LSC suggest presenting the fake advertisement as a one-pager (Nevanlinna et al., 2018). However, to obtain more in-depth responses, we modified the fake advertisement into a narrative format. The narrative was performed in a presentation format. The following paragraphs present the content of the presentation.

The narrative begins acknowledging that discovering ore and expanding mine's lifespan are dependent on ore exploration (Figure 17). In the recent years, the mining productivity has been in decline and discovering new deposits harder (Lala et al., 2015). Consequently, geologists are faced with increasingly challenging conditions. Therefore, the LASO-LIBS teams' mission is to help geologists to make most out of their resources.

Figure 17. First fake advertisement illustration (modified based on Bennee, n.d.)

The second part highlights the importance of geological analysis. With the Figure 18 on the background, we narrate that geologists are the mine's chief intelligence officers as they create resource models, which comprehend the key information about the ore deposits, which affect the profitability and success of the mine.

Figure 18. Second fake advertisement illustration (modified based on Harinotov, n.d.)

The third part changes direct the audiences focus to the importance of high-quality data. To provoke the thinking, we raise a rhetorical question whether the industry experts believe that any two geologists who were to swap sides on the logging table would create the same results. As a response to the challenge of homogenizing logging data, the LASO-LIBS sample scanner is presented with Figure 19.

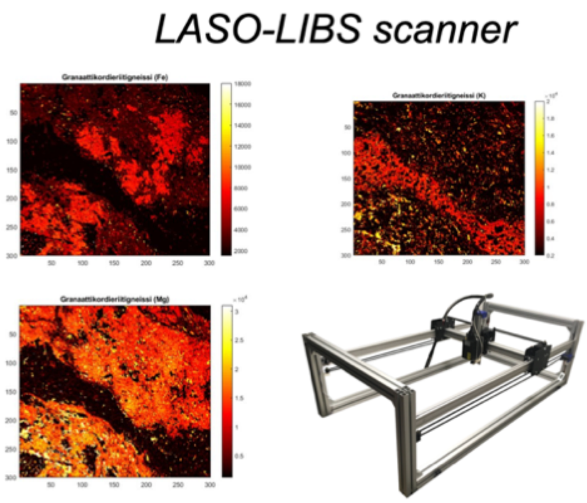

Figure 19. Third fake advertisement illustration

Next, we present a visual customer journey of what logging looks like with the sample scanner, Figure 20 depicts a part of the customer journey. The customer journey takes place at a logging facility that a geologist can relate to. In the narrative the logging process is explained one step at a time, and the features are animated to appear one at the time.

Figure 20. Fourth fake advertisement illustration (modified based on Adwo, n.d.)

The fake advertisement concludes with a value proposition, and a visual summary of it as depicted in Figure 21. The top row describes that the sample scanner allows the geologists to do real-time logging and enhance the reliability of the geological reporting. Consequently, geologists can optimize which drill core samples they send to analysis, reduce dilution, and increase capital efficiency and make more revenue.

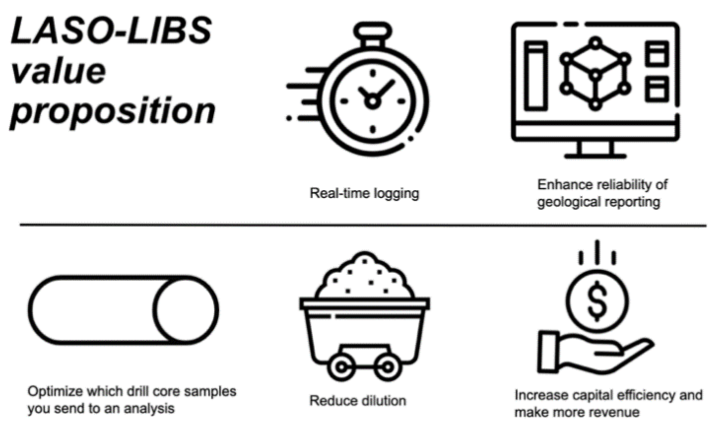

Figure 21. LASO-LIBS value proposition

Based on the feedback, the fake advertisement successfully addresses the concern of reliability of the core log. The discussion reaffirms the insight that individual differences between geologists' cause data variability, which is a major concern for the mines. Furthermore, the interviewees say that the logging is often not fast enough to keep up with drilling, creating bottlenecks. Therefore, a solution that can address both speed and reliability are interesting.

An area of the value proposition that the interviewees do not think the sample scanner can directly address is reducing dilution. The interviewees point out that there are multiple steps between logging and concentration. Since dilution is affected by several processes, logging alone cannot improve it. Furthermore, measuring loggings' impact along the mining process chain is challenging. Based on this insight the first hypothesis was revised as follows.

Hypothesis 1. Drill core logging is slow, expensive, and unprecise. The slow speed results in logging backlog and errors in resource modeling.

Finally, in the interviewees' mind, the sample scanners' mobility is a competitive advantage and could be emphasized more. According to the interviewees, mobility is advantageous for both operational and exploratory logging.

4.7.2 Revised value proposition

Following the fake advertisement feedback, we iterated the value proposition in two key aspects. First, the mobility aspect is integrated into the value proposition, highlighting that the sample scanner can be used in any conditions. Secondly, the value proposition addresses that the sample scanner can minimize backlog.

"With a LASO-LIBS sample scanner, geologists can log and analyze geochemical and geomechanical data reliably in real-time anywhere despite the conditions. As a result, the geologists can focus on their core competences while optimizing drilling programs and keeping the logging backlog at minimum"

Based on the empirical data the logging tasks that geologists prefer include inspecting and analyzing the geological features, such as lithology and anomalies, we highlighted in the value proposition that the sample logger is an auxiliary tool for a geologist that allows them to minimize time spent on mundane tasks. However, the sample scanner is complimentary, the benefits that it offers are extended the scope of logging locations and an ability to optimize drilling programs due to the real-time homogeneous data.

Based on a competitor's analysis, half of the companies emphasize technical features in their value proposition. For the companies that elaborate on the subsequent value of implementing the solution, the most common value is reliable information. The result aligns with the customer insight and market research. The second most common aspects are efficiency, cost reduction, increasing mineral value, real-time analysis, and enhancing revenue. Similarly, to our value proposition, only one company promises to accelerate logging speed and improve drilling programs.

The sample scanners' value proposition differs from the competitors in three main aspects. Firstly, it proposes mobility. As previously mentioned, the logistics between the field and analysis facilities can be impractical during a drilling program. Therefore, a fixed solution or slow analysis results are unlikely to optimize drilling programs. Secondly, the sample scanner is the only solution providing geomechanical information. In mines, mechanical properties are important indicators of the strength of the ore and have a direct impact on the excavation and concentration processes. Finally, the value proposition addresses collaboration. Moreover, the aim is to communicate to the clients that our solution does not replace a geologist but rather augment their ability to analyze faster and more precisely.

4.7.3 Business model

After validating the value proposition, LSC proceeds to business modeling. The canvas for business modeling contains both business model and market size as shown in Figure 22. Therefore, the focus is on the revenue structure. Since the aim of this study is to design a business model for a startup, the business model needs to address how to establish basic business infrastructure, such as key activities, customer relationships, and channels.

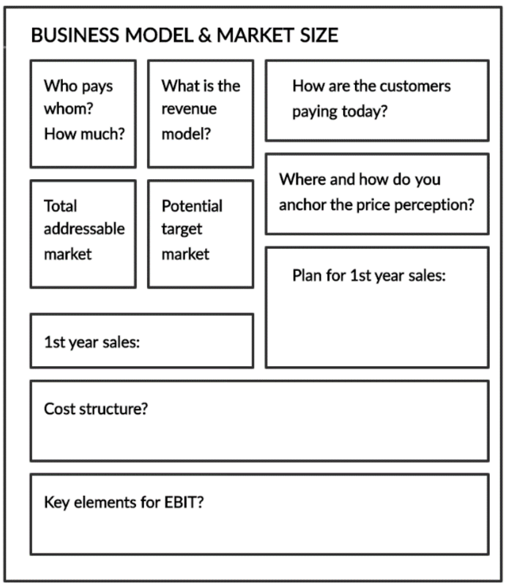

Figure 22. Content in business model & market size canvas (created based on Nevanlinna et al., 2018)

Osterwalder et al. (2010) business model canvas considers these aspects. Therefore, it was selected as the business model framework for this research. The filled business model canvas is depicted in Figure 23. The segments will be discussed one-by-one next.

Customer segments

In the beginning our primary customers are Fennoscandian metal mines. The characteristics of our target customers are that they are challenged with the accuracy of their core log and want to increase the reliability of their logging process with quantifiable data. At a later stage, we will expand our customer base to ore exploration service providers and companies. The primary customer segment differs from the competitors who target primarily ore exploration companies.

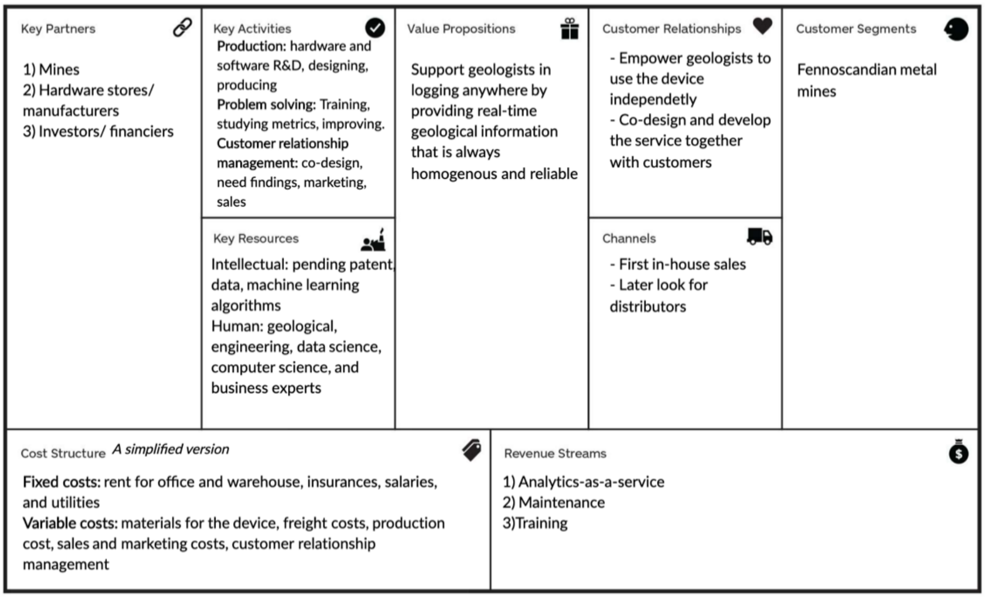

Figure 23. Business model (Created based on Osterwalder et al., 2010)

Customer relationships

The customer relationship strategy concentrates on building cooperative relationships with clients by asking them to join as co-designers to develop the service to ensure that the service can cater their needs. The goal is to become a trusted partner for mining companies. The plan to achieve this is to solve customers' challenges related to geological reporting and empower them to improve processes and operations with the LASO-LIBS method. The competitors' customer relationships cannot be assessed in detail due to lack of data. However, since the industry is small, and many of the company owners are former mining professionals, close and cooperative customer relationships are likely.

Channels

At the beginning the sales can be managed in-house as there are 32 metal mines in the Fennoscandia. The aim is to have a few high-volume clients with whom the solution is refined. In the meanwhile, the startup can develop an internationalization plan and establish a distributor, sales and service network in preparation to scale the business. Also, establishing or joining a mining equipment network is a prospective solution. Competing companies have either their own sales channels or use a distributor for their sales. One of the competitors is owned by the local geological survey, which is likely to have an extensive network of other geological surveys and mining companies.

Key activities

The key activities at the early stage include production, problem solving, and customer relationship management. As the LASO-LIBS method requires extensive research and development, the primary focus of the production is software and hardware development. The development will be done collaboratively with the customers who are interested in co-development. At first, production will be done in-house. However, a possible development trajectory is to license the hardware and focus on software development. Problem solving concentrates on helping customers to integrate the sample scanner into their processes and enable the geologists to use the scanner independently. The software and user experience will be improved gradually based on both user metrics and customer feedback. Customer relationship management consists of co-design with the customers. In addition, we will do ethnographic studies where we observe how the users use the sample scanner to identify development areas for software and hardware functionalities and user experience. Also, customer acquisition through sales and marketing will require extensive effort.

Key resources

The key intellectual resources that the company has are a pending patent, the machine learning algorithms and the big data of the geological samples. Human resources include the experts that work for the project. Similarly, the customers who will act as co-designers are included to the group. The key resources are likely to be relatively similar in the competing firms. Many of the companies have a patented technology and software of their own. In comparison to the publicly available data on the competing firms' human resources, LASO-LIBS has a relatively large percentage of commercial expertise.

Key partners

The most important partners for LASO-LIBS are the mining companies with whom it collaborates with. The mining companies can concurrently clients and co-designers who help with product and service design. The second key partners are hardware stores that supply hardware components for the device. In the beginning, the LASO-LIBS will assembly the devices on its own. As the business grows, the startup can either begin to manufacture the device or license the hardware and focus solely on the software. The third key partners are the startups' financiers. Due to limited data, the competitors' key partners cannot be appraised.

Cost structure

The cost structure is a rough estimate of the likely costs that startup will experience at the beginning. The fixed costs include the office and warehouse rents, salaries, insurances, and utilities. Variable expenses consist of hardware costs, assembly, logistics, sales, marketing and customer relationship management costs. Due to limited data, the competitors' cost structure cannot be appraised.

Revenue streams

In the beginning, we will monetize the sample scanner with an analytics-as-a-service model. The rationale for the decision is manifold.

The core value from the sample scanner derives from the analysis. Since the analytical model is based on machine learning algorithms, the more data it processes, the better it becomes. Therefore, the value of the analytics will gradually improve. At the same time, the hardware is easy to replicate and does not increase in value per se. Therefore, focusing on the intangible aspects of the service provides a better intellectual property protection as well as better likelihood for a sustainable competitive advantage.

Simultaneously, the hardware is inexpensive in comparison to the competitors. Providing the hardware for free is likely to support a rapid market expansion and ease customer acquisition. The aim is to build an extensive LASO-LIBS sample scanner network that generate a continuous stream of recurring revenue while improving the machine learning algorithms. The plan will have an impact on the financing options, and the startup will likely need to rely on equity financing to cover the hardware cost.

Besides generating recurring revenue, additional sources of income consist of maintenance and training. The revenue from maintenance comes from troubleshooting the need for maintenance, and depending on the cause, repairing the device, selling spare parts, or doing software updates. The training fee is a consultancy fee that is charge on-hour basis from the clients.

The competitor analysis indicates that the competitors either sell the device or provide analysis as a service. One of the companies offered also meter-based analysis fee for the drill cores that are analyzed at the company's laboratory. Based on the interviewees' feedback, they have not previously encountered an analytics-as-a-service monetization model for an analytical instrument. The other interviewees said that he perceives the model risky, yet interesting to explore.

5. Discussion

This chapter discusses the key findings of this study. The discussion consists of analyzing the findings that answer the research questions and LSC as a theoretical framework for service vision creation. The first chapter discusses the most prominent customer needs and their implications. Next, the second chapter discusses how the needs affected the service concept selection and the third chapter examines how the service concept can be monetized. The fourth chapter discusses the applicability of LSC for new business creation and compares the results to other literature.

5.1 Key customer needs

The most significant needs that emerged from the study can be categorized into analytical, technical, and human needs. As will be described below, these needs are often conjoined. The criticality of the needs was evaluated based on their prevalence and criticality on the operations. In addition, the competition to address these needs was considered. Table 7 illustrates with a color code the criticality of the needs. Red signifies high criticality or competition whereas green signifies low.

Table 7: Customer need evaluation

Need	Challenge	Competition
Quality and type of data	Reporting accuracy	Geochemical/mechanical data
Speed of retrieving data	Operational efficiency	Speed
Access to retrieving data	Field process optimization	Mobility

The most prominent needs for geological reporting within the mining industry are improving the quality of geological reporting and expediating the data retrieval. The entire mining process chain relies on the resource modeling, ensuring the reliability and accuracy of data is of chief importance. Currently logging is, to a vast extent, a manual process that relies on geologists' interpretation and attention to detail. Many authors that have researched drill core logging concur with the view (Jakubec et al., 2004; Murphy & Campbell, 2007; Marjoribanks, 2010; Day et al., 2013). The empirical data suggests that due to individual differences, the mining companies would like to have unequivocal quantitative geochemical data as a foundation for geological interpretation. The reporting quality and data fluctuations appear to be the most pressing issue for exploratory logging. While manual logging was perceived as error-prone, it was also described as time-consuming. Due to the slow speed, mining companies have a backlog. Consequently, the companies have less time to develop the processes.

This study identified that geological uncertainty and consequent risk correlate positively with the need to implement analytical instruments to reinforce geological intelligence. Hence, ore exploration, which is the most uncertain phase in the mining value chain, has the most demand for analytics. Exploratory logging often takes place in field conditions, which precludes the convenient use of currently available precise analytical instruments. The precise analytical instruments are either fixed or heavy-weight, making them immobile solutions. Furthermore, most mining and ore exploration purchase drilling programs as a service as drill rigs are capital-intense investments. Because drill rigs are scarce during a high season, the drilling programs are commonly brief and intense, with a tendency to over drill, which is indicated as mass production in Figure 24. Due to inaccessible geochemical data, time constraints, and scarcity of drill rigs, geologists determine drilling programs based on visual analytics and gut feeling, which leads to geological speculation and results in unoptimized drilling programs. This deadlock is depicted in Figure 24.

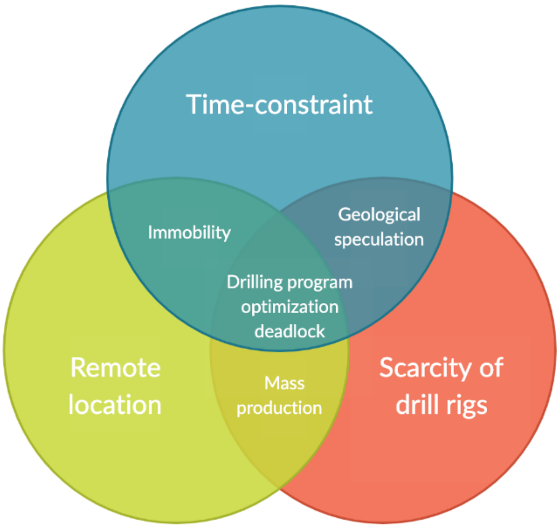

Figure 24. Drilling program optimization deadlock

According to the customer insight, geologists perceive the expense of drilling program as compulsory, yet believe that the cost could be reduced by discontinuing the drilling programs sooner if desired outcomes do not appear. Furthermore, drilling program optimization is likely to provide a better quality-price ratio for drilling. To achieve this, geologists need analytical instruments that are portable, require minimal sample preparation, and work in difficult conditions in order to optimize the drilling programs.

Although vast majority of needs were business-related, some human needs also emerged. The empirical data suggests that geologists would like to spend more time on analytical and creative tasks instead of mundane reporting. Despite the geologists in general showed openness towards automation and optimization of logging, they displayed some concern and rejection towards replacement of their work. Thematically this finding belongs also to human and artificial intelligence relationship research. As the branch of research is relatively new, no research concerning the topic within the mining context was found for this study. While human-computer interaction is relevant for developing and designing the sample scanner, it is beyond the scope of this study. Therefore, we simply interpreted the dichotomy between desire to self-actualization and concern over replacement as a need to feel in charge of the process and focus on core competences.

5.2 Service concept

Based on customer insight, we created three service concepts that address the most pressing needs. The service concepts are a sample scanner for logging, a mine wall scanner for geological recording, and a mill feed scanner for the concentration feed analysis. A service concept that had most demand from the customers was a sample scanner. The outcome did not surprise as logging received most concern in the need-finding stage. Testing, however, indicated that both mine wall and mill feed scanning methods surfaced interest, which would benefit from further validation.

Although prototyping did not disprove any hypotheses regarding the sample scanner, it diversified our understanding of the range of geological samples geologists want to scan and set criteria for a minimum viable product and service. In the beginning, we assumed that the scanner will be used for drill cores only. The geologists, however, mentioned that at the early stages of exploration, the samples consist mostly of easily extractable samples, such as small rocks, till, and soil. Consequently, we altered the scanners' name from a drill core scanner to a sample scanner.

The critical aspects of the physical features of the sample scanner are a light-weight frame and modularity of components. As discussed earlier, currently the weight of analytical instruments contributes to the drilling program optimization deadlock. Therefore, keeping the weight light allows geologists to carry the sample scanner to the field. Modularity emerged as an important factor since the design should enable quick repair at any location. Furthermore, the geologists would like to be able to fix the device by themselves. Modularity will require close co-design with the customers to learn how they approach the repair and what kind of documentation and technical support we should establish.

The key component of the service will be an analytics dashboard. Through discussions, we identified that the minimum viable dashboard should contain three main visualizations of the scanning results. The rectangle with a grey frame represents a drill core box and the five narrow rectangles represent drill cores. First, the dashboard should have an overall visualization that displays a heatmap and a list of elements and minerals found in the samples. Figure 25 does not contain a heatmap, instead, it displays the second requirement, which is anomalies. These are depicted with red dots. Third, the dashboard should have a visualization for mineralization zones.

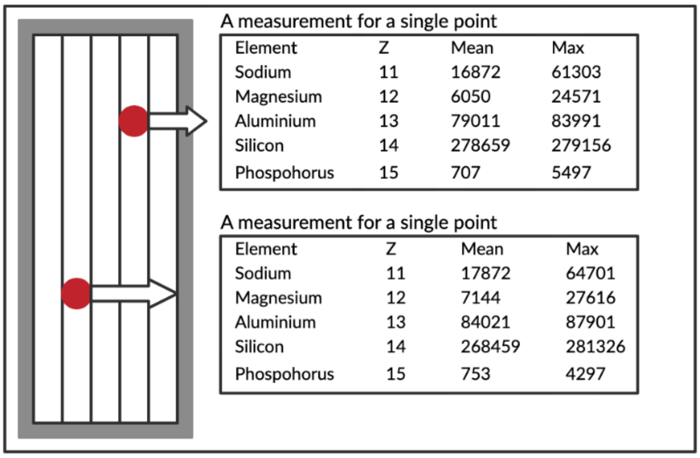

Figure 25. An example of the dashboards 'visualization

The critical geochemical data that should be displayed on the dashboard include the mineral and elemental information. The information should include the mean and maximum value of the information in question. Figure 25 displays mean and maximum values for the anomalies. The mean value is the average concentration of the elements within the given area. The maximum value, on the other hand, presents the highest single concentration of the element within the area. These values indicate if the sample has a sufficient concentration of desired elements to reach economic ore production. Fourth, the map should display mineralization zones. Furthermore, the dashboard should indicate two units of length. First, the length of the area that the values represent. For instance, a single point or the entire drill core. Second, the depth from which the drill core is extracted.

Prototyping also provided customers' views on monetization. The results supported the earlier findings from the need-finding interviews. Mining companies showed that they are interested in purchasing or leasing, while ore exploration companies and service providers were more inclined to leasing. The commercial aspect resulted in the customer segmentation re-evaluation, which reinforced mining companies' position as the primary customer segmentation. The mining companies' willingness to commit to the product financially provides more options for business model design, and ultimately gives more freedom to choose from financing options during a scaling phase.

5.3 Business model for monetization

The preliminary business model to monetize the sample scanner is to offer the analysis service with an analytics-as-a-service model. The primary considerations for setting the monetization model included the impact on acquiring clients and growing market share, as well as the impact of financing alternatives.

The interviews indicated that a tendering threshold is approximately EUR 60,000 within the mining companies. Therefore, we set the device price to EUR 60,000. According to discussions and literature review, geochemical laboratory tests cost between EUR 50 to 100 per meter in Finland. We benchmarked our initial pricing estimates against this price range. We assessed that despite the real-time optimization benefits LASO-LIBS can offer before it is recognized as an official reporting code, the customers are likely to be willing to pay less for the service.

Table 8 depicts a simplified hypothetical revenue forecast in the Finnish market with the presumption that LASO-LIBS has one client in the first year and the number of clients increases by one annually while retaining the old customers. The presumption for the meter-based pricing models is that one client equals one percent of exploration drilling. The total drilling quantity was 273 kilometers in 2017 (Tukes, 2018), which is used as a fixed number for the calculation.

Table 8: Revenue forecast for different monetization methods

Monetization options	1st year	2nd year	3rd year	4th year	5th year	Total
A-A-A-S meter fee EUR 25	€38,250	€106,500	€174,750	€243,000	€311,250	€873,750
A-A-A-S meter fee EUR 30	€51,900	€133,800	€215,700	€297,600	€379,500	**€1,078,500**
A-A-A-S meter fee EUR 35	€65,550	€161,100	€256,650	€352,200	€447,750	**€1,283,250**
Device EUR 60K + annual fee EUR 25K	€85,000	€110,000	€135,000	€160,000	€185,000	€675,000
Device EUR 60K + annual fee EUR 30K	€90,000	€120,000	€150,000	€180,000	€210,000	€750,000
Device EUR 60K + annual fee EUR 35K	€95,000	€130,000	€165,000	€200,000	€235,000	€825,000
Device 60K + A-A-A-S meter fee EUR 10	€87,300	€114,600	€141,900	€169,200	€196,500	€709,500
Device 60K + A-A-A-S meter fee EUR 15	€100,950	€141,900	€182,850	€223,800	€264,750	€914,250
Device 60K + A-A-A-S meter fee EUR 20	€114,600	€169,200	€223,800	€278,400	€333,000	**€1,119,000**

The table shows that the analytics-as-a-service (A-A-A-S) model generates most revenue upon growing market share if the price per meter is over EUR 30. The formula for calculating the analytics-as-a-service is total drilling quantity (in meters) * price/ 100)*market share – cost of new device. The calculation, however, shows that the revenue is lower in the first year in comparison to other models as the cost of the device is deducted. While this model has the highest earning potential, it also contains the highest risk as the startup bears the hardware costs. At the same time, the customers do not have to commit to the service for any specific time. While the cost of acquiring customers is likely to be lower than in other models, the fee for customer relationship management is likely to be higher. This model is also most prone to drilling quantity fluctuations.

The calculations show that device sales and annual fee options generate the most stable flow of income as the flat pricing protects it from the fluctuations. While the total revenue is 18 percent less than in the device sale with metering fee and 30 percent less than in analytics-as-a-service, the model is likely to require less equity capital for growth than the other models.

The last monetization option is a hybrid between the analytics-as-a-service and device sale with an annual fee. The strong point of this option is that reduces the capital risk for manufacturing hardware, which is present in the analytics-as-a-service option. Therefore, the startup will have more room to consider alternative financing options. However, the device fee is likely to slow down customer acquisition. The volume is a critical factor for the meter-based fee since the aggregated analysis is the primary source of income. At the same time, we assume that the clients expect a lower meter-fee than in the analytics-as-a-service option due to the device purchase, which results in lower earning potential.

Based on these estimates, we recommend analytics-as-a-service as the first monetization method to rapidly scale the scanning method globally. The model provides a dual benefit from the big data accrual as the machine learning algorithms improve and revenue accumulates. We hypothesize that the pricing method could develop network effects. Network effects within this context imply that the value of the analysis method increases as the customer base grows. At the same time, the clients will become more committed to the service and market entry will become more difficult for the competitors.

To tap bigger data volumes, the LASO-LIBS method should get recognized as an official reporting code, so that the mining companies would be more likely to apply it to operational logging, where the largest drill core volumes reside. Furthermore, the startup could also consider establishing a partner network to form an ecosystem within the mining industry. The partner network may support scaling efforts by introducing a potential client base that the startup can approach.

5.4 Applicability of Lean Service Creation

This chapter discusses the applicability of LSC as a theoretical framework for service vision creation and compares the findings to other similar studies. The discussion concentrates on evaluating the applicability of LSC primarily through the principles and practices as the canvases share these aspects in common. The limitations of the study will be discussed on a canvas-level.

The principles of team-centricity and transparency helped us to establish transparent culture within the team as well as discover effective collaboration methods. Despite all team members had different professional and academic backgrounds, LSC provided mutual tools and language for the service development. Despite some of the team members having a limited knowledge of service development, the clear structure of the canvases enabled everyone to engage in the development process. Pekkinen (2019) also discovered Lean Startup to be a good tool for facilitating multidisciplinary collaboration.

By working on the canvases that encourage openness and transparency, we gradually increased openness in communication. The impact was visible in more direct and constructive feedback and a broader range of ideas during ideation sessions, which lead to considering more alternatives before narrowing down the scope. Adopting the LSC way of working was relatively effortless because the team was formed during the commercialization project. Therefore, we did not have previous habits or practices that could conflict with the LSC method. Pasanen (2016) noted in his study that applied LSC within a large international telecom company that LSC works best within autonomous teams and organizations with a low hierarchy.

The principles a problem-orientation and iterative learning had the most tangible impact on the projects' outcome. The practice underpinning the principles is a Build, Measure, Learn feedback loop that develops the teams' hypotheses through customer engagement until a customer insight has been clarified. The Build-Measure-Learn feedback loop provided clear benefits at all stages. By validating our hypotheses from the beginning, we minimized wasting time and resources on ideas that did not resonate with the customers. Simultaneously, the process helped us adopt a customer-centric learning mindset. Table synthesizes the evolvement of the hypotheses, and the impact that validation had on the design process.

Table 9: Summary of the hypotheses

Hypothesis	Key insights	New hypothesis	Main implications
1. Drill core logging is slow, expensive, and unprecise. Besides expenses from drilling and logging, the mines experience mining process chain productivity loss due to inaccurate logging.	"Logging is slow and error-prone..I don't see that the process has implications to dilution." Interviewee I - Homogenizing reporting is critical, yet determining far-reaching consequences are hard. -Drilling is more expensive than logging	Drill core logging is slow and unprecise, therefore mining companies would like to optimize the logging process.	**Service design:** create visualization tools that enable geologists perceive details and big picture quickly. **Business model:** precision and speed included to value proposition **Area of application:** exploratory logging
2. Identifying geomechanical properties is likely to provide a competitive advantage for the LASO-LIBS method in both ore exploration and mining operations.	"The key features I analyze in drill cores are mineral and elemental composition." Interviewee K (ore exploration company) -Geochemical information is most critical during ore exploration - Only mining companies are interested in geomechanical information	Mining companies are likely to perceive indentifying geomechanical properties as a competitive advantage.	**Customer segementation:** mining companies are primary customer segement. **Businesss model:** included to value proposition **Area of application:** exploratory logging and mill feed screening
3. Due to the challenging field conditions, the ore exploration companies, are likely to perceive the portability of the LASO-LIBS method as a competitive advantage.	"Portability of LASO-LIBS is an advantage." Interviewee I(mining company) -Both mining and ore exploration companies find portability critical -No competitors can offer same analysis in the field conditions	Mining industry companies are likely to perceive the portability of the LASO-LIBS method as a competitive advantage.	**Product design:** Portability is a key priority **Businesss model:** the value proposition empahsizes portability. **Customer segmentation:** mining and ore exploration companies
4. We hypothesize that companies that have a dense drill hole spacing grid are most interested in optimizing their drilling programs.	- The empirical data does not support the hypothesis - The results indicate exploratory drilling programs are more likely interested using LASO-LIBS - Operational logging is perceived as a routine task		**Customer segmentation:** Mining companies that do active ore exploration are target customers. Ore exploration companies and service providers are secondary customer groups. **Area of application:** exploratory logging
5. We hypothesize that the mining companies will value information that can help them select best samples for the laboratory.	"I do not see great benefit from LASO-LIBS to operational logging because the samples are sent to laboratory in any case" Interviewee A -The empirical data does not support the hypothesis		**Customer segmentation:** Supports the conclusion made in hypothesis 4.
6. Real-time geochemical and geomechanical information before the milling process can help mines to optimize the mill settings.	"In addition to mechanical porperties, knowing RQD and feed size are important information for adjusting the mill settings." Interviewee C (mining company)	We hypothesize that a minimum viable product for the conveyor belt scanner includes besides geochemical and geomechanical properties, information on RQD and feed size.	**Product desing:** Out of all concepts, conveyor belt scanner requires most R&D. Supports decision to choose sample scanner as the first concept. **Customer segmentation:** metallurgists are a potential customer segment

The Build, Measure, Learn feedback loop revealed that none of our initial hypotheses were fully correct. Discovering the erroneous assumptions, was the most useful tool in understanding the benefits of customer engagement and validation. At the same time, the process revealed that the team needs to be aware of confirmation and overconfidence biases to avoid searching only for feedback that supports original hypotheses and careful not to assume the current knowledge and information are adequate for decision-making. In this study, we were most biased about the importance of geomechanical properties in the mining process chain as it is a unique aspect of the LASO-LIBS scanning method. Although geomechanical data is critical especially in the milling process, it is an auxiliary feature in logging. Although studies that have applied LSC do not discuss encountering biases during the process, there is plenty of literature that discusses how human-centered design methods can help reduce cognitive biases (Liedtka, 2014; Razavian et al., 2016).

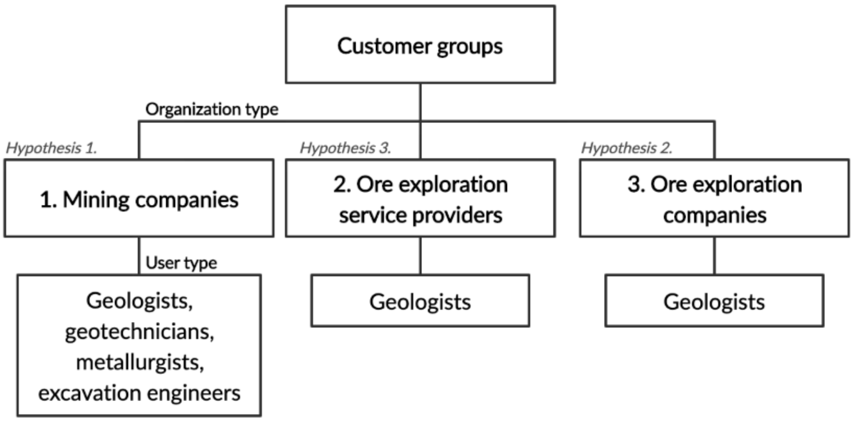

Figure 26. Customer segmentation

The customer-insight from Build, Measure, Learn feedback loop influenced the outcome of the service vision. The most significant impact on of the business model came from refining the value proposition and customer segmentation. Figure 26 presents how iteration helped us not only to prioritize the customers based on organization type but also identify user types.

Prototyping also helped us to set criteria for minimum viable product and service. Simultaneously, it also helped us to establish a preliminary co-designing relationship with clients. Multiple studies establish defining the criteria for a minimum viable product or service as one of the primary benefits of using human-centered development methods (Junnonen, 2015; Tauciuc, 2018; Pekkinen, 2019). At the same time, surprisingly few studies mention forming a customer relationship as a benefit. Overall, the Build, Measure Learn feedback loop helped us to gradually refine and build the concept. Multiple other studies also conclude that the LSC method helped them to create tangible and validated outcomes (Antinranta, 2016; Mallander, 2017; Björklund, 2018; Lahti, 2018; Jokela, 2019).

The fifth LSC principle is keeping a holistic view of the project. The supporting practices include project management and working canvases. Although, we did not apply the project management canvases in this study, we were able to oversee the progress and prepare in advance for the next phases by keeping track of the canvases we wanted to fill in. One of the most distinct benefits of holistic view was in a formation of the value proposition as it requires both strategic overview and detailed understanding of the market. We formed the value proposition by integrating analysis of the customer needs, market and introspection of the strengths and weaknesses the LASO-LIBS method has.

An area in which LSC had limited applicability for this study is the business model design. The primary limitation of the LSC business model canvas is that it focuses on cost and revenue structure. For a new business, that does not have clientele, revenue is the most uncertain aspect of the business. Furthermore, in our case, the Business Finland funding restricts making revenue, which complicates evaluating the possible monetization method. Mallander (2018) denotes in her study that creates a service vision for a new business that the business model and market size canvas did not meet the business model needs. In her mind, the financial projections are not broad enough to meet the forecasting standards they have. Therefore, she chose an alternative method to address the need.

The business modeling canvas has a wide scope as it evaluates concurrently the financial projections and market size. In this study, we assessed the market size and potential during the market research to understand early on if analytical tools for drill core logging have business potential. Traditionally, market size estimation is integrated into a market research study. Moving market size estimation to the need-finding stage could save later effort if the market is deemed upfront unprofitable. Therefore, we propose a market assessment canvas, which could be positioned alongside the immersion canvas. The canvas is depicted next to the current business model and market size canvas in Figure x.

The proposed market assessment probes the market more minutely by introducing questions that inquire about the market growth, thus giving an insight into the maturity of the market and demand for the service in question. The canvas also prompts the team to evaluate demand drivers within the market as well as market structure to understand the underlying market mechanisms, which may influence the intended business. Finally, the canvas also suggests the team conducts a risk assessment of potentially disruptive forces that can change the business environment.

Figure 27 depicts the business model and market size canvas and proposed business model canvas. The most considerable limitation of the current business model is that it does not describe how the business works. Magretta (2002) proposes that business model should describe a competitive strategy, which aims to overcome the rivals. For Cassadesus-Masanell and Ricart (2010), a successful business model explains how the value is delivered to the customer in practice. Against these definitions, the LSC business model canvas does not answer what the intended business model is. We chose Osterwalder et al. (2010) Business Model Canvas because it meets the definitions' criteria of a business model.

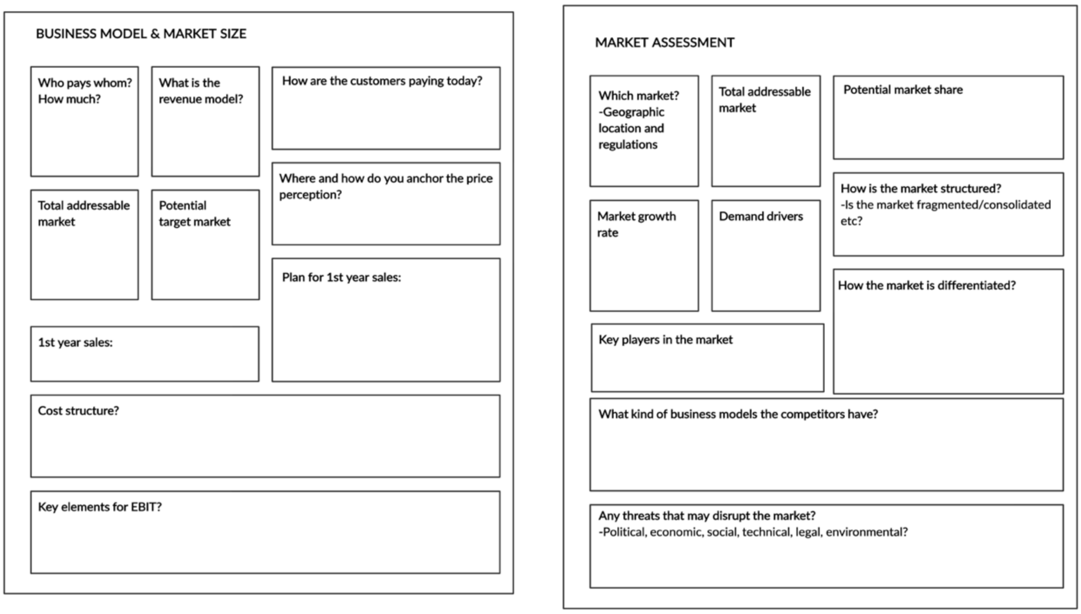

Figure 27. Suggested market assessment canvas

Although the Business Model Canvas (see 2.2.3) sufficiently addresses the basic building blocks of the business model, there are certain relational and strategic aspects regarding value proposition and financial segments that increase the startup failure risk. The proposed business model, which is depicted in Figure 28, suggests that the business model could be augmented from these aspects. The proposed segments are customer journey, partners and networks, market positioning, risk management, and organizational structure.

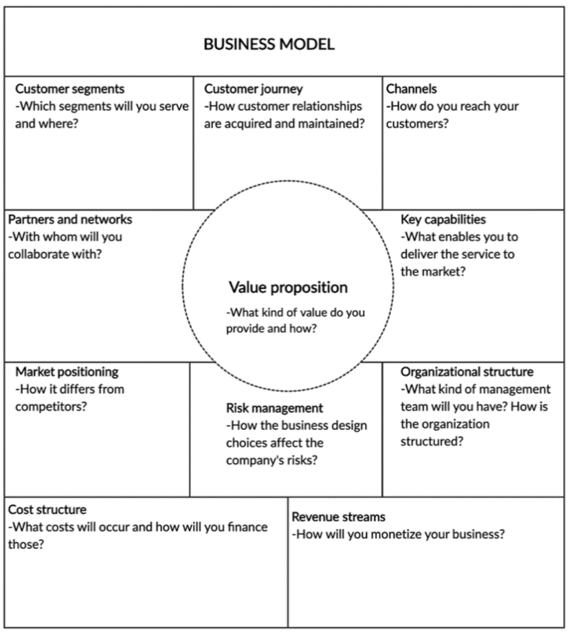

Figure 28. Suggested business model canvas

From a value creation perspective, it is important to consider the entire customer journey from acquisition to customer relationship management (Edelman & Singer, 2015). The current Business Model Canvas addresses customer relationship maintenance. Widmer (2016) considers the lack of a relational value creation perspective among the key shortages of the Business Model Canvas. Without the human-centered mindset from the LSC, the relational aspect might have been missed, despite that, it is not a part of the LSC business modeling process. Consequently, we propose that the segment would be augmented to look at the customer relationship holistically from customer acquisition to termination.

Collaboration is vital for startup success. Research indicates that in addition to business partners, professional networks influence commercial success as they can facilitate knowledge exchange and provide support for entrepreneurs (Bosma et al., 2004; Walter et al., 2006; Zacca et al., 2015). The role of collaboration heightens during the scaling phase when the startup attempts to gain a competitive scale and market leadership (Picken, 2017). Business Model Canvas views collaboration from a business perspective only. Widmer (2016) notes that the Business Model Canvas views the process from a customer and company's perspectives excluding other stakeholders. In our study, the networking aspect and its importance emerged through the Business Finland funding. Therefore, the proposed version augments the segment to encompass both partners and networks.

Customer needs and market positioning have a dynamic relationship (Picken, 2017). The customer profiles and needs change as the service evolves from early adopters to the majority. Therefore, updating market positioning is critical for startup success. According to Picken (2017), many entrepreneurs are not aware of the synergy between needs and position. Besides perceiving this synergy, evaluating the market positioning provides a strategic insight into how it differs from the competitors. The Business Model Canvas does not take competitive positioning into account. Widmer (2016) agrees with this view in his study by stating that the canvas does not take competition into account. Therefore, we suggest the startups consider the market positioning as a part of the business model.

The CB Insights (2019) startup postmortem inquiry indicates that the most common cause for startup failure is unvalidated customer need. However, all aspects of the business model entail risk and certain choices may increase the uncertainty. For instance, a narrow revenue focus may create seasonality and a cost structure may result in liquidity issues (Van Gelderen et al, 2006; Picken, 2017). Coes (2014) discusses in his dissertation that entrepreneurs consider a lack of risk assessment in Business Model Canvas as a limitation since startups have inherently high risk. Therefore, the proposed business model canvas includes a risk assessment segment that prompts the team to consider how the business design choices affect risk management.

Defining organizational structures early on can save a startup from challenges that arise when the company begins to scale. The organizational structures encompass e.g. the composition of the management team, management systems and processes, and preservation of the entrepreneurial culture (Eisenmann & Wagonfeld, 2012). Business Model Canvas inquires what kind of key resources the company has, which includes human resources. However, the canvas does not define the roles further. Sydänmaa (2016) evaluates the lack of team formation segment as a key shortcoming of the Business Model Canvas. Hence, the proposed business model canvas expands the scope of specifying organizational structures.

6.Conculsions

This thesis presented a service concept along with a business model for the LASO-LIBS scanning method based on the identified customer needs. This chapter concludes the study by first discussing the managerial implications and theoretical contributions. Second, the limitations of this study are evaluated, and a new research is suggested based on the findings.

6.1 Managerial implications

This study results in several operational and strategic managerial implications for the LASO-LIBS team. These insights may benefit also other companies that provide analytical instruments to the mining industry. Furthermore, the mining industry's needs regarding geological reporting are not well researched, so this study contributes to the research gap.

Customer insight shows that the mining process chain has several areas that lack real-time geochemical and geomechanical data. The areas that benefit from the real-time data are exploratory drill core logging, mine wall recording, and mill feed scanning. The minimum viable product for the sample scanner and mine wall scanner includes geochemical data that shows mineral and elemental concentration, lithology and anomalies. Moreover, the device must be portable and require a simple power source. The minimum viable product for mill feed scanning, on the other hand, requires geochemical and geomechanical data, as well as sample size and RQD.

In terms of competition, drill core logging is the most saturated area as geological uncertainty increases the need for analysis. Currently, none of the competitors can provide a portable high-quality analytical instrument that works in the field conditions. From the customers' perspective portability for high-quality analytical instrument is a must, since ore exploration field conditions and time constraints restrict the companies from accessing logging facilities and laboratories during drilling programs. Lack of geochemical data results in unoptimized drilling programs. Mill feed scanning has the second most competitors in the industry. Milling is among the highest operational expenses in the mining industry, which makes it an interesting application point. The minimum viable product, however, will require research and development for feed size and RQD measurement. Mine wall scanner has the least competition, yet at the same time tunnel wall scanning is not perceived as critical as logging or feed scanning as the impact is harder to measure.

This study identified that mining companies are the most promising customer base for the LASO-LIBS scanning method since ore exploration is critical for the mine's continuation. Furthermore, the mining companies indicated they are willing to co-design and collaborate on research and development, whereas ore exploration companies and service providers are more likely to require a ready solution. The close collaboration with the clients is also a good building block to customer relationship management and customer retention. In terms of cash flow and recurring revenue, mining companies will provide a more stable and higher volume of data whereas ore exploration companies experience seasonality. Finally, mining companies are also potential customers for all three service concepts.

6.2 Theoretical contributions

This thesis contributes to the theoretical discussion of LSC as a theoretical framework for startup service vision creation. As a part of the discussion, this thesis reflects the current approach to business model creation and suggests two new canvases for business modeling and market assessments. The canvases are depicted in chapter 5.4. The new business model canvas is a conceptual tool that can be applied to any business that does not have the existing business infrastructure. Furthermore, this study proposes that a startup should consider the market size already at an earlier phase of commercialization to evaluate the business opportunity to minimize efforts to enter a market that does not entail a significant business opportunity.

6.3 Limitations

Confirming the validity of a qualitative study is challenging since the empirical data consists of unmeasurable data. This study obtained empirical information through contextual and semi-structured interviews and questionnaire. The interpretation of these findings is subjective to my interpretation and hard to generalize to other social environments. Similarly, the interviewees may have answered the need-finding questions from their point-of-view rather than from the company's perspective. Due to this limitation, the list of interviewees (3.2.3), list of interview questions (Appendices A and B) are included in the thesis for the readers' evaluation of the validity.

Three other main limitations of this study include both internal and external validity factors. Firstly, the limited scope of interviewees may also affect the generalizability of the need-finding results. Most of the interviewees were geologists, which may affect the outcome of the study. While geologists are responsible for geological reporting and analytical tasks, the findings of this study indicate that other mining professionals, such as metallurgists, have significant needs and challenges regarding geological data. Consequently, a broader scope of interviewees may introduce new needs or change the emphasis of the needs presented in this study. Secondly, since the terms and conditions in the Business Finland TUTL funding prohibit making revenue during the commercialization project, the business model could not be tested. Therefore, the results are hypothetical until the business model can be tested. Finally, since the external data regarding drill core logging cost is reported as part of the overall operating costs, it is inaccessible. For business secrecy reasons, companies do not understandably want to disclose the information. Consequently, it is challenging to evaluate the financial impact of logging.

6.4 Suggestions for future research

From a theoretical perspective, Lean Service Creation and academic innovation commercialization could be researched more. Lean Service Creation is a new method for service vision creation. Vast majority of the case studies research corporate innovation. There are only few studies that have applied the framework within the startup context. Further research on best practices for new business creation could aid the design process. In this study, particularly the business model tools did not meet the requirements that a startup has for business modeling. Further discussion and new versions of the tools could broaden the applicability of LSC. Moreover, studies that discuss service and business model creation for academic innovation are even more scarce. Research on the limiting factors that come from funding and ways to deal with them creatively could be especially beneficial. Since validating pricing was particularly difficult, studies and frameworks on how to validate pricing under the restriction of making revenue would be valuable.

From a managerial perspective business model and geochemical reporting standards are interesting areas for further research. While this study was able to identify and prioritize customer high-level segments, more granular segmentation can be advantageous for sales and marketing. Furthermore, the customer base research could be expanded beyond Fennoscandian market, as the potential client base is only 32 mines. This study was not able to propose a detailed pricing strategy. While the project has revenue making restrictions, it could create further pricing simulations to estimate profitability under different pricing strategies. Also, further interviews on pricing thresholds and investigate the willingness to pay could be useful. Although, the potential startup may be able to acquire and service clients at the beginning on its own, investigating possible distributor channels and partners could be useful in case the startup want to focus on its core competence only or wants to scale faster. Finally, the study indicates that the logging volume and consequently cost is higher in operations than in exploration. However, operational logging did not attract broad interest among interviewees as the LASO-LIBS method is not recognized as an official reporting standard. Therefore, researching where and how official reporting standards are created could be insightful.

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Appendix

Appendix A: Interview questions

The questions are prioritized in the following order. Prioritization group 1 questions are asked if the duration of the interview is 30 minutes. Prioritization group questions 1 and 2 if the interview lasts 45 min, and all questions are asked if the interview time exceeds 45 minutes.

Table A1. Interview questions for mine geologists

Question	Prioritization	Category
Briefly introduce yourself and describe your role	1	Background information
What are your main tasks and goals?	1	Background information
What is your typical workday like?	2	Background information
Who are the people inside and outside the company you collaborate with?	2	Background information
What channels do you use for sharing information with these people?	3	Background information
What kind of geological model/models do you have/use in your mine?	1	Deposit modeling
What kind of geological data you gather from the mine site (e.g. cores hand samples, cuttings)?	1	Deposit modeling
When and how do you update the geological model?	2	Deposit modeling
In which system(s) do you maintain your geological model?	3	Deposit modeling/ info and system
What kind of information and parameters do you collect and/or follow?	1	Information and systems
What kind of information would you like to have to support your work but is not currently available?	1	Information and systems
What kind of role drill cores play in your work?	1	Drill cores
What kind of activities do you have that involve drill cores (or dc data)?	2	Drill cores
How frequently and how much are drill core samples taken in your mine?	1	Drill cores
Where, how, and by whom are the drill core samples analyzed?	1	Drill cores
How long does the analysis take?	2	Drill cores
In which format the results of the analysis are? (element/mineral etc.)	2	Drill cores/ info and systems
What kind of impact if any, a nearly real-time analysis could make to your operations?	2	Drill cores
Are there any challenges in analyzing the drill cores?	1	Drill cores

Where is the data about the drill cores stored (and analyzed)?	3	Drill cores/ info and systems
In which format is the drill core data stored?	3	Drill cores/ info and systems
Would you like to store the drill core data in any other format, but is not currently available?	3	Drill cores/ info and systems
Do you have a digital archive of your drill core library?	3	Information and systems
If the mine has a digital core sample archive, how are the samples digitized?	3	Information and systems
If the mine doesn't have a core sample archive, can you evaluate what kind of impact may the digital archive have on your operations? If the response is positive response, do you have any plans to digitize your drill core archive?	3	Information and systems

Table A2. Interview questions for ore exploration geologists

Question	**Prioritization**	**Category**
Briefly introduce yourself and describe your role	1	Background information
What are your main tasks and goals?	1	Background information
Do you have a typical workday? If so, what is it like?	2	Background information
What is the type of companies and people (work title) you collaborate with?	2	Background information
What channels do you use for sharing information with these people?	3	Background information
What are the most important aspects in an exploration project?	2	Exploration
What are the most important sources of information during an exploration project?	1	Exploration
How do you access this information?	1	Exploration
Is there certain information you would like to have/ that would bring added value to your client but is not currently available?	1	Information and systems
What kind of samples do you collect during ore exploration?	1	Samples
What kind of role drill cores play in your work?	1	Drill cores
What factors lead to taking drill core samples? Who makes the decision?	2	Drill cores
How, where and by whom are the drill cores analyzed? How long does it take to get the results?	1	Drill cores
In which format the results of the analysis are? (element/mineral etc.)	1	Drill cores/ info and systems
What kind of impact if any, a nearly real-time analysis could make to your operations?	1	Drill cores

Table A3. Interview questions for geotechnicians

Question	Prioritization	Category
Briefly introduce yourself and describe your role	1	Background information
What are your main tasks and goals?	1	Background information
What is your typical workday like?	1	Background information
Who are the people inside and outside the company you collaborate with?	2	Background information
What channels do you use for sharing information with these people?	2	Background information
What is kind of geological information do you need for your work?	1	Geotechnical information
What is kind of information of the rock's mechanical properties do you need for your work?	2	Geotechnical information
How do you currently monitor geological and mechanical properties information?	1	Geotechnical information
How easily is this information accessible? Is there any information that would be useful to have but is not available?	2	Information and systems
What kind of parameters do you follow?	1	Information and systems
What kind of software and systems do you use?	3	Information and systems
How is drill and blast design created? What are the aspects considered in the process?	2	Operations design and planning
How are mine's short/medium/long term plans and their reconciliation created?	2	Operations design and planning
What kind of activities do you have that involve drill cores (or dc data)?	2	Drill cores
When and why are drill cores extracted?	1	Drill cores
Where, how, and by whom are the drill core samples analyzed?	1	Drill cores
How long does the analysis take?	2	Drill cores
What kind of impact if any, a nearly real-time analysis could make to your operations?	2	Drill cores
Do you have a digital archive of your drill core library?	3	Information and systems
If the mine has a digital core sample archive, how are the samples digitized?	3	Information and systems
If the mine doesn't have a core sample archive, can you evaluate what kind of impact may the digital archive have on your operations? If the response is positive response, do you have any plans to digitize your drill core archive?	3	Information and systems

Table A4. Interview questions for metallurgists

Question	Prioritization	Category
Briefly introduce yourself and describe your role	1	Background information
What are your main tasks and goals?	1	Background information
What is your typical workday like?	2	Background information
Who are the people inside and outside the company you collaborate with?	2	Background information
What channels do you use for sharing information with these people?	2	Background information
Can you briefly explain different stages in the conversion process?	1	Milling process
How do you follow that the milling process works as intended?	1	Milling process
When the milling process may have to be adjusted? How frequently does this happen?	1	Milling process
How do you monitor the incoming and outgoing material flows?	1	Milling process
How useful do you perceive real-time information about material flows?	1	Milling process
What kind of analysis equipment do you use in your work?	1	Information and systems
What kind of information do you need for your work?	1	Information and systems
What kind of parameters do you follow?	1	Information and systems
Are some of the parameters challenging to follow?	2	Information and systems
Is there certain information you would like to have but is not currently available?	1	Information and systems
What kind of software and systems do you use?	2	Information and systems
In which format the data in these systems?	3	Information and systems
Can you import data from external sources to the software/systems?	3	Information and systems

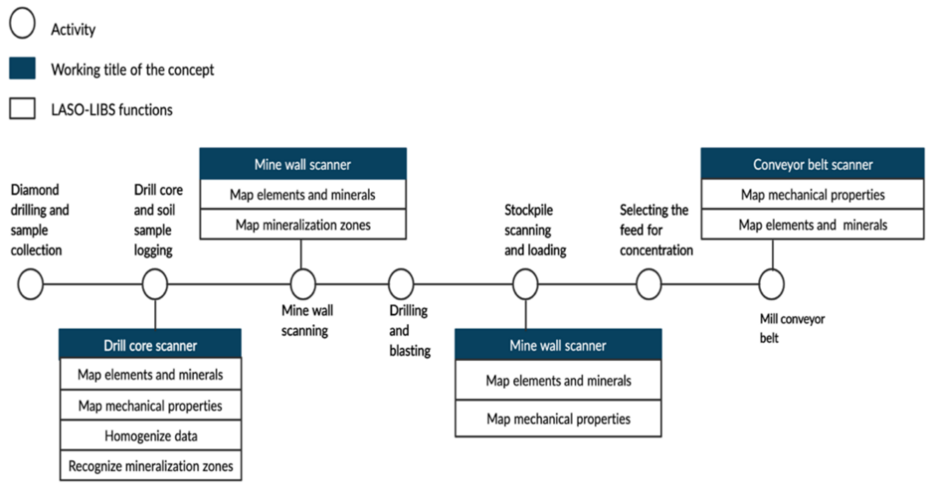
Appendix B: Customer need and service model validation questionnaire

Eight industry experts received this email. The emails were customized based on the previous discussion, or in case the recipient was a new contact, more thorough background information was provided. Below is an example message for a previously acquainted interviewee.

Hello (recipient name),

We discussed in the Fennoscandian Exploration and Mining Conference in October. Based on several conversations and interviews, I have formulated a hypothesis of possible LASO-

LIBS applications during different stages of the mining lifecycle. The hypotheses are mapped out in the picture below. It would be highly valuable if you can briefly respond to the questions below in order to receive feedback on my hypothesis and discover how you would like to purchase LASO-LIBS scanning method.



With LASO-LIBS (Large Area Scanning Open-source Laser-Induced Breakdown Spectrometer) scanning method geological samples, such as drill cores and soil samples, can be scanned and their elemental and mineral composition, as well as mechanical properties, can be defined from a spectral analysis, which is based on laser-induced plasma. In contrast to the competing technologies, such as HSI, XRF, FE-SEM-EDS, LASO-LIBS is fast and can measure up to 1000 measurement points per second. Furthermore, the geologist does not have to prepare samples in advance in advance. LASO-LIBS can measure both light and heavy elements. Also, the equipment is light (20kg), so it is also suitable for remote ore exploration.

1) Is any of the applications above relevant for your company? If not, why?

Questions 2-4 are for those who answered affirmatively to the question 1.

2) Which of the LASO-LIBS application would be most valuable for your company? Why?

3) In case LASO-LIBS is proven to be useful to your company for instance through a pilot test, in which way would you prefer to purchase LASO-LIBS? (for instance, service, leasing, equipment purchase, or something else?)

4) How do you currently purchase analysis results or equipment?

5) May I use your answers anonymously in my thesis?

Thank you for your responses!

Best Regards,

Emilia Xue

Appendix C: Lean Service Creation Canvases

Figures C1 and C2 display 20 main canvases of Lean Service Creation. In this study, all the canvases depicted in Figure C1 and first eight canvases

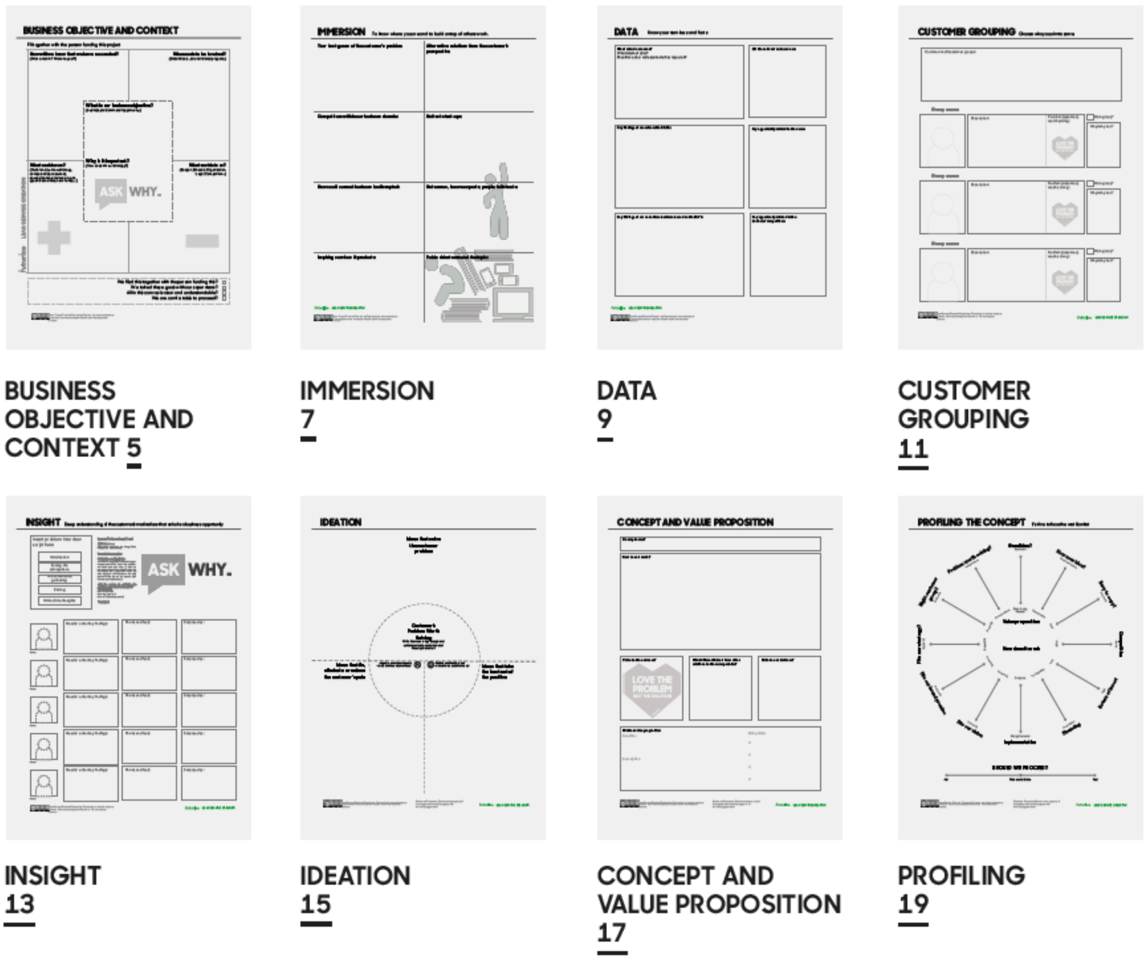


Figure C1. The first set of LSC canvases (Nevanlinna et al., 2018)

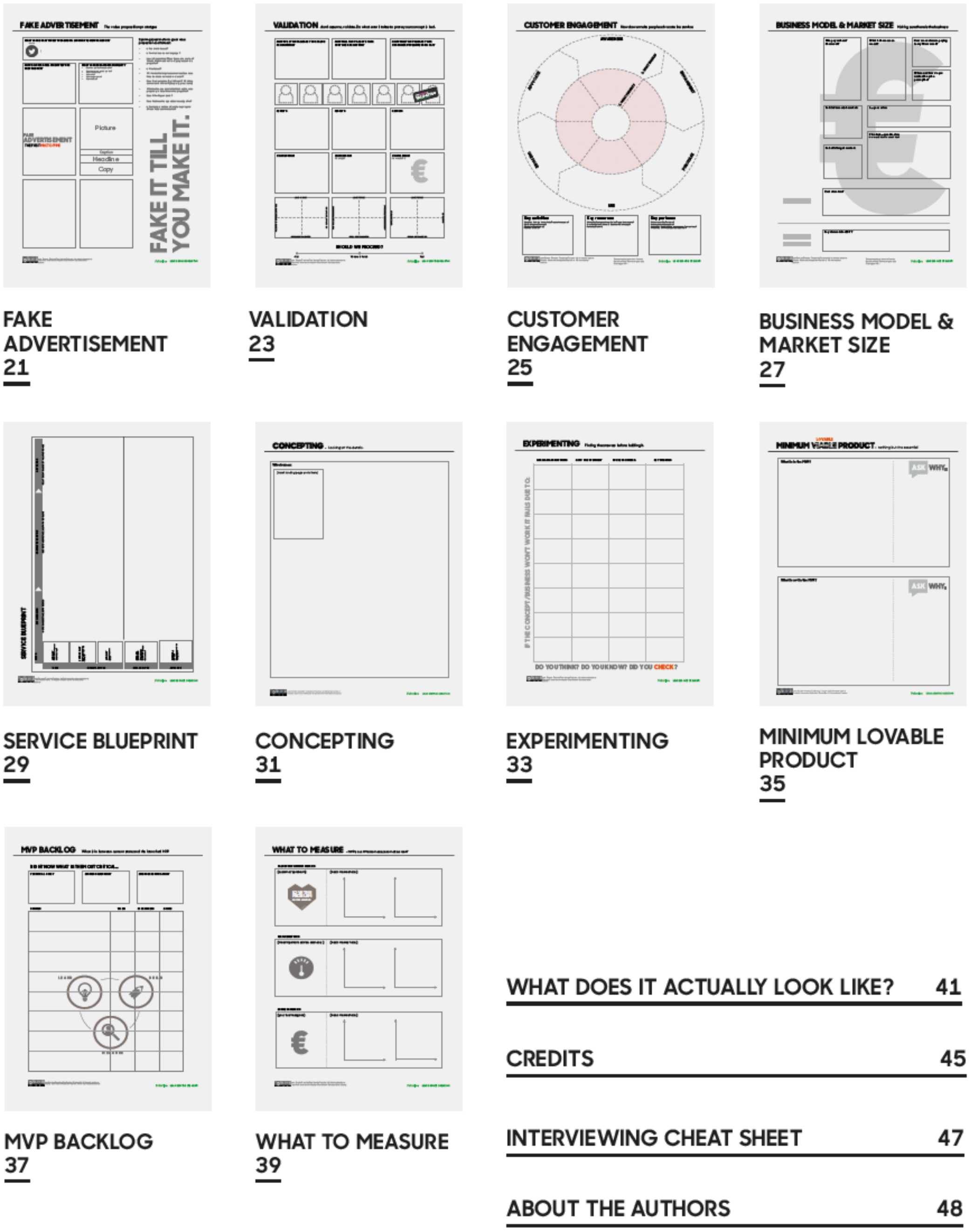


Figure C2. The second set of LSC canvases (Nevanlinna et al., 2018)

Appendix D. List of competitors

Table E: List of competitors

Company	Method	What	Measured quantities	Measured points per second	Scanned in a drill core box	Weight	Service model	Users
Company A	XRF	A drill core elemental analysis tool	elemental concentrations, geological structure, texture, minerals, density	N/A, "digital data available within an hour"	No	550kg	Rental, machine + a technician. Drill cores analyzed in Stockholm cost approximately 50-60 EUR per meter	Geologists and metallurgists
Company B	XRF	A drill core elemental analysis tool	Chemical elements	2 min/m	Yes	500-1500kg	N/A	Geologists
Company C	UV fluorescence	A drill core logging tool	Minerals, drill core imaging, 360 core imaging, quantitative fracture analysis, drill core image orientation, structural analysis, geotechnical parameters: RQD, FD, FS	N/A	Yes	130kg	Purchase, rent, or DTM does the service on site	Scientists
Company D	HSI	A drill core elemental analysis tool and software	Chemical elements, mineral maps	15 sec/ a box - more than 200 boxes/2000 m in an 8-hour shift	Yes	1000kg +	Purchase	Geologists and geotechnicians
Company E	XRF + AI	A drill core elemental analysis and logging tool and software	chemistry, structures, density and photography for exploration and mining	1 cm/sec	Yes	1000kg	Purchase, service	Geologists and geotechnicians
Company F	XRF	A drill core elemental analysis tool	high-definition wet, dry, and close-up photos of the rock core or chip samples, elemental information	N/A	No	2000-3000kg, carried inside a van	Service, accompanied with company F's drilling program or standalone service	Geologists, managers
Company G	XRF/LIF/LIBS/HSI/IR/MgS/Raman options available	A drill core elemental analysis and logging	elemental composition, minerals and RQD-value, photographs of cores	N/A	Yes	Approximately 150kg, carried inside a van	Service	Geologists

		tool and software						
Company H	HSI and RGB imaging	A drill core logging tool	Elemental and mineral composition	N/A	Yes	Approximately 500kg	N/A	Geologists