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Helping Systems Engineers to Include Human Values in Early Specification of Systems

Master's thesis
Industrial Design master's programme
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To my daughter and son.
– Joy comes from the act of creating.

Summary

The thesis is publication-based and complemented with the paper “*Inclusion of human values in the specification of systems: bridging design and systems engineering*” published in 2019, July, in INCOSE International Symposium, volume 29, no. 1, pp. 284-300.

The purpose was to investigate ways to apply Design Thinking principles in the context of Systems Engineering to increase the attention of early specifications of systems in human values. It sought to answer the question “*How to ensure that systems engineers include human values in the early specification of systems?*” by introducing changes to the activities of identifying stakeholders and describing use case scenarios. These activities affect greatly the specification of systems.

The overarching research methodology was a combination of **case study** and **participatory action research** (PAR). The intervention – foundational to PAR – was steered by the human-centred design process and resulted in the creation of an artefact used to perform the above-mentioned activities. The case study provided the background to implement a quasi-experiment comparing the pre-intervention specification of a system with the specification of the same system which resulted from the application of the artefact.

The results of interest of the research can be summed up to, 1) the artefact – a set of two visual canvas used to identify stakeholders and describe use case scenarios, 2) the requirements generated during the intervention, and 3) the feedback provided by the participants.

The research concludes that the artefact helped to better specify human values. The application of the artefact ensures visibility of it. Consequently, the number of requirements covering these values increased significantly. Moreover, besides the small number of the survey’s respondents, participants had reported the intervention and the artefact to be successful.

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Chapter 1

INTRODUCTION

1. Background

Global trends

It is notoriously hard to systematically launch commercial successful products and services, regardless of physical, service, or digital settings. Only the very best designs now stand out from the crowd, given the rapid rise in consumer expectations driven by the user preferences, instant access to global information and reviews and the blurring of lines between hardware, software, and services. Companies need stronger design capabilities than ever before and Design Thinking increasingly becomes more important. (Sheppard et al., 2018). Pinto et al. (2019) stated that

This shift is a response to the increasing complexity of modern technology and modern business (Sheppard et al., 2018). Gartner, a research and advisory company and a member of the S&P 500, has listed on their Hype Cycle for Emerging Technologies, for the third year in a row, a trend towards human-centric technology (Gartner, 2015, 2016, 2017). Increasingly, corporations and professional services firms are working to create design-centric cultures. *“Technology will continue to become more human-centric to the point where it will introduce transparency between people, businesses and things”* (Gartner, 2016). This is happening because the technological complexity of products, services, and processes are constantly increasing. Users do not deal well with high levels of complexity and need their interactions with technologies and other systems to be intuitive and highly gratifying (Kolko, 2015). Design Thinking is an essential tool to create those kinds of interactions for simplifying and humanizing. Such qualities need to be at the centre of organizations and spread transversally (Kolko, 2015). The Design Thinking process is a system that overlaps perspectives. Viability represents the business perspective; desirability echoes the user’s perspective; and feasibility contains the technology perspective (Chasanidou et al., 2015). The “sweet pot for innovation” is at the intersection of these perspectives, i.e. when all three perspectives are present and balanced (Brown, 2009).

H-SEIF Project

Kongsberg, a small town in Norway, is home to several world-class companies ranging from the energy sector (oil & gas) to the defence, maritime, automotive and aviation sectors. Most of these companies are product owners and not merely product producers. A common denominator for most of the companies is the methodology employed throughout the product lifecycle, i.e. from concept to design, to production, to market launch, maintenance, and finally to retirement. Systems Engineering practices are foundational for these companies. Moreover, the fact that they do not compete in the same markets helped to create a unique industry cluster. Consequently, there has been several cross-company projects fostering and improving collaboration and “ways of working”. Not seldom, these projects include companies from other clusters and places from all over Norway.

The University College of Southeast Norway, currently University of South-Eastern Norway, executed a qualification project in 2016 founded by Oslofjordfondet and named “Framing the Systems Engineering Innovation Platform”. Through active collaboration with both academia and industry, the project came to three main conclusions (Falk et al., 2016). Firstly, there is a strong need for integrating human aspects (physiological, psychological and emotive) in Systems Engineering. Secondly, it is important to validate the solutions with respect to human needs in a cost-effective manner. Thirdly, it concluded that the degree of innovation depends on the way the design team collaborates when they create complex systems.

The research team identified research gaps in two main directions:

1. The collaborative business aspect of system engineering.
2. The human aspects related to innovations of complex systems.

The Human Systems Engineering Innovation Framework (H-SEIF) was established in 2017 aiming at the second research gap. H-SEIF aimed at increasing the innovation efficiency by systematically including human factors in product development. The project core lies in Kongsberg, with cooperation with other industrial clusters in Raufoss and Ulsteinvik, and it will directly stimulate innovation within each industrial partner as well as within the clusters.

Located in Kongsberg is Kongsberg Innovation, Semcon Devotek, TechnipFMC and University College of Southeast Norway. The Kongsberg partners, recognized for their strong application of Systems Engineering, were experiencing a global trend towards more human-

centric innovations, and the need to quickly validate their ideas and products. This trend is represented by the Design Thinking movement in e.g. Silicon Valley and Stanford (Brown, 2008, Buchanan, 1992, Cross et al., 1992, Kimbell, 2009, Lockwood, 2010, Nelson & Stolterman, 2012, Rowe, 1987), and the theories are transferring to the University of South-Eastern Norway through close collaboration with Stanford School of Design.

Researched company

Semcon Devotek, currently named Semcon Norway, was the company that participated in this research. It is a development company based in Kongsberg, Norway, with headquarter in Gothenburg, Sweden. It develops, for more than 20 years, advanced technical products on behalf of customers in various industries, including automotive, maritime, oil and gas, industrial and defence sectors. The areas of expertise include systems engineering, mechanical design, numerical analysis, machining and production, product testing, dynamic systems and control, electronics development and embedded development. The company is an independent technology provider that takes the product all the way from idea, through prototyping, simulation, production and testing to finished product.

Semcon Devotek recognized the need of better include the human values in projects. Consequently, it expected to design and develop products or systems that create more value to its customers by focusing on delivering the right user experiences. The company trusts that a good balance between aspects of business (viability), human values (desirability) and technology (feasibility) will result in more successful products (see appendix A. A3 Customer Interest).

2. Objectives and research question

Current trends resulting of the Design Thinking movement, H-SEIF project and Semcon Devotek provide the context of this research. The researcher sought to identify opportunities to bridge Systems Engineering and Design Thinking approaches, especially human-centred design, and proposed a solution to connect both. The identification of such opportunities as well as the creation of possible solutions were framed by principles of Design Thinking.

The hypothesis is that the introduction of changes to the activity of identifying and analysing human stakeholders will improve the understanding of the stakeholders' expectations and will contribute to better capture it on stakeholders' requirements. In the same fashion, introducing

improvements on the description of “use case scenarios” involving human actors, should result in better understanding of human experiences and the interactions that will facilitate it. Thus, the system requirements will specify these interactions and expected delivered experiences.

This research aims to answer the question “How to ensure that systems engineers include human values in the early specification of systems?”

An answer to the question implies a change in the underlying motivations and/or ways of working of systems engineers involved in the case study. Moreover, this research clearly aims at improving practical aspects of the application of Systems Engineering. The hypothesis is that during the application of Systems Engineering the analysis of human stakeholders covering desirability aspects (emotional, cultural and social wishes), will result in stakeholders’ requirements addressing those aspects. Similarly, the description of use case scenarios considering the interactions with the actors and how these interactions should be perceived, will result in system requirements specifying the human experience.

3. Methodology

Central to the research was **case study** methodology. The methodology is widely used in organizational studies in disciplines of sociology, industrial relations, and anthropology (Hartley, 1994). Case studies consist of detailed investigation of groups within an organization, or one or several organizations, in order to provide an analysis of the context and processes involved in the phenomenon under study (Meyer, 2001).

As a research strategy, Yin (2014, 2017) and Eisenhardt (1989) give valuable insights into the case study, but little guidance regarding design decisions and execution planning. On one hand, the methodology has produced several poor case studies leading to criticism, especially from the quantitative field of research (Cook & Campbell, 1979). On the other hand, this is a strength because it allows tailoring the design and data collection actions to the research question. Thus, the approach is particularly useful for responding to how and why questions about a present set of events (Leonard-Barton, 1990).

Also central was **participatory action research** (PAR). PAR is a democratic and self-reflective investigation that researchers undertake with the collaboration of those being studied, for the purposes of acting or making change (Baum et al., 2006, Reason & Bradbury, 2001). The main element of PAR lies on *"the attitudes of researchers, which in turn determine how,*

by, and for whom research is conceptualized and conducted" (Cornwall & Jewkes, 1995). It differs from conventional research in three ways. Its purpose is to enable action – it seeks to understand and improve the world by changing it; both the researched and researcher share the power to deliberate, “transforming” throughout the process the researched into researcher; and lastly, PAR does not remove data and information from their contexts and encourages the active involvement of the ones being researched (Baum et al., 2006).

Ideally, PAR is a process where researchers and participants develop methods and goals, participating in the gather and analysis of data, and implement the results in a way that raises consciousness and promotes changes in the direction and control of the participating group or community (Reason, 1994). Smith (1997) describes PAR as a dynamic process that develops from the unique needs, challenges, and learning experiences specific to a given group.

In this research, case study and PAR form the overarching research strategy. PAR seeks to understand and improve the world by changing it. In the context of the case study, the **Design Thinking framework** (Fig. 1), in particular the human-centred design process (Brown, 2009, Tschimmel, 2012), was extensively used and sets the framework for the application of participatory action research. The application of the Design Thinking approach resulted in an artefact (referred as *new tool* in the published paper) – a set of canvasses. The artefact was designed, tested and used in order to improve the quantity and quality of the requirements created to specify a system by the engineers applying the Systems Engineering approach.

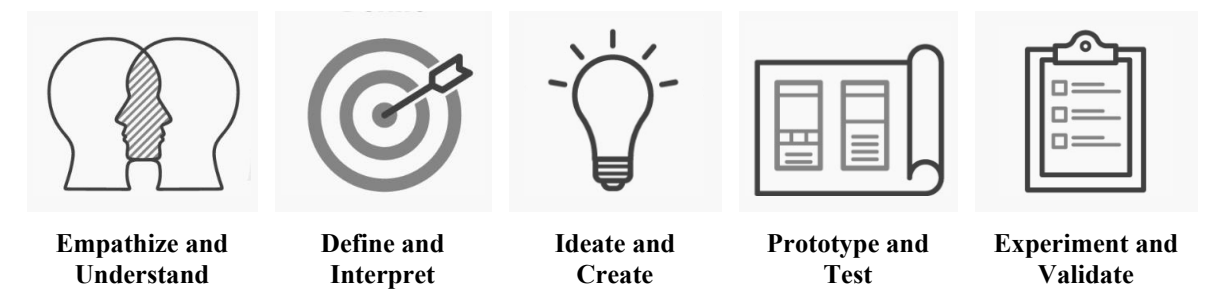


Figure 1. Illustration of the Design Thinking approach applied in PAR
Illustrations copyrighted to Teo Yu Siang and Interaction Design Foundation.

The case study focuses on the design and development of a multi-disciplinary and highly complex solution for the maritime market. The project demanded expertise across the main competencies available at the company – systems engineering, mechanical design, numerical analysis, machining and production, product testing and validation and embedded development (software and electronics to control dynamic systems). On the account of having a better balance between desirability, viability and feasibility aspects, the project also requested

knowledge of user interaction and experience, usability and ergonomics, design management and marketing. The core members of the project team are the project manager, the system architect and the discipline leaders – mechanical, embedded, production & assembly, testing & validation and design. As for other project teams in the company, team members are pulled in or out throughout the development according to the project plan and specific needs. Six of these members had actively participated in the case study, namely the project manager, the systems architect, the lead designer and three systems engineers. The behaviour of the engineers involved in all phases of the case study were closely followed by the researcher. This research represents a traditional use of case studies in process evaluations, but the method helped to analyse and document the interference (Yin, 2017).

Table 1. Roles and experience of the participants of the case study.

Participant's role	Quantity	Years of experience (professional)	Years of experience (role specific)
Systems engineer	3	1-3	1-3
Design leader	1	12	7
System architect	1	11	5
Project manager	1	14	9

The case study investigates a **quasi-experiment** (Leedy & Ormrod, 2005, Mettler et al., 2014, Gerring & McDermott, 2007). It was set up to compare the stakeholders' requirements and systems requirements initially generated by the project team following the Systems Engineering approach in use at the company – control group, with the stakeholders' requirements and systems requirements generated by the systems engineers using the artefact – test group. The generated requirements are the dependent variables whereas the method facilitated by the artefact is the independent variable (with impact on the dependent variables). This research uses a quasi-experiment because at the time of the study it was not feasible to randomly assign engineers to the exercise due to limitations of company's available resources.

In order to validate the hypothesis, the researcher used the work produced by the systems engineers, i.e. the numbers of valid requirements specifying human values generated as the result of the use of the artefact. The data was statistically analysed using the previous number of requirements specifying human values as the reference. The researcher looked for relations between the use of the artefact and the generated requirement, e.g. the source of each requirement on the canvasses. The results are presented in the paper.

The engineers participating in the study responded to a survey aiming to capture their feedback regarding the efficiency and effectiveness of the artefact as well as the likelihood of using it or recommending the use of it in future projects. The results of the survey were statistically analysed and reported on the published paper.

Under the Design Thinking framework, the researcher collected data through informal and semi-structured interviews with the participants. It also registered observations of the work done by the systems engineers and systems architects. This data served to understand the underlying motivations and ways of working of the systems engineers that participated in the study. As a result of the experiment, the participants have produced several filled canvasses analysing the elicited human stakeholders and describing the defined use case scenarios. These canvasses were the basis for generation of requirements and could have been analysed against previous methods to perform the same work, but the data produced and captured under the Design Thinking framework is outside of the scope of the current research.

4. Significance and limitations

The researched company applies extensively the Systems Engineering approach. Due to its importance, it has created a department of nearly ten individuals (approx. 10% of all employees) in order to keep the competence always at its best. Its development processes (Fig. 2) is an adaptation of the Systems Engineering vee model (Blanchard, 2011, Buede, 2016).

Due to the timeframe of the project that constitutes the case study and the period of the research it was not possible to follow the management of the generated requirements all the way to the

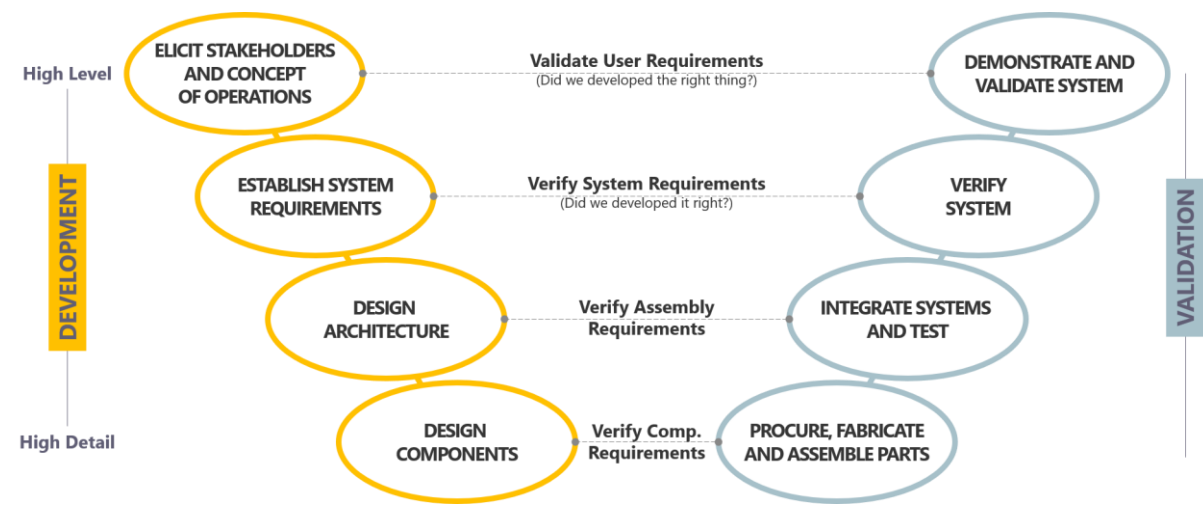


Figure 2. The Systems Engineering process used in the company.

design and production of the components of the system. Neither it was possible to experience any trade-off of requirements as this often occurs during the design and production phases. Moreover, it was not possible to verify, analyse nor document the impact of the work produced on the system as the system has not been delivered by the end of the research. This means that all validation phases of the vee-model were not considered.

This research does not provide strong evidence why the system specifications created or used at the company for other projects and by other teams have limited or poor coverage for human values. Systems engineering and other technical experts have stated that specifications covering feasibility aspects are strong because that is at the centre of company's expertise. Requirements for viability aspects are often well covered because that is central to the customer and therefore not missed. There are a couple of possible reasons for poorly address human values in specifications: 1) the company's customers seldom have a strong focus on desirability aspects and 2) verification of requirements specifying human values is perceived "subjective" by the engineers and such verification is not aligned with their *normal* traits (Pinto et al., 2019).

The benchmark to measure the number of requirements generated that specify human values is the number of existent requirements prior to the experiment. A better configuration would be to have two similar teams of systems engineers whereas one team would elicit stakeholders and write stakeholders requirements, describe use case scenarios and write system requirements using the artefact and another would perform the same activities without applying it. The work of the latter would be the benchmark to evaluate the work of the former. In order to avoid a priming effect that could decrease the quality of the results, the existent specification of the system at the time of the experiment was hidden from the engineers chosen to apply the artefact.

5. Ethical considerations

This research follows the ethical guidelines of the Finnish National Board on Research Integrity TENK (2019) and the general guidelines for research ethics of the Norwegian National Research Ethics Committees (2016).

People who participate in the research was treated with respect. Their dignity and autonomy had never been at risk. All participants were informed of the research plan and had agreed to participate voluntarily, and their identity protected from the public domain. Their consent was informed, explicit, voluntary but not documented because the company's Employee Handbook

and the work contract covers the ethical requirements for this type of activity. The research was professionally executed resulting on a research paper presented at the 29th Annual INCOSE International symposium, Orlando, FL, USA, 20-25 July 2019.

The main objective of the researcher was to produce good consequences and that any adverse consequences are within the limits of acceptability. The research is a quest for new knowledge, with critical and systematic verification and peer review. The researcher engaged in reference practices, which fulfil requirements for verifiability and form the basis for further research. Honesty and transparency were foundational. The researcher had no funding and have not received any other monetized compensation for his work.

The project that served as case study is protected by a non-disclosure agreement (NDA) between the researched company and its customer. The researcher complied with it and have abstracted or anonymized data that could break the NDA. All data has been stored on the databases own and maintained by the researched company until 2023, at least. It is possible to access the research data under consent and control of the researched company.

6. Overview of the thesis

I choose to do a publication-based thesis. It means this shortened thesis is complemented with a published paper. The title of the paper is “Inclusion of human values in the specification of systems: bridging design and systems engineering” and it was published in 2019 in INCOSE International Symposium, volume 29, no. 1, pp. 284-300. The paper can be found as an annexure. As a result of the research, largely due to the methodology applied, an artefact was created to ease and facilitate the work of the systems engineers researched. The artefact is a set of visual canvasses and can be found as appendix.

The thesis is organized on three chapters. Chapter 1 includes the background of the research; the objectives and the research question; the presentation of the methodology employed; the significance and limitations of the research; ethical considerations and; this section explaining how the shortened thesis is compiled. Chapter 2 is divided in two sections. One presenting a broader perspective of the findings than the perspective presented in the paper. The other section presents the outcomes of the research. On the last chapter, I expose my conclusions and discuss avenues for further research as well as research done following this one.

Co-Authors of the paper. The paper was co-authored by Kristin Falk and Marianne Kjørstad. Kristin is an Associate Professor at University College of Southeast Norway, where she is responsible for the subsea track and fronting research on Systems Engineering. She holds a PhD in Petroleum Production and a Master in Industrial Mathematics, both from Norwegian University of Science and Technology. She has worked with product development in the oil and gas industry for more than 20 years. Her industrial experience ranges from subsea systems development in large multinational companies to developing drilling service solutions in a start-up company. Research interests include autonomy, innovation and front-end Systems Engineering. Marianne Kjørstad is a PhD student at the University of South-Eastern Norway, where she focuses on how to better include the human aspects within early phases of 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 on the autumn of 2017.

Chapter 2

FINDINGS AND OUTCOMES

7. Findings

The researcher participated and supported the introduction of the Systems Engineering approach in the company eight years prior to this research, thus having an internal perspective of the motivations and challenges of the changing. The main responsible for the introduction of the Systems Engineering approach in the company, among other staff with technical and managerial roles, noticed that human values are poorly covered in most of the specifications regardless of project or team. The tendency seems to be to consider human values in terms of ergonomic requirements specifying human factors. These requirements address physiologic, mechanical and environmental constraints that have direct impact on the systems' performance and fall on the category of non-functional requirements which express the levels of HSE – health, safety, environment – security, reliability, to name a few. These requirements are necessary to deliver the specified functionality and performance but do not cover the emotional, psychologic and perceptive aspects that drive user interactions and experience delivered.

Surprisingly, the researcher found that standards providing recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems such as the ISO 9241-210:2010 for instance are not known or applied. On the other hand, MIL-STD-1472G, a standard of the Department of Defence of the USA which presents human engineering design criteria, principles, and practices to be applied in the design of systems, equipment, and facilities is well-known. A possible reason for it is the fact that historically, the company had designed and developed mechanical (sub-) systems for the defence, automotive and oil & gas industries that do not required a great focus on human values and interactions. Due to market and strategic changes, the company has evolved to become more exposed to the impact of considering, or not, human values and human interactions for both physical and digital systems (appendix A. A3 Customer Interest).

Looking for the reasons behind specifications that poorly address human values and therefore fail to deliver good user experiences, the researcher mapped and analysed the processes and tools in use to specify systems. Close dialogues with relevant knowledge experts revealed interesting findings such as: *“I know I should take ‘more’ the human values into the*

specification, but it is just very easy not to...” (system architect, 2017). The program manager (2017) stated: *“Systems engineers are educated to ignore the subjective, fluffy requirements! We’re used to validate ‘specs’ on the testing laboratory, environmental chambers, test rigs.”*

The reasons found for a poor or limited number of requirements specifying human values, besides the ones listed in the paper (Pinto et al., 2019), were the following:

- the company’s process description does not recommend any method or tool to identify (and analyse human) stakeholders other than mention and describe their “needs and expectations”;
- the company’s process description recommends a structure to describe the “use case scenarios” that is purely functional and does not address any non-functional outcome.

As presented in the paper (Pinto et al., 2019), this research focusses on the first two phases of the Systems Engineering approach. The set of canvasses (see appendix) were created to help the engineers to better perform the activities that impact the most on the generation of stakeholders’ requirements and system requirements.

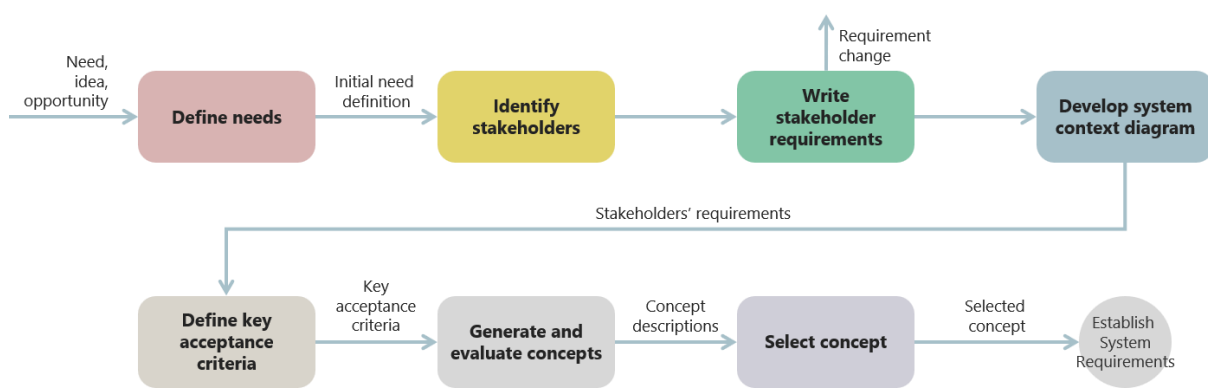


Figure 3. Activities of the “Elicit Stakeholder Requirements & Concept of Operations” phase

The researcher found that the activity “Identify stakeholders” directly and heavily impacts the outcome of the “Write stakeholder requirements” activity. Moreover, the analysis of (human) stakeholders provides opportunities to re-visit and improve the outcome of the “define need” activity. Figure 3 shows the sequence of activities prescribed by the Systems Engineering approach. Similarly, the activity “Understand use case scenarios” heavily impacts on the “Write system requirements” activity. The activities prescribed under the second phase are illustrated on figure 4. The content generated in these activities is stored and managed in Enterprise Architect, a Sparx Systems tool for full life cycle modelling of, among others, software and systems engineering. Enterprise Architect has built-in requirements management

capabilities and helps to trace high-level specifications to analysis, design, implementation, test and maintenance models using UML, SysML, BPMN and other open standards.¹

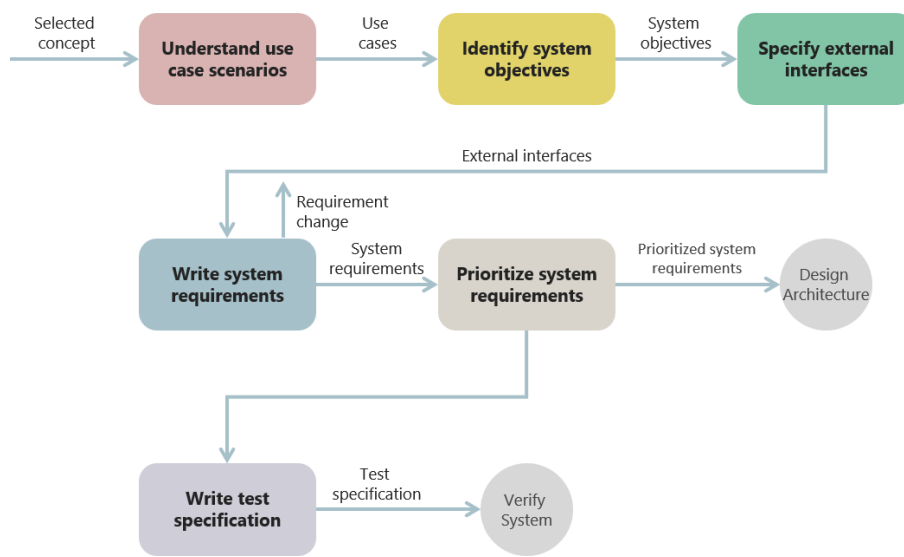


Figure 4. Activities of the “Establish System Requirements” phase.

The reason why the research focusses on these activities is because they are the ones that provide possibilities to address human aspects of the system. Stakeholder needs and interests are transformed into a set of stakeholder requirements, which may be documented in the form of a model, a document containing textual requirement statements or both (Faisandier, Roedler, & Adcock, 2018). The company’s process describes stakeholder requirements as fundamental because they:

- form the basis of system requirements activities.
- form the basis of system validation and stakeholder acceptance.
- act as a reference for integration and verification activities.
- serve as means of communication between the technical staff, management, finance department, and the stakeholder community.

¹ Enterprise Architect. (n.d.). Sparx Systems. Retrieved April 14, 2020, from <https://www.sparxsystems.com/products/ea/index.html>

Step	Action	Uses	Results	State
1	The driver clicks the remote control for keyless entry.			
2	The system validates the signal and unlocks the car doors.			
3	The driver opens the driver's door and sits in the driving seat.			
4	new step...			

Figure 5. Example of a use case scenario in Enterprise Architect. Copyright to Sparx Systems.

System requirements are the set of requirements at the *system level* that describe what the system should deliver to satisfy the stakeholder needs and requirements. It describes the functions of the system and is expressed in an appropriate combination of textual statements, views, and non-functional requirements; the latter expressing the levels of safety, security, reliability, human factors, that will be necessary (Walden et al. 2015, Faisandier, Roedler, Adcock et al., 2018).

According to the company's process, system requirements play major roles in Systems Engineering, as they:

- form the basis of system architecture and design activities,
- form the basis of system integration and verification activities,
- act as reference for validation and stakeholder acceptance, and
- provide a means of communication between the various technical staff that interact throughout the project. generate.

8. Outcomes

The set of visual canvasses (referred in the paper as *new tool*)

The findings listed helped to understand, framed the problem and to identified opportunities to help systems engineers to better generate requirements specifying human values. Applying the Design Thinking approach, the researcher iteratively co-created an artefact to be used on the activities that directly impacted the generation of stakeholders' requirements and systems

requirements, i.e. the “Identify stakeholders” activity from the phase “Elicit Stakeholder Requirements & Concept of Operations” and the activity “Understand use case scenarios” of the phase “Establish System Requirements”, respectively.

The artefact was designed considering the Systems Engineering protocols in use at the company and is compatible with the features that characterize the analogue tools used by the company’s systems engineers. The artefact (appendix B. and appendix C.) consists of two canvasses:

- the **Human stakeholder canvas** – a graphic structure that prescribes a formal way to list the human stakeholders and their main interests, and
- the **Use case scenario canvas** – a graphic structure to describe the use case scenarios involving or interfacing humans.

The Systems Engineering approach in use at the company recommends identifying stakeholders and describing their “needs and expectations”. The Human stakeholder canvas facilitates that activity and ensures the distribution of the “needs and expectations” through *desirability*, *viability* and *capability* categories. It tackles directly one of the causes of the problem, i.e. lack of guidance to consider the human values of stakeholders.

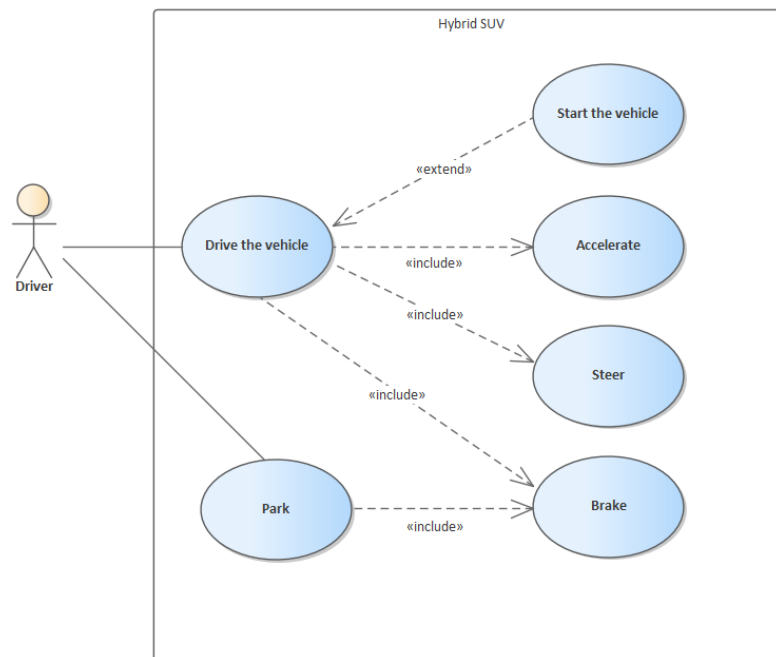


Figure 6. Example of a use case diagram in Enterprise Architect. Copyright to Sparx Systems.

To describe the “use case scenarios”, the company approach recommends a structure that does not allow for non-functional outcome. Figure 5 shows an example of a use case scenario described in Enterprise Architecture. Use case scenarios are supplemented with use case diagrams (fig. 6). The use case scenario canvas requests the system engineer to describe the “*human interactions*” that support the use case. Additionally, the engineer also describes how shall the actors “*experience*” both the interaction and use case.

Both canvasses of the artefact have digital versions (PowerPoint and Excel) for the convenience of the engineers. It complies with the company’s design guidelines; it is self-explanatory and very easy to use.

Produced work: human stakeholders’ analysis and description of use case scenarios

The systems engineers used the artefact to re-analyse seven human stakeholders (Table 2) and to re-described eleven use case scenarios involving human actors (Table 4). Prior to the experiment, the list of stakeholders and the use case scenarios existed on the system model. The application of the artefact resulted in seven human stakeholder canvasses and eleven use case scenario canvasses. The artefact was used in a couple of other projects after the experiment outside the context of the case study. All those canvasses are outside the scope of this research.

Produced work: generated requirements

The experiment resulted in 109 text-based requirements, i.e. 55 stakeholder requirements that resulted from the application of the human stakeholder canvas, and 54 systems requirements that resulted from the application of the use case scenario canvas. All generated requirements were registered. Each one was classified as valid – if it was a new one, i.e. not existent in the system model; or as invalid – if covered by an existent requirement on the system model. The valid requirements specifying human values were categorized as such. The origin of each requirement was also registered. The origin refers to the type of canvas that a requirement was generated from, i.e. a human stakeholder canvas or a use case scenario canvas. The source was also registered. For requirements generated from a human stakeholder canvas the sources were “desirability”, “viability” or “capability”, and for requirements generated from the use case scenario canvas, sources were “preconditions”, “description” (or steps), “interactions” and “experience”.

Table 2. Summary of the human stakeholder analysis and correspondent requirements generated.

Analysis of Human Stakeholder	Number of requirements	Number (% of total) of valid requirements	Specifying human values (% of valid)
System's Owner	8	3 (38%)	2 (67%)
Vessel Owner	7	1 (14%)	0 (0%)
Captain	7	2 (29%)	2 (100%)
Deck Crew	7	1 (14%)	1 (100%)
Operations Team	8	2 (25%)	2 (100%)
Maintenance Personnel	7	0 (-)	0 (-)
Onsite Operator	11	2 (18%)	0 (0%)
Grand Total	55	11 (20%)	7 (64%)

Table 3. Summary of the number of generated stakeholders' requirements by source.

Sources on Human Stakeholder	Number of valid requirements	Specifying human values	Percentage of req. for human values
Desirability	6	6	100%
Viability	1	0	0%
Capability	4	1	25%
Grand Total	11	7	64%

Table 2 shows the number of requirements generated for each analysed human stakeholder. Most of the requirements generated were not valid because the requirements of the previous existing specification, i.e. the existing system model, were specifying the same. Interestingly, two thirds of the valid requirements specify human values. This happened possibly because for the first time the human stakeholders' analysis considered human aspects of the stakeholders, facilitated by the "human stakeholder" canvas. This seems explicit especially for "desirability" which is the source of 86% of the requirements specifying human values (Table 3).

Table 4. Summary of the use case scenario description and correspondent requirements generated.

Description of Use Case Scenario	Number of requirements	Number (% of total) of valid requirements	Specifying human values (% of valid)
Handling, Storage, Transport	10	5 (50%)	1 (20%)
Grooming	8	4 (50%)	1 (25%)

Inspection	7	0 (-)	0 (-)
Initialisation of System	4	0 (-)	0 (-)
Installation Onsite	2	0 (-)	0 (-)
Maintenance and Service	3	1	0 (-)
Operations Surveillance	3	0 (-)	0 (-)
Replacement of Broken Robot	1	0 (-)	0 (-)
Run Shutdown Procedures	4	0 (-)	0 (-)
Run Start-up Procedures	5	0 (-)	0 (-)
Sched. Inspection & Cleaning	7	4 (57%)	4 (100%)
Total	54	14 (26%)	6 (43%)

Table 5. Summary of the number of generated system requirements by source.

Sources on Use Case Scenarios	Number of valid requirements	Specifying human values	Percentage of req. for human values
Preconditions	2	0	0%
Steps (description)	6	0	0%
Interaction	1	1	100%
Experience	5	5	100%
Grand Total	14	6	43%

Table 4 shows the number of system's requirements generated for each of the use case descriptions. Like the stakeholders' requirements, most of the systems requirements generated were not valid probably due to the same reasons. The percentage of valid requirements specifying human values is considerably lower than the percentage of valid stakeholders' requirements specifying human values, 43% and 64% respectively. However, if one considers the source of the system's requirements specifying human values (Table 5), all of them can be traced back to the "interaction" and "experience" sources. The result shows that the canvas can be the reason why the requirements specifying human values were generated.

Participants' feedback

The artefact was experimented by the case study participants and by two other system engineers outside the case study. Everyone who tested the artefact was interviewed and asked to answer a survey (see appendix D.).

One section of the survey aimed to finding how the participants perceived the artefact compared with previous ways of identifying stakeholders and describing use case scenarios and how the resulted specification was compared with the previous one. The results, as presented in figure 9 in the paper, show that participants see both the analysis of stakeholders and stakeholders' specifications, i.e. the method and the results, as better or strongly better than the previous ones. In the same way, most of the participants see the description of use case scenarios and the resulted system's specification as better or strongly better, with a minority of participants (33%) who do not see an improvement on the method nor an improvement on the results (17%). It is worth to notice that none of the participants has perceived the artefact as slightly worse or worse for the analysis of human stakeholders nor the description of use case scenarios.

Figure 8 in the paper shows that participants agree that the artefact provides broader and deeper analysis of the human stakeholders and broader and deeper descriptions of the use case scenarios. Exception for 33% of participants who do not agree the description of use case scenarios is deeper regardless of considering it broader. The results also show (see paper, Figure 10) that the engineers strongly agree that artefact helps them to better specify systems and recommend the artefact for other projects.

Chapter 3

CONCLUSIONS AND FURTHER RESEARCH

9. Conclusions

The conclusion section in the paper gives detailed evidence that the experiment resulted in a concrete improvement of the system specification covering human values without compromising other aspects. It argues that the artefact is the reason why such improvement occurred. The artefact is the answer to the research question because it promotes a broader way to analyse human stakeholders and describe use case scenarios. The artefact ensures that systems engineers address human values while carrying out the mentioned activities. It turns those values visible and therefore not neglectful. Being visible, the human values are considered in the requirements for both the stakeholders and the system.

The hypothesis presented in this research calls for the cognitive bias "what you see is all there is" (WYSIATI) introduced by Kahneman (2011). Essentially, WYSIATI bias helps us to build the most coherent story out of whatever we have at hand. It explains how irrational we are when making decisions and how easily we jump to conclusions based on limited evidence (Kahneman, 2011). Compared with the previous methods prescribed to carry the activities that highly impact the early specification of systems, the artefact gives visibility to content that otherwise was not, especially content related to human aspects. Thus, the engineers have a broader content to support the specification of the system.

The application of the artefact aims to improve the inclusion of human values during the initial phases Systems Engineering. The artefact consists of two canvasses. One of the canvasses facilitates the identification and analysis of human stakeholders in the "Elicit Stakeholder Requirements & Concept of Operations" and the other facilitates the description of use case scenarios in the "Establish System Requirements" phases of the Systems Engineering approach.

The canvas "human stakeholder" facilitates a systematic analysis of human stakeholders – the activity "Identify stakeholders" – and ensures that desirability aspects are considered by the system engineer. The researcher concludes that the canvas helps to produce content that seems to be richer from a desirability perspective than before. The stakeholders' requirements are the

direct result of this activity and the identification of the needs. Consequently, the number of requirements covering human aspects increased significantly (see paper, table 4).

In the same fashion, the canvas “use case scenario” facilitates a systematic description of the use cases and ensures that interactions with the actors and expected delivered experiences are addressed as early as at the system level. Use case scenarios are the first and foremost step of the phase which main outcome is the set of requirements that specify the system. To a high degree, use case scenarios (in Systems Engineering) result of the decomposition of the stakeholders’ requirements and needs. The descriptions are a speculation exercise in the (conceptual) solution space. It is obvious in the experiment that these exercises helped to generate requirements specifying human values as shown in table 4 in the paper.

The control group is the stakeholders' requirements and systems requirements prior to the experiment by the project team . Table 3 in the paper shows that there was one stakeholders’ requirement related to human values from a total of forty-one, including requirements of *non-human* stakeholders, and one system requirement specifying human values from a total of one-hundred and seven. The test group is the stakeholders' requirements and systems requirements generated by the systems engineers using the artefact. Table 2 and table 4 show the number of requirements, the origin, how many were considered valid and how many specify human values. Table 3 and table 5 show the sources of the valid requirements and how many specify human values. Based on these results the researcher concludes that the artefact proved to be successful supporting the system engineers to generate more requirements covering human aspects both at the stakeholders’ level and at the system level. The participants involved in this research have concluded the same as shown in figure 10 in the paper.

10.Avenues for further research

The number of participants and respondents in the survey limits the validity of this research. The researcher collected data from six project team members in the feedback survey. The number of responses is too low for the results to be processed statistically. The result from the survey can be considered a tendency rather than a quantifiable result. Moreover, the research methodology has limitations because the active role of the researcher in the case study can result in biased conclusions. Therefore, similar research should be carried out in other companies and with more participants that will constitute reliable samples.

Subsequent to this research, Sjøkvist (2019) has studied how methods typically used in the Design Thinking approach affect the communication and consideration of human values in the early phase of Systems Engineering. The study was carried out in the same company using the early phase concept study conducted for a customer in the construction industry as its case. It focused on eliciting stakeholder needs and requirements and defines human values as emotional needs, influenced by environmental and personal factors. The human stakeholder canvas created and tested in this research was central to Sjøkvist's study.

Sjøkvist extended the study to the activities that provide content to the canvas – interviews and observation of stakeholders and uses the canvas as a visual mapping tool that contributes to a mutual understanding of the stakeholder needs and a better communication between the team members and with the customer. The canvas provides input to the definition of human value stakeholder requirement. With respect to the canvas, the study concluded that it contributed to a mutual understanding among the project participants and contributed for the increasing awareness of human values but did not conclude whether the template is effective for eliciting stakeholder requirements.

In the context of systems engineering, besides the early specification, it is paramount to follow throughout the design, development and realization of the system how the requirements are being fulfilled. Especially highly complex systems evolve during the phases preceding its “realization” through several iterations. Limitations or incompatibilities from several domains will call for trade-off of requirements. It would be of interest to understand how requirements specifying human values are traded-off and if there is a tendency or not to privilege these over others.

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APPENDIX A. A3 Customer Interest

Product Development based on Human Behaviour

Author	Responsible	Doc. Nr	Issue	Project & task	Date
Frode Island Bergan	Hans Peter Havdal	NA	NA	H-SEIF	2017-11-03

Description

The main customer are the internal development team in Semcon Devotek. In this document the customer of the H-SEIF project will be referred as development team, when referring to the customer we mean a customer of Semcon Devotek.

The target is to increase the customer value to our customers by:

- Improved evaluation of product ideas to effectively stop projects with low user value
- By better combining knowledge about customer value and technological competence to come up with more disruptive products
- Creating more desirable products, focusing on functions and performance that actually gives value



Introduce other parts of Semcon to the findings from this project to improve the organization as a whole.

When running development projects we have experienced:

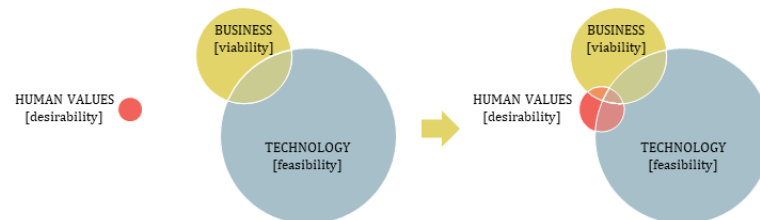
- Engineers turn projects starting with focus on human values into "technical only" projects in later stages.
- Engineers often put all the effort in the "behind the scenes", resulting in a not pleasant user experience.

Systems engineers are taught (indirectly) to ignore designers, as requirements should have a metric that allows the requirement to be tested, where applicable. Human related requirements become difficult to verify in an engineering fashion. As a consequence, these requirements are poorly specified or simply ignored. Too often the development team thinks of themselves also as the customer; the result is a product developed for engineers (technical driven) instead of a product developed for the customer / end user (experience driven).

The competitors are still considered to be either hard core engineers or hard core designers with focus on human factors. None with a successful combination.

Analysis

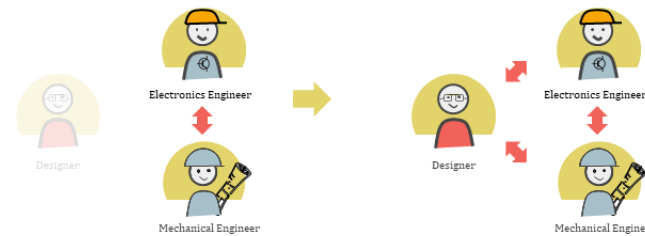
The development teams want to develop technically advanced products that the users appreciate and give profit to our customers. Being part of the development team of a successful product gives the average engineer extra motivation. Semcon Devotek believes that a good balance between business, human values and technology will result in more successful projects.



Analysis cont.

The previous illustration shows that Semcon Devotek needs to improve the balance between human values and the other two. Today we have 1 designer and about 60 engineers, the balance needs to be altered and the collaboration improved.

In Semcon Devotek the technology focus is higher than the business focus. However if you look at the joint effort from both Semcon Devotek and the customer, which have a business focus most projects have a good balance between business and technology.



Design is a competence like an engineering competence, requiring knowledge, skills and abilities to succeed. One target for this project is to increase the understanding and awareness of human values among the engineers. It should be as natural for an engineer to collaborate with a designer as with another engineer – regardless if mechanical electronic, software or other.

Conclusion

A successful H-SEIF implementation will improve the product development processes. Semcon Devotek will be a more attractive partner for our customers' top management. Semcon Devotek expects to increase the amount of projects considered strategic to our customers.

The key-take-aways from H-SEIF are:

- A growing culture for looking into human values in development projects
- Mutual respect and understanding between designers and engineers
- Methods for maintaining a balance between business, human and technical perspective throughout the projects.

Actions to close knowledge gap






Semcon Devotek are increasing the focus on human values early in more and more projects.

Identify pilot project candidates to:

- Increase focus on human values in the early phase
- Test new methods for identifying human values
- Test new methods for incorporating human values into systems engineering
- Find methods for balancing human values and technology through projects





Customer Interest




APPENDIX B. Human stakeholder canvas

ENTER THE STAKEHOLDER'S NAME				AUTHOR	DOC. NR	ISSUE	PROJ. & TASK	DATE	semcon
				ADD AUTHOR	DXXXXXXXX	A.XX	XXXXXXXX-XXX & XX	YYYY-MM-DD	
<p> PROFILE</p> <p>Who is the Stakeholder? Is it an Active or Passive one? Primary or secondary? Say more.</p>				<p> ROLES AND RESPOSIBILITIES</p> <p>Describe the responsibilities and roles of the Stakeholder.</p>					
MAIN INTERESTS									
<p> DESIRABILITY</p> <p>What are the emotional, cultural and social wishes of the Stakeholder? What shall the stakeholder be proud of?</p>			<p> VIABILITY</p> <p>What revenues and benefits is the Stakeholder looking for? More turnover? Lower costs? More intangible assets (brand awareness, customer loyalty, patents)?</p>				<p> CAPABILITY</p> <p>What is the stakeholder's functional goal? What functions, tasks and performance the stakeholder needs to improve life?</p>		

APPENDIX C. Use case scenario canvas

ENTER THE USE CASE SCENARIO				AUTHOR	DOC. NR	ISSUE	PROJ. & TASK	DATE
				ADD AUTHOR	DXXXXXXXX	A.XX	XXXXXXXX-XXX & XX	YYYY-MM-DD

 DESCRIPTION What to achieve in this case? What is the context and background for it?	 ACTORS Who are the primary actors? Who are the supporting actors?	 PRECONDITIONS What are de conditions that must be true for this use case to begin?	 GUARANTEES What are de conditions that must be true at the end of this use case?
---	--	--	--

 DESCRIPTION 1. What is the sequence of steps in which nothing goes wrong?	 INTERACTIONS • How shall the actor (user/operator) interact? What are the necessary interfaces for it?	 EXPERIENCE • How shall it look, sound and feel? How shall the actor perceive the interactions?
---	--	---

APPENDIX D. Feedback survey

Demographics	< 3 years	3 to 10 years	> 10 years
1) What is your experience?			

Assesment of activities and results compared with the control group - Section 1	Much worse	Worse	The same	Better	Much better
2) Compared to the previous method to analyse stakeholders, how do you rate the new one?					
3) How is the current stakeholders' specifications compared with the previous specifications?					
4) Compared to the previous method to describe use case scenarios, how you you rate the new one?					
5) How is the current system specifications compared with the previous specifications?					

Assesment of activities and results compared with the control group - Section 2	No	Yes
6) Compared to the previous method, is the analysis of the stakeholders broader?		
7) Compared to the previous method, is the analysis of the stakeholders deeper?		
8) Compared to the previous method, is the description of the use case scenarios broader?		
9) Compared to the previous method, is the description of the use case scenarios deeper?		

Feedback of participants	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
10) The tool helps to better specify systems.					
11) After participating in the experiment, I understand better the importance of specifying for human values.					
12) I recommend the use of the new tool for other projects.					
13) Please leave a suggestion for improvement and/or a comment.					



Inclusion of human values in the specification of systems: bridging design and systems engineering

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Abstract. This paper investigates a method for ensuring that systems engineers generate requirements related to human values. It looks at the work of a project team that designs and develops complex systems in a company recognized for the application of Systems Engineering to deliver innovative systems. The research data was drawn from a real project. We developed a tool that prescribes a structure to analyze human stakeholders and to describe use case scenarios. The tool enabled the systems engineers to generate twenty-five new requirements all of which were added to the system specification. Thirteen of these requirements contain aspects related to human values. Initially, the specification included only two requirements related to human values. We conclude that the importance of specifying human values has increased among the engineers of the team. Further investigation is ongoing in order to evaluate the potential of generalizing the new tool, its efficiency and effectiveness.

Introduction

Large organizations are putting design thinking much closer to its centre. This shift is a response to the increasing complexity of modern technology and modern business. Gartner, a research and advisory company and a member of the S&P 500, has listed on their Hype Cycle for Emerging Technologies, for the third year in a row, a trend towards human-centric technology (Gartner 2015, 2016, 2017). Increasingly, corporations and professional services firms are working to create design-centric cultures. “Technology will continue to become more human-centric to the point where it will introduce transparency between people, businesses and things” (Gartner 2016). This is happening because the technological complexity of products, services, and processes are constantly increasing. People do not deal well with high levels of complexity. They need their interactions with technologies and other systems to be intuitive and highly gratifying. Design thinking is an essential tool for simplifying and humanizing. It helps to create those kinds of interactions. Such qualities cannot be extras, they need to be core and spread to the whole organization (Kolko 2015). The design thinking process is a system that overlaps perspectives. Viability represents the business perspective; desirability echoes the user’s perspective; and feasibility contains the technology perspective (Chasanidou et al., 2015). The “sweet pot for innovation” is at the intersection of these perspectives, i.e. when all three perspectives are present and balanced (Brown 2009).

University College of Southeast Norway conducted a study in 2016 involving both the academia and the industry. It investigated how to foster innovation when applying Systems Engineering to design

complex systems. They concluded that there is a strong need to ensure the integration of human values in Systems Engineering (Falk et al., 2016).

System Engineers can use principles of sociotechnical design to integrate human values (Cherns 1976, Clegg 2000, Norman et al., 2015). It is the responsibility of the systems engineer to specify the needs of the stakeholders, including their human values (Muller 2009). We found during our research that system engineers specify the human values through the lens of Human Factors (ergonomics) and Health, Safety and Environment (HSE). Regardless, we found that ISO 13407:1999 Human-centered design processes for interactive systems (revised by ISO 9241-210:2010) is not followed nor known at the company.

Schwartz (2012) states that when we humans think of our values, we think of what is important to us in life. Each human holds and ranks numerous values. A high ranked value for one may be of minimal importance to another. According to the value theory (Schwartz, 1992, 2006), the conception of *all* values specifies six main features: 1) Values are beliefs; 2) Values refer to desirable goals; 3) Values transcend specific actions and situations; 4) Values serve as standards or criteria; 5) Values are ordered by importance and; 6) The *relative* importance of multiple values guides action. What distinguishes one from another is the type of goal or motivation that it expresses. Environmental factors such as culture and social aspects, as well as personal factors such as education, mental status, physical status, and preferences, influence human values (Muller 2009). In this research, we define these underlying values and motivation as human values. The pursuit of the human values relevant for the human stakeholders is driven by the questions: 1) What are the emotional, cultural and social wishes of the stakeholder? 2) What shall the stakeholder be proud of? 3) How shall interactions with the system look, sound and feel? And 4) How shall the actor perceive the interactions?

The application of systems in design has been that design needs to learn from systems thinking while the need of systems field to learn from the field of design seems minimal (Collopy 2009). Sevaldson (2017) argues that systems' approaches to design have partly failed in design because of the attempt to apply several complexes, prescriptive, and analytic theories in a field that practices generative, adaptive and dynamic design and the application of design approaches (generative, adaptive and dynamic) in systems engineering is difficult due to the opposite nature of the fields. While systems' approaches focus on "objectively measure" results, design approaches consider "subjectively perceived" results more than systems approaches do.

This research seeks an answer to the question "How to ensure that systems engineers include human values in the early specification of systems?" In order to find a solution, the researcher applied the design thinking framework because such an approach keeps the focus on the human aspects of the problem to be solved. We did the following:

1. Created a tool to analyze human stakeholders and describe use case scenarios;
2. Redid the stakeholders' analysis of human stakeholders and re-described the use case scenarios involving human stakeholders;
3. Generated stakeholders requirements and system requirements based on the results of the previous step and;
4. Updated the system specification with the new requirements.

We did participatory research in addition to semi-structured interviews with the team members and used qualitative and quantitative data to draw conclusions. The case study of this research is the design and development of a real system. It is a multidisciplinary project of an autonomous product/service for the global maritime vessel fleet. The client of the project estimates the overall cost of development to be more than 12 million USD, being roughly half of it associated with the project team that participated in this research. The tool consists of a set of two one-page graphic templates created to perform analysis of stakeholders and describe the use case scenarios. These templates are:

1. The human stakeholder canvas, to analyze each of the human stakeholders,
2. The use case scenario canvas, to describe use case scenarios.

The former is set to be the basis to generate requirements at the stakeholders' level and the latter to be the basis to generate systems requirements. The benchmark to evaluate the results of the application of the tool is the latest status of the stakeholder requirements and the system requirements before the application of the tool.

Background

The company that participated in this research is an engineering consultancy company. For more than 20 years, it designs and develops technically advanced products that are highly innovative from both functional and performance points of view. The company provides expertise in mechanics and mechatronics, electronics, control systems, and software. Currently, it supplies a wide range of markets including defence, aerospace, oil and gas, health and general industries. Figure 1 shows the vee model (Blanchard 2011, Buede 2016) adapted for the company's development processes and it serves as a good example of the application of systems engineering. The company recognized the need to include human values in project design and the need to develop products or systems that create additional value to customers through a focus on delivering appropriate user experiences. The belief that a good balance between business, human values and technology will result in more successful projects goes in hand with the Design Thinking approach.

The "Elicit Stakeholder Requirements & Concept of Operations" (Fig. 2) and the "establish system requirements" (Fig. 3) phases of the process govern the specifications on which this research focuses.

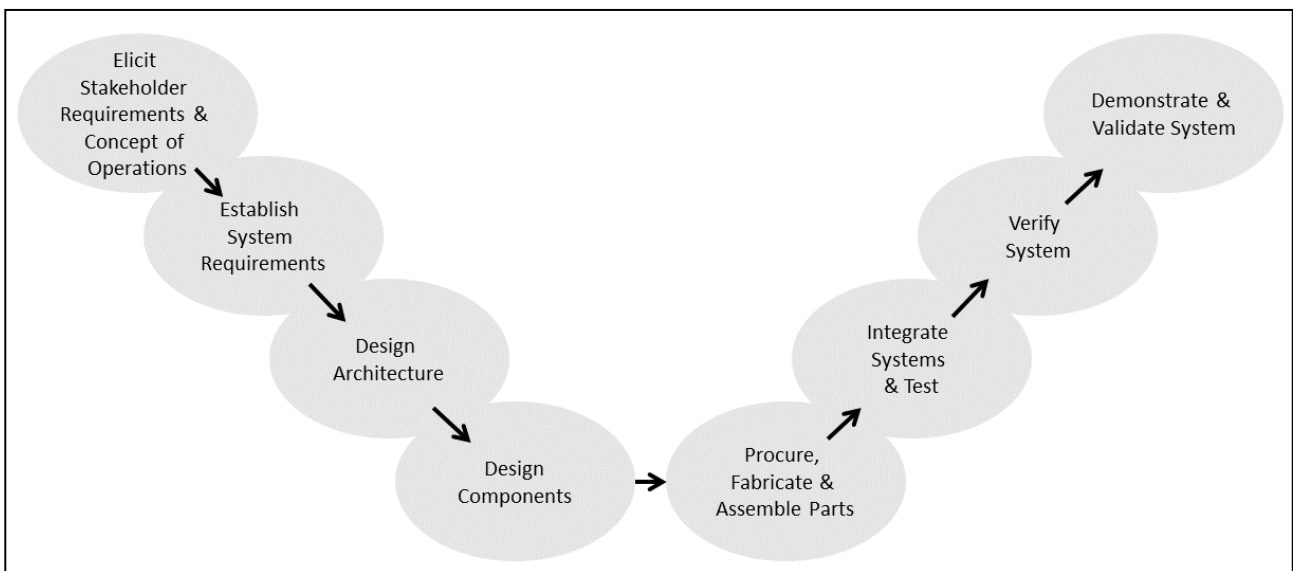


Figure 1. Illustration of Systems engineering processes at the company

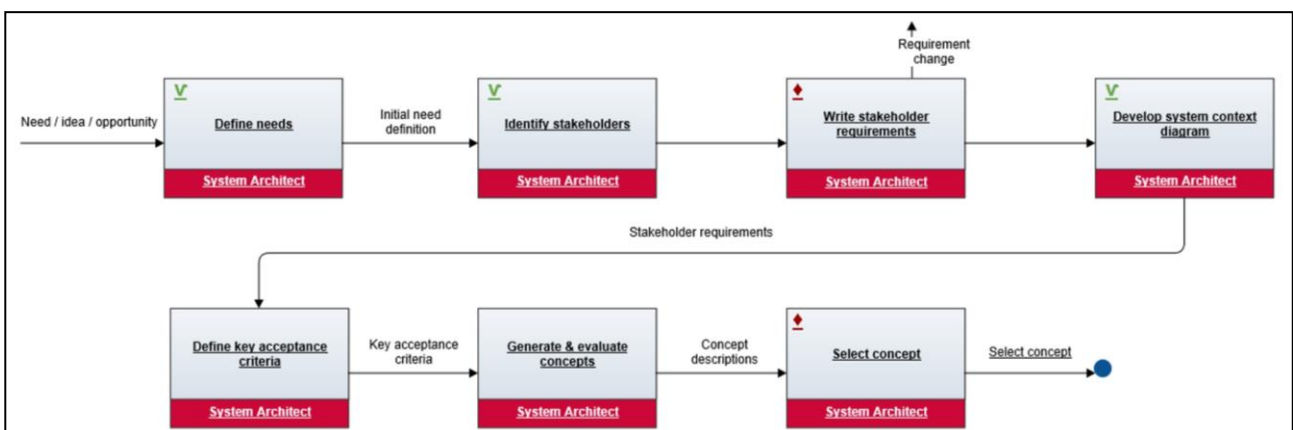


Figure 2. Tasks of the "Elicit Stakeholder Requirements & Concept of Operations" phase

The system architect is responsible for both phases and consequently for the blocks of each phase, while the system engineers are the ones who execute the tasks represented by the blocks. The arrows between the blocks represent the outputs and inputs from each task. The upward directed arrow on the blocks “write stakeholder requirements” (Fig. 2) and “write system requirements” (Fig. 3), illustrates that is an iterative task because stakeholder requirements and/ or system requirements can change during the process. The content produced during these two phases is stored using a software tool called Enterprise Architect. It is a visual modelling and system design tool, based on the Unified Modelling Language (UML) of the technology standards consortium Object Management Group (OMG). At the time of the research, there was no specific method or tool to execute the tasks of these phases.

Prior to this research, the system engineers did not have a prescribed tool to carry on the tasks of analyzing human stakeholders nor describe the use case scenarios involving human stakeholders. To collect stakeholder needs and requirements, system engineers use several techniques or methods such as structured brainstorming workshops; interviews and questionnaires; technical, operational, and/or strategy documentation review; simulations and visualizations; prototyping; modeling; feedback from verification and validation processes; review of the outcomes from the system analysis process; use case diagrams; activity diagrams and; functional flow block diagrams (SEBoK 2018). None of the ones mentioned above are used with focus on human values.

The aim of the “elicit stakeholder requirements & concept of operations” phase is to understand the problem from different stakeholders’ perspectives describing the needs and features required by them in their language. Based on that, the system engineer generates stakeholders’ requirements and rate them according to their importance. The context diagram represents the system of interest as a “black box”, which shows the relevant borders, actors and systems interacting with it as well as the major information flow between the entities and the “black box”. The key acceptance criteria consists of three to five most important stakeholder requirements. If they are not fulfilled the project will be a failure. They should be defined explicitly, while the project team should be regularly reminded of them. Concepts and optimal solutions are generated and selected, applying the most important requirements and impact on the critical project parameters: cost, time and quality.

At the “Establish System Requirements” phase, the system engineer aims to understand what the actors do by describing as many as possible use cases spanning through the system’s complete

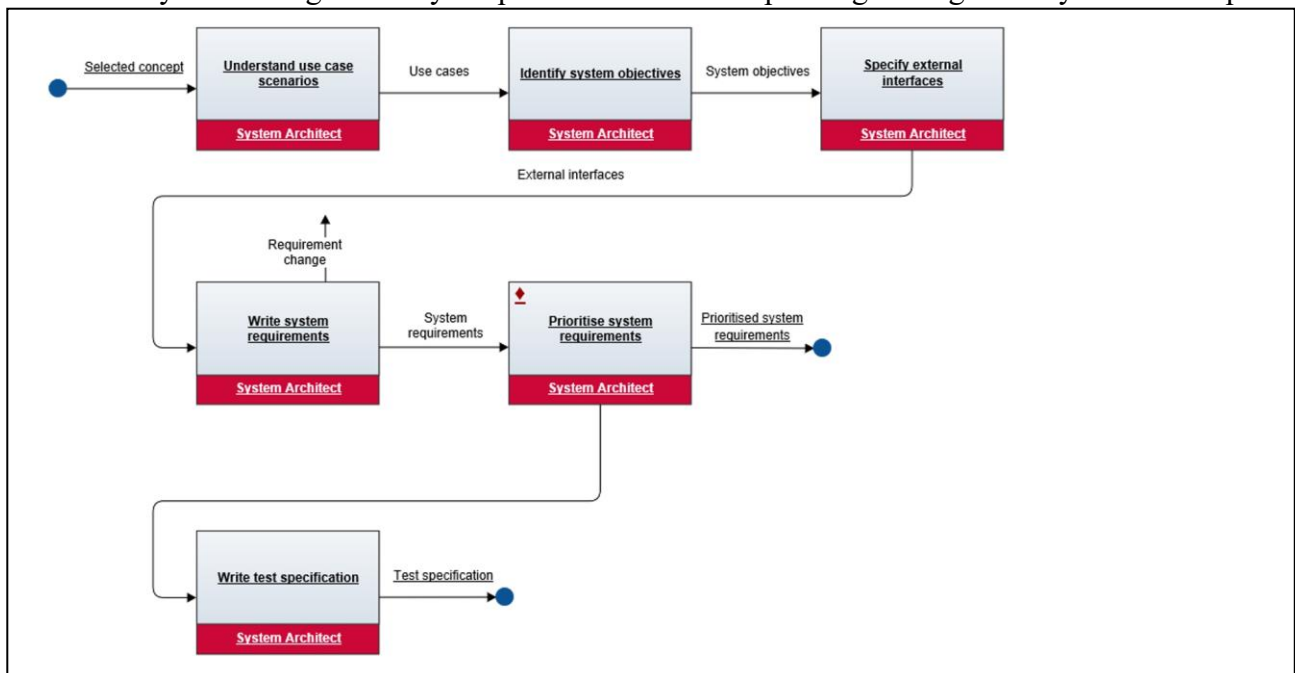


Figure 3. Tasks of the “Establish System Requirements” phase

lifecycle. It is in this phase that the system engineer defines the non-functional requirements (characteristics) for the system. Based on the system context diagram from the previous phase, the system engineer defines in detail the external interfaces. The written system requirements should be decompositions of the stakeholder requirements, detailing them from stakeholder language to engineering language. The goal is to ensure consistency of system requirements created in previous steps, maintain traceability and a more detailed written agreement of the targets of the product development at any stage of the project, and prioritize the system requirement to help to focus on the important parts and support later decisions. This phase is also partly a high-level description of the test needs.

Methodology

A case study (Yin 2017) using participatory action research (Baum et al., 2006) was used to explore the research question within real-world settings. The case study method comprises in-depth and holistic investigation of phenomena that cannot be studied independently from the context in which it occurs (Pare 2004). This study drew on both qualitative and quantitative methods such as surveys and unstructured interviews. It used unstructured interviews because it enabled the researcher to obtain the required information while giving participants the freedom to respond and elaborate responses. This study illustrates a more traditional use of case studies in process evaluations, but the research method has also been used for analyzing and documenting the intervention (Yin 2011).

The interviews with team members supported the conclusions of the research. Six team members actively participated in the survey and interviews that were facilitated by the researcher. The discussions included two formal group meetings with eight and ten system engineers external to the case study. In these group meetings, the researcher presented the development of the research project and collected feedback. Minutes of meeting were recorded. Approximately three months after concluding the group discussions and the application of the tool, participants were asked to respond to the survey. This allowed the researcher to test the use of the tool after its implementation and receive ongoing feedback.

Table 1. List of responders of the survey.

Participant	Role	Experience
3	System engineer	<3 years
1	Designer	>10 years
1	System Architect	3 to 10 years
1	Project Manager, Mechanical	3 to 10 years

In this research, design thinking provides a framework for using participatory research approaches to facilitate the implementation of the tool. The researcher closely followed the efforts of the individuals that were involved in all phases of the study. The amount of requirements generated based on the application of the tool is the data used to draw conclusions. The results of the application of the tool can be measured by the number of new requirements generated based on the analysis of human stakeholders and description of use case scenarios involving human stakeholders, especially those related to human values that were originated on “desirability” and on “experience”.

Study case

The team is designing and developing a solution for the global maritime vessel fleet. The solution is part of an autonomous and multidisciplinary product/service. It consists of:

- A high performance and environmental friendly hard coating and the application of it;
- A solution to maintain autonomously the condition and performance of surfaces coated with the hard coating, and;
- The global infrastructure that supports the necessary logistics to provide the service.

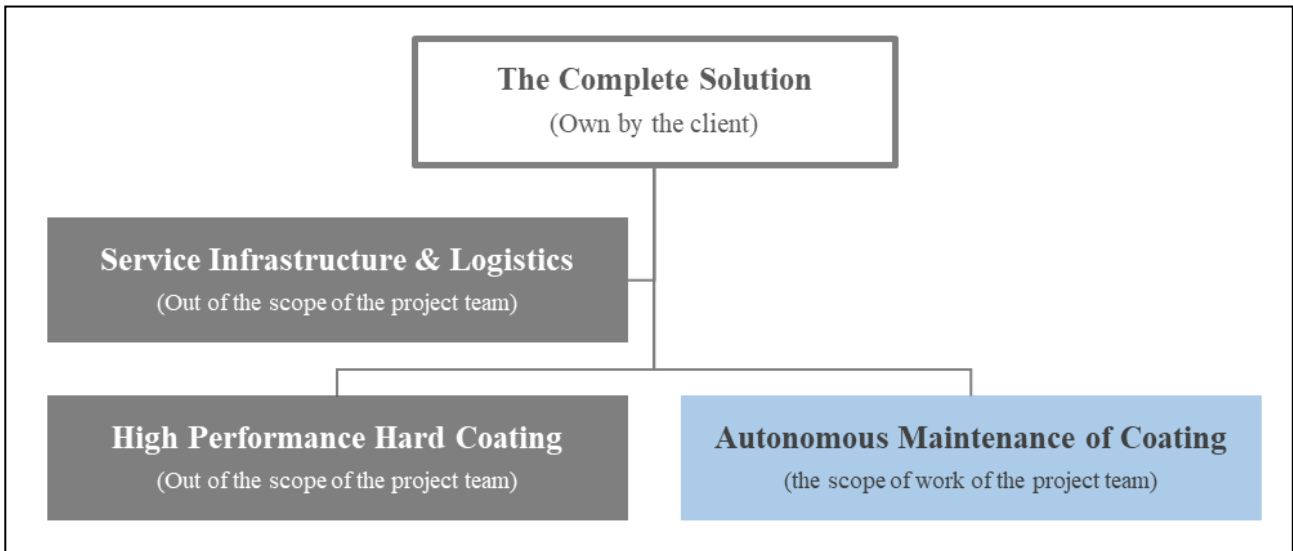


Figure 4. High-level structure of complete solution

In this case, the team is responsible for the design, development and test of the work package Autonomous Maintenance of Coating (Fig. 4). It is a highly complex project and requires expertise from many different disciplines including mechanics, mechatronics, electronics, software, artificial intelligence, materials, production technology, design management, marketing, ergonomics, usability and user interface and experience. The number of members of the team has changed during the execution due to specific needs of the project, the project plan, unexpected issues and availability of resources. A number of members is central to the project, namely the project manager, the system architect, the design leader, the technical leaders of mechanical systems, embedded systems, production and assembly, and test and validation. The professional experience of the members ranges from three to twenty years. The system engineers selected to use the tool have less than three years of experience and had not been part of the project before. The project began two years before this study was completed and it is expected to be finished in three years after. The project was planned using a stage gate approach whereas the next stage depends on the successful results of the current one. The overall project includes 1) the feasibility study; 2) concept detailing; 3) design and production of a prototype to test basic functionality; 4) design and production of a 2nd generation prototype to test increased functionality; 5) fully functional prototype and an early version for industrialization and; 6) commercial release. This study took place on stage 3.

Design Thinking Framework

The researcher applied the design thinking approach (Fig. 5), especially the human-centred design process (Brown 2009, Tschimmel 2012). This approach helped the researcher to understand the

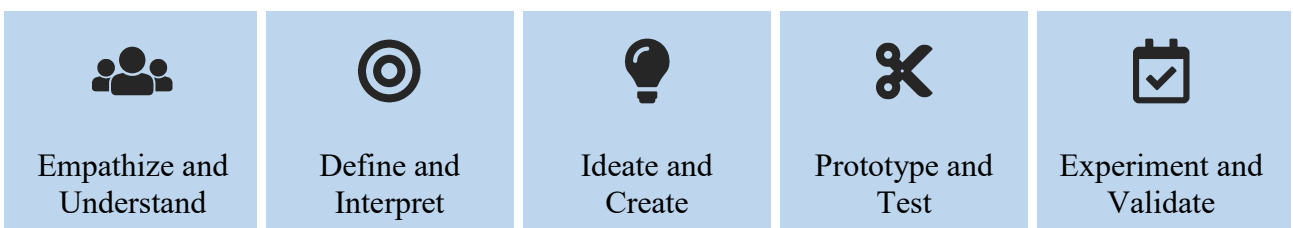


Figure 5. Illustration of the Design Thinking approach applied

company's development process, how system engineers perform their work and to find a solution to ensure that the specification of systems will include requirements specifying human values. The solution found was a new tool to analyze human stakeholders and describe use case scenarios. The researcher created a tool in collaboration with the system architect of the study case, and with the consultancy of another system architect and four potential users, external to the project.

Empathize and understand

The researcher has worked in the company since the introduction of the systems engineering approach eight years earlier, thus having supported and participated in the process. The program manager who was responsible for the introduction of the approach realized that system engineers very often overlook human aspects when specifying and developing systems. Human values are specified in ergonomic terms, i.e. requirements specifying human factors that eventually refer to standards. In addition to these reasons, the researcher and the active team members participating in this research, improved their understanding of defining and specifying the system through unstructured interviews. This shared approach towards generating understanding created empathy amongst the team members (Miettinen et al., 2016). The processes and tools in use to specify systems were mapped and analyzed aiming to find the causes of a poor generation of requirements related to human values.

Define and Interpret

Based on the findings of the previous phase, the researcher defined the problem landscape by identifying causes that would justify the absence of requirements that specify how human interaction with the system should be perceived and experienced. The following causes were found:

- The engineers applying systems engineering approaches tend to translate human values into HSE and/or ergonomic requirements;
- The approach of system engineers is mainly functional and aims for objectively-measured results;
- The lack of awareness of the significance of well-defined human values.

The system architect explained: *"I know I should take 'more' the human values into the specification, but it is just very easy not to..."*

The program manager stated: *"Systems engineers are educated to ignore the subjective, fluffy requirements!"*

Ideate and create

Based on the findings of the previous phases, the researcher designed the tool that facilitated analytical processes of the human stakeholders and the descriptions of use case scenarios. It takes into account the team's current protocols, which are strongly based on traditional systems engineering. The design of the tool considers the main features that characterize the toolbox in use at the company, which is:

- Suitable to print on A3 paper sheets;
- Supported with digital versions such as PowerPoint slide and/or Excel spreadsheet;
- A self-explanatory one-page structure that enables an immediate overview;
- Visually consistent with the current design guidelines.

The tool consists of two one-page graphic structures that prescribe a new way to analyze stakeholders (Fig. 6) and to describe use case scenarios (Fig. 7).

Prototype and test

The tool was introduced to a selected system engineer (engineer “A”) for testing. The system architect introduced engineer “A” to the existing model of the system, who used the tool to analyze the human stakeholders and describe the use case scenarios related to human stakeholders. The researcher facilitated and closely followed the work, focusing on the process of applying the tool rather than on the content generated. This phase served to test the tool as well as to train engineer “A”. The canvasses were improved, taking into account the observations and findings of the training, in addition to the input of engineer “A”, the system architect and other engineers involved previously. The improved versions of the canvasses consisted of the tool used to gather the data of this research.



Experiment and validate

The application of the tool consisted of two well-defined phases:

1. The use of the tool to analyze the human stakeholders and describe the use case scenarios related to human stakeholders, and;
2. Generate requirements based on the content created with the tool.

Application of the tool. Engineer “A” applied the tool to redo the analysis of the human stakeholders and to re-describe the use case scenarios. Engineer “A” applied the tool on the model of the system existent prior to this study. The model included detailed information about the system in terms of stakeholders (identification and main interests), categorization of stakeholders and relations between them, concepts of operations, use case scenarios, customer views, stakeholder requirements, system requirements, requirement analysis and functional breakdown structures. The system architect reviewed the content generated and agreed on which content to process further, i.e. to generate requirements.

ENTER THE STAKEHOLDER'S NAME		AUTHOR	DOC. NR	ISSUE	PROJ. & TASK	DATE
		ADD AUTHOR	DXXXXXXXX	A,XX	XXXXXXXX-XXX & XX	YYYY-MM-DD

 PROFILE Who is the Stakeholder? Is it an Active or Passive one? Primary or secondary? Internal or external? Say more.	 ROLES AND RESPONSIBILITIES Describe the responsibilities and roles of the Stakeholder.
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MAIN INTERESTS		
 DESIRABILITY <ul style="list-style-type: none">• What are the emotional, cultural and social wishes of the Stakeholder? What shall the stakeholder be proud of?	 VIABILITY <ul style="list-style-type: none">• What revenues and benefits is the Stakeholder looking for? More turnover? Lower costs? More intangible assets (brand awareness, customer loyalty, patents)?	 CAPABILITY <ul style="list-style-type: none">• What is the stakeholder's functional goal? What functions, tasks and performance the stakeholder needs to improve life?

Figure 6. The human stakeholder canvas

Generating requirements. To perform the second phase of the application, the researcher supported by the system architect, introduced another system engineer to the project and tool. For reasons of simplification, this individual is referred to as engineer “B”, who created text-based requirements based on the content generated from phase one, i.e. the application of the tool to re-analyze human stakeholders and re-describe use case scenarios.

Requirement traceability is recommended to increase the systems specification quality and avoid undesirable problems such as building functionality no one uses or insufficient change impact analysis (Walden et al, 2015). In order to comply with best practices of requirements traceability, the engineer identified the source of each requirement in relation to the content generated with the new tool and grouped the requirements originated from the analysis of human stakeholders’ canvasses as stakeholder requirements and those that originated from the use case scenarios as system requirements. The system architect reviewed all requirements, validated and added a number of them to the specifications. Consequently, engineer “B” updated the system model reflecting the new data about human stakeholders, stakeholder requirements, use case scenarios and system requirements,

Feedback of the participants. Qualitative data was collected, consisting of close dialogues and open discussions with the participants throughout the complete study, especially during the phase of empathy and understanding. Observations were conducted of the participants, for example, by supporting, participating and facilitating the activities of the application of the tool. Afterwards, participants completed a survey focusing on their perception of the tool and the value added to the project. Participants also commented on their raised awareness of the importance of inclusion of human values in the early specification of systems.

ENTER THE USE CASE SCENARIO

AUTHOR	DOC. NR	ISSUE	PROJ. & TASK	DATE
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<p>DESCRIPTION</p> <p>What to achieve in this case? What is the context and background for it?</p>	<p>ACTORS</p> <p>Who are the primary actors? Who are the supporting actors?</p>	<p>PRECONDITIONS</p> <p>What are de conditions that must be true for this use case to begin?</p>	<p>GUARANTEES</p> <p>What are de conditions that must be true at the end of this use case?</p>
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<p>DESCRIPTION</p> <p>1. What is the sequence of steps in which nothing goes wrong?</p>	<p>INTERACTIONS</p> <ul style="list-style-type: none"> How shall the actor (user/operator) interact? What are the necessary interfaces for it? 	<p>EXPERIENCE</p> <ul style="list-style-type: none"> How shall it look, sound and feel? How shall the actor perceive the interactions?
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Figure 7. The use case scenario canvas

Results

The results of this research can be divided into three outcomes, namely the tool, the generated requirements and the feedback received from participants.

The tool

The new tool consists of:

1. The human stakeholder canvas – a graphic structure that prescribes a formal way to list the human stakeholders and their main interests (Fig. 6), and;
2. The use case scenario canvas – a graphic structure to describe the use case scenarios involving or interfacing humans (Fig. 7).

In comparison to the previous method of listing and analyzing stakeholders, the new tool proposes the distribution of the stakeholder's main interests in three categories, namely desirability, viability and capability (Fig. 6). A Microsoft PowerPoint template was created to ease the application of it. This template can be printed and used analogously. The canvas is self-explanatory and did not require significant training efforts of the engineers in order to apply it.

Compared with the previous description of use case scenarios, the new tool adds two fields which are the description of the human interaction that supports the use case and how the actors shall experience not only the interaction but also the complete use case (Fig. 7). As for the other canvas, the researcher created a Microsoft PowerPoint template that can be printed and used analogously. It is self-explanatory and required no training efforts to be used.

Generated requirements

Engineer "A" analyzed a total of seven stakeholders and eleven use case scenarios, i.e. the number of elicited human stakeholders and described eleven use case scenarios related to human stakeholders existent on the system model prior to the application of the tool. Based on these, engineer "B" generated text-based requirements, which are 55 stakeholder requirements that resulted from the stakeholder analysis, and 54 systems requirements that resulted from the use case scenarios. All requirements were recorded according to the origin, source and validity. The origin of requirements refers to the type of canvas, i.e. human stakeholder or use case scenarios. The source refers to which "box" on the canvas the requirement can be traced. A requirement was recorded as valid if it was a new one, i.e. not existent in the system model. Table 2 shows the number of requirements generated based on the application of the tool, and the number of requirements considered valid and the number of valid requirements related to human values. The valid requirements were added to the system specification. The specification was review and approved by the project team and the client.

Table 2 exhibiting a random sample of generated requirements

Text-based requirement	Origin	Source	Is it valid?	Is it related to human values?
The system needs to be perceived as a Green-solution in the global market	Stakeholder (The Client)	Desirability	YES	YES
The solution needs to make service and support available 24/7	Stakeholder (The Client)	Capability	YES	NO

It must be possible to lift the containers on to vessel's deck	Use case scenario (Handling, Storage and Transport)	Steps	YES	NO
The HMI and the GUI must be user-friendly, ensure clear communication and provide information easy to read	Use case scenario (Run Start-up Procedures)	Human Interaction	NO	NO
Status of booking must be possible to check at all times	Use case scenario (Scheduling of Inspection & Cleaning)	Experience	YES	YES

Feedback of participants

Besides the participants involved in the researched case study, two other engineers working at the company have used the tool in different projects. All participants were part of unstructured interviews and answered a survey. Figure 8 shows the responses to a section of the survey that aimed to know if the engineers perceived the new tool as being broader and deeper than the previous one. Figure 9 shows the responses of a group of questions which aimed to find how the engineers perceived the new tool in terms of application and results specifically for each of the canvasses and Figure 10 shows how likely the engineers will recommend tool and how much they value it from an overall perspective.

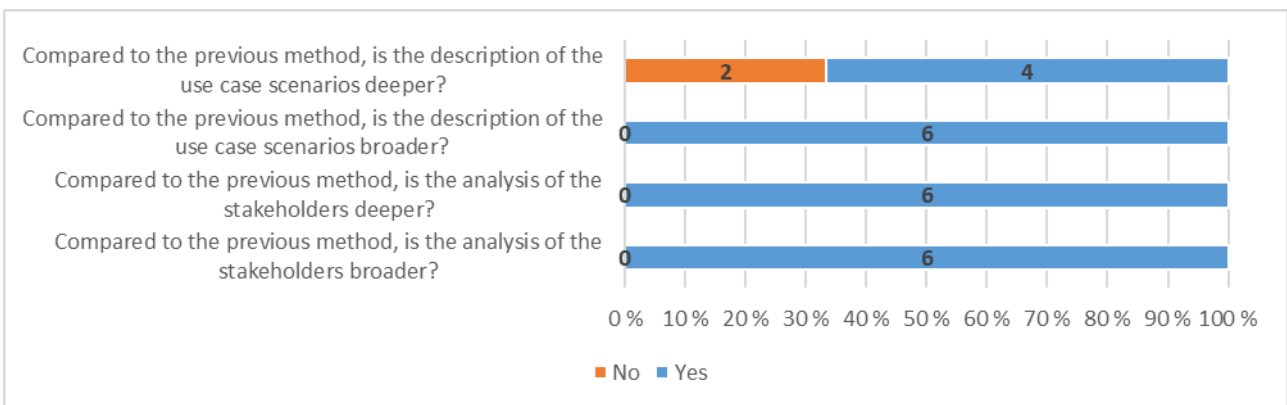


Figure 8.

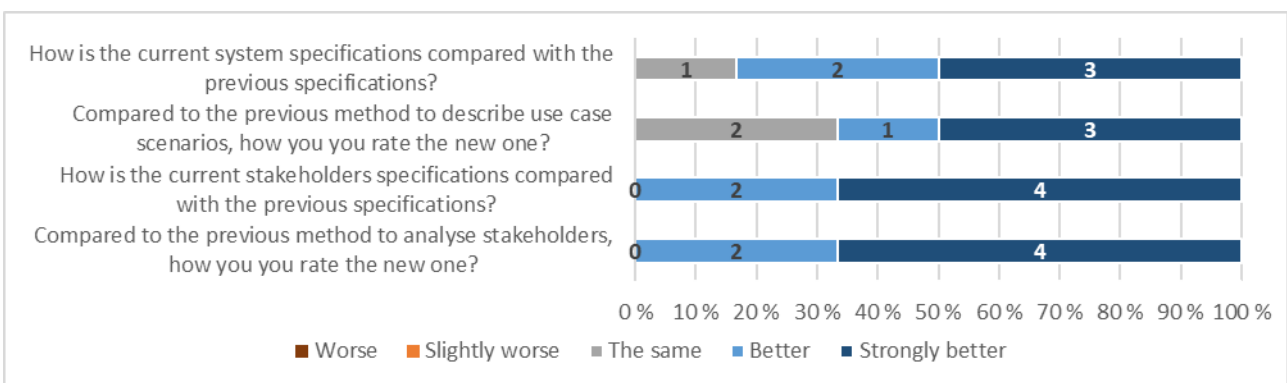


Figure 9.

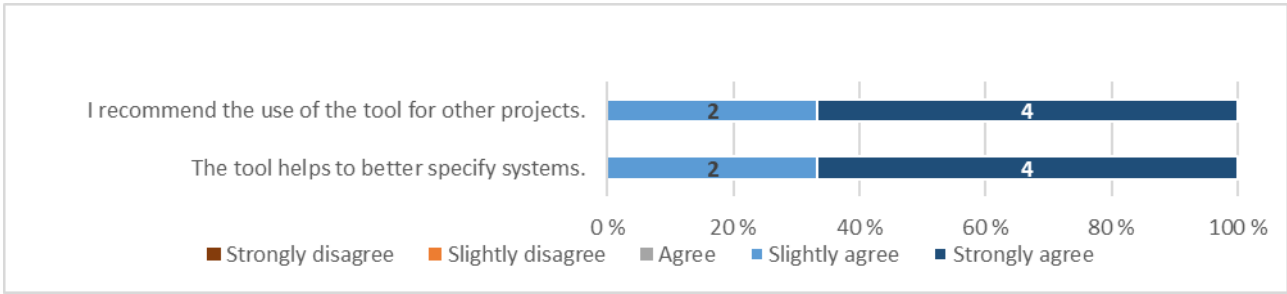


Figure 10.

Conclusion

This research has investigated how to ensure that systems engineers include human values in the early specification of systems. We have introduced a new tool, and tested the tool in a real innovation project. The total number of stakeholder requirements prior to the experiment were 41 (See table 3). One of these specifies human values, representing only 2%. The number of new stakeholder requirements generated by using the new tool was 55 (see Table 4). This surpasses the number of requirements prior to the experiment. Only 11 of the 55 are valid, i.e. requirements that were added to the specification because they are new and relevant for the system. Seven of the valid requirements contain aspects related to human values, representing 64% of the requirements added. The total number of requirements related to human values increased from one to 8, i.e. from 2% to 15% of all requirements.

Table 3 shows the number of requirements existent (benchmark) prior to this study

Requirement	Total number of requirements	Number of requirements relate to human values
Stakeholder requirements	41	1
System requirements	107	1

Table 4. Number of generated requirements

Requirement type	Generated requirements	Valid requirements	Valid requirements related to human values
Stakeholder requirements	55	11	7
System requirements	54	14	6

55% of the valid requirements stem from “desirability”. With desirability we mean "what are the emotional, cultural and social wishes of the stakeholder", see Figure 6. On one hand, this could show the importance of the tool to help to specify human values, knowing that engineers tend to translate them into HSE requirements. On the other hand, one could expect 100% of these to be from desirability, with viability being secondary and capability as means to an end as suggested by Osterwalder et al. (2014). The engineers were not trained within the context of this research to identify the relationship between a requirement and a human value. There is a risk of misinterpretation by the engineers which values the stakeholders actually hold. Taking the system requirement “The solution needs to make service and support available 24/7” as an example: it is a new requirement but is not

recorded as related to human values (Table 2). One might argue, however, that from a client’s perspective, this requirement can be related to “trust” and be considered a human value.

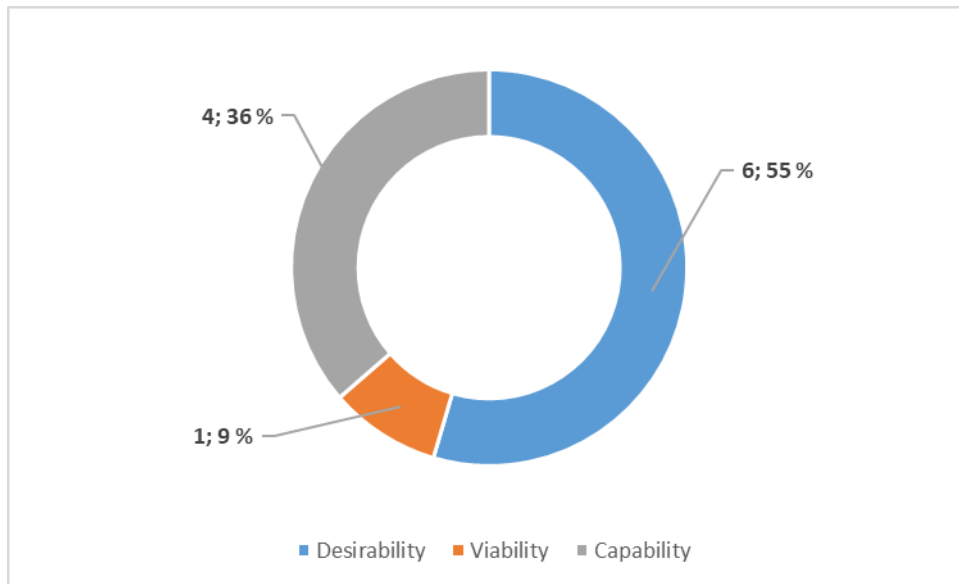


Figure 11. Source of valid stakeholder requirements related to human values

There were 107 requirements on the system level. Less than 1% of these specify human values. Of the 54 generated requirements, 14 were considered valid (Table 4), and therefore added to the system specification. Of the 14 valid system requirements, 8 do not specify human values, representing 57%. All new requirements that do not contain aspects related to human values are sourced on the use case scenario canvas (Fig. 7), specifically from “preconditions” (75%) and from “steps” (25%), see Figure 12. Neither “preconditions” nor “steps” are new to the description of use case scenarios. This result indicates that the new tool provides a broader or more detailed description than before, helping to generate more requirements. Almost half of the system requirements, 43%, contains aspects related to human values. All of these are sourced on the two boxes added to the regular use case scenario description, i.e. “human interaction” and “experience” (Fig. 13). Systems requirements containing aspects related to human values increased from one to 7, i.e. from 1% to 6% of all system requirements. This increase is similar to the one verified with the stakeholder requirements.

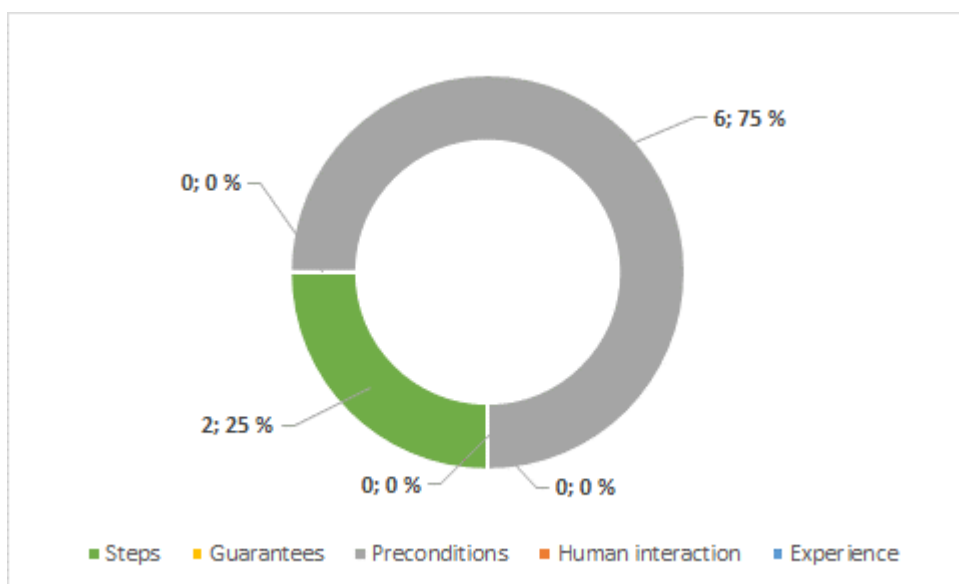


Figure 12. Source of valid requirements that do not relate to human values

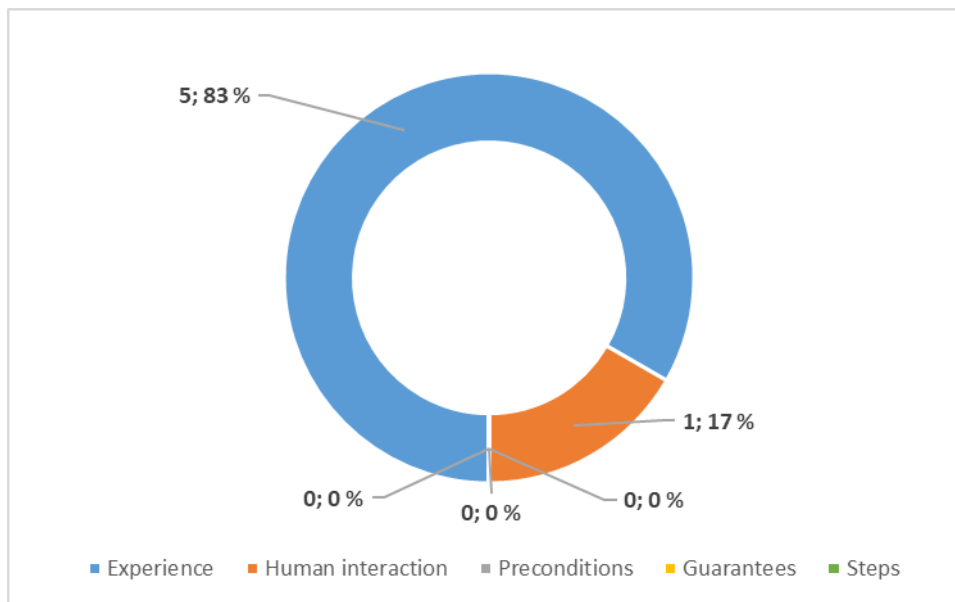


Figure 13. Source of systems requirements related to human values

The participants involved in this study have reported that the tool helped them to better analyze the human stakeholders and to better describe the use case scenarios related to human stakeholders. Consequently, the number of requirements related to human values in the system's specification has increased from one to eight at the stakeholders' level and from one to seven at the system's level.

The application of the tool in the context of this study does not consist of new work in terms of eliciting stakeholders. The tool was applied to an initial number of stakeholders and use case scenarios. It aimed at re-analyze the existing human stakeholders and re-describe existing use case scenarios. This approach explains why the 55 generated human stakeholders' requirements did not simply replace the existent 44. Moreover, the tool presents a way to ensure that human stakeholders are taken care of when specifying systems, reducing the impact of human values being perceived differently between systems engineers.

It is important to note that the research does not provide a quantitative analysis showing that poor generation of requirements for human values is not happening on other projects or teams, i.e. that poor generation happened only on the current case. Both the system architect and the researcher observed that poor generation of requirements happens across projects and with different teams, but this happens only in connection with human values. Probably the reason is that some of the requirements related to human values are difficult to objectively verify and required a "subjective perceived" verification.

Even though our results indicate that the application of the new tool helps systems engineers to include human values in the early specification of systems, further investigation is ongoing in order to evaluate the potential of generalizing the tool, its efficiency and effectiveness. One aspect that will require special attention is the mindset of the systems engineers applying the tool. It is beneficial for the goal of caring about values of the human stakeholders that engineers look at the system from the outside. They should focus on how the system shall be perceived and not only looking from the inside, that is, looking at what the system is meant to deliver. Investigating the requirement 'Status of booking must be possible to check at all times' from an inside perspective, the requirement is a basic functionality. However, from an outside perspective, it defines how the user perceives the system. It does it by removing the anxiety of the user that results from not knowing the status of an operation. Furthermore, knowing the status of an operation at all times helps to build confidence and trust in the systems. Trust is a value that defines the success or failure of a system or business for the matter.

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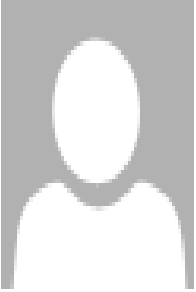
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Biography



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