Antti Valtteri Karjalainen

# CUSTOMER NEEDS IDENTIFICATION FOR ON-LINE OPTICAL IMAGE ANALYSIS BASED PARTICLE ANALYZERS IN THE MINERAL PROCESSING INDUSTRY

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**THESIS**
**ABSTRACT**

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The aim of this thesis was to research and identify customer needs for an optical on-line particle analyzer. The research focused on operators in the industrial mineral processing industry. Metso Automation Oy commissioned the thesis to gain information concerning the current market operators' view of particle analysis as a part of their processes. As part of product development, this information was gathered to assist in the decision whether to continue to further stages of product development.

The research conducted for this thesis first contained the theoretical background for product development and customer needs identification, as well as information about the business environment of Metso Automation. The empirical research then consisted of a number of interviews. These interviews were done with operational level managers of industrial mineral processing companies, a strategic level manager of an international industrial mineral processor and a representative of a competing particle analyzer producer. These interviews were recorded and literated. Once documented, the contents of the interviews were analyzed and customer needs were identified.

Research showed while size measurements were seen as a priority, optical particle characteristics and shape were seen as highly important. Particle shape was seen as problematic in various mineral processing stages, yet no reliable analysis method exists in the market. Lacking adequate analysis equipment within the processes, industry operators relied on laboratory measurements. This was seen as a cumbersome method, but had no alternative. Based on the research results, operators in the industrial mineral processing industry have a need for image analysis based particle analyzers, which are specifically designed to function within their processes.



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**OPINNÄYTETYÖ**
**TIIVISTELMÄ**

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| Kajaanin ammattikorkeakoulu | Bachelor of Business Administration |

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| | |
|---|---|
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Tämän opinnäytetyön tavoite oli tutkia ja kartoittaa asiakastarpeita prosessiin sijoitettavalle optiselle partikkelianalysaattorille. Tutkimus keskittyi teollisten mineraalien jalostusteollisuuteen. Metso Automation Oy antoi toimeksi tämän opinnäytetyön saadakseen tietoa nykyisistä markkinoiden toimijoiden näkemyksistä liittyen partikkelianalysaattoreihin osana heidän prosessejaan. Opinnäytetyön aikana hankittu tieto kerättiin avustamaan päätöksenteossa siitä, jatkettaisiinko tuotekehitystä seuraaviin vaiheisiin.

Tätä opinnäytetyötä varten tehty tutkimus keskittyi ensin teoriaosuudessa tuotekehitykseen, asiakastarpeiden kartoitukseen ja Metso Automation Oy:n liiketoiminnan ympäristöön. Sen jälkeen tehty empiirinen tutkimus koostui haastatteluista. Nämä haastattelut käytiin opinnäytetyön tekijän ja usean markkinoilla toimivan yrityksen operatiivisen tason managerin, strategisen tason managerin, ja yhden kilpailevan yrityksen edustajan välillä. Haastattelut äänitettiin ja litteroitiin. Litteroinnin jälkeen haastattelujen sisältö analysoitiin ja asiakastarpeet kartoitettiin.

Tutkimus osoitti partikkelien kokomittauksen olevan toimijoiden prioriteetti. Sen lisäksi partikkelien muotoa ja optisia ominaisuuksia pidettiin hyvin tärkeinä. Partikkelimuoto nähtiin ongelmallisena useissa mineraalijalostuksen vaiheessa. Siitä huolimatta markkinoilla ei tutkimuksen aikana ollut luotettavaa mittaustapaa partikkelikoolle. Riittävien prosessiin sijoitettavien mittalaitteiden puutteessa toimijat käyttivät kattavasti laboratoriomittauksia. Nämä nähtiin kömpelöinä, mutta vaihtoehtoja ei ollut. Tutkimustulokset osoittivat, että teollisten mineraalien jalostusteollisuuden toimijoilla on tarvetta kuva-analyysipohjaiselle partikkelianalysaattorille, joka on kehitetty erityisesti prosessiin sijoitettavaksi.



| | |
|---|---|
| Kieli | Englanti |
| Asiasanat | Asiakastarpeen kartoitus, tuotekehitys, Front-End Prosessi, asiakastarve, partikkelianalyysi |
| Säilytyspaikka | ☐ Verkkokirjasto Theseus<br>☐ Kajaanin ammattikorkeakoulun kirjasto |

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# *List of abbreviations*

| Abbrevition | Meaning | Page |
|---|---|---|
| B2B | business-to-business | 5 |
| B2C | business-to-consumer | 5 |
| micron (µm) | micrometer | 33 |
| Oy | osakeyhtiö | 2 |
| Oyj | julkinen osakeyhtiö (public limited company) | 2 |
| P.I.R. | post-implementation review | 12 |
| QFD | quality function deployment | 24 |
| R&D | research and development | 6 |
| ROI | return on investment | 6 |
| USD | United States Dollar | 2 |

# 1 INTRODUCTION

Metso OYj is a multinational corporation with several branches of business operations. The corporation had net sales of 5.6 billion USD in 2010 (Metso Corporation, 2011). As of the start of 2012, the business operations of Metso have been divided into three main parts. These include Mining and Construction, Automation and Pulp, Paper and Power. The Services department has also been made a separate department, as opposed to merely being a supportive action as part of other business lines. In the new division of departments, Automation was moved into its own business line, as opposed to before, when it was a part of the Energy and Environment Technology business line. The department of Metso Automation Oy in Kajaani is a part of the Automation branch of Metso. This thesis is, however, a collaborated effort between the Automation and Mining and Construction branches of Metso, effectively attempting to combine the resources and know-how of both automation and mining departments of Metso.

The world-renowned marketing expert, Philip Kotler, has stated "Innovate or evaporate." (Kotler, Kotler on marketing : how to create, win, and dominate markets, 1999, s. 8). While investing in an innovative product is an expensive venture and can be compared to betting on a horserace where only one in ten bets succeeds to turn profit (Cooper, 1993, s. 10), Kotler states that "While innovation is risky, non-innovation can be fatal" (Kotler, Kotler on marketing : how to create, win, and dominate markets, 1999, s. 52). Metso sees that in order to maintain and increase its competitiveness, it must not only research new technologies to benefit the customer, but to also find new and innovative ways to market existing technologies. Cooper agrees that innovation is essential in order to remain competitive in the market.

Metso Automation Oyj in Kajaani has a long history of producing automation and analysis devices for the paper and pulp industry. The premise of this thesis is to focus on one possible industry into which Metso could expand operations. The hypothesis is that Metso could expand its business operations into the industrial mineral industry using the current analysis and automation technology already in use in the paper and pulp industry. Previous, preliminary research (Karjalainen, 2011) indicated that operators in the industrial mineral processing industry could benefit from automation solutions, such as on-line particle size and shape analyzers. The aforementioned research viewed the target market as a whole and focused on understanding the main competition, conditions and trends in the market. While it gave an overview of the target market, it did not go into detail concerning real customer and user needs or product requirements. It did, however, discover apparent gaps in the market for analyzers designed specifically for on-line use as opposed to modifications of laboratory equipment, which abound in the market. Metso already has an optical particle analyzer designed for use in pulp and paper processing. Thus the aim of this thesis is to answer questions regarding the extent of how far the current technology must and can be redesigned to suit the differing application. This thesis additionally attempts to discover whether expanding business operations is viable, or should further investment of time and resources be limited or cut entirely.

This thesis attempts to answer the aforementioned questions by gathering information about customer needs and analyzing possible business opportunities. According to the authors of Principles of Marketing (Kotler;Armstrong;Saunders;& Wong, 1999, ss. 292-293) businesses begin their purchasing behaviour by defining their needs and problems in their current operations. Thus in order to satisfy their needs as well as is feasibly possible, it is important for Metso Automation to interact with the businesses and to discover their needs and possible demand for an optical particle analyzer. The goal is to ultimately transform customer needs into a preliminary draft of the future product in development. The draft will not be part of this thesis, but a list and analysis of product requirements for the analyzer will be included.

# 2 THEORETICAL BASIS

As this thesis focuses on discovering customer needs to further product development, it is important to first understand what is meant by these terms and what kind of theoretical basis the thesis research is based on. These questions will be answered in this chapter.

## 2.1 Customer Need

As a basic marketing concept, customer need is based on basic human needs (Kotler;Armstrong;Saunders;& Wong, 1999, s. 10). Human needs theories suggest that basic human needs are universal and are either hierarchical (Maslow, 1954) or simultaneous and complementary (Max-Neef, 1991, ss. 13-23). Maslow's hierarchy of needs has been one of the cornerstones of modern psychology for over 50 years, and even though improvements on the theory have been presented (Villarica, 2011), it remains firmly in use in both psychology and marketing literature.

Maslow's hierarchy focused on human needs and is often used in consumer marketing, but the same principles can be applied to businesses (Campbell, 2009). The first and most important need for any company is to survive. The company will act in a manner which aids the satisfaction of this need the most. Once the most acute threat of extinction has been prevented, the company will focus on securing its prolonged survival and security in the market. Once these needs are satisfied, a company can direct resources into softer values. These could include shifting into green business initiatives, social activities such as sponsorships and ethical trade. Knowing what kind of customer needs are present in a market and what needs a product satisfies can help in properly positioning the product in the market and aiding the creation of a good marketing mix (Jobber, 1998, s. 210).

As the potential customers of the particle size analyzer are businesses, addressing customer need is simpler than addressing the needs of consumer customers. This view is, however, superficial. The potential customers are businesses as well, so they also are required to create their products to suit their customers' needs. This creates a chain of needs which must be satisfied in order to create a product which is focused on the core needs of the customer. The needs of the customer's customer come apparent in the example of a construction aggregate producer supplying road construction and maintenance companies. In order to build lasting roads, the aggregate material should be as cubical as possible as well as of a certain size dispersion. This requirement makes the aggregate producer focus on not only the size, but shape consistency of his produce. Subsequently in order to satisfy his need to monitor the quality of his product, the particle size analyzer will have to be able to measure consistency in both size and shape of the feed material.

## 2.2 Business-to-business Marketing

As was already mentioned in the previous segment, the potential customers of the optical on-line particle analyzer are businesses as opposed to consumers. Metso is thus operating in a business-to-business (B2B) marketing environment. Most related literature sees marketing from mostly, if not only a business-to-consumer (B2C) view. While entire chapters are written on the different aspects of consumer marketing, business-to-business marketing is viewed mainly by highlighting its differences to consumer marketing. This segment attempts to describe the B2B as it relates to the mineral processing industry, while referring to literature comparing B2B to B2C marketing.

As is often the case in the B2B market (Kotler;Armstrong;Saunders;& Wong, 1999, ss. 277-279), the industrial mineral processing market has relatively few companies. These mining and processing companies typically operate in several locations within their home countries and additional locations internationally (Karjalainen, 2011). This international nature of business expansion is forced by the geographically concentrated nature of industrial minerals as well as profitability in lower wage leveled nations (Nickels;McHugh;& McHugh, 2008, ss. 367-368) (Brown;Walters;Idoine;Shaw;Wrighton;& Bide, 2012).

While the industry has only a few operators, these companies operate on a large scale and have large amounts of resources. While single mining companies could be even family operated, the organizations and concerns they belong to are usually of global scale (Karjalainen, 2011). This kind of market environment creates a need for networking as personal selling is seen as much more common than in B2C markets (Nickels;McHugh;& McHugh, 2008, ss. 368-369).

Finally the buying behavior of businesses is seen as rational and need-based. Analysis equipment for the mineral processing industry is seen as an investment. These investments are procured based on supposed corporate benefit through gaining advantages over their competition or increasing profitability. Rational needs and goals of purchases are prevalent as opposed to sentiment-based purchasing behavior.

## 2.3 Product Development and Innovation

Product development is about innovating products, not merely inventing them. Jobber clarifies the difference as follows: “Invention is the discovery of new ideas and methods. Innovation occurs when an invention is commercialized by bringing it to market.” (Jobber, 1998, s. 257) Merely creating a new concept or product is not enough. The developed product must be implemented into the company’s marketing processes before it can be called innovative. Cooper sees the innovativeness of products as divided into three categories: low, moderate and highly innovative products. In his assessment he compares innovativeness levels to ROI (Return on Investment) and success percentages of new products in development. According to Cooper’s research, both low and highly innovative products have good success percentages and high ROI. The most troublesome product development projects seem to be the moderately innovative ones. They show significantly lower ROI and success percentage, than either of the extremes (Cooper, 1993, ss. 14-16).

Product development aims to create products and services which satisfy customer needs. As Metso already has used the particle size analyzer technology in applications in the paper and pulp industry, the product development referred to in this thesis is of a low innovative nature. Cooper refers to such product development as “modifications to existing products; redesigning products to achieve cost reductions; and repositionings” (Cooper, 1993, s. 15). Metso is already using the required technology, so modifying the product package and repositioning the product into the new market is more likely than reinventing the whole product. Returning to Cooper’s research results concerning innovation levels affecting ROI and success percentage, Metso has a good possibility to turn innovation into profits with low innovation product development if a feasible market is found. This is highly affected by the low R&D costs related to modifying existing products to suit alternative applications.

The following section compares traditional, generic product development process models to the one used in Metso. These models are discussed to better understand the current situation in the project and to see what needs to be accomplished in order to further the project.

### 2.3.1 Generic Product Development Process

According to Karl T. Ulrich and Steven D. Eppinger (Ulrich & Eppinger, 2003, s. 2), "The economic success of manufacturing companies depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low costs." In order to discover these needs and to create according products, product development is needed.

A product development project should include a well planned process. While Ulrich and Eppinger agree that companies employ very different methods to product development, they strongly suggest having a well defined product development process (Ulrich & Eppinger, 2003, s. 12). Daniel Fraknoy agrees on this, though he mentions that larger companies have a higher need for well structured and documented product development processes, than companies employing few people (Fraknoy, 2009, ss. 43-44). The benefits of a well structured product development are as follows:

- **Guarantee of quality:** A well planned product development process involves checkpoints. These checkpoints are used to evaluate the feasibility and quality of the developed product. If the checkpoints are chosen with care, they will guarantee the quality of the final product.

- **Coordination of teamwork:** Product development personnel following a well structured and planned process are more aware of their roles as a part of their development team. Proper process structuring will create awareness of when each person's inputs are needed in each phase of the process, as well as which team members are likely to hold the needed information and resources at any given time.

- **Planning of milestones:** As a structured process has checkpoints, so does it have milestones to keep track of progress. Milestones are used to schedule the product development process into the project timeframe. This helps keep the pace of the development process up to the required speed.

- **Benchmarking:** Comparing the ongoing activities of a development process to the set goals, checkpoints and milestones will give management valuable information on team successes and failures. This information can be used to create more insightful development processes in the future, as well as modify the ongoing process to better fit the chosen timeframe and quality checkpoints.

- **Discovering areas of improvement:** The feedback from all process activities and benchmarking can be used to discover areas of improvement in the current and future projects.

Ulrich and Eppinger have combined the various steps, or activities of product development into a generic product development process. As seen in Figure 1, These steps are grouped into phases numbering from 0 (zero) to 5 (five) and include activities from multiple organizational departments simultaneously. Like Cooper's Stage-Gate process, Ulrich and Eppinger emphasize the coordination of departments in the product development process. The coordination and constant communication between departments ensures that all parts of the product development organization have the same goals in mind. This helps in keeping the project cohesive, effective and efficient. Other authors agree, that product development needs to be a combined effort between all departments of marketing, R&D, manufacturing and design. Other departments such as management and finances are to create a foundation for the product development activities. Välimaa and co-authors claim, that whatever the size and industry of the company, only a coordinated effort of all the aforementioned departments can lead to a competitive product. (Välimaa;Kankkunen;Lagerroos;& Lehtinen, 1994, s. 26)

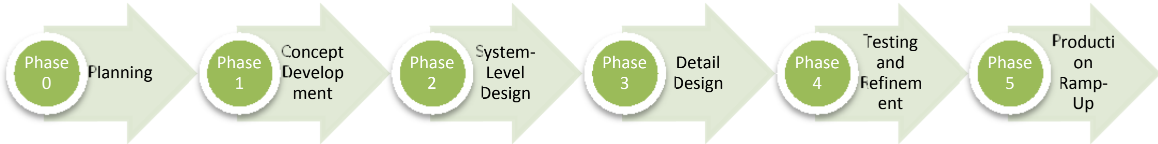


**Figure 1: Generic Product Development Process by Ulrich and Eppinger (2003)**

**Phase 0, Planning:** "Phase zero", or the process planning phase is a prequel to the actual product development process. It consists of numerous activities from multiple departments in order to create a project proposition to be approved or disapproved based on its feasibility. The planning phase lays the foundation on which the rest of the product development process is built on. This is why the information gathered during this phase is especially crucial to the success of the development process.

Phase 0 begins once an idea has been generated for possible product development. The possibilities of the idea then need to be researched and identified. Technological research is done to discover available or attainable technologies in order to accomplish turning the idea into an innovation. The market is researched for business opportunities relating to the generated product idea. Rough market segments are identified and defined. Attainment of financial resources is planned. The first product platforms and architecture are deliberated. Production capabilities and restraints are estimated, as well as likely supply chain strategies.

The planning phase includes information collecting activities and resource mapping. This research work is vital in order to create a realistic basis for the product development process, should the development project be approved to begin. With more realistic and precise information about the background of the product idea and environment, the management can have better judgment concerning the approval of a given development project.

**Phase 1, Concept Development:**

When a product development project has been approved for initial research, it moves into phase one. In phase one, the product idea or concept is refined and developed, while further research is done to investigate the feasibility of the project. Many of the research topics are similar to the ones in the previous phase, but they are now investigated more thoroughly and with a usually larger human resources.

The concept development phase again includes activities for all business departments to accomplish simultaneously. Marketing research is continued to investigate and identify lead users in the selected target segments. The main customer needs of the target segment are mapped, as well as competing products already in the market serving those needs. In the meantime product design concepts are considered and developed. This phase should also include the construction of the first prototype, once the concept has matured to the building stage. Legal restrictions, such as patents, need to be investigated. Possible patents will then be compared to the design concepts and changes will have to be made in order to ensure legality. Based on planned financial resources and an economic analysis, the feasibility of production is estimated.

With the more precise information gathered, one or several concepts can be chosen to be developed further. The first prototypes should reveal strengths and weaknesses in design, while thorough market research indicates which direction the product development will need to take in order to satisfy customer needs (Välimaa;Kankkunen;Lagerroos;& Lehtinen, 1994, ss. 29-30).

**Phase 2, System-Level Design**

When the selected concepts have proven their validity as prototypes as well as business opportunities, they are moved into Phase 2. This phase includes activities which define the product to the most miniscule details. It also begins to focus on the sale, and after-sale actions.

The product is designed and documented on a system-level. Blueprints of every subsystem and component are created. Product construction and assembly schemes are documented. Specifications and preliminary process flows of final assembly are created. The development team will assess their component manufacturing capabilities and decide on which components will be produced and which ones will be made by the company. Key component suppliers are investigated. Target costs and sales prices are set. Product family expansions are considered and service issues are estimated.

As this phase sets clear goals on costs, sales price and design characteristics, it clarifies and finalizes many significant aspects of product development. Blueprints of all subsystems and interfaces keep design work focused towards a concise product package. Once all this has been accomplished, the product is ready for the next development phase.

**Phase 3, Detail Design**

The third phase of a generic product development process includes activities which begin to move the process away from prototype testing and into production activities. Further details are added to the product blueprints and procurement of necessary production tools is started.

Precise specifications are set concerning component geometry, materials and tolerances for difference. Assembly schemes are broadened into complete industrial design control documents including all necessary information for setting up production lines. Process flows are specified to piece-part level. Processes for observing and controlling quality are set. Production tools are designed and manufactured, or procured. On the basis of service packages and product families that were developed in the previous phase, a marketing plan for the product is created.

While earlier phases have focused more on the expansion of ideas into working concepts, phase 3 clearly sets a more industrial tone to the project. Activities are steered towards a future launch of the new product. The amount of personnel involved in the project is expanding as well as the overall investment on the company's behalf.

**Phase 4, Testing and Refinement**

The fourth phase already has a product prototype, a marketing plan and assembly schemes for production. The activities of this phase revolve around preparing for starting production, as well as final testing in a realistic environment.

An alpha prototype is built using "production-intent" parts. Tests regarding product reliability and performance in realistic use are conducted. Later, a beta prototype will be built using the production line meant to produce the final version. While these testing phases are ongoing, final design changes are made and regulatory approvals are sought. Assembly processes are fine-tuned and quality systems are refined. Final tests are typically performed by the customers. In the human resource side, a work force is trained. Finally a sales plan is made including promotional materials, as the company prepares for the product launch.

When the production lines have been built and the customers have gotten involved in the testing of prototypes, the amount of commitment to the project is very high. Large amounts of financial, human and time resources have been spent and tied to the product's success or failure. The company's belief in the developed product will be high for it to have reached this phase and so it is rare to have a project killed in this phase.

**Phase 5, Production Ramp-Up**

In the final phase of the generic product development process, the ready production line is started and any minor issues are solved before launching the product on a full scale. The developed product is likely sold to a select group of customers, who in return evaluate the product in its final form. Once the work force is fully trained and all production issues are solved, the product is launched. Production lines are used to their full extent to enable intended distribution amounts. This marks the end of the generic product development process by Ulrich and Eppinger.

What their development process does not take into account is the post-launch development of the product. This phase can be seen in the next segment regarding Cooper's Stage-Gate process, where it is referred to as the Post Implementation Review (P.I.R.). An even better presentation of the evolving state of commercialized products can be seen in Metso Automation's innovation diagram. There the product life cycle process shows the support and development of ready products in order to prolong product life. While it is interesting, that it has been left out of the generic product development process, low-innovative product development is not a direct part of the thesis topic and will thus be left out.

### 2.3.2 Cooper’s Stage-Gate Process

Cooper’s Stage-Gate process is a modification of the generic product development process introduced by Ulrich and Eppinger. While the basic principles remain the same, it has some changes in the order of activities performed in each stage. After its first presentation, Cooper's Stage-Gate process has been referred to in various product development books and is used in many successful companies. Metso's own product development process is seen in a later section, and it is also a variation of Cooper's process.

As seen in Figure 2, the process consists of five development stages. These stages begin from low commitment, low cost acitivies. As the process moves through the stages, required commitment to the project increases in both financial and human resources. The gates separating stages are used to evaluate the success of the new product. At each gate, criteria are set for the product. The product must meet all the criteria in order to validate continuing the process. As the required resources for each subsequent stage increase, it is important to know when to continue and when to give up on a given product. If any of the criteria are not met, further commitment to the development process is unwarranted and thus the product development is killed. Cooper calls this the Go/Kill decision.

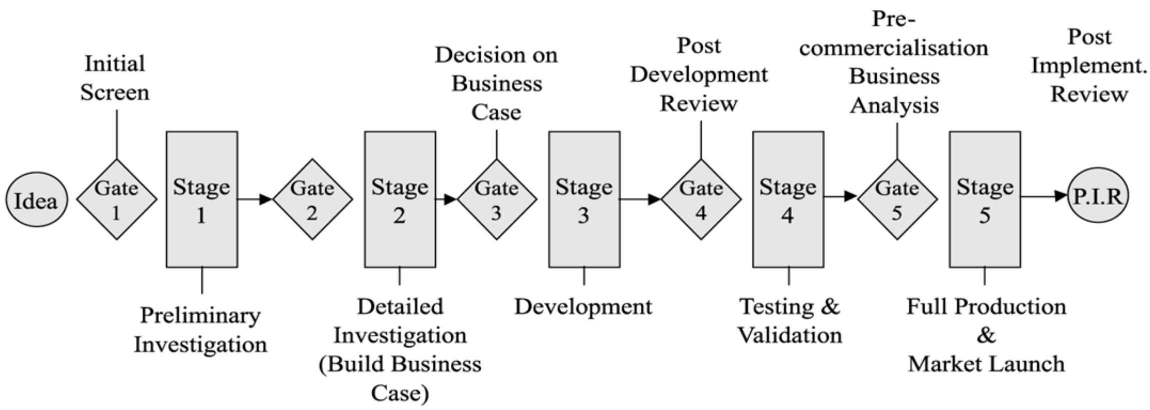


**Figure 2: Cooper's Stage-Gate Process (Cooper, 1993, s. 108)**

Much like Eppinger and Välimaa, Cooper emphasizes that there are no separate R&D stage, marketing stage, production stage and so on. The various stages of the process combine activities from multiple departments in a company and they should not be seen as separate activities with independent goals, but more supporting of each other.

Cooper originally showed the stage-gating process without idea generation or P.I.R. stages, but they were later added to the process tree. Idea generation had been originally left out as it was not seen as a function which could be influenced by company actions. In his book in 1993 (Cooper, 1993, ss. 121-132), Cooper does, however, refer to various ways to stimulate idea generation in a company. Once an idea is generated, it is submitted to initial screening at Gate 1.

The Gates are not only waypoints at which a Go/Kill decision is made, but they also function in less clear cut ways. Product development projects are not worked on in a clinical environment, where outside influences and other projects would not influence decisions. Thus According to Cooper, Gates should also incorporate prioritization decisions between projects, act as quality control checks and determine the direction the development process will take.

Gate 1 is seen as a flickering green light. This refers to a very low level of commitment to the project even if it is allowed passage. The initial idea is analyzed only superficially and a quick decision is made whether the idea is worth investing any time or resources. At this gate, all ideas are sifted through and any promising idea can be given passage to Stage 1 for preliminary investigation of the idea.

Stage 1 consists of inexpensive information gathering functions. As Cooper explains, the technical merits of the project, market prospects and financial assets are evaluated and assessed. Preliminary technical assessment tries to determine the needed product specifications and requirements, how they could be achieved, the feasibility and attainability of reaching said requirements, how and where the product could be manufactured as well as how much production could cost. Likewise the preliminary market assessment includes the gathering of basic information about current market conditions, product acceptance and competition. The financial assessment consists of sales amounts, costs and required investments. These estimates will realistically be based on very limited information and speculations. The results should, however, give some idea of the financial variables involved and act as a "sanity check" as Cooper calls it. There is no point in investing significantly into a project yielding only minor profits and opportunities. (Cooper, 1993, ss. 132-137)

All the aforementioned information is gathered with very limited finances for Gate 2. While educated guesses, estimates, inaccurate statistics and superficial knowledge will make up most of the results, they should still show the probable direction of the project. Gate 2 is used to evaluate the results and to determine how the project should be handled inside the company. Stage 1 might have discovered clear reasons to kill the projects, which were not thought of in the idea generation phase. Whatever the outcome of the research, it is critical for the continued success of a company to identify when to continue investment on a valid opportunity and when to kill a unprofitable venture.

This thesis can be seen as part of Stage 1 in Cooper's Stage-Gate process. It does not attempt to answer all questions regarding the Go/Kill decision at Gate 2. It merely answers a select part of them concerning product specifications, product acceptance and technical feasibility. The earlier market research (Karjalainen, 2011) focused on answering questions about the competitive situation, market trends and preliminary product requirements. Together they should form a valid information source for evaluation at Gate 2, though more research should be done on all three segments of research in order to provide a proper analysis for the next gate.

### 2.3.3 Metso Automation's Innovation Process

Metso Automation uses an innovation process which is adapted from Cooper's Stage-Gate product development process. It also utilizes five main gates in the product creation process, as Cooper uses in his new product development process. Two additional phases are added for the research process. The first research phase includes technical assessment, while the second phase is thorough research. This kind of separation of research and technical development is common in businesses working in technology-based industries. According to (Crow, 2001), "Technology development and applied research are often performed on a separate track from product development to avoid significant risks and time until a technology is ready to be deployed for development." While Cooper includes technical assessment as part of Phase 1, Metso has it as a separate phase due to their industry specific needs.

In Figure 3, the roadmap process shows all internal and external variables affecting the project before any official phase or gate. All items listed in the roadmap process contribute to the kind of projects presented and undertaken by the company. These are also in turn affected by research, customer and product feedback. Information about future market and technology trends and market intelligence is gathered through research. Customer and product feedback can spark new ideas on improvements or new products. Then internal modifiers such as the vision and strategy of the company, resources and core competencies drive idea generation into a certain direction. This creates an environment which facilitates the generation of ideas which support the company's other projects. While this focuses ideas to be supportive of the company line, it might discourage more radical, high-risk/high-reward proposals ideas from being brought forward. This could lead to missed opportunities.

While not strictly part of the product development process, the product life cycle process does contribute to it through feedback, available resources and management's strategy concerning the future of the product. After the initial launch of a product, support and resources are gradually moved onto other projects as the product ages. As obsoletion nears, it is increasingly unlikely that improvement ideas are resourced.

This thesis is steadily located in Phase 1 of Metso's innovation process. While the technology already exists, business operations in the mineral processing industry are still in the concept phase. As it is seen in Metso, this thesis is located in the roadmap process before actual product development stages in concept generation. The research being done for the thesis is centered on Phase 1 in the research process tree and returns information to parts of the roadmap process. The interviews will be evaluated to determine which direction needs to be taken in the product creation process. While the roadmap's lower part depicts company resources, core competences and idea generation, they are left out of this thesis. The focus of the thesis and the interviews used to gather the required information will focus on the top part of the roadmap process. The top part views the innovation process from a business creation point of view, while the bottom half relies more on technical advantages.

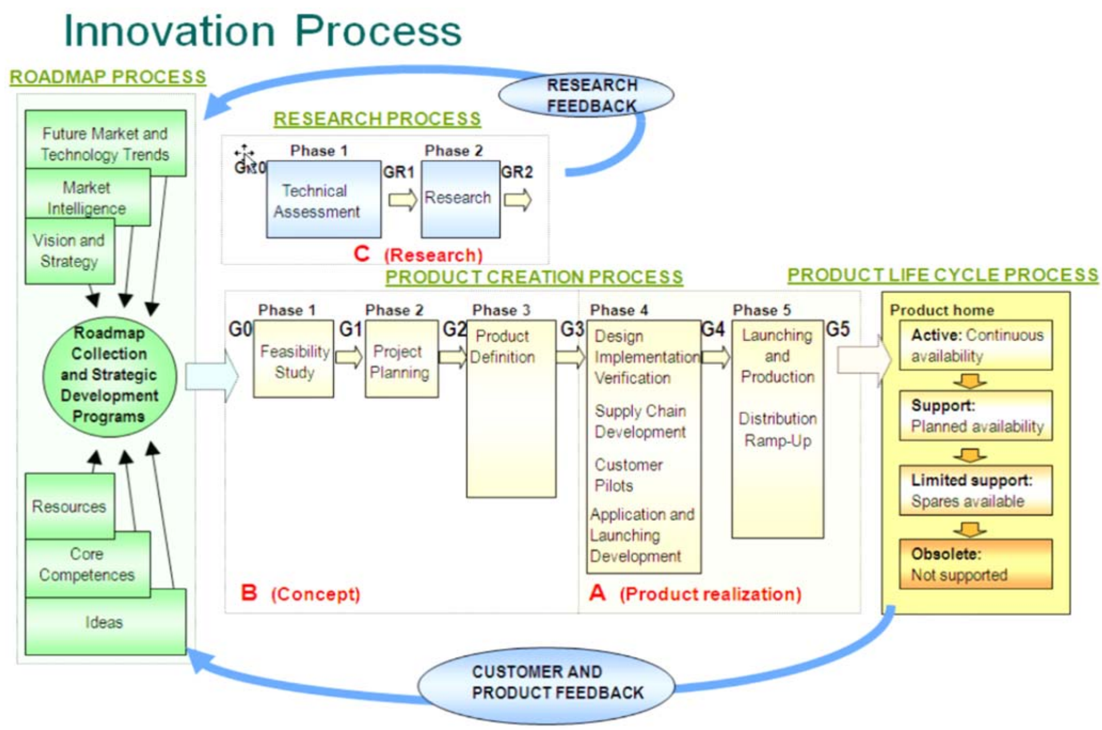


Figure 3: Metso Automation's innovation process

### 2.3.4 The Front-End Process

The previous segments explained the three relating product development models. Ulrich's and Eppinger's generic product development process set the base. It was then adapted by Cooper into his Stage-Gate process and finally by Metso Automation to fit their organization and business environment.

The research conducted during this thesis belongs to Phase/Stage 1 or each product development model. Ulrich and Eppinger called it the Concept Development phase; Cooper referred to it as the Preliminary Investigation Stage and Metso labels it as Technical Assessment and Feasibility Study. This early stage of product development is referred to as the Front-End Process (Ulrich & Eppinger, 2003, s. 16).

While Peter A. Koen (Koen, 2001, s. 46) uses the term Fuzzy Front-End to discuss mainly idea generation and similar activities in Phase/Stage 0 of product development processes, Ulrich and Eppinger's Front-End Process aims to be a structured way to achieve concept development in Phase 1 of their generic product development process. In this phase, the fuzziness referred to by Koen is lessened through planned activities. Figure 4 depicts the Front-End Process by Ulrich and Eppinger.

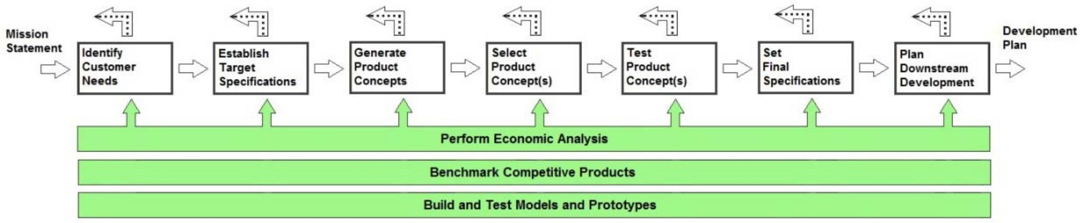


Figure 4: The Front-End Process (Ulrich & Eppinger, 2003)

As can be seen in the image above, the Front-End Process consists of product development activities in a sequential flow chart. Some activities require others to be completed before they can be started. Ulrich and Eppinger, however, remind that in practice, activities can overlap as necessary. Some phases will also be completed multiple times before moving to next phase. The arrows above each process phase represent the fact that at any process phase, situations may change in the development process. This could be due to new information regarding the market, human resource changes, new competitor products, or any other change which effects the development process. These changes can force the project to move back to a previous process phase, or even to kill or halt the process entirely. (Ulrich & Eppinger, 2003, s. 16)

The next segments will discuss the first two phases in detail. Later phases of the Front-End Process are explained more briefly due to them not being an integral part of the thesis.

2.3.4.1 Customer Needs Identification

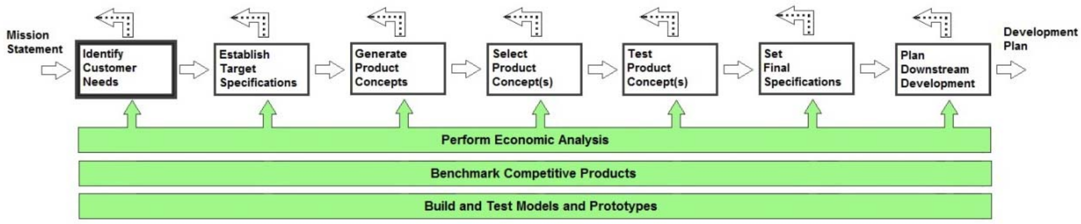


**Figure 5: The first phase of the Front-End Process is the Customer needs Identification.**

The first stage of Ulrich's and Eppinger's Front-End Process is the customer needs identification phase. It has been highlighted in Figure 5. As the name implies, this phase includes activities focusing on understanding the customer. As a new product developer, the goal is to create a product which the customer wants, and not only needs. It is claimed, that the product developer often assumes the customer segment to want something with no reliable source of information. This assumption often proves to be wrong and the product fails. That is why it is important for product development and the Front-End Process to include customer needs identification in its first phases. Only by integrating effective customer needs identification methods into the development process, can the development team discover and understand customer values and the needs associated with these values. (Huotari;Laitakari-Svärd;Laakko;& Koskinen, 2003, s. 9)

Customer based product development should start by discovering customer needs. The needs of the customer are not dependant on the product concept being developed, but are independent of the developer's actions. The development team should thus try to discover customer needs without any thought on how they will eventually attempt to fulfill those needs. Any bias or mental constraint towards a concept at this stage could also bias the needs identification results making them unrealistic. Later concept selection and specifications setting phases will rely on customer needs identification, but will typically also have to make compromises in order to remain technically and economically feasible.

Reflecting on Cooper's (Cooper, 1993, ss. 14-16) definition of high-, medium- and low-innovative product development, the level of innovativeness does not affect the importance of customer needs identification. According to Ulrich and Eppinger (Ulrich & Eppinger, 2003, s. 55), incremental products need to satisfy customer needs in the very same way as revolutionary products need to. In order to satisfy customer needs, the needs must be first discovered. The customer needs identification phase can be broken into several activities as seen in Figure 6. Those activities will be discussed in process order in the next segments.

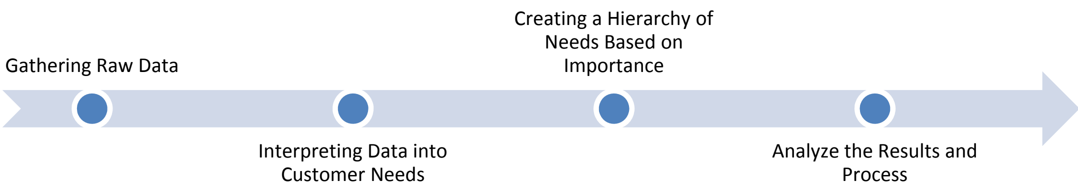


Figure 6: Stages of Customer Needs Identification

### 1. Gathering Raw Data

The first step of customer need identification is the gathering of raw data. This data can be collected using a multitude of methods. This segment will cover some of the most commonly used methods.

**Secondary Sources:** Collecting information from secondary sources does not provide the development team with direct customer needs, but it can result in deeper background knowledge. Information sources can be found in different data banks, articles, statistics, newspapers, related magazines and community journals. Electronic sources include search engines, company websites, recordings of varying formats etc. The use of consults from outside the industry can also be a valuable source of customer needs information. Often a fresh viewpoint can bring new ideas to the development process. (Parantainen, 2007, ss. 154-155)

The collection of background information is important, as it can help understand the underlying reasons for customer needs. Using reliable secondary sources can also gain the development team information without unnecessary use of resources. Huotari and co-authors mention that in some cases, secondary information by itself is enough. The use of an adequate amount of secondary sources is emphasized, as well as careful selection of sources. The risk with using secondary sources is the inaccuracy of the gained information. Huotari adds that in specialized fields with very specific problems, it is, however, almost certain that not ready answers can be found through secondary sources. Another issue in using secondary data sources is that the researcher could unknowingly have a bias towards the researched topic. Additionally secondary sources can provide very scarce and shallow information regarding the specific customers targeted. (Huotari;Laitakari-Svärd;Laakko;& Koskinen, 2003, ss. 25-27)

**Questionnaires and Surveys:** Questionnaires and surveys are often used when a wide sample is from the target customers is wanted. They provide a rather low-cost method of gaining customer information from a large geographic area, or a large customer group.

The prerequisite for a successful questionnaire or survey is a rather deep understanding of the customer segment. This limits their use as a data collection method in high-, or medium innovative product development projects, as they typically include new target customers. Ulrich and Eppinger also agree on the restricted use of questionnaires and surveys. The authors comment that they can be used in later product development stages, but it is unadvisable during the Front-End Process. "...written surveys simply do not provide enough information about the environment of the product, and they are generally ineffective in revealing unanticipated needs." (Ulrich & Eppinger, 2003, s. 57)

**Focus Groups:** The idea of a focus group is to gather a small number of target customers to discuss about the product and related matters. The conversations are typically semi-structured and could include a marketing researcher, or a member of the development team as a facilitator. In consumer marketing, the attendees are typically given a modest monetary reward in exchange for their attendance.

During the discussion, the focus group could be observed, or videotaped for live and later analysis. The focus group is seen as a flexible, fast and often very informative way to gain knowledge from the main customers. This knowledge will be of qualitative nature, as focus groups tend to be too small for representative quantitative research.

Focus group discussions typically reveal most needs regarding the asked questions. This can be achieved with an effective attendee group. If some individual is assertive by nature and begins dominating the conversation, other views can be left unspoken. This disruptive behavior was observed by Huotari and coauthors (Huotari;Laitakari-Svärd;Laakko;& Koskinen, 2003, s. 38). Additional problems may arise from a facilitator who either controls discussion to little or too much. The former will allow discussion to stray from related topics and the latter will not allow for hidden needs to be presented.

**Interviews:** Both phone interviews and face-to-face interviews have direct interaction between the researcher and one, or few, interviewees. Much like the focus groups, interviews are typically only semi-structured in order to allow constructive deviation from the main topics. This freedom allows for hidden needs to be brought to the attention of the development team.

With only one or few interviewees, the role of the facilitator increases. As with focus groups, the interviewees need to be selected carefully in order to provide realistic and representative data. Ulrich and Eppinger point out that interviews with a single interviewee tend to reveal a lower amount of customer needs, than focus group discussions. The authors, however, add that several 1-person interviews reveal the same amount of customer needs as one focus group of the same total discussion time. As interviews tend to be less costly than focus groups and achieve similar results, Ulrich and Eppinger recommend the use of interviews as the primary data collection method in the Front-End Process (Ulrich & Eppinger, 2003, s. 57).

**Customer Selection**

Whatever the data collection method used, choosing the correct customers is important in order to gain valid and sufficient information. Customer variety is necessary to gain representativeness, but some focus should be towards lead users. Lead users are said to be the ones who adapt to new products significantly faster than other user groups. They are the first customer group to investigate the possibilities of new products and thus are the first to voice their needs. The lead users' needs are typically also the needs of the majority of users once they get accustomed to the product. By selecting lead users as targets for customer need identification, the development team can discover and preemptively satisfy the needs of the other user groups.

**2. Interpreting Data into Customer Needs**

Customer needs should be documented in order to ensure consistency and that no details are forgotten. In this phase the remarks made by customers are translated into needs concerning the product being developed. At this point in the development process, the needs should be expressed and documented according to what the product has to be able to do, not how to accomplish it. Customer oriented product development should focus on the needs of the customer regardless of whether the product can satisfy the needs. Thus the voice of the customer should be expressed as a product attribute, whether it currently has the attribute or not.

Customer needs documentation should be done as specifically as the raw data was provided. This ensures that no amount of information was lost during the translations. Information received in the raw data collection phase needs to be kept as intact as possible to convey the original message to the development team. The needs should be documented in a neutral tone to avoid bias. Need priority will be included in later phases. Finally it is important to note that not all customer needs can realistically be satisfied. In some cases customers express needs for product capabilities, which are outside the limits of technical possibilities or economic feasibility. In other cases customers might express needs which conflict with each other. In these cases the development team should not try to resolve the conflict, but document both needs as equal. All needs, whether conflicting or fantastic, should still be documented and reviewed to ensure that all product possibilities are investigated.

### 3. Creating a Hierarchy of Needs Based on Importance

Once the raw data has been translated into customer needs, it is time to organize them into manageable groups. Similar needs, or needs referring to the same product parts are gathered and grouped. From these a primary need is formed. This primary need gives a broad description of the required product capability. All related needs are included under the primary need. These are called secondary needs. Secondary needs explain the primary need in more detail and refer to needs requiring specific product capabilities. During this process, redundant statements can be removed. The development team, however, needs to be careful to only remove statements with identical meaning.

Once primary and secondary needs have been organized, it is time to create a hierarchy based on the importance of the needs. As contradicting needs, as well as economic and technical restraints require the development team to make trade-offs between the needs to be satisfied, a hierarchy can help them decide which needs should be focused on and which ones left out.

The relative importance of needs can be identified by either relying on the number of times a certain need was presented by the customers, or by relying on the market knowledge the development team has. Further surveys can be used to determine the hierarchy between primary needs. If further surveys are used, not all needs need to be asked about. Needs which can be easily implemented, or are obvious product qualities, can be left out of the survey. If there are contradicting needs, customers can be asked to choose one or the other in a survey.

By organizing customer needs into a hierarchy, the development team sees which qualities will be critical to product success. As Ulrich and Eppinger mention, customers will never be pleasantly surprised by critical needs being satisfied, they expect them to be (Ulrich & Eppinger, 2003, s. 67). This statement refers to the customer's idea of what the product should be able to do in order to even exist in the market.

**4. Analyze the Results and Process**

Once the customer needs identification has been completed, the development team needs to review their data collection and analysis process. While data collection and customer needs identification is not an exact science, reviewing the results and methods can help in using the obtained information to its full extent as well as assist in future efforts.

While reviewing, the development team needs to ask themselves whether they reached all the important customer groups with adequate questions to discover enough hidden needs. Should follow-up surveys or other data collection methods be used? Which customer groups were the most informative? Does the entire development team and all related company personnel know of the results? How could the process be improved? All these questions aim to maximize the benefit of the customer needs identification process before moving onto the next phase in the Front-End Process.

2.3.4.2 Establishing Target Specifications

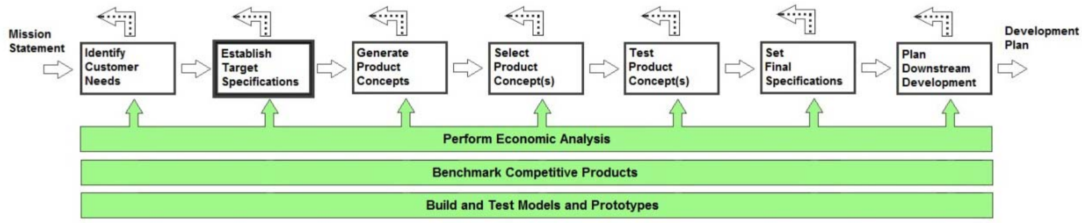


Figure 7: The second stage of the Front-End Process is Establishing Target Specifications.

In the previous phase of the Front-End Process, the development team gathered raw customer data and transformed them into customer needs. They then categorized and prioritized them into a customer needs hierarchy. The next step is to transform these needs into product specifications. This is phase is highlighted in Figure 7.

The previous phase focused on what the product needs to be able to accomplish. Now it is time to establish how the product will accomplish the actions required of it to satisfy customer needs. Prioritized customer needs will gain a higher importance value when setting initial product specifications.

Even though ideally product specifications would be set just once and the product built accordingly, it is more realistic to assume otherwise. Initial specifications will give the development team a good foundation of limits to work towards. These initial specifications will most probably change during the product development process, as well as being defined more precisely as later testing reveals technical issues or contradictions. For this thesis, the product specification setting methods of Metso Automation are the most related. This is because they are the natural continuation of the customer needs identification done in this thesis. Metso Automation uses the Quality Function Deployment method to transfer customer needs into product specifications. It is presented in the next segment.

**Quality Function Deployment**

A well-defined product and product development process is essential in avoiding the most common mistakes in new product development (Soin, 1998, ss. 319-320). Quality function deployment (QFD) aims to systematically transform the needs of the customers, as expressed by the customer, to design characteristics of a product. Otherwise known as customer-driven engineering, QFD aims to define the product parameters, address issues expressed by customers, visualize cross-functional issues and dependencies, streamline and focus internal processes, document accumulated knowledge, and understand market positioning (Soin, 1998, ss. 321-323).

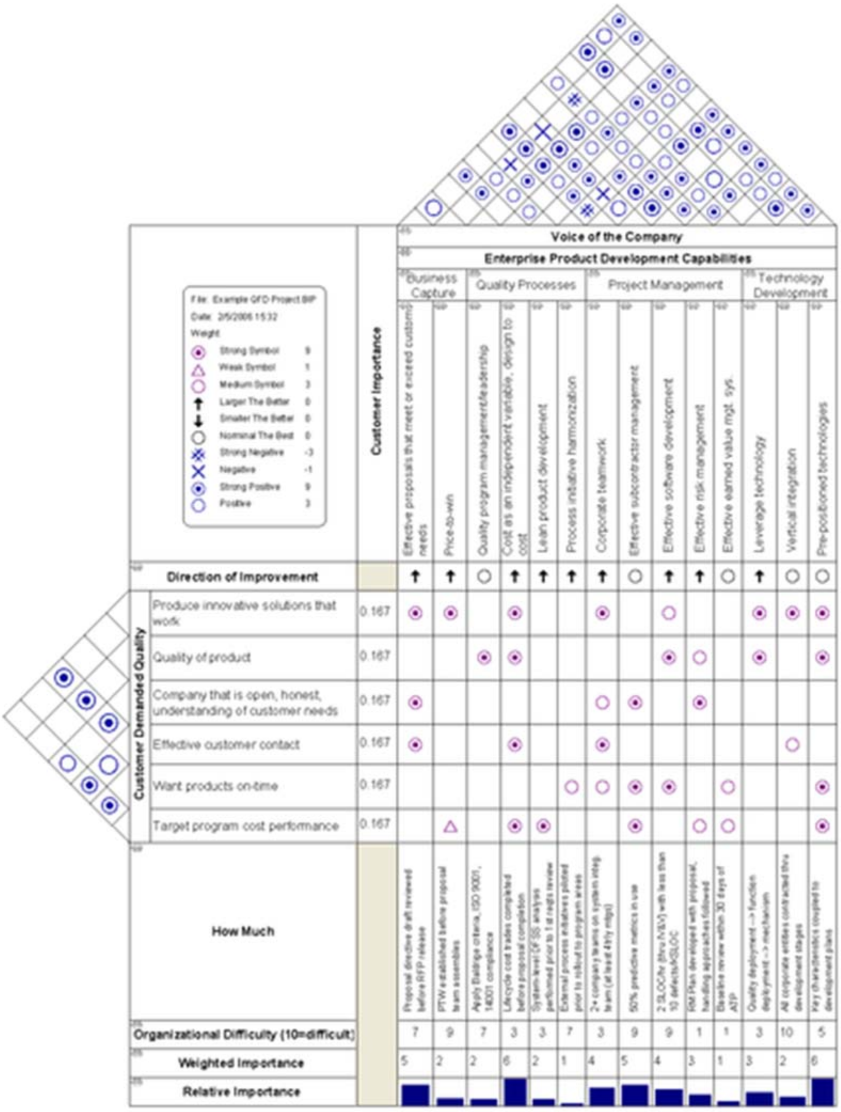

Figure 8: Example of a house of quality

While QFD is not limited to the use of a single method or matrix style, the house of quality depicted in Figure 8 is a framework commonly used in structuring and visualizing QFD. First in the top left corner is the legend. On the left side of the house are customer needs and demands concerning product attributes. The correlation of these demands to other demands is shown in the triangular portion on the side of the house. At the top of the house are product abilities or company actions to improve the offering. These are again correlated to each other in the triangular portion at the top of the house. Customer demands are compared to the strengths of the product, or company actions in the center of the house. Demands are given weight depending on the value customers give to various abilities of the product. Difficulty of fulfilling these demands is also included in the example image. The house of quality can be modified to fit various additional information such as comparing competing products and development costs.

The use of QFD began in 1972 by Mitsubishi and has since spread into wide use among a number of successful companies around the world. These companies include Toyota, Ford, Proctor & Gamble and Hewlett-Packard to name a few (Oakland, 2003, s. 81). Metso is no exception and uses QFD and the house of quality to coordinate cross-function teamwork in product development. The customer needs and demands information gathered for this thesis will form the starting point for constructing a house of quality for the on-line particle size analyzer product development. The demands will then be compared to the current capabilities or similar products in the Metso product line. Strengths and weaknesses will be visualized, as well as priorities and difficulty of improving the product to better suit customer demands.

### 2.3.4.3 Other Front-End Process Activities

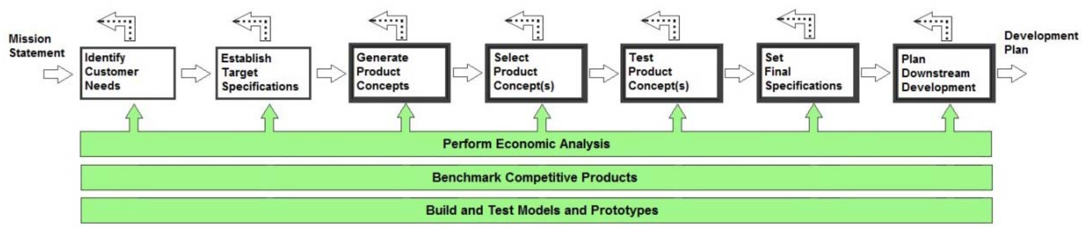


Figure 9: The later stages of the Front-End Process

Even though this thesis focuses on the first two activities in the Front-End Process by Ulrich and Eppinger, the process itself includes five further activities. Those activities are highlighted in Figure 9 and will be briefly presented in this segment.

**Generate Product Concepts:** In this phase the development team attempts to satisfy customer needs by inventing as many possible solutions as they can. This phase can be seen as an elaborate problem solving phase, where innovative thinking and creativity are highly valued. This phase should provide the team with numerous product concepts, each trying to satisfy customer needs as widely as possible.

**Select Product Concept(s):** Using the resulting concepts of the previous phase, now the development team systematically analyzes each concept. The most promising concepts are identified and kept, while the others are removed from further development. As Ulrich and Eppinger comment, this phase typically requires multiple iterations before the most fitting concepts are selected (Ulrich & Eppinger, 2003, s. 17).

**Test Product Concept(s):** The few concepts to survive elimination are moved to testing. These product concepts are tested how well they satisfy customer needs in reality. Any appearing problems in the concepts are identified and remedies are sought. If the product concept fails in the eyes of the customers, the product development will likely return to a previous phase or be terminated entirely.

**Set Final Specifications:** With the concept testing phase completed, it is time to revisit the specifications set before the testing phase. These specifications will now be adjusted according to test results and product constraints. These new limits will be documented with more precision to specific values.

**Plan Downstream Development:** The final phase of the Front-End Process by Ulrich and Eppinger includes activities about creating a basis for future product development. The main activity of this phase is to create a detailed development schedule and plan for future development phases. Documentations of customer needs, concept details and specifications, human resources and financial assets are gathered and combined to make a contract book (Ulrich & Eppinger, 2003, s. 17).

**Perform Economic Analysis:** As the concept is turned into a developed product, the continuation of the development process must be justified by proving a business opportunity. In order to do this, an economic analysis is performed. The economic analysis includes, but is not restricted to development and manufacturing costs, cash flow estimates, marketing and support costs, unit price, production volumes and sales revenues. This activity is part of no specific stage of the Front-End Process, but is performed and updated through the entire process.

**Benchmark Competitive Products:** Once the target market segment is selected and throughout the development process, competitive products serving the same customer groups should be investigated. Prototype performance, customer value and design should all be benchmarked against the competing products. This can help in not only understanding the market situation, but to also position the developed product into the market. The positioning in turn can influence market entry and marketing strategies.

**Build and Test Models and Prototypes:** Throughout the product development process, various prototypes are necessary to build. Concepts need to be realized in order to prove them valid or non-valid in actual planned use. Prototypes begin from relatively simple constructs as "proof-of-concept" and slowly evolve into more finalized and marketable products. This phase is not only part of every phase in the Front-End Process, but it is part of every stage in the generic product development process all the way to product launch.

### 2.3.5 Service Based Product Development

In its earlier days Metso had a product based market strategy with services such as maintenance being in a supporting role for the physical products. This has since changed and the current market strategy is highly service based. Services are the seen as stable and reliable sources of cash flow. Rather than having services support products, new products developed and are designed to support services.

With services being the central idea upon which the product package is designed, the priorities of product design differ from traditional product development. After-sales functions such as ease of maintenance and parts replacement are thought of already during the development process. With Metso the service and product package does not end there. The package includes installation, process knowhow and expertise, which are then taught to the users. With the inclusion of Metso products, the process expertise is also used to optimize the user's processes. The process can then be supervised in order to maintain a high level of quality. This way Metso effectively creates a relationship of mutual interest between itself and the customer through continuous services.

# 3 METHODOLOGY

The basis for customer needs identification is the belief, that the customer himself has best knowledge about his needs (Kärkkäinen;Piippo;Salli;Tuominen;& Heinonen, 1995, s. 5 (A2)). In order to discover customer needs in the chosen customer segment, information needs to be collected from the customers themselves. Due to financial restraints, data collection will be done mostly inside the Finnish borders. Market research conducted by the Geological Survey of Finland (Finland's Minerals Strategy, 2010, ss. 8-16) indicated that the market has a few large players which dominate the market. As there are only a few potential customers in the market, research for this thesis will be conducted mainly by interviews. Interviews were chosen over questionnaires, as questionnaires tend to have a lower response percentage. Additionally interviews offer more interaction possibilities between the interviewer and interviewee (Ulrich & Eppinger, 2003, s. 56). The received answers are expected to be qualitative and not quantitative. The qualitative nature of the responses is suitable for the thesis research, as the needs and expectations of individual customers will be taken into account when designing the final product for their specific application. This view is supported by reputed market research experts. (Burns & Bush, 2008, s. 232)

By the end of the project, a total of four interviews were done. All interviews were done as semi-formal face-to-face discussions with pre-determined, but unrestrictive topics. Two of these interviews were given by operative level managers in mineral processing plants situated in Finland. One interview was given by a strategic level manager of a global mineral processing company with over 200 mines and mineral processing facilities globally. The last interview was given by a representative from a global competitor with wide networks already existing in the industry. With these interviewees it was speculated, that the answers of each respondent could be viewed against the answers of the others in order to mitigate personal biases. This could prove useful especially in the case of the competitor's interview.

## 3.1 Reliability

As was covered in the raw data collection segment of the Front-End Process by Ulrich and Eppinger, choosing the interviewees is an important task, which can affect the effectiveness of the whole research process. In order to provide variety, but still focusing on the lead users, the four aforementioned interviewees were chosen.

The selected interviewees would offer their views of the product from different viewpoints depending on the interviewees company and personal role in their companies. Customer1 and Customer2 offer their input from an operational level, where first-hand experiences of competing products and processes can be valuable assets to the thesis research. They are seen as the lead users. ICustomer3 works on a strategic level and has a wide area of expertise concerning mineral processes and their measurement needs. His inputs can be assessed as being part of a more senior management's view point. Competitor1 is a representative of a company, which already supplies the market with a similar particle analyzer. Assuming that he is co-operative, Competitor1 can provide input on how the market is seen from the viewpoint of an analyzer supplier.

All interviewed customers have already had transactions with Metso. They have involved themselves in previous product development projects and are eager to assist in future projects as well. The reliability of their responses is considered to be very high. Competitor1 has not been involved in earlier product development processes with Metso, due to his status as a competitor in the market. While there is no strict reason why co-operative efforts couldn't be done with Competitor1, no such projects have been started so far. Thus from an academic viewpoint, the reliability of Competitor1's answers can be seen slightly lower than those of the customers. By no means is the truthfulness of Competitor1 being denied, only a level of uncertainty is present due to no previous co-operative efforts.

## 3.2 Interview Guide

The interview guide, which can be found in the appendices, is used to keep the interviews on topic. It is only semi-structured in order to provide enough freedom for the interviewees to discuss hidden customer needs. The interview was structured according to interview guides made by customer needs identification experts (Kärkkäinen;Piippo;Salli;Tuominen;& Heinonen, 1995, s. 7 (B3)).The interviews were all done in Finnish, so the interview guide is in Finnish as well.

The first questions of the interview guide are broad and easy to answer. Their goal is to gain some background information of the interviewed companies, as well as get the interviewee to relax, should there be some anxiety. First the interviewee is asked to describe their company's mineral process very shortly. Then the importance of particle size is discussed from three viewpoints. These are the viewpoints of productivity and process of the company, their customers and ecological effects. The first two viewpoints focus on the core business effects of particle measurement, while the third discusses the global trend of trying to preserve the natural environment as well as possible.

The second part of questions go into more detail on particle analysis. The location and precision of particle measurements in the process are discussed. While particle size is the main focus, shape and other particle characteristics are discussed in hopes of discovering business opportunities through differentiation against laser diffraction analyzers. This topic will be discussed more thoroughly in the results chapter.

The third part of the interview guide includes questions about how particle measurements are performed as the time of the interviews. Mechanical separation and optical analysis are discussed, as well as using analyzers for informative uses and automated process control.

The fourth step in the interview guide focuses on optical particle analyzers, and specifically on optical image analysis. The interviewee's past experiences are discussed, as well as perceived strengths and weaknesses. Eagerness to include optical image analyzers in their processes is asked.

The last section of the interview guide is specific to experiences concerning Metso. These discuss earlier co-ordinated projects between Metso and the interviewee. While these questions were part of the interview guide, the answers and discussions created by these questions will not be included in this thesis. This is due to the possibly secret nature of the discussed topics.

## 3.3 Scope and Limitations

This thesis will target industry operators in the field of industrial mineral processes of slurry and dry feeds. As the goal is to create a particle size analyzer meant for on-line use, all laboratory use is excluded from the scope of the thesis. All manual at-line and off-line use is excluded as well. Similarly industry operators needing measurements of airborne particles (sprays, fumes etc.) are excluded, as they are presumed to be beyond the capabilities of the current particle size analyzer. Preliminary research on the likely competitors has already been done (Karjalainen, 2011) and is thus also excluded from the thesis.

# 4 RESULTS

This chapter analyzes the information received during the four interviews. The chapter is divided into segments according to the main questions asked during the interviews. The question-specific conversation is followed by a concluding segment, which attempts to illustrate the main discoveries of this thesis. All interviews were in Finnish, so this chapter will use paraphrasing rather than direct citations. The literations of the interviews as well as further information concerning the interviewed companies can be found in the appendices. In this chapter the interviewed companies will be referred to as Customer1, Customer2, ICustomer3 and Competitor1. Customers one and two refer to front-end operators. The interviews were answered by operational level managers from these companies. ICustomer3 is a mineral processing company of global scale. ICustomer3 has over 200 mines and processing plants around the world. The questions in the interviews were answered by a strategic level manager from ICustomer3. Competitor1 is an international company with an existing offering to the particle analyzer market. The company has a wide network in the industry and serves a multitude of industries.

## 4.1 Importance of Knowing Particle Size

The first and foremost question to have been answered was whether it is important to know particle size at all. If knowing the particle size was regarded as important, then the next question asked where and why is it important. The three main topics discussed were the importance to the process itself and productivity, the customers and ecological factors.

### 4.1.1 Process and Productivity

All interviewees strongly agreed that particle size is a critical factor in their processes and productivity. According to ICustomer3, particle size has a clear correlation to energy usage in the process. He stated that in their processes, energy accounted for 40% or all process costs. While other interviewees gave no exact numbers, it was invariably agreed on, that particle size control has clear a correlation to energy usage.

When discussing the issues related to particle of suboptimal sizes, several issues were raised. If particles in the material feed are left too coarse, it slows the process, lowers throughput and causes expenses by increasing the recycle cycles of the feed. This refers to the various size reduction methods used in mineral processing such as crushing and milling. If the feed material is deemed too coarse after milling, it is fed back into the mill for further reduction until it is of adequately small size. With fewer cycles of milling necessary, the energy usage per ton of material is reduced and thus cuts costs of processing. Likewise if the feed material is ground too much and the particle size is unnecessarily small, it is again a waste of energy. Too small particles also cause problems by forming clots in slurry processes, or by causing mechanical strain as dust in dry processes.

Regarding particle size, the most critical process point is froth flotation, as referred to by Customer1 and ICustomer3. Flotation aims to separate the valued mineral from other accompanying stones by taking advantage of the valued mineral’s flotation behavior. The slurry feed is pumped into a flotation chamber and air bubbles are blown into the mix. With the correct bubble size and speed as well as the correct particle size, the valued mineral attaches itself to the bubbles and rises to the top of the chamber. It forms froth on top of the liquid and is then gathered onto further processing stages. The stones with differing flotation behavior will not attach onto the bubbles and will sink to the bottom of the flotation chamber from where it is collected. Flotative and separative agents can be used depending on the mineral being gathered. As flotation relies on the valued mineral having a specific surface area and weight, particle size is vital to the success of this process stage.

When asked about production capacity, none were hesitant to illustrate the importance of optimal particle size. As businesses trying to use economies of scale, maximal production capacity is crucial for obtaining profits. This, however, cannot be done at the expense of quality. As ICustomer3 stated, if the quality isn’t correct, the capacity cannot be correct.

### 4.1.2 Customers

ICustomer3's aforementioned phrase concerning quality fits well to the overall market situation. Particle size is not only important to the mineral processing company, but to its customers as well. According to ICustomer3, the role of mineral processing companies in today's market is very customer oriented. Customers demand products of very strict specifications regarding particle size. Competitor1 went as far as to explain how a deviation of a few microns can be fatal when the final product should be under 10 microns, while a similar deviation would not be of consequence in products of over 100 microns. According to all interviewees, customers need products of small enough size, but as coarse as possible within their required limits. Customer1 and Competitor1 stated that their customers require the mineral's particle size to be small in order to have a large surface area per grain in order to be effective in use, but coarse enough so that environmental effects such as rain and wind will not mitigate the mineral's effectiveness in use. This goes well with the idea, that avoiding excess size reduction can reduce costs of the mineral processor as well.

It was stated, that all production is steered towards set customer quality specifications and norms. These specifications are used to set products into categories of pureness and size. The market seems to be reliant on Sedigraph based size determination methods. This method is based on the sedimentation speed of particles in a liquid. In short, sedimentation of particles is dependent on the size, density and viscosity of a particle as well as the density and viscosity of the liquid it is in (UCL DEPARTMENT OF GEOGRAPHY). While the Sedigraph will be discussed in later segments, it is important to know that customer quality specifications are based on the results this method gives. These specifications then affect the size ranges into which mineral processors must differentiate their products into in order to comply with the market demands.

### 4.1.3 Ecological Factors

In the earlier segment concerning productivity, it was mentioned that optimal particle size will maximize production capacity. This not only affects productivity and profits due to economies of scale, but also lowers expenses due to low quality production, or waste generation. With a higher percentage of market grade product produced from the, the lower the amount of waste generated. Three out of the four interviewees mentioned that large particle size dispersion is problematic, as it creates issues in waste control.

According to Icustomer3, the generation of dust is always a sign of an inefficient process. Apart from the issues it creates in machinery wear, dust also creates waste control issues. Smaller particles are more prone to be moved away from dedicated waste areas by winds. This could have a detrimental effect on the local flora and fauna, especially in nearby lakes.

ICustomer3 also mentioned that a steady material flow in the process creates a safe working environment for the plant workers. While this does not affect the ecological environment, lowering the amount of work-related accidents should only be seen as a benefit. Again large particle size dispersion increases the need for human interference in cases of blockages, machinery wear etc. The more human interference is needed, the more opportunities there are for accidents.

### 4.1.4 Where in the Process Does Particle Size Matter the Most?

It has been established that having particles of a certain size is important in the mineral processing industry. The next step is to locate where in the process the information is the most vital. With all four interviewees listing several differing locations in their process chain as the most important ones, there seemed to be some variety on priority. Two process stages did, however, rise above the rest as the most critical stages where a certain, steady particle size is crucial.

The first stage, which was already touched upon in segment 4.1, is the flotation. Three of four interviewees saw the flotation stage being the most influenced by particle size. As was explained in the aforementioned segment, flotation separation relies on the flotative characteristics of particles in the feed material. As the characteristics are influenced by mass and surface area among other factors, steady particle size is beneficial to flotation separation. Flotation invariably dampens the material. Due to this, flotation is a phase in the process from which it is difficult to recycle the material back to the milling stages especially in processes using dry milling methods. Milling wet feed material in mills meant for dry feeds will create clogging problems and drying the wet material back into a dry state for more milling cycles is very expensive and thus unfeasible financially. For these reasons, particle size has to be invariable before the feed material enters the flotation stage.

The second crucial stage in the process is unsurprisingly the final product. The mineral processing market is very customer oriented and the customer quality standards are particle size dependent as was mentioned in the earlier segment. Thus it is clear that a particle size of low fluctuation is important to the processor, as this enables the processor to comply with customer demands of minerals of a certain size.

Additional locations in the process chain were spoken of as regarding the importance of knowing particle size. Customer1 stated that their mineral deposits contain varying types of the same value mineral depending on the geographical location. This heterogeneity has had effects the characteristics of the mineral. The slightly differing structure of the same mineral from a different location was said to affect the natural particle size, solidity and abrasiveness of the material. Customer1 further explained that despite attempted homogenization, changes in the material could be seen as mining operations changed location. If the change in the feed material could be seen in the early stages of the processing chain, crushing and milling could be optimized to best suit the new type of feed.

Optimization seemed to play a large part of the benefits to other process stages as well. Crushing and milling stages were seen as a point of improvement. With constant information on feed and output particle size, size reduction stages could be optimized to minimize recycling of coarse material back into the mills. This would have direct lowering effects on energy usage per ton as well as an increase in tons of produce due to less time spent reducing the size of the same material.

Finally as a guideline it was pointed out that the finer the final product, the more precisely the particle size must be known. This increase in demand for precision in finer particles could limit the range of usefulness of the particle size analyzer. This would then correspondingly set limits to the applications the analyzer could be applied to.

## 4.2 How Particles are Analyzed at the Moment

The interviewees were asked about their current particle size analyzing methods. They were questioned concerning the sizes of particles needing measuring in their processes as well as how particle analysis was done at the moment. Questions were presented relating to technological aspects as well as manpower used in the interviewee's current particle analysis methods.

### 4.2.1 The Sizes of Particles Needing Measurement

Having different minerals and different mineral processes, all the interviewees also had differing answers. While these individual operators had varying needs, the compilation of their answers gives some indication to how wide a size range the analyzer could function in. Technical restraints prevent the analyzer from functioning on the whole size range simultaneously. Instead it could be built in such modular fashion, that it could function on set size ranges at a time. These size ranges should be selected and adjusted to suit the process stages the particle sizes correspond to in any given mineral process.

Customer1 stated that particles measured before their flotation stages are 95% under 115µm. Before flotation their feed is measured to contain 50% of the particles under 40µm. The final products range from under 10µm to 30µm. Larger particles than the aforementioned are separated using sieving.

Customer2 produces a more coarse product and has a final product size range of 20-250µm. After the crushing stage, 80% of Customer2's material is below 20mm. The mill input is by average 25% below 75µm. Post-milling product is roughly 80% under 210µm. If the final product's particle size would constantly remain within the boundaries of 20-250µm, they could be able to use over 90% of their produce. At the moment their yield is fluctuating slightly below 90%.

ICustomer3 and Competitor1 act on a strategic level of management and thus do not have such accurate numbers. ICustomer3 briefly stated that the first stage where measuring is logical is after the first crushing stage. The size of those particles is several millimeters. This corresponds to the sizes mentioned by Customer2 in their crushing stages. ICustomer3 also mentioned that their most coarse final product is 8µm and coarser. Competitor1 emphasized on operators preferring sieving methods over on-line analyzers when measuring particle sizes over 100µm. He saw sieving as a reliable, low-cost, low upkeep and simple-to-use method to measure particles of sizes where minor deviation was permitted.

While the possible measuring range could be as wide as from below 10µm to above 20mm, the upper range might not be feasible. Competitor1 could very well be right about less expensive methods reigning in larger particle sizes. The earlier research (Karjalainen, 2011) discussed the issues of measuring very fine particles with optical analyzers. Tests had shown the realistic lower limits of optical analyzers to be somewhere between 2-5µm. This would prevent and optical analyzer from competing with laser diffraction devices for the market of measuring very fine particles. With these limitations in mind, it seems that the most feasible measuring range for a marketable on-line optical particle analyzer would be 5-100µm. This size range would situate the analyzer in milling circuits, flotation stages and quality control of final products.

### 4.2.2 Currently Used Measuring Techniques and Manpower

When discussing the current measuring and analyzing techniques with the interviewees, it became clear that on-line particle analyses with anything but laser diffraction based devices are very rare if not nonexistent. As laser diffraction analyzers are limited to measuring the estimated size of particles, all other tests concerning optical qualities are left to be done by laboratory personnel. Also the quality of the current so-called on-line analyzers was brought to question.

Customer1 and Customer2 both use laser diffraction based on-line analyzers in their processes. In the case of Customer1, the laser is not seen as adequate by itself due to the lack of shape analysis in the laser. An at-line analysis is also performed using another laser diffraction device. Customer1 mentioned that most of their measurements were still done by hand

and that they use laboratory analyses heavily. In the enrichment stage Customer1 also uses an old particle size analyzer relying on a hammer-and-anvil type of mechanical measurement.

Customer2 also uses several laser diffraction analyzers, but uses them solely for informational purposes. Laser diffraction analyzers are not seen as reliable enough to warrant controlling processes with them. In addition to the laser analyses, each day  a sample is analyzed in a laboratory. The results of the on-line and the laboratory analyses are compared to ascertain the validity of the on-line device's results. Customer2 sees the largest weakness of the laser to be the lack of a possibility to identify minerals in the material from each other. As their process involves three different minerals with differing uses and size requirements, their current on-line methods are inadequate to analyze the minerals individually. Customer2 is in need of an analyzer which could identify minerals and create different size analyses for each mineral separately.

Competitor1 agrees with the current issues of on-line particle analyzers mentioned by Customers one and two. Competitor1 goes as far as stating that 90% of operators in the market use laboratory analyses as opposed to on-line analyses. The process is rarely adjusted automatically. Competitor1 sees this as a wide problem for the processors. In his words, when it is noticed through laboratory analyses that a process is off course in some way, it has been in that state for a long time and the effects can be substantial. He sees that moving to on-line analyses and automated process control is the future of the market and would see it go in that direction. The main point in on-line analysis is predictability. The opportunity to see machinery wear, changes in the feed material and other possible issues is seen as an important improvement by Competitor1.

ICustomer3 has done wide ranged researched of his own concerning on-line particle analyzers. He states that while researching possible analyzers for their own processing plants, he discovered that most analyzers in market were not originally designed for on-line use, but were modifications of laboratory devices. This was seen as a weakness by him. With the interior parts having been designed to less demanding environments, these so called "on-line" devices would not last in a real process stream. Another issue was the method of collecting samples to the on-line analyzers. As the analyzers were not originally designed for on-line sampling, many sample collection methods seen by him were giving false results due to clogging or unrepresentative samples of particles. Icustomer3 does, however, have highly automated processing plants. While automation is seen by him as a progression and improvement, human involvement on a supervising level is still seen as necessary. While all manner of safety valves, overflow drains and other precautions are important, no automated system can react as intelligently as a well trained employee.

When asked about the manpower invested into measurements and analysis, both operational level managers from Customer1 and Customer2 replied that no employee is dedicated solely to maintain the analyzers and to view results. According to Customer1, the headcount in Finnish processing plants has been minimized so that each employee has a variety of responsibilities. The employees working on instrumentation also maintain the results as well as the analyzers themselves. Customer2 stated that maintaining their current on-line analyzers takes approximately half a day per week.

Laboratory testing was widely discussed and seen as a slow process. ICustomer3 that their processing plants had an average of two people working in laboratories and that most of their time and resources was spent on size analyses. It was further specified that the Sedigraf size analysis takes priority due to it being the customer quality standard. While Competitor1 agrees that performing analyses for the mineral processing industry is done in an old-fashioned way, Customer2 presented the issue of laboratory tests taking a long time to perform. According to his experience, a simple laboratory particle size analysis could take a few hours, while a more complex size analysis with mineral separation and segmentation would take an entire day. This timeframe corresponds to the issue presented by Competitor1 concerning the long reaction times related to laboratory analyses. If a process sample is taken in the morning and it takes an entire day to get the results, the processing facility has already lost a day of possible benefits of optimization.

## 4.3 The Importance of Shape Analysis and Other Particle Qualities

As current on-line analyzers seemed limited to measuring and estimating particle size, the interviewees were asked about other important particle qualities. The large amount of laboratory analyses was a sign, that size is not the only particle quality that matters in the processes of the interviewees. As the processed minerals differed, also the required information about them differed.

Customer1 has a need for particle shape and aspect ratio analyses. His process is tuned to produce not only a desired size range, but also maximizing the aspect ratio of the particles. This creates a higher quality product for the market Customer1 serves allowing premium pricing for a higher quality product. Their problem is that there currently are no on-line shape analyzers available, so all analyses must be done by at-line and laboratory testing. While the current method works, an on-line analysis would give more present information on the process. Another important piece of information for Customer1 is the whiteness of the feed material. This correlates to the pureness of their final product and is used to measure quality. According to the interviewee, previous prototypes used to test whiteness on-line have proved ineffective. Thus with no other option, laboratory tests have been used to determine whiteness.

Customer2 also has a process which benefits from optical information. Their feed contains minerals of several colors. As the final product consists of mostly just one mineral, color analysis of the feed would again determine pureness. No on-line analysis method has been utilized for this measurement. Another point discussed by Customer2 was particle shape. Their material's particle shape is seen as problematic for sieving, as it is not ball-like and has a high aspect ratio. With particles of this shape, sieving is highly effected by the particle's alignment related to the sieve. Particles which could go through the sieve mesh aligned vertically will not pass the mesh when aligned horizontally. This creates issues in size measurement, as the sieve results could vary depending on how long the sieve is shook and would thus be misrepresentative of true particle size distribution. This issue was also mentioned by Competitor1.

ICustomer3 also mentions shape, purity and whiteness to be problematic in his processes. His company has seen fit to use a laser diffraction analyzer and a Sedigraph as a compromise for shape analysis. Additional laboratory tests are run to set and keep track of correlation estimates. With a wide range of operations, ICustomer3 mentioned how surface area, porosity, opacity and abrasiveness are important to know in addition to size, shape and color. While not all are seen equally important, Icustomer3 states his willingness to immediately procure an on-line analyzer capable of measuring some of the aforementioned particle qualities.

## 4.4 Optical Particle Analysis

According to the interviews, the current on-line analyzer market seems inadequate to satisfy the needs of mineral processing operators. This is why Metso seeks to establish whether there is a possible business opportunity in introducing an optical on-line particle analyzer to the market. The interviewees were asked to present possible weaknesses in currently used analyzers based on their experiences as well as consider how an optical on-line analyzer would affect their process. The interviewees also listed the most valued capabilities and traits of on-line analyzers. Lastly the price range of the current analyzers and possible new entrant products was discussed.

### 4.4.1 Aspects Worth Improving On in the Current Products

While some weaknesses of specifically laser diffraction based analyzers have already been covered, this segment expands on the topic of what needs to be improved in order to better satisfy the needs of the industry operators. Some of the issues discussed here will have been mentioned earlier as well.

Competitor1 stated that processors will rely on more traditional, mechanical separation and measurement methods for coarse particles. As was explained, this preference has to do with cost-efficiency, simple use and maintenance as well as reliability. Customer2 has also presented reliability as a problem. On-line analyzers are used for merely informational purposes in their process, not to automate process optimization.

The interviews showed that the most unreliable part of on-line analyzers is the sample collection mechanism. All except Competitor1 talked in length how obtaining a representative sample from the process to the analyzer is surprisingly problematic. The interviewees mentioned how sampling tubes would slowly gather material into points and turns where the flow was slower. This would then create blockages disrupting measurements. When the blockage would then start to move, the analyzer would give highly inaccurate readings due to the unusual concentration of particles. Another problem in sample collection seems to be in collecting a realistic dispersion of particles into the analyzer. As finer particles move through the process pipes differently than coarser ones, taking a sample from only the side or center of a process pipe will result in an unrepresentative sample to analyze. If the preliminary sample is already unrepresentative then analyzing it will give no more realistic results.

Another problem encountered by Customer2 was in analyzer maintenance. While having an on-line analyzer attached to their process, they noticed how the analyzer's cuvette began to get dirty over time. A dirty cuvette or lens will understandably lessen the accuracy of an analyzer. Customer2 saw that while manual cleaning of the cuvette was doable, it was a clumsy and unnecessary step in maintaining an analyzer. When asked what would be an acceptable maintenance cycle, once per month was said to be a good cycle time. Once per week was said to be a bit short.

Icustomer3 states that as Sedigraph measurements are the customer standard, on-line analyzer should be benchmarked so that they correlate with the results of a Sedigraph. Only with reliably correlating results could slow laboratory tests be lessened, if not removed entirely. ICustomer3 continued to discuss the development phase of particle analyzers. He saw the laboratory-based analyzers having been modified for on-line use as a weakness. According to him, a modified analyzer cannot function as well as an analyzer specifically developed for on-line use. ICustomer3 additionally stated that development is too focused on the measurement itself, while dismissing other parts of the analyzing process. This issue also relates to sample collection problems. Finally ICustomer3 feels that the industry operators have yet to fully understand the potential of on-line analyzers as optimization tools. In his words there is real demand for not only the analyzing equipment itself, but a wider service package including training to use and maintain, support and scheduled checks from the manufacturer itself.

### 4.4.2 Benefits and Requirements of an Optical Particle Analyzer

The interviewees were asked for their views on how an optical analyzer could benefit them if installed into their process. Competitor1 saw the market as being very accepting if the analyzer could lessen the need for laboratory tests and make the process more productive through optimization. He especially referred to real-time process optimization through automation based on analyzer results.

ICustomer3 had a very similar view. Optical particle characteristics such as dimensions, porosity and viscosity were highlighted as laboratory analyses which ICustomer3 would be very happy to see automated with an on-line solution. ICustomer3 also mentioned having researched the option for an on-line Sedigraph, but no feasible result had been obtained so far. Thus if correlation to the Sedigraph could be made, this would be of interest for ICustomer3.

Customer1 recapped his view on laser diffraction devices not being able to understand the aspect ratios of particles and saw this as a clear weakness. The ability to actually see the dimensions of the particle would be of high value to ICustomer1, as the material's particles have a high aspect ratio. He also reminded of the benefits to them if color analysis were possible with an optical analyzer. With no knowledge of successful tests concerning color analysis, verifying the inclusion of this capability could not be done on my part.

Customer2's process involves following the behavior of three minerals with differing characteristics. Thus their main benefit was seen as being the possibility to identify minerals in the feed material from each other. This would then enable separate size distributions to be calculated for each mineral. A further benefit was seen in the ability to measure the feed's pureness in the enrichment stages. Both of these benefits rely on the analyzer's ability to perform color analyses.

In addition to discussing benefits of an optical particle analyzer, the interviewees were asked of the required traits. As previous experiences with adopted laboratory analyzers had proven short-lived, robustness was presented at the most important aspect. As the process environment contains varying levels of dust, dirt, harsh climates, vibrations and other hazardous elements, the analyzer needs to designed to withstand these factors both inside and outside the analyzer's shell.

As mentioned when discussing sampling, an on-line analyzer needs to be designed with on-line sampling in mind from the very first stages. This is to ensure effective and reliable sample collection and transportation to the analyzer with no clogging or choke points. Ass interviewees agreed also, that the reliable function and results are a very top priority for an analyzer.

Further presented by all interviewees, was the need for simple and easy installation, operation and maintenance. ICustomer3 presented examples of automated analyzers giving false warnings when a line had been shut down for the duration of a holiday or weekend. Hundreds of mobile phone messages had been sent to the process overseer warning of low feed levels. Such mishaps should not happen and should be recognized during software design according to ICustomer3. Competitor1 agrees on having reliable remote-control over analysis and process controlling functions as highly important.

Other presented requirements included the ability to measure particles of a large size range. No specific size range was mentioned. The exact requirements regarding the measurement width would depend on the mineral and process the analyzer is installed into. Safe operation, compactness, reasonable procurement and maintenance costs were also included in the requirements for an optical analyzer.

### 4.4.3 Price Range

As there are no marketed on-line optical analyzers, getting an exact price range from the interviewees was impossible. The topic was discussed, however, and the procurement costs of competing products were presented. As the interviewees saw the analyzer as an investment towards quality control and process optimization, Return On Investment (ROI) was considered by most as a measure for pricing the analyzer.

Competitor1 and Customer1 produced an estimate of 2-3 years' ROI. Customer1 commented that the analyzer would not gain its ROI from lessening the need for human resources. In his opinion the headcount was already to a minimum and would not change with more automation solutions. Customer1 saw the ROI coming from process optimization through energy savings as well as capacity maximization.

ICustomer3 saw a shorter 14 month ROI period as acceptable for an investment of approximately 100 000 Euros. From a strategic point of view, ICustomer3 explained how a more costly investment would have to be accepted by a higher level of management. In his words, an investment of 50 000 Euros could be decided upon by even a plant manager, while an investment of 250 000 Euros would most likely need approval from strategic level management. ICustomer3 proclaimed that needing only the approval of lower level management would increase the chance of the investment being approved, thus increasing the chance of getting a sale.

Customer2 had a differing approach to the procurement cost. According to him, the procurement of an analyzer would not be calculated based on ROI time. In their concern such equipment is seen as a tool for raising the quality level of their product. The value of the analyzer would not only be in higher profits, but through giving their customers better product quality as well. Customer2 did, however, remark that upkeep costs should remain low to moderate. When comparing to their experiences with the price levels of laser diffraction based analyzers, Customer2 gave an estimate of 50 000 - 100 000 Euros to be acceptable.

# 5 DISCUSSION

The previous segments discussed each main topic separately. The focus was on revealing the currently used particle analysis methods, as well as problems and needs arising from the current situation. This segment combines the aforementioned information and attempts to analyze it. As stated at the beginning, the aim of this thesis is to gather information on customer needs and to create guidelines for use when designing the particle analyzer.

As was hypothesized before the interviews, the reliability and level of co-operation of the interviewees was high. All questions were answered with detailed and thoughtful replies. While four interviews are few compared to consumer-based data collection standards, they appear adequately representative. The amount of market operators on a national level is very limited and most processes differ from others only superficially. A semi-structured interview guide functioned well, as it gave the interviewees a chance to freely discuss related matters. This freedom of speech is seen as an important part of data collection in the front-end process (Ulrich & Eppinger, 2003, s. 57).

The interviews showed that industrial mineral processors have a clear need for particle analysis. This need stems from customer demands regarding particle characteristics such as size, shape and optical qualities. So far the lack of adequate on-line analysers has forced industry operators to rely heavily on laboratory tests for all but size measurements. Even size measurements on all but round particle shapes remain a matter of educated guesses through calculations and correlation patterns laid onto analysis results. The operators themselves expressed how the current on-line analyzers were barely adequate for even informational purposes and how laboratory tests consume high amounts of time and resources. These areas of improvement in the market situation can be seen as a business opportunity. The interviewees expressed their desire for improvement, so there appears to be a want as well as need for new products in the market. The want of the customers should not be underestimated, as according to reputed authors, it is one of the main pillars of product development (Huotari;Laitakari-Svärd;Laakko;& Koskinen, 2003, s. 9).

When presented with the idea of analyzing particles through the means of on-line image analysis, interviewees responded positively and with eagerness to participate in possible product tests at their processing lines. The main advantage of optical analyzers was seen to be their versatility. A multitude of analyses could be done using images taken from the process. Particle shape was seen as a priority, while colour analyses and particle differentiation were also seen as highly important depending on the mineral process. It seems that the more laboratory analyses an on-line device could perform, the better. While it may not be financially feasible to include as many analysis capabilities into a single analyzer, designing the analyzer to modularly fit supplementary testing devices could very well be feasible. This would allow the base product to remain in a relatively low cost range, while allowing customers to better find combined solutions to fit their needs. This method of design and production is often referred to as mass customization (Agile Product Development For Mass Customization, JIT, Build-to-Order, and Agile Manufacturing ). With this in mind, it is still safe to say that shape analysis should be included in the base product. This is due to shape analysis being the most differentiating analysis capability, as compared to the market's currently prevalent laser diffraction based analyzers.

As an interviewee stated, mechanical separation methods are preferred over more resource demanding analyzers, when measuring coarse particles. While this may very well be the case, it does not completely limit the range of applications an optical analyzer could be marketed towards. Similar to laser diffraction devices, sieving can be affected by irregular particle shapes (Glendon & Dani, s. 267). If a proper application is found for an optical analyzer in coarse materials, this leverage could be used to further show why optical analysis can be superior to sieving. With current knowledge, however, applications relating to coarse materials shouldn't be seen as the main target market. With the information gathered in this thesis, the target market should be in processes involving particles of irregular shapes, optical characteristics and of sizes between 5 and 100 microns. The range could be widened to allow analysis of coarser particles as well. Referring to previous research (Karjalainen, 2011), widening the range to coarser particles will invariably desensitize the analyzer towards detecting very fine particles. As such, an option of measuring ranges should be offered with the analyzer.

Other analyzer traits to be considered during designing were presented by the interviewees as lacking in current products. The most important traits of on-line analyzers were seen to be ruggedness, reliability low need for maintenance. An interviewee pictured the ideal analyzer as being so self-maintaining, that they could "set it and forget it." While that ideal is likely impossible, it shows the opinion of mineral processors regarding maintenance. Reliability was seen as a major issue in all on-line products in the market. Most issues had to do with sample collection and transportation to the analyzer. The interviews portrayed a clear disappointment towards the sample collection methods of current market products. This should be a very high priority in designing the optical analyzer.

Believing that the interviewees adequately represent the industry, it seems that industry operators are accustomed to analyzers costing 50 000 - 100 000 Euros. The prices of on-line analyzers have rapidly dropped in the past decade. While an on-line analyzer cost over 200 000 Euros in the 1990's, the current competition has driven prices down. As laser diffraction devices could be seen as the most direct competitors of on-line optical analyzers, they should cost little to no more than their competition. In this case, a market based pricing could be feasible, as "more-for-same" and product distinctions appear a valid differentiation strategy (Kotler;Armstrong;Saunders;& Wong, 1999, s. 460). (Mohr;Sengupta;& Slater, 2005, s. 290)

# 6 CONCLUSION

The main goal of the thesis was to identify the customer needs for an optical image analyzer in the mineral processing industry. As an early step of the Front-End Process, the results of this thesis will act as guidelines for a Go/Kill/Recycle decision as well as further product development steps should the Go decision be made.

Early in the thesis process it was realized, that the market is small and well networked. In order to get an opportunity to interview the correct people, the readily built networks of Metso were used. Without the ready network, convincing managers to spare their time for interviews would have surely been a hard achievement. The small market size also dictated the research methods used, as well as the level of product customization options to be developed.

As all interviewed companies represented a different aspect of the market, the research results seemed to have provided a wide array of customer needs. These customer needs will now have to be more thoroughly prioritized and turned into initial product specifications. While the next product development phase is not part of the thesis's scope, it is important to understand where the results will be used and how they benefit the company.

While the processes of the interviewees and other researched mineral processing companies have their differences, the core of their processes remain the same. The customer needs identification of this thesis clearly showed a need for more widely capable on-line analyzers. Each interviewee could mention several areas of improvement in the current analyzers in the market. If this is leveraged on by Metso, there is a real business opportunity in the market.

SOURCES

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APPENDIX 1 Interview guide

Haastattelukysymykset:

Esittely

Voisitko kertoa hieman yrityksesi tuotteista ja niiden tuotannosta?

Kuinka tärkeitä partikkelikoko ja kokohajonta ovat teidän:

-Prosesseille ja tuottavuudelle?

-Asiakkaille?

-Ympäristön suojelun kannalta?

Kuinka tarkasti partikkelikoko täytyy tietää prosessejanne ajatellen?

-Kuinka paljon partikkelikoot voivat heitellä ylä-, ja alakanttiin?

Entä onko partikkelin muoto tärkeä koon lisäksi?

-Entä onko muut partikkelin ominaisuudet tärkeitä? (väri, huokoisuus jne?)

Minkä kokoisia partikkeleita työstätte missäkin prosessinne vaiheessa?

Missä vaiheessa prosessia koette tietyn partikkelikoon olevan tärkeimmillään?

-Vain valmiissa tuotteessa, vai välivaiheessa?

Miten teidän tuotannossa seurataan partikkelikokoa?

-Mekaaninen lajittelu Vs. optinen analyysi. Millaisia kuluja seurantaan liittyy?

-Ohjaus Vs. automaattinen. Millaiset miesvarat on kiinni koon seurannassa?

Oletteko tutustuneet optisiin partikkelianalysaattoreihin?

-Koetteko, että niistä olisi hyötyä teidän tuotannossanne? Miksi/ miksi ei?

-Mitä vahvuuksia ja heikkouksia koette analysaattoreiden omaavan?

Mikäli olisitte hankkimassa optista analysaattoria, mitkä yritykset tulisivat mieleenne? Keihin todennäköisimmin ottaisitte yhteyttä?

Mitkä analysaattorin ominaisuudet olisivat tärkeimpiä juuri teidän tuotannossanne?

Paljonko olisitte realistisesti valmis maksamaan optisesta analysaattorista perustuen nykyisiin tietoihinne laitteista?

Kuinka suhtautuisitte Metsoon mahdollisen on-line partikkeli analysaattorin tarjoajana?

-Millaisia ajatuksia Metso herättää yleisesti?

Mikäli Metso laajentaisi liiketoimintaansa mineraaliteollisuuden on-line analysaattoreihin, millaisia ohjeita voisitte kokemuksellanne teollisuudesta antaa?