29th Annual INCOSE international symposium
Orlando, FL, USA
July 20 - 25, 2019

Eliciting Human Values by Applying Design Thinking Techniques in Systems Engineering

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Abstract. The objective of this study is to investigate the effect of Design Thinking techniques for capturing and communicating human values in the early phase of Systems Engineering. To develop products, systems, or services that satisfy the stakeholders, the systems engineer (SE) must understand the emotional needs of the stakeholder. The goal is to derive stakeholder requirements from the need analysis to create solutions that satisfy the quantitative and emotional need of the stakeholders. A development project team conducts three field visits where they interview and observe stakeholders in their work environment. The project team uses visual mapping tools to communicate and discuss findings and to create a mutual understanding of the stakeholder needs. We evaluate the method using interviews, surveys, and analyses of the derived requirements. The results indicate that the team gained a better understanding of the human values and succeeded in deriving human values into stakeholder requirements.

Introduction

This study implements techniques from Design Thinking in stakeholder analysis to better integrate human values in stakeholder requirements. Engineers need to learn about human values to develop a system that satisfies the stakeholders. A study conducted by The University College of Southeast Norway (Falk, et al. 2016) investigated how to bring forward innovation of complex systems. The study identified a need for integration of human values in Systems Engineering to ensure that human aspects are not lost in engineering. Shafaat & Kenley (2015) emphasized that the lack of a human, cognitive aspect is a weakness in the Systems Engineering framework.

Semcon Devotek is an engineering consultancy company that provides technical expertise in the development of mechanics, electronics, control systems, and software for customers in fields such as maritime, energy, industry and infrastructure. The company is a part of Semcon Group, an international technology company that strives to create innovation by offering product development based on human behavior. Semcon Devotek has recognized the need for creating added value to their customers, by including the human values in innovation projects.

Case. The development project examined in this research is an early phase concept study conducted for a customer in the construction industry. The customer is an international supplier of construction machinery and equipment. Challenges related to poor productivity and hazardous operations are common in the construction industry. Due to stricter regulations, the customer needs a system that improves the operational working environment by reducing emission from the construction machines during operation. The challenge is to reduce the emissions without compromising the effectivity of the machine or the operator.

Problem. Semcon Devotek has a strategy to offer product development based on human behavior. However, there is a gap between the "state of the art" in human-centric product development and the current practice in the company's development projects. Following the Systems Engineering process, the systems engineer (SE) elicit stakeholder needs and requirements based on information from the client. The emotional needs are often not included in the stakeholder requirements. Emotional needs are influenced by both environmental factors such as culture and social aspects, and personal factors such as education, mental status, physical status, and preferences (Muller, 2009). In our research, we define these aspects as *human values* in product development. According to Muller (2009), it is the responsibility of the SE to bridge the gap between the human values and the engineering tasks of a project. Semcon Devotek needs a method that captures emotional needs from the stakeholders and communicates that knowledge to other project members and customer.

Figure 1 illustrates that the goal is to integrate human values, in order to create a solution that satisfies emotional needs as well as the customer's business model and the technological aspects. The IDEO approach defines the balance between desirability, viability, and feasibility as "the sweet spot for innovation" (Brown, 2008).

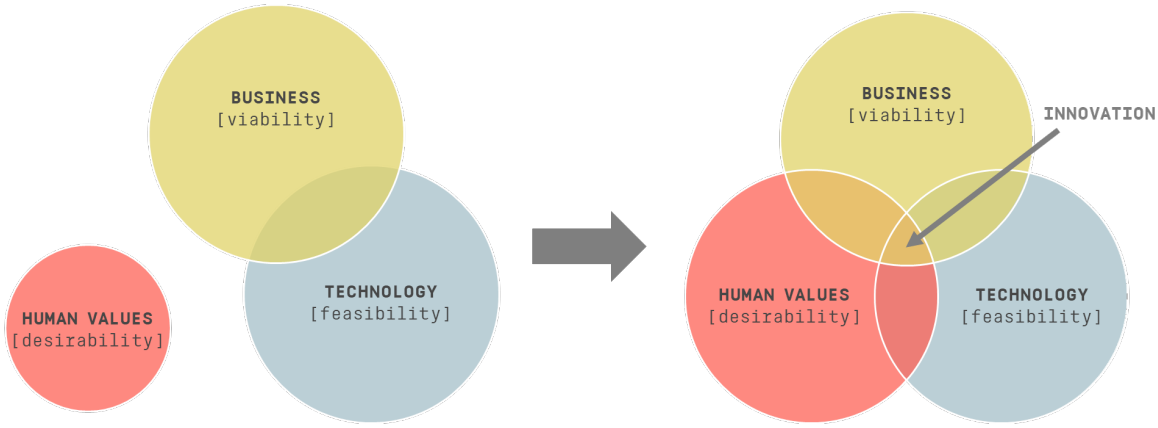

Figure 1. By integrating the human values to the product development, we will create products that satisfy the emotional needs of the stakeholders, as well as the technological and economic requirements

Claim. A systematic method for interviewing and observing the stakeholders in order to capture emotional needs will make the SE able to include the human value in the stakeholder needs and requirements.

- By interviewing and observing stakeholders, the engineers will learn about the human value in the context of the system.
- Documenting the learnings using a visual mapping tool will contribute to a mutual understanding of the stakeholder needs and better communication between the team members and with the customer
- The visual maps will provide input to the definition of human value stakeholder requirement.

State of the art

Human-centered design (HCD) integrates the human perspective in all steps of the problem-solving process. ISO 9241-210 (2010), the international standard for human-centered design for interactive systems, defines HCD as an approach to make systems more *usable* by focusing on the use of the system. ISO 9241-210 (2010) describes *usability* as "the extent to which a system, product, or service can be used by specific users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". HCD is not only important in the development of consumer products.

Usable systems can reduce stress or harm, improve the productivity and the wellbeing of the users in any workplace.

Design Thinking is "a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology and the requirements for business success" (Brown, 2008). A Design Thinking approach offers a number of process models and toolkits for not only designers but also for multidisciplinary teams within business innovation. Tschimmel (2012) reviewed five Design Thinking models that are widely applied in business and innovation; the *3 I* model and *HCD* model from IDEO, the *Double Diamond* model from "Design Council", the *Design Thinking Model* of the Hasso-Plattner Institute and the *Service Design Thinking Model* published by Stickdorn and Schneider (2011). These models, as described in the following, support the integration of the human aspects, the available technical resources, and the business opportunities and -constraints (Tschimmel, 2012).

The *3 I* model describes three phases, *Inspiration, Ideation*, and *Implementation* (Brown & Wyatt, 2010). The inspiration phase includes activities such as the identification of design problem and observation of the behavior of the user or target group in the context of the problem. In the ideation phase, the design team processes the learnings from the observation phase. The designers use insight to create concepts and ideas for solving the defined problem or opportunity. The designers use visual presentations for sharing concepts and ideas. During the implementation phase, the designers use prototypes and visual models when proposing business ideas (Brown & Wyatt, 2010).

IDEO's *HCD* model also includes three process phases, *Hearing, Creating,* and *Delivering.* The HCD model introduces several activities for understanding the user's needs, such as observation, workshops, and participatory design (Tschimmel, 2012). The Double Diamond model describes the processes of converging and diverging in the phases of *discovering*, *defining, developing,* and *delivering* (Design Council, 2015).

Plattner described *empathy* as the centerpiece of a human-centered design process. "In order to design for people, you must gain empathy for who they are and what is important to them" (Plattner, 2013). In the Design Thinking process guide, Plattner (2013) described an iterative process of empathizing, defining, ideating, prototyping, and testing. Figure 2 describes the Design Thinking process in six iterative steps where empathize mode is defined as *understand* and *observe*.

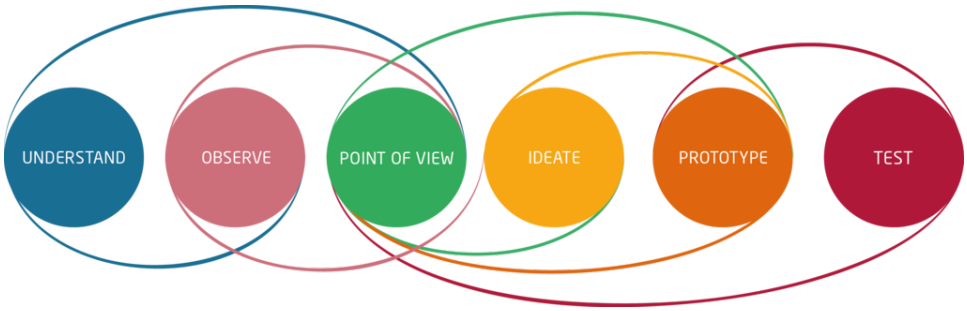

Figure 2. The Design Thinking Process steps with iterative loops, as presented by the Hasso-Plattner Institute of Design (Hasso-Plattner Institute, 2018).

Plattner's (2013) process guide encourages the designer to observe the users and their behavior in the context of their lives. During the understand mode, the designers should collect existing information about the topic, for instance by doing literature reviews. The observation mode refers to activities such as stakeholder interviews and observation of users to gain insight about their needs.

In the transition between the *empathize* mode and the *define* mode, the designers move from observing and engaging to unpacking and making conclusions from what they learned by observing and interviewing stakeholders. The process guide proposed to document the information with mapping techniques, to achieve an understanding of the needs within the multidisciplinary team. The purpose of the *define* mode is to bring clarity and focus to the design space. The designers shall define a

meaningful and actionable problem statement, called the *point of view.* The point of view should be a guiding statement that focuses on the insights and needs of the user. In the *ideate* mode, the designers combine the insight from empathy mode with their creativity to generate concepts. In an iterative process of sketching and prototyping, the designers move towards a solution by failing and learning. In *test* mode, designers perform user tests to retrieve feedback from the prototype and the users (Plattner, 2013).

Systemic Design and Systems Thinking. Systemic Design is an approach within the field of design that integrates Systems Thinking as a mean to support designers working with complex design projects (Lurås, 2016). Systems Thinking is a holistic approach for dealing with complexity. It offers techniques for discovering patterns and relationships, and for reinforcing changes to achieve a certain outcome (Haines, 2000). System Oriented Design (SOD) is a category of Systemic Design applied at the Oslo School of Design and Architecture. SOD focus on helping designers to cope with complexity, using tools such as Giga-mapping to help seeing patterns and to synthesize knowledge (Sevaldson, 2013). Skjelten (2014) recommended structured maps as good tools for sharing experience, needs, relations, and journeys. Moreover, to achieve a mutual understanding between the actors. Visual representation makes it easier to discover knowledge gaps and to sort out information that is not important or relevant (Skjelten, 2014).

Applying Design Thinking in Systems Engineering. Watanabe, Tomita, Ishibashi, Ioki, & Shirasaka (2017) suggested a joint method of Design Thinking and Systems Thinking as a framework for problem definition. They stated that engineers are turning their focus to the early phase of systems development in order to achieve innovative system development. The Design Thinking approach is considered to work effectively in the domains "why" and "what" in innovative system development, i.e. problem definition and stakeholder requirements (Watanabe, et al. 2017).

Tomita, Watanabe, Shirasaka, & Maeno (2017) wrote that Systems Engineering methodology has expanded its application into creating innovation and designing societal systems and that Design Thinking has attracted attention as a methodology for solving ill-defined problems. He emphasized that Design Thinking embedded, in Systems Engineering is effective for creating innovation.

Wade, Hoffenson, & Gerardo (2017) emphasized that the concept phase of System Engineering, also known as *Design* in the larger community outside of Systems Engineering, is critical because it determines cost, complexity, and value of a system. Wade et al. (2017) compared existing design paradigms for designing complex products: Design Thinking, Systems Thinking, Systemic Design, engineering design, Systems Engineering, agile systems, and software engineering. The proposed framework entitled "Systemic Design Engineering" unifies the strengths of each of these existing paradigms.

Zhao (2015) explored the synergy effect of Design Thinking and Systems Thinking. She found that the biggest potential for system performance improvements based on findings from Norwegian high-tech organizations, is to incorporate Design Thinking principles of empathy, creativity, and efficiency in discovering user needs, requirements, for idealizing solutions, and in modeling and systems integration. Zhao points out that Systems Thinking and Design Thinking shares important similarities in how to solve a new system development problem. Both approaches incorporate multi-disciplines, and starts with user needs and aim for user satisfaction (Zhao, 2015).

Shafaat & Kenley (2015) reviewed the design-related activities in Systems Engineering and the treatment of design in the INCOSE Systems Engineering Handbook (v.3.2.2). They described Systems Engineering design as an iterative learning process. "While designers are acquiring design skills and context knowledge, they also are gradually gathering knowledge about the problem they are working on" (Shafaat & Kenley, 2015). They emphasized the importance of active participation of the design team in the evolution of the problem description. The learning processes, the social processes, and the cognitive processes are iterative processes in which is important to achieve a consensus among actors with different interest (Shafaat & Kenley, 2015).

Human Values in Architecture Frameworks. The Panel of Human Factors and Medicine in the NATO Research and Technology Organization defined an outline for the NATO Human View, an architectural view that includes the human as a part of the system (Handley & Smillie, 2008). Handley & Smillie (2008) claimed that architecture framework originally based on the DoDAF framework, has been developed to involve new concepts of SE, but no one has managed to include the human as part of the system. The Human View shall ensure that the architecture captures the socio-technical elements such as human operator activities, tasks, communication, and collaboration between stakeholders (Handley & Smillie, 2008).

Research methodology

In this study, we apply an industry-as-laboratory research approach (Potts, 1993). The approach is applicable in Systems Engineering research as it allows us to study the effectiveness of the human value method by actively participate in a real industry case (Muller, 2013). We use data from in-depth interviews to understand the current state of working in the company. We evaluate the effectiveness of the method by analyzing stakeholder requirements that derive from the method, together with feedback from project participants and customer, collected in a survey.

In-depth interviews. We interviewed the SEs in Semcon Devotek to acquire insight about how they conducted stakeholder analysis in their previous projects, and how they consider the effectiveness of the current method for capturing human values. The questions in the interview were open and broad, as we wanted to hear their reflections about human values and stakeholder analysis. In-depth interviews allow us to achieve a broader understanding of the point of view of the engineers, which facilitates a qualitative analysis (Seidman, 2006). Table 1 presents the population of the interview participants. All the participants consented to the interviews and were informed of the purpose of this research. We have anonymized all information to ensure that answers cannot be traced back to the respondents.

Participant	Role	Experience
1	Systems Engineer, Mechanical Systems	1-5 years
2	Systems Engineer, Embedded Systems	1-5 years
3	Systems Engineer, Program Manager, Embedded Systems	5+ years
4	Systems Engineer, Embedded Systems	5+ years
5	Project Manager, with systems engineering experience, Mechanical Systems	10+ years
6	Systems Engineer, Mechanical systems	1-5 years

Table 1. In-depth interview participants.

We used a semi-structured interview-guide, which is useful for eliciting information about specific topics (Berry, 1999). To obtain comparable data, the interviews also contained seven survey questions. Survey questions provide quantitative data about the current state that we present as Likert scales, for comparison and analysis. The interview-guide consists of 17 questions. The first part focuses on the current way of working with stakeholder analysis in Semcon Devotek. The second part focuses on the potential value of the new method. Appendix A lists the interview questions.

Evaluation of method. The engineers need requirements that specifies human values to design a system that satisfies the emotional needs of the stakeholders. To evaluate the effectiveness of the method, we compare stakeholder requirements regarding humans with the initial specification provided by the customer. For the analysis, we consider human value requirements as those that address how people experience the system or make it more desirable for the people who interact with the system. Requirements derived from Health, Safety, and Environmental (HSE) regulations are not considered. By counting requirements that specifies human values, we obtain quantitative data for evaluation of the method.

We conducted a survey to learn how the project members and customer evaluate the effectiveness of the activities during the project. Table 2 presents the population of survey respondents.

Respondent	Project	Role	Experience
1	Operational safety	Technical lead	5+ years
2	Operational safety	Project Engineer	1-5 years
3	Operational safety	Project Engineer	1-5 years
4	Operational safety	Project Manager	10+ years
5	Operational safety	Customer (single point of contact)	N/A
6	HSE aluminum industry	Systems Engineer	1-5 years

Table 2. Feedback-survey respondents

One SE in a secondary project case performed the same survey. The project applied the method in a study that investigated possibilities for improving health and safety conditions in the aluminum industry.

Net Promoter Score (NPS) is used to evaluate the Likert scale results. In addition to rating the survey questions from strongly disagree to strongly agree, we asked the respondents to elaborate the answer in order to provide more feedback about the application of the method.

Current way of working

Semcon Devotek follows a Systems Engineering development process combined with principles of Lean Product Development. The internally described process shall serve as a tool for the engineers and managers to ensure the quality of the activities and deliverables in every development project. Appendix B presents illustrations of the current process for the definition of stakeholder requirements and the concept of operation (CONOPS). The phase for stakeholder requirements and CONOPS involves the following activities; defining needs, identifying stakeholders, writing stakeholder requirements, defining key acceptance criteria, and generation and selection of concepts.

Traditionally, Semcon Devotek developed technical solutions to the automobile industry and to the oil and gas industry. In such projects, the customers specified the detailed requirements, and Semcon Devotek were only responsible for the technological solution. Due to development in the market, Semcon Devotek now aims to create value to their customers by including human values in the development process.

Pinto (2018) developed and tested out a visual mapping tool for better including the human values in the Semcon Devotek development process. The tool consists of one-page templates for human stakeholder analysis and use case scenarios. The purpose of the template for *human stakeholder analysis* is to generate human value stakeholder requirements. The *use case scenario* template is for defining systems requirements. The study tested the templates in a multidisciplinary development project in the company. The results were promising in terms of including human values in the requirements. This research applies the visual mapping tool to pursue an effective method for capturing and communicating human values in the internal development process.

Understanding and communicating human values in the development project

We implemented a systematic method for eliciting human values in the development project that use traditional Systems Engineering activities for defining stakeholder needs and requirements. We observed the project team from the startup of the project to the selection of concepts. Figure 3 presents the activities performed and the output from these activities. The blue boxes with a solid outline represents the method for capturing and communicating human values.

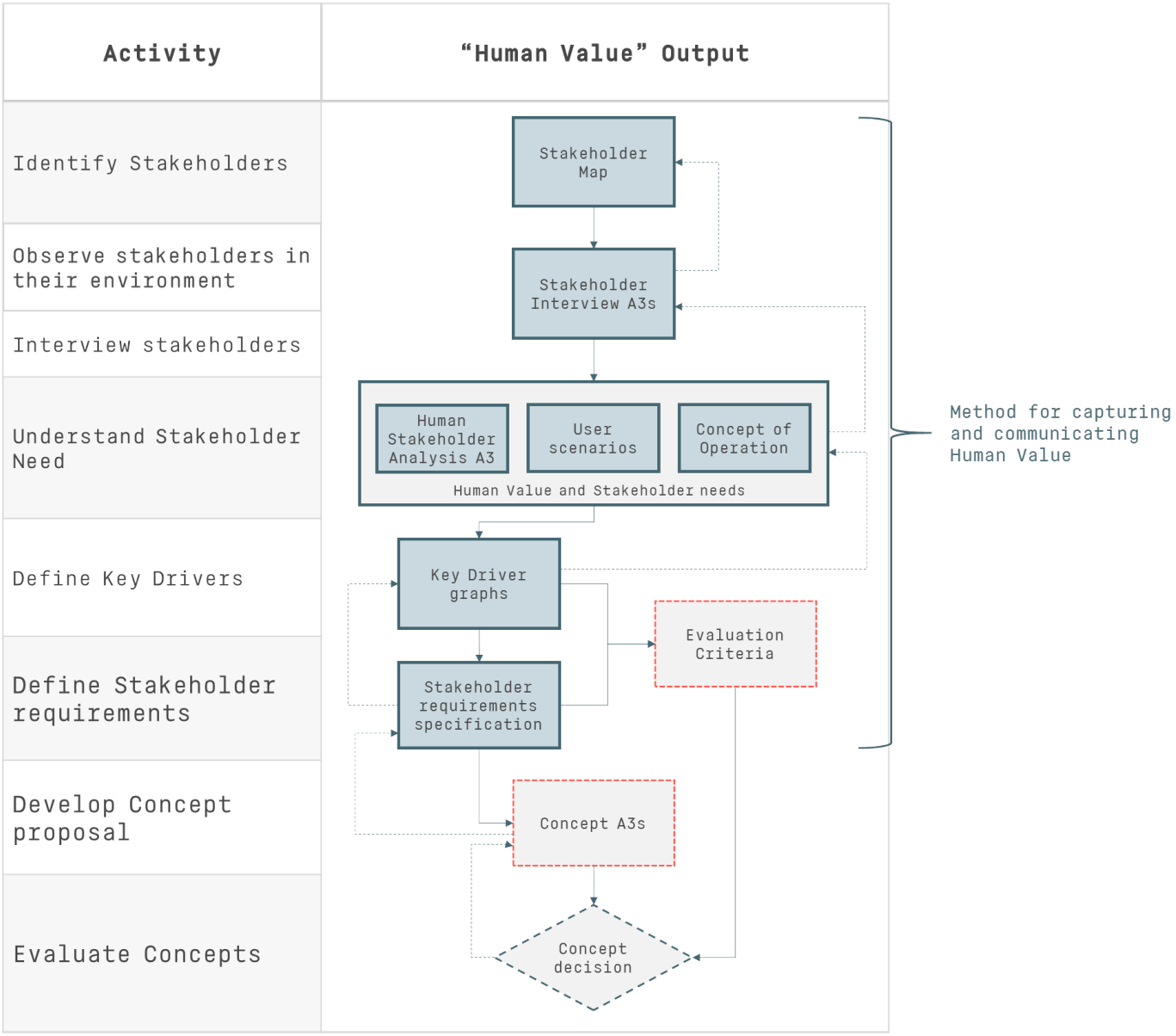

Figure 3. Description of the process conducted in the project, including the method for capturing and communicating Human Values.

Identifying stakeholders. The project team conducted initial research during the startup phase. The customer introduced the business and products to the project team in a kick-off meeting. They explained the problem and presented the stakeholders and their needs. The information gave a starting point to the stakeholder map. The stakeholder map evolved during the stakeholder analysis phase, as the team discovered new stakeholders and acquired new information. The project team used the stakeholder map as a tool in conversations within the team and with stakeholders. It created the basis for the stakeholder interviews, use case scenarios, and the concept of operations.

Stakeholder interviews and observations. The collection of human values was an iterative process. By performing multiple rounds of field visits and stakeholder interviews, we expected the team to achieve a broader understanding and a deeper insight of the problem and its context. For each field visit, the project team had more knowledge than at the previous visit, which allowed them to discover new details. The field visits had two main purposes:

- To learn about the customer's problem and the operations that cause the problem
- To learn about the stakeholders and the human aspects of the system.

The project team performed three visits to different construction sites. They wanted to visit both small and large construction sites, as the customer explained that large construction companies have different needs than smaller companies. The team learned that regulations and controls are stricter in urban areas than in rural areas, due to neighbors and surrounding properties. Table 3 presents the visited construction sites and the interviewed stakeholders.

Construction site	Company	Stakeholders
1. Small scale property in urban area	Small company with two employees	- Machine operator, 5 years of experience. - Service engineer / maintenance - Sales engineer from supplier (client)
2. Large scale road construction project in rural area	Company with approx. 80 operators located on the site, working shifts.	- Machine operator, 30 years of experience - HSE team - Site manager / operation planner
3. Medium scale road construction project in urban area	Company with approx. 15 operators located on the site, working shift	- Machine operators, 10 years of experience - 2 site workers - HSE manager

Table 3. List of visited construction sites and the interviewed stakeholders

A semi-structured interview-guide was prepared for each of the planned stakeholder meetings. The interview-guide worked as a checklist during the visit but were not rigid lists of questions. The purpose was to have a flexible game plan that allowed unexpected subjects to come up. Before the visits, the team asked for permission to take photos and videos of the construction sites and the operations.

By observing stakeholders perform and explain their work, the team registered how the workers interacted with the current system and the environment. Two people from the project team conducted the stakeholder interviews. One guided the conversation while the other observed and took notes. In addition, they recorded the interviews on audio, in order to have full focus on the conversation.

The SE created *Stakeholder Interview A3s* for each stakeholder, containing a high-level summary. The interviewers used the A3s for notes during the interviews and for further documentation after the interview. The Stakeholder Interview A3 has allocated fields for the tasks and responsibility of the stakeholder, in addition to the pains and gains related to the daily work interacting with the system. By documenting the learnings from stakeholder interviews on an A3, the knowledge was available for other members in the project team and to the customer. Appendix C presents an example of the stakeholder interview template, as well as the stakeholder map and an example of the applied interview guide.

Understand Stakeholder Need. The knowledge acquired during field visits provided input to the need statement. The SE together with the project team translated the learnings into top-level descriptions of the need. Figure 4 shows the *Human Stakeholder Analysis A3* (Pinto, 2018), that was used to specify the *desirability, viability,* and *feasibility* for each stakeholder group. The purpose was to identify human values for the definition of stakeholder requirements.

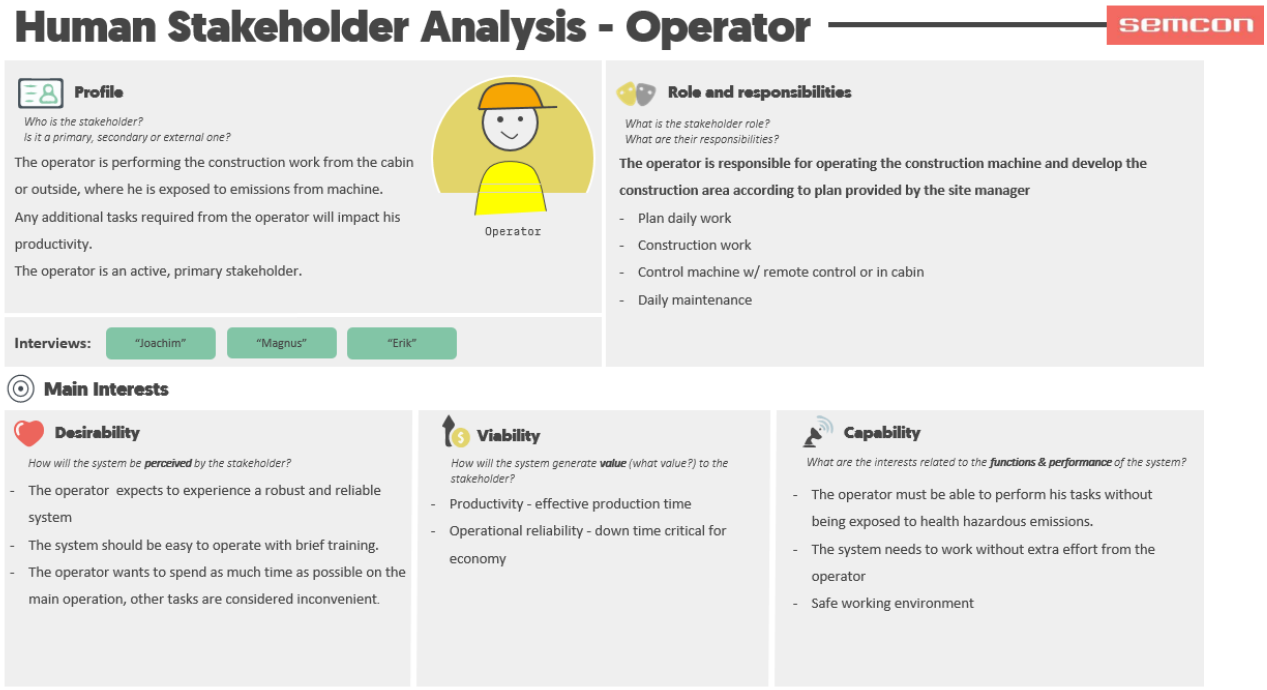

Figure 4. The Human Stakeholder Analysis describes the desirability-, viability-, and feasibility needs of the operators.

In addition to the Human Stakeholder Analysis, the project team created visual maps of user scenarios and CONOPS. In addition to facilitate open discussions, such visual maps are a part of the documentation provided to the customer, for the reasoning of the concept selection.

Defining key drivers and stakeholder requirements. The human stakeholder analyzes, together with the user scenarios and the CONOPS, formed the foundation for the key drivers and the stakeholder requirement specification. The purpose of the key driver graph was to keep the traceability between stakeholder requirements and the stakeholder needs and to create a basis for discussions during concept development and concept evaluation.

Concept generation and selection. The project team sketched and described concept ideas on concept-A3s. The project team generated concepts in internal brainstorming sessions and in workshops with the customer and other experts from the construction industry. In the workshops, the workshop facilitator presented the material from field visits and stakeholder analyzes to provide context to the problem. The concept was later evaluated in multiple iterations. The SE defined the criteria for evaluation based on the input from stakeholder analyzes, key drivers, and stakeholder requirements, with the purpose of highlighting the human values in the selection of possible solutions.

Results and analysis

Interview analysis. This chapter presents the main results from the initial in-depth interviews of the respondents in Table 1. Figure 5 presents the first part of the result.

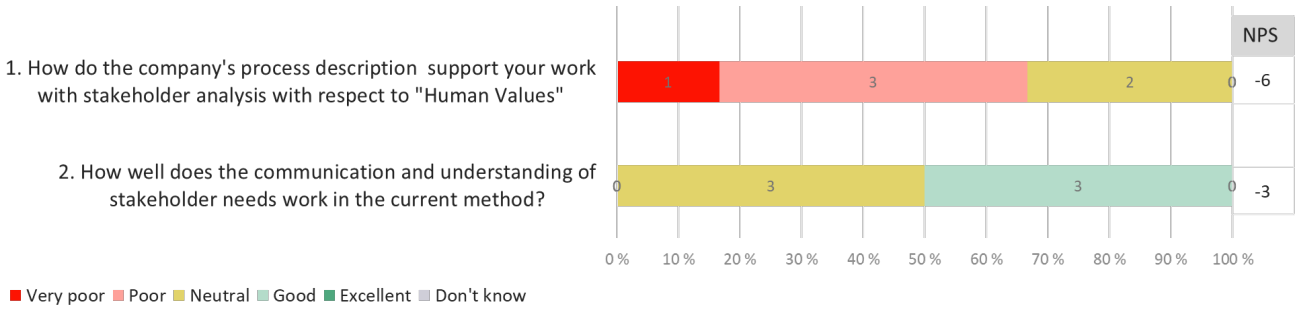

Figure 5. Survey questions provided to SE engineers to measure current state, part 1

The SEs in Semcon Devotek experience that the process description for product development does not provide sufficient support to their work of collecting and communicating human values. It provides limited guidance for the elicitation of the stakeholder needs and requirements, especially in terms of human value.

The interview participants consider the communication and understanding of the stakeholder needs as *good* or *neutral*. The SEs usually document stakeholder analyzes in A3s, reports, or in the architecting tool Enterprise Architect (EA). The choice of documentation depends on the size of the project, the customer's preferences, and the preference of the SE performing the stakeholder work. The process description does not specify how the SE should document the analysis work.

Figure 6 presents the second part of the survey results. One respondent says that needs discovered in stakeholder analysis are to a *low* degree included in the definition of stakeholder requirements. Three respondents say that they are included in a *high* degree, while two people do not know.

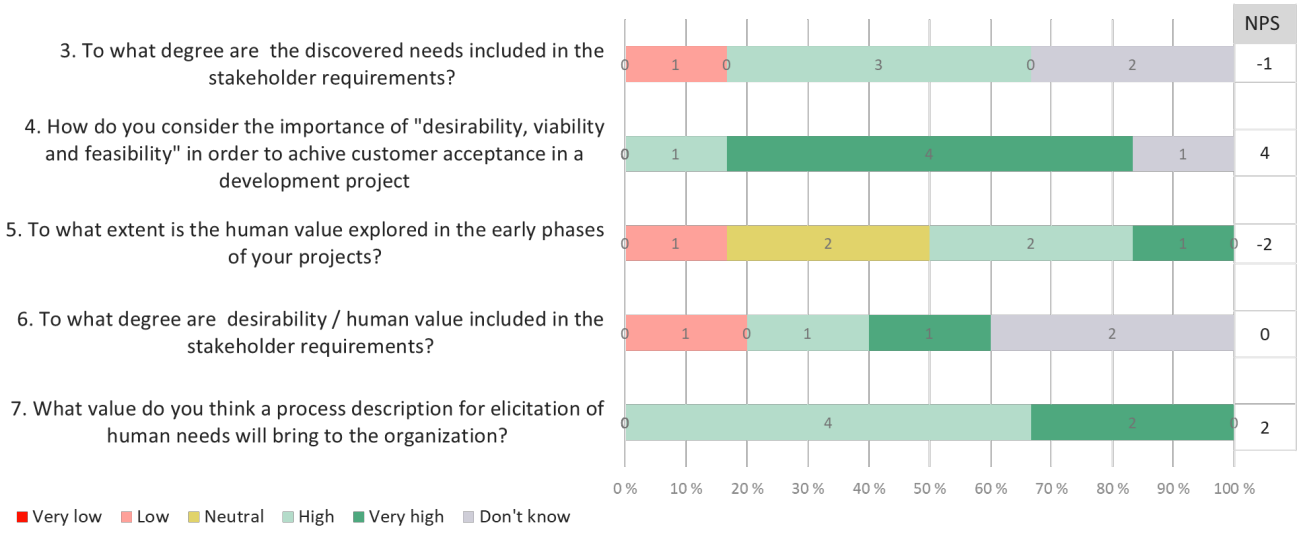

Figure 6. Survey questions provided to SEs to measure current state, part 2

We learned that the respondents experience a different degree of focus on the human aspect in projects. One of the respondents had experienced one project with a *high* focus on human values, and one with very *low* focus. Another respondent had experienced everything from *low* to *very high* awareness of human values. How the human values are included in the stakeholder requirements also varies between the different projects.

Four out of six interview participants consider the importance of *desirability, viability,* and *feasibility* as *very high,* one thinks the importance is *high,* and one does not know. One participant expresses that the three aspects should be important drivers in every development projects. The SEs believe that a process description for elicitation of human needs will benefit the company, as it improves the quality of the deliveries.

Analysis of stakeholder requirements. We compared initial requirements from the customer specification with the stakeholder requirements derived from field visits and stakeholder interviews. Appendix D presents the requirements addressing humans, provided by the customer, and the stakeholder requirements defined in this study. We found that the customer's requirement specification had three main drivers in addition to reduce emissions. The system needed to be robust, inexpensive, and user-friendly. The specification listed operators and maintenance personnel as important stakeholders. We identified the following findings:

- Three stakeholder requirements specify how the stakeholders should perceive the system. The initial specification includes one, regarding the visual branding of the products.
- The stakeholder requirements consider more stakeholders than the customer specification. In addition to operator, maintainer, and customer, they also include neighbors, manufacturer, and construction companies.
- In total, the stakeholder requirements included 12 requirement that addresses human factors or human values. The initial specification contains seven requirements for human factors.

Feedback survey result. Figure 7 presents the feedback survey results from the respondents in Table 2. We used NPS to analyze the Likert scale results. NPS assumes that respondents who "strongly agree" will promote our method. Those who answer "neutral", "disagree", or "strongly disagree" will probably complain about the method (Reichheld, 2003). We consider NPS above zero as a positive score.

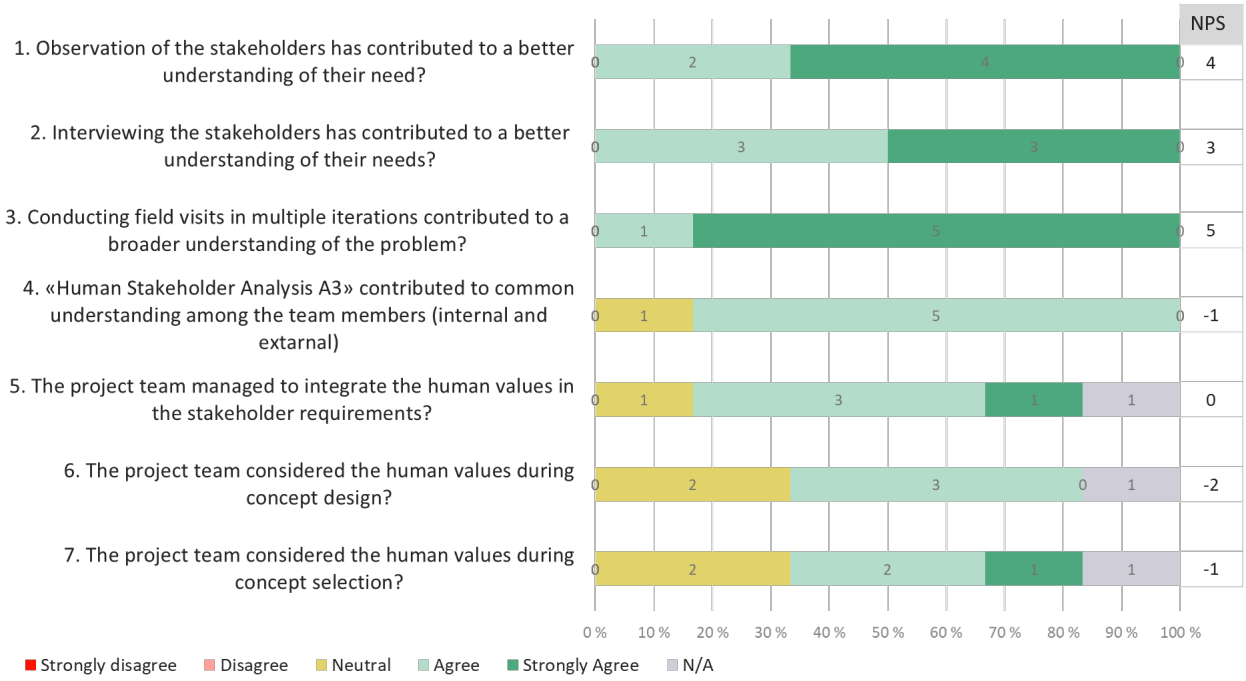

Figure 7. Result from survey provided to project team members, including customer, to measure effectiveness of the method.

The results from the feedback survey indicate that the respondents, including project manager and customer, experienced that the team obtained a better understanding of the needs, by observing the stakeholder's work and by interviewing them in the context of their work.

The respondents experienced that they achieved a broader understanding of the problem by conducting multiple iterations of the field visits, as they gained more confidence in the knowledge they acquired. Meeting stakeholders with different perspectives and problems contributed to the broader understanding.

One respondent pointed that he/she did not look at the Human Stakeholder Analysis A3s during the project, thus, he/she rated the value of the A3 as *neutral*. The other five respondents *agree* that the

Human Stakeholder Analysis A3s contribute to a mutual understanding among the team members. The NPS is -1. Three of the respondents *agree* that the project team managed to include the human values in the stakeholder requirements while one respondent *strongly agrees.* The NPS is 0.

Three respondents *agree* that the team managed to consider human value while developing concepts, while two respondents are *neutral.* The response results in an NPS at -2. We received a comment from one participant that "user experience" could have gotten more attention through the concept development phase.

One respondent *strongly agrees* that the team considered the human needs during concept selection, while two *agrees*, and two responds *neutral*, which gives an NPS at -1. One respondent commented that human value should be more visible in the key drivers and evaluation matrices.

The SE in the additional aluminum project case responded N/A on the last two questions in the survey, as the project had not reached the stage of concept development and evaluation at the time of the survey.

Discussion

There is a need for better including human values in Systems Engineering to ensure that human aspects are not lost in the development of new systems. The team of engineers has captured and communicated emotional needs in order to include human values in the specification of the system.

Design Thinking offers tools for understanding the user, and for processing the knowledge into meaningful need definitions. Watanabe et al. (2017), Zhao (2015), Wade et al. (2017), Tomita et al. (2017), and Shafaat & Kenley (2015) suggested approaches from Design Thinking in order to include the human as a part of the system.

From the feedback survey, we learn that the project participants experience the stakeholder interviews and observation as effective activities for understanding the needs of stakeholders. The respondents from the feedback survey indicate that conducting multiple field visit facilitates a better understanding of the problem and its context. Observing and engaging with stakeholders complies with the Design Thinking *empathy* mode. Plattner (2013) claimed that to design for people, the designer must gain empathy for who the people are, and what is important to them.

Project participants experienced that use of photos, videos, and visual descriptions are significant for obtaining knowledge and mutual understanding of human values. Plattner (2013) stated that using mapping techniques in the transition between *empathize* and *define* mode would help to achieve a mutual understanding of stakeholder needs. This is also widely used by designers, to help understanding complex systems (Sevaldson, 2013). By documenting the stakeholder interviews and observations on *Stakeholder Interview A3s,* we observed that the project participants were able to synthesize the learnings from field visits. The A3s provides a point of view of real persons related to the problem of interest.

Five out of six survey respondents agree that the Human Stakeholder Analysis A3s, developed by Pinto (2018), contribute to a mutual understanding among the project participants. Complex problems can be hard to grasp and communicate with only words. We also observed that visual presentations helped the actors to see the whole picture and facilitate discussions. The customer experienced that Human Stakeholder Analysis A3s were effective for communicating with managers and other external stakeholders. The Double Diamond model (Design Council, 2015) illustrates the alternating modes of diverging and converging. Plattner (2013) described that the purpose of the define mode is to bring clarity and focus to the design space. However, the negative NPS in the feedback survey indicates that the respondents would not "promote" the Human Stakeholder A3s. We consider the Human Stakeholder Analysis template as a contribution to the increasing awareness of Human Values in the project, but we cannot conclude whether the template is effective for eliciting stakeholder requirements at this point.

The stakeholder requirements contain nine requirements that address human factors, such as usability. These requirements don't address human value directly, but they will contribute to the desirability of the system indirectly. Three requirements specify emotional factors such as how the stakeholder experiences the system. From the NPS in the feedback survey, we learn that the respondents are not convinced that the team managed to include human values in the stakeholder requirements. This indicates that the organization needs to conduct further studies on how to transform human values into good requirements. An interesting finding is that the stakeholder requirements represent more stakeholder groups than the customer specification does. This indicates that the field visits resulted in an understanding of not only the primary stakeholders but also secondary or external stakeholders.

Results from the feedback survey indicate that the awareness of human values could have been stronger during concept development and concept selection. The challenge with human value is that it is hard to grasp, and difficult to measure. We observed that the team tend to forget human values during the concept generation and during concept evaluation. This indicates that the company needs to further investigate how to maintain awareness of human values during the design phase. The project team has discussed that key drivers should highlight human values explicitly, as a mean to keep awareness during concept development and evaluation. Handley et al. (2008) suggested a Human View in the system architecture framework, as a mean to integrate human as part of the system. This may ensure that human values are visible in the specification of the system through the project life. For the definition of systems requirements, Pinto (2018) introduced use case scenario templates in Semcon Devotek. The participants in his study experienced increased awareness of human values (Pinto, 2018).

We learn from in-depth interviews that the importance of exploring human values is not equally recognized and communicated within Semcon Devotek, nor is it always communicated to customers. Awareness of human values varies from project to project due to multiple reasons. In some cases, the customer's budget is too low for an extensive investigation of stakeholders and their needs. Other times, the time limits are too short. SEs also experience that confidentiality agreements prevent them from engaging with essential stakeholders, which forces the team to settle with information provided by the customer.

In previous studies on human values performed in the company, the customer has provided information about stakeholder. This paper emphasizes the value of engaging with real stakeholders to elicit human values. The customer was positive to the team's approach of exploring stakeholders and human value, and they experience that the approach creates value to their business. The project team and the SEs have discussed the importance of communicating the value of stakeholder interviews to new customers, to integrate human values with technology- and business aspects.

Learnings from the in-depth interviews indicate that there is a need for a more comprehensive process description to ensure that human values are included in stakeholder needs and requirements. However, due to the large variability in projects, such process description needs to be flexible. It is not obvious which activities will bring value to a specific project in beforehand. By using the process description as a toolbox, together with reference cases from earlier projects, the project team should be able to explore human values and to utilize this knowledge when designing a solution that satisfies the stakeholders.

Validity. The number of respondents in the survey and interviews limits the validity of this research. We collected data from six SEs in the in-depth interviews, and from six project members in the feedback survey. We chose participants based on their experience with Systems Engineering and their relevance to the project case. We consider the result from the interviews and survey as tendencies rather than quantifiable results, as the number of responses is too low for the results to be processed statistically. The industry-as-laboratory research method also has limitations, because the active role of the researcher in the investigated method can give biased conclusions.

Conclusion

This study applies Design Thinking techniques to understand and communicate human values in Systems Engineering. A systematic method for interviewing and observing stakeholders enables the SE to include human values in the stakeholder needs and requirements. Project participants experience that stakeholder interviews and observations are valuable and suitable for acquiring knowledge about stakeholder needs, including human values. An iterative process of field visits and interviews contributes to a broader understanding of the problem. We consider visual maps as effective tools for communicating human values, which results in increased awareness among project participants.

Application of the method in the development project resulted in nine requirements addressing humans in terms of usability, and three requirements specifying human values. The initial customer specification included seven requirements for usability and one for visual branding. We find that the activities for exploring human values have resulted in more stakeholder requirements. However, the feedback results do not strongly indicate whether it was the Human Stakeholder Analysis A3 that contributed to the definition of human value requirements, or if it was the increased awareness of human values in the project.

From in-depth interviews, we find that the SEs consider human values as an important aspect of product development. We consider the method to applicable to companies developing systems that interact with human stakeholders. However, the SE must evaluate the needs and constraints in every project and plan the activities accordingly.

Future research. We recommend investigating further the effectiveness of Human Stakeholder Analysis A3s as a tool for deriving stakeholder requirements. The study should also suggest a method to improve the quality of requirements for human values, including how to validate such requirements. Further studies are also necessary to ensure that human values become visible when designing the system and included in system requirements and detail design. The study identified that a Human View in the architecture framework is a possible solution.

Acknowledgments

This research is part of a larger research project on Human Systems Engineering Innovation Framework (H-SEIF), funded by the Norwegian government through Oslofjordfondet.

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Biography

Nina Marie Sjøkvist has worked as an engineer in mechanical systems development at Semcon Norge AS since 2015. She is often involved in the early phases of product development projects, such as the stakeholder analysis and requirements definition phase. She graduated from the Systems Engineering Industrial Master program at the University of South-Eastern Norway in 2018. The master program also included a semester at Stevens Institute of Technology in New Jersey, USA. She also holds a bachelor's degree in mechanical design engineering from 2013.

Marianne Kjørstad is employed as a PhD student at the University of South-Eastern Norway, where she focuses on how to better include the human aspects within early phase systems engineering to provide innovations. Marianne holds a Master of Science in Product Design and Manufacturing from the Norwegian University of Science and Technology. She has worked in the oil and gas industry for over 10 years, before starting in the academia focusing on research on systems engineering. She started her PhD study autumn 2017.

Appendix A

Depth interview guide (English)

A. Introduction

a) My master thesis
b) Consent of recording and info about anonymity

B. Personalia

a) Name and age
b) Experience, how long have you worked in Semcon Devotek?
c) Work tasks and responsibilities

C. General stakeholder analysis

a) To what extent do you use the process description (Devotek Management Norm) in the first phase of a project (stakeholder analysis)?
b) How do the company's process description support your work with stakeholder analysis with respect to «Human Values»?

Very poor	Poor	Neutral	Good	Excellent	Don't know

c) Can you explain how you / your projects perform the stakeholder process from startup to the definition of stakeholder requirements?
d) Can you describe what method you have used for communicating and understanding between the project members and to client?
   - How well does the communication and understanding of stakeholder needs work in the current method?

Very poor	Poor	Neutral	Good	Excellent	Don't know

e) How much time is allocated in the project plan to perform stakeholder analysis and investigation?

f) To what degree are the discovered needs included in the stakeholder requirements?

Very low	Low	Neutral	High	Very high	Don't know

D. New method

a) What is your understanding of the terms «desirability, viability and feasibility»?
   - How do you consider the «importance of desirability, viability and feasibility» in order to achieve customer acceptance in a development project?

Very low	Low	Neutral	High	Very high	Don't know

b) To what extent is human values explored in the early phases of your projects?

Very low	Low	Neutral	High	Very high	Don't know

c) To what extent are desirability / human values included in the stakeholder requirements?

Very low	Low	Neutral	High	Very high	Don't know

d) How would a process description for exploring human values support your work with stakeholder analysis?

e) What value do you think a process description for elicitation of human values would bring to the organization?

Very low	Low	Neutral	High	Very high	Don't know

Appendix B

Current way of working in Semcon Devotek

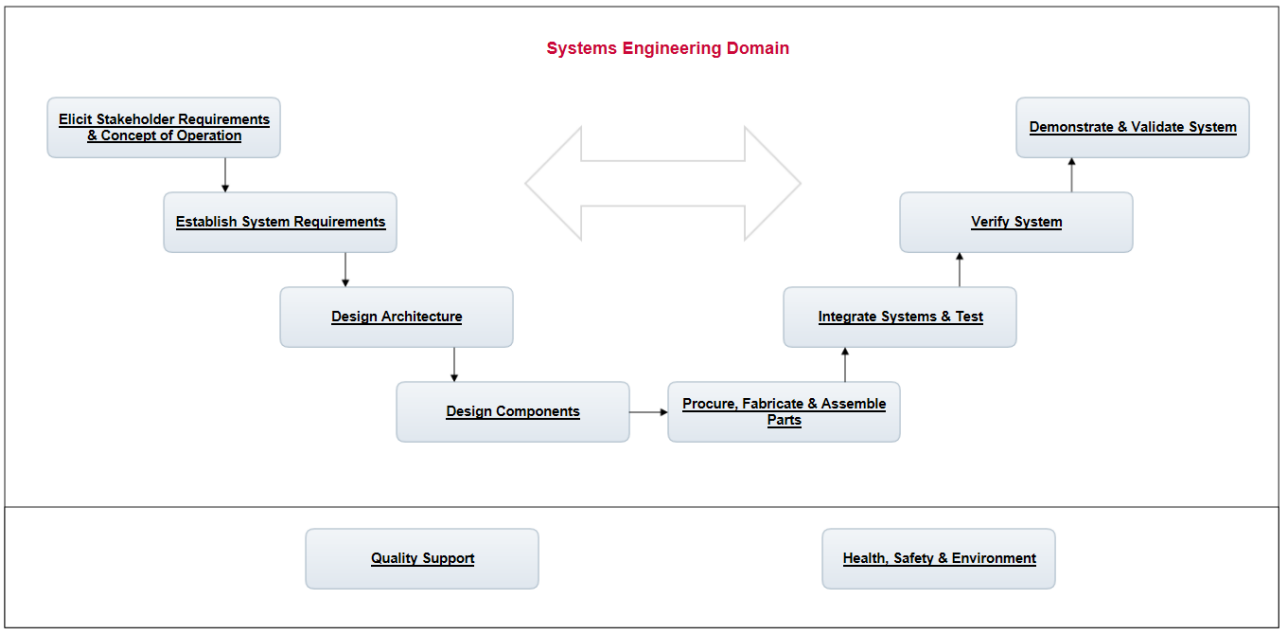


Figure B1. Semcon Devotek process description overview

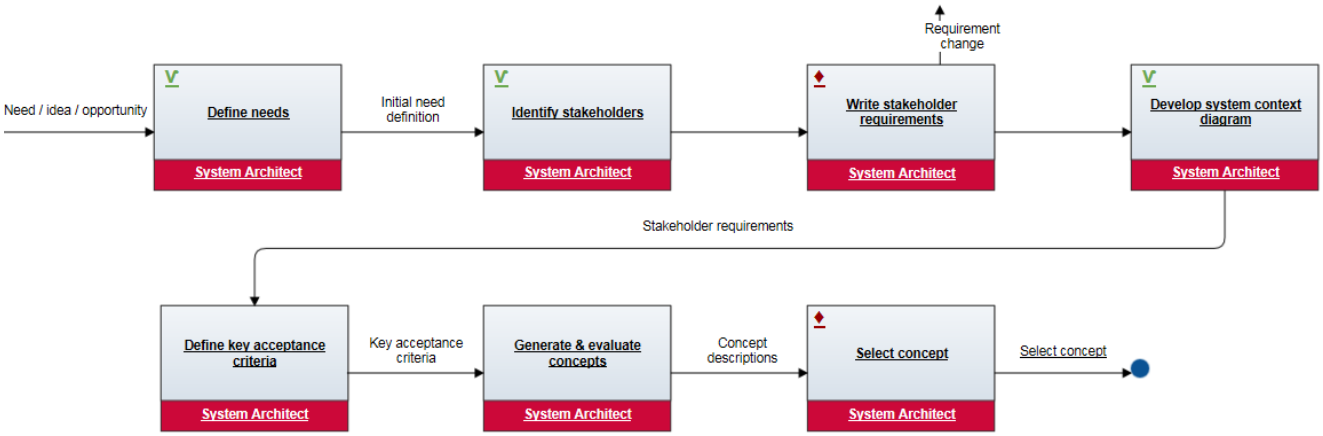
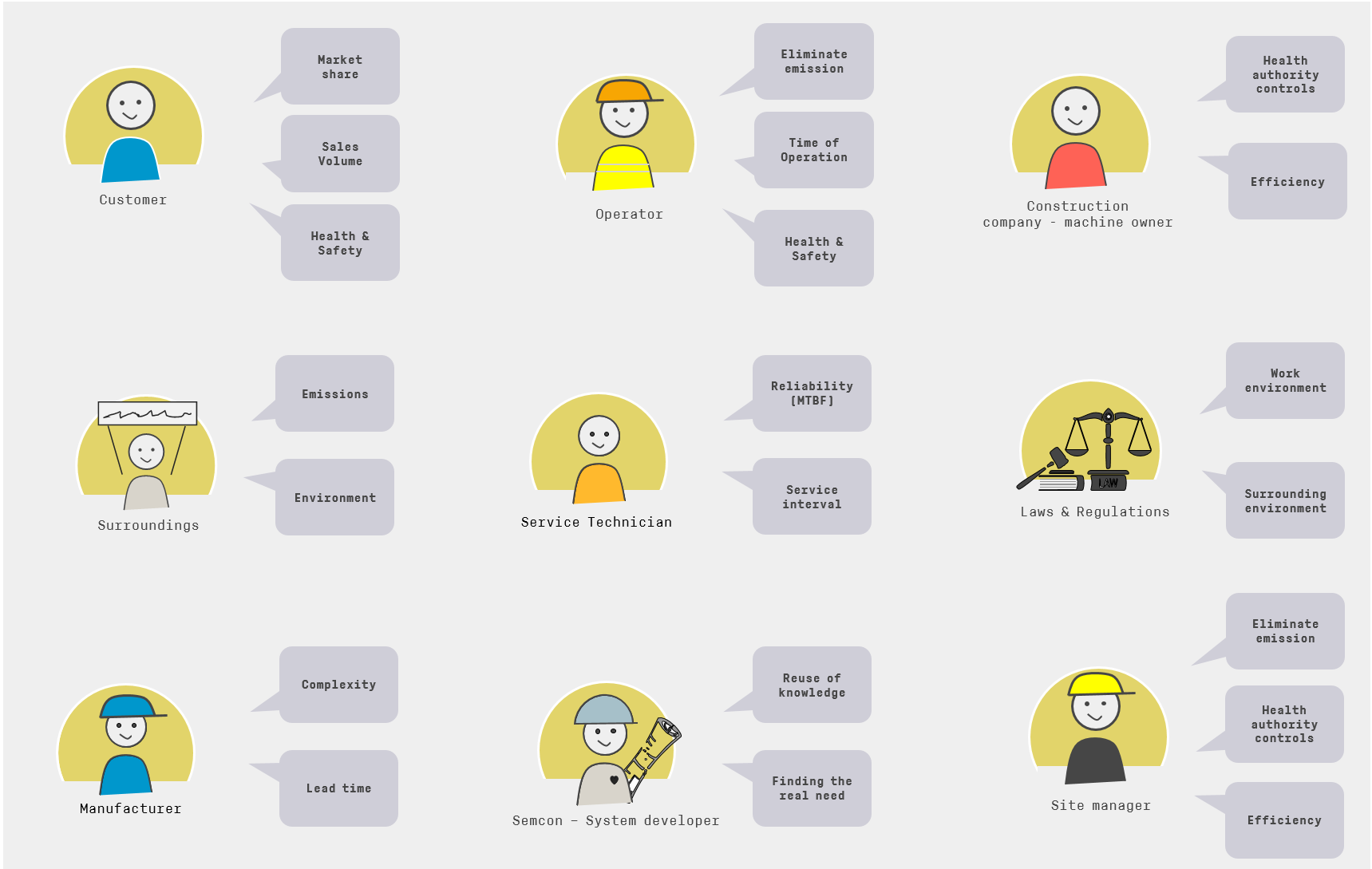


Figure B2. Process for "Elicit Stakeholder Requirement and Concept of Operation"

The arrows between the blocks in Figure B2 represents the outputs and inputs from each activity. The upward directed arrow on the stakeholder requirements block, illustrates that stakeholder requirements often changes during the design process, and that the activities are iterative.

Appendix C

Information in this appendix has been edited to remove confidential information about the project.



Operator «Joachim» in Kongsberg

semcon

Profile

Who is the stakeholder?
Is it a primary, secondary or external one?

- Joachim , worked in construction industry 10 years.
- Works in a medium sized company
- Aware of the health issues, but do not think that much about it in the daily
- He is a primary and active stakeholder

Role and responsibilities

What is the stakeholder role?
What are their responsibilities?

- Perform operation in according to plan provided by manager
- Responsible for performing safe operation.
- Responsible for the daily maintenance of his machine, and to hand it over in proper condition to next shift

Tasks

Pains

Gains

INTERVIEW GUIDE – MACHINE OPERATOR (60 MINUTES)

A. Opening.

a] Interview introduction

1. Who we are and what we are doing.

B. Personal background questions.

a] What is your name and age?

b] Where do you live?

c] Do you travel to/from site every day?

1. How long is your stay on the site?

d] How long is your working day?

C. Transactional questions.

a] When will this project finish for you?

b] In which site were you before this one?

c] Do you know what will be your next site?

d] Did you work for other companies before?

e] For how long do you work for this company?

f] Always as a "driller"?

g] Please tell me about your work experience.

h] How long have you been operating this machine?

i] Have you been working with other machines?

1. Which ones?
2. For how long?
3. Which one do you prefer? Why?

j] Did you have training for this machine?

1. When, where, how long?

k] Did you have training for other machines you used previously?

l] Who decides about which machine to use?

D. Go deeper questions.

a] Can you please explain [or show] what you do?

1. How do you know what to do? Who informs you?
   - Does anyone check the work during or after?
2. How do you prepare your work and the machine?
3. What can go wrong?
   - How often does it go wrong? :]
4. When is your work finished?
   - What do you deliver?

     → To whom? [Who is your internal customer?]
5. What happens after your work? Blasting?

b] What are the easiest things you do?

1. Which improvement do you think was the most important in the last years?

c] What are the most difficult aspects of your job? [Guide the dialogue towards environment aspects: surroundings, site cleaning, available space, weather, noise, etc.].

1. How would you solve it?

E. Fade-out questions [still important].

a] Who performs the maintenance of the machine? You or company's technical staff?

b] Who orders the service for the machines?

1. Who performs it?
2. Does it take long?
   - Do you [like to] get a replacement machine?

c] What would you improve/change generally in your work?

d] What would you improve/change specifically on the drilling machine?

e] Do you have a good story to tell about your work? A funny or a scary one, maybe?

Appendix D

Stakeholder	Client Requirement specification	Human Value?
Operator	Require minimal operator effort	No
	System needs to be operational without major daily maintenance	No
	Strive for an automatic system	No
Maintenance personnel	Strive to ease serviceability	No
	Ease of cleansing	No
	Service interval needs to fit with the service interval of existing machines	No
Client	Visual strength - important for customers that choose the brand	Yes
Total requirements addressing humans	**7**	
Total human value requirements	**1**	

Table E1. Requirements specifying human factors and human values, provided by customer

Stakeholder	Client Requirement specification	Human Value?
Operator	The system needs to be automatic	No
	The system needs to require minimum effort from operator	No
	The system performance needs to be independent of operator's skill	No
Maintenance personnel	The system needs to provide easy handling and access to parts during maintenance	No
	Only require standardized tools	No
	Service interval needs to fit with the service interval of existing machines	No
Client	The system needs to be perceived as robust and reliable	Yes
	The solution needs to be perceived as innovative	Yes
Neighbours	The system needs to be perceived as environmental friendly	Yes
Manufacturer	The design needs to support easy assembling and standardized work	No
	System needs to be designed for "poka-yoke" production	No
Construction Company:	System needs to Improve productivity compared to today's solutions	No
Total requirements addressing humans	**12**	
Total human value requirements	**3**	

Table E2. Stakeholder requirements for human factors and human values defined by project team