

# Issues in Capturing and Utilizing Non-Functional Requirements along the Road to Servitization

C. N. K. Toller , C. Johansson and M. Bertoni

Blekinge Institute of Technology, Sweden

 [carl.toller@bth.se](mailto:carl.toller@bth.se)

## Abstract

The design process aims to maximize the value in the end solution. For traditional manufacturing firms pursuing a servitization strategy, non-functional requirements become more important compared to before. Therefore, this paper investigates issues in capturing and utilizing non-functional requirements for value creation in a servitizing firm. A single case study was conducted, which resulted in six issues across the design process. It was evident from the research that the firm requires new support to enable a better inclusion of non-functional requirements in the design process.

*Keywords: product-service systems (PSS), requirements management, case study, value-driven design*

## 1. Introduction

The main purpose of a designer is to maximize the value of a product, service, or system. This task is not as simple as it might sound since the construct of value is often complex and multifaceted. The challenge through the design process is to find the maximum value somewhere in the trade-off between the fulfillment of different requirements while acknowledging influencing constraints (Robertson and Robertson, 2013). Requirements can be divided into functional that address those related to the direct purpose of the system and non-functional which address the overall qualities of the system (Adams, 2015). However, finding value in a PSS is different from finding it in pure product businesses.

In a PSS, the products and services are combined to increase the value delivered (Kuijken et al., 2017) thus allowing the designer to achieve value fulfillment through either enhancing the physical product or improving the services connect to that product. The most common approach toward a PSS-oriented business is through servitization, shifting from selling pure products to selling a system of associated products and services (Kuijken et al., 2017). According to Machchhar et al. (2022), services in a PSS can only provide value in the non-functional domain while the products can be both functional and non-functional. This is because the core purpose/function of the PSS is still bound to the product as for a pure-product solution. Ultimately, this means that the servitization transition will put additional strain on capturing and utilizing the non-functional requirements in the design process since the non-functional requirements increase in importance for the overall value delivery.

However, as manufacturing firms have a tradition of delivering predominantly functional value to their customers, this is often overlooked and non-functional requirements are neglected in favor of functional ones. In general, there is a perception that functional requirements are of higher importance than non-functional even though there is no supporting theory for this statement (Gomez Sotelo et al., 2018). The issue when neglecting non-functional requirements is that a large portion of the underlying needs might be left unfulfilled, leading to a significant impact on the overall perception of the system (Adams, 2015).

Previous research has found multiple fallacies and problems in the requirement elicitation process (Christel and Kang, 1992; Esterman et al., 2008; McDermid, 1989). In common for papers within this research field is that they often address it from a marketing perspective or target the quality of the process. However, there is little research done using the design process as a foundation and looking through the lens of the designer. For companies that have adopted a linear approach in the product development process, the capturing and utilization of requirements are often divided between different departments stressing the importance of taking the designer's perspective further. In PSS, there has been little research done in connecting the designers with the "real needs" and looking at a more holistic level for translating needs to requirements to value (Toller and Bertoni, 2021). All in all, this shows that there is a need for studying how requirements, primarily non-functional, are managed in manufacturing companies when commencing their servitization journey.

The aim of this paper is then to broaden the body of knowledge by looking at issues that exist in capturing and utilizing non-functional requirements for value creation in a servitizing manufacturing firm. The research question connected to the research and paper is:

*What issues exist for capturing and utilizing non-functional requirements to create value as an organization starts its servitization journey?*

The firm investigated in this study has for several decades provided equipment for the infrastructure sector and almost exclusively operated in a pure-product business. However, they are now at the start of their servitization journey and has since a few years adopted a value-centric approach in the design process. However, they see a need for a better understanding of how this influences the design process and designing for the highest value.

The remainder of the paper is structured as follows. Firstly, relevant theoretical knowledge is provided in Section 2. In Section 3, the methodology is presented and in Section 4, the results from the empirical study are described. Finally, reflections and critical remarks are given in Section 5, and the paper is concluded in Section 6.

## 2. Theoretical Framework

The foundation for this case study is built on value, needs, and requirements. Before the results are presented, it is important to understand how these aspects are defined. Therefore, the customer needs, fundamentals of requirements, and their relation to value are introduced below.

Starting with the needs, Griffin and Hauser (1993) define a customer need as "a description, in the customer's own words, of the benefit to be fulfilled by the product or service". Within Systems Engineering, Faisandier (2012) describes customer needs as a necessity or desire expressed by the customer or stakeholder. It is important to emphasize that needs are not per definition a one-dimensional criterium but can have different characteristics (refer to Kano model) and change depending on the market segment (Matzler and Hinterhuber, 1998). Moreover, Faisandier (2012) chose to distinguish the needs by maturity to illustrate that the needs obtained by a company are not necessarily equivalent to the real needs for a given scenario. Before the needs can be specified to requirements, they must be perceived and expressed by the customer as well as retained by the provider (Faste, 1987).

A product's requirements are the specification of what a product does for its user and which constraints it must fulfill for a given context, expressed in an abstract and technologically neutral fashion (Robertson and Robertson, 2013). Requirements can be seen as both a collection of needs and goals from a customer as well as conditions posed by a stakeholder (Pohl, 2010). This means that the source can be either customer or stakeholder, including the provider.

Within systems and software engineering literature, the requirements are often broken into functional and non-functional. In this construct, the functional requirements are directly related to the intended purpose of the system in what it must do for the customer, while the non-functional requirements can be seen as the system qualities (Adams, 2015). The functional requirements are typically easily quantifiable and transferrable to a specific module or component in the system while non-functional requirements are more global and might target multiple modules and components (Cysneiros and Yu, 2004).

Looking at the relationship between needs and requirements, [Ryan et al. \(2015\)](#) define the distinction to be that needs are the tacit explanation of the desired state in a natural form while requirements are the explicit and formal description of this state. The target of requirement elicitation is then to, as clearly as possible, translate the naturally expressed needs to formal requirements without introducing biases ([Gomez Sotelo et al., 2018](#)). It is the requirements that are used for the validation of the system and, therefore, a complete and correct translation is critical. Similarly, [Ulrich and Eppinger \(2012\)](#) use the terminology of “product specification” which is comprised of a metric and numerical value to describe what has to be fulfilled to achieve the satisfaction of needs.

Expanding this to incorporate value, it can be said that value is the benefits compared to the costs, applicable to both the customer and provider perspective ([Miles, 1972](#); [Rondini et al., 2020](#)). Cost is typically straightforward even though it can incorporate recurring expenses and aspects beyond the acquisition itself, e.g., operational, support, and disposal cost. The benefits side is more complex as it can incorporate multiple perspectives that can be difficult to quantify. Using the definition of a need as expressed by [Griffin and Hauser \(1993\)](#) and the value definition by [EN12973 \(2020\)](#), the benefits can then be seen as the satisfaction of needs. The concrete measurement of the benefits is then the fulfillment of requirements using the previously defined relation. For the functional requirements, this becomes a straightforward task to quantify and measure, for example, engine power and fuel consumption. On the other hand, non-functional requirements are typically more difficult to specify and evaluate as they address the whole system and can be interpreted differently depending on contexts ([Cysneiros and Yu, 2004](#)). Despite this, there are examples where non-functional requirements are quantified, e.g., CO<sub>2</sub>-equivalent for sustainability and noise and vibration in comfort. Concluding this in a statement, value can be seen as the degree of fulfillment of needs with respect to all system constraints, which is measured in terms of functional and non-functional requirements compared to inclined cost.

### 3. Methodology

The single case study and qualitative analysis aimed to depict the current state of elicitation and implementation of non-functional requirements at the case company. Qualitative research is defined by [Savin-Baden and Major \(2012\)](#) as research that targets “how people make sense of their ideas and experiences” and through that draws conclusions of the underlying constructs that shape these perceptions. The overall method is depicted in Figure 1. The remainder of this section will go through the internal steps of the method in more detail.



Figure 1. The overall methodology used in the case study

#### 3.1. Data Collection

The choice of collection methods for a case study should be made based on the ability to answer the aim and research questions ([Blessing and Chakrabarti, 2009](#)). Interviews, observations, and documentation (including both documents and records) were selected as they include both qualitative and quantitative data, increase the potential for triangulation, and were believed to best support the aim.

The first data collection method was semi-structured interviews. This style was deemed to be the most beneficial due to the exploratory style of the research but still allowing consistency and traceability. The sampling for the interviews was two-folded, first, theoretical sampling was conducted where participant selection was based on peoples' expertise or relation to the studied case. Later, an opportunistic sampling was conducted to leverage the increased understanding of the case and its influence on people ([Savin-Baden and Major, 2012](#)). Each interview was about an hour in length and was recorded by the interviewer. Throughout the case study, a total of eight interviews were conducted across the three departments of Marketing, R&D, and Management.

Based on the interviews and ongoing correspondence with the case company, further sources of information were identified. Examples of sources were travel reports, datasheets, and project specifications. Findings made within the sources were documented and marked. As the information

regarding requirement elicitation and product development is typically confidential, the findings were anonymized.

### 3.2. Data Refinement and Analysis

In qualitative analysis, the core purpose is to provide and explain the correlations and causalities to a specific occurrence of events. [Blessing and Chakrabarti \(2009\)](#) list three requirements for causality to exist: (1) a time order, the cause must happen before the effect, (2) a high degree of relationship between the nodes must exist, and (3) exclusion of rival factors. The justification of the causality can be based on assumption, observation, experience, or literature depending on its source of evidence.

However, the obtained data must be refined before any analysis can occur. For this purpose, the interviews were transcribed and included in a case database, along with the observations and documentation, something [Yin \(2014\)](#) mentions as critical for data collection in case research. Moreover, the extracts from the transcripts were refined for readability, complemented with contextual notes, and anonymized. The transcripts were also distributed to the interviewees for validation and as quality assurance. A total of 227 unique entries were included in the case database.

The next step was to critically analyze and find causalities. For this project, the case database and all its entries were reviewed. Firstly, all entries were marked with topics and bundled to main findings. To ensure repeatability and transparency, all identified findings were marked with the corresponding entries. The findings were then consolidated and categorized into a set of issues. Once the analysis was completed, it can be sent out to the case participants for review. This serves as validation and helps to avoid errors and misinterpretations ([Miles and Huberman, 1994](#)).

## 4. Results

This paper represents a single case study at a manufacturing firm that has just started its servitization journey. The case company has been almost exclusively focused on providing high-value products to the infrastructure sector and operated around a pure-product strategy. However, the company has recently seen potential in adopting a PSS approach and is actively seeking ways to initiate this servitization. It is in this ambition that a need for identifying issues or obstacles regarding their needs- and requirements management arose. It was decided to focus on the non-functional requirements since a servitization of a product-oriented business increases its importance and these requirements are rather unexplored at the case company.

Ultimately, the qualitative study conducted at the case company resulted in a list of six identified issues when it comes to capturing and interpreting non-functional requirements for value maximization. These issues represent obstacles that affect the organization at different levels and in different phases in the development process. Figure 2 shows the issues, including which product development phases they affect. The process model presented by [Ulrich and Eppinger \(2012\)](#) was used as a representation.

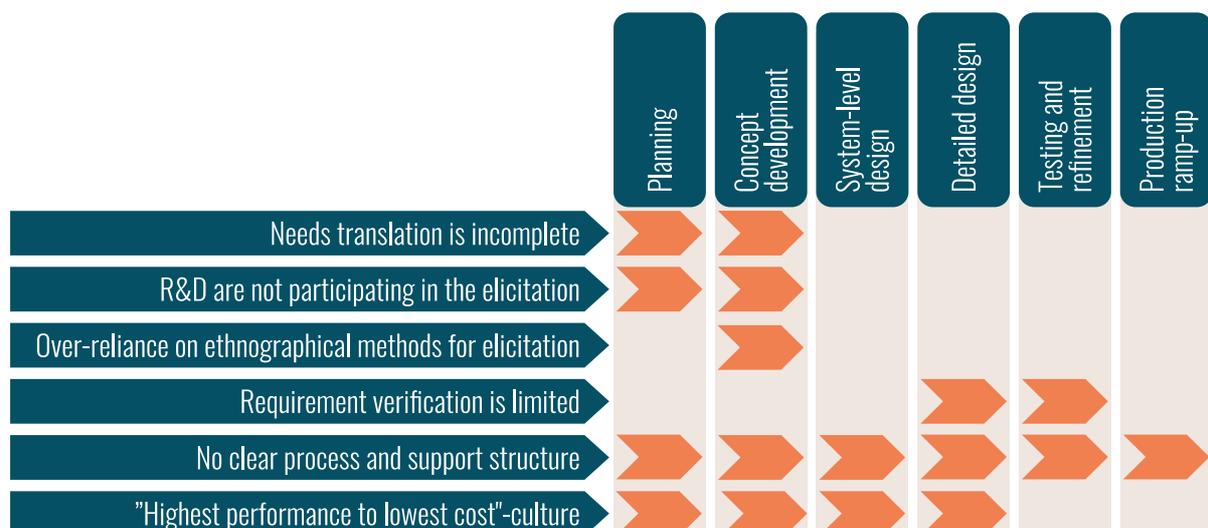


Figure 2. Issues found throughout the product development process

At an overall level, most of the issues appear to affect the development process in the planning- and concept phases. This is unsurprising as these phases are the ones addressing the need- and requirement elicitation to the largest extent, and the prerequisites for the actual development are determined in these steps. However, some issues interfere with later design and development phases as well as the final ones. Most issues manifest in one of two phases while there are two that span broader and are more holistic. The remainder of this section will go through each issue individually and explain in more detail how they manifest, affect, and interfere in the development process.

#### **4.1. Needs translation is incomplete**

The first identified issue refers to that the needs collected by the marketing department remain in their workgroups. The collection of needs is exclusively made by the marketing department which stresses the importance to achieve a complete and correct translation to requirements that are later used by the R&D and designers. Based on the case study, several indications of an incomplete translations process were found. The first was that not all needs found were later mapped. From a functional requirements perspective, the translation was comprehensive indicating most of the needs in that domain were covered. On the other hand, the non-functional requirements were scarce and to a large extent missing in the requirement specifications. Most of the non-functional requirements are related to serviceability whileilities such as comfort and reliability are missing or only touched briefly. The general structure of the requirement specification was skewed to the functional domain and rarely acknowledged the non-functional aspects, apart from serviceability. Finally, the mapping between the needs and requirements is poorly documented itself which strips the designer the ability to go back and see from where the requirement originates and thus better grasp their rationale and contextual heritage.

As previously mentioned, needs can have different characteristics in how the fulfillment of a need correlates to customer satisfaction (Matzler and Hinterhuber, 1998). According to the Kano model, the relation can be characterized as must-be, one-dimensional, and attractive requirements. From the case study, it was shown that these characteristics were not translated to the requirement specification causing a loss of information. Because of this, the decision-making at both an individual and group level was not able to include these aspects in the trade-offs between contradictory requirements as well as assessing the overall value delivery. Looking more specifically at the non-functional requirements the ones which were translated mainly were of the must-be style, e.g., "feature x shall be present" or "component should last x number of hours". There is no indication if exceeding the requirements will lead to higher satisfaction or if they remain the same. The descriptions of the requirements remain incomplete, and the complexity depicted in the needs is lost due to this. The style in the requirement specification strips the designer of the possibility to understand how the degree of fulfillment correlates to the degree of provided value as well as offering any support in tradeoff analysis. Ultimately, the designer is restricted in making well-informed decisions when the rationale of the requirements is unclear.

#### **4.2. R&D not participating in the elicitation**

Connected with the previous issue, this one also applies at the need-requirement junction. The organizational structure of the case company is so that the product development process is conducted linearly. The marketing department is responsible for the acquisition of the customer and stakeholder needs and translating these to requirements while the R&D department is responsible for the conceptual and design of the products. This means that the respective department is an expert in their fields. However, this also means that the people who are realizing the needs are disconnected from the source of the needs. At the case company, the R&D department is rarely attending field visits. Field visits can serve as a good forum for seeing the PSS in its operational context and obtaining first-hand information from multiple stakeholders. The field data reveals that most of the field visits, with a few exceptions, are made by the marketing department without any member from R&D participating. The main justification for this was down-prioritization by R&D due to limited resources. Nonetheless, the issue with R&D not attending field visits is that marketing and R&D have different ambitions, expertise, and points of view, which cause them to focus and acknowledge different aspects at a field visit. This viewpoint was acknowledged by the marketing department as they saw it to avoid the

multiple steps of filtration between customer and designer. With each step, there is a risk that important contextual information goes lost in the translation between functions.

The extended design process paradox, as shown by [Johansson \(2019\)](#), illustrates the criticality to obtain knowledge early on in a project while the design freedom is high and the committed cost is low. Concerning this, it is wise to obtain as much knowledge as possible about the operational scenario and needs and not just for the marketing but the R&D department as well. Through the participation of designers in field visits, the non-functional requirements can be perceived by the R&D department directly and thus increase the knowledge early in projects while reducing the risk of misinterpretations in the communication between marketing and R&D.

### **4.3. Over-reliance on ethnographic methods for elicitation**

Ethnographic methods such as interviews, observations, and focus groups are well established in requirement elicitation and product development. However, the case company expressed limitations when working in this domain. Firstly, it is a time-consuming process and not able to cover all different markets, operational sites, and environmental contexts. The case company has a global market and thus their PSS solutions need to work in this vast variety of context and operational scenarios. Secondly, it is a people-oriented process and thus at risk of being influenced by personal perceptions, misinterpretations, and miscommunications. Finally, the workload related to a comprehensive elicitation hinders them from being done often and regularly, resulting in sparse and ad-hoc efforts for collecting needs, typically guided by convenience and perceptions rather than any objective motivations. This led to Voice of the Customer which is out of date and hard to justify complete need coverage.

Further, they expressed that "when you ask 1000 customers, you get 1000 responses, and you cannot make everyone happy". They stated that it was difficult to perform a just and objective prioritization. Instead, the decisions were often made by using perception and previous experience. Looking at a data-driven elicitation, recent research has shown great potential in using data for value co-creation ([Machchhar et al., 2022](#)). The case company has this potential as they already collect operational data, but they lack tools and models for taking this step. It might therefore be possible to mitigate and avoid some of the fallacies in the ethnographic methods by exploring the potential in data-driven methods.

### **4.4. Requirement verification is limited**

As explained in Section 4.1, the non-functional requirements are to a large extent excluded from the translation and requirements specification. Ultimately, this leads to verification and validation which is centered around the functional requirements. It is important to validate the non-functional requirements as well because they represent different parts of the value delivery, qualities of the entire system in contrast to the performance of specific features. The lack of non-functional requirements in the requirement specification as well as no clear way to measure their fulfillment resulted in the exclusion of these requirements in the validation. This attitude is then further cascaded to the design phase as it causes a skew toward focusing on meeting the functional requirements. In the detail-design and test and refinement phase, the time and cost aspects become critical, and then the resources are pushed toward meeting the set, functional goals, in favor of unmeasurable non-functional ones.

Onward, the case company depicted the validation process as challenging since they lacked clear measurement for success and value. This is partly explained by the fact that the relation between fulfillment and satisfaction is neglected in the translation process between needs and requirements. A project manager said that "it is one thing to confirm that a lamp is present or that certain power output is reached but other requirements and needs we can only verify via perception or not at all". At a holistic level, the case company lacked measurements and evaluation criteria to assess how well they fulfill the requirements as well as how this influences the satisfaction and value of the system.

### **4.5. No clear process and support structure**

A solid process and support tools are critical for successful requirement elicitation and utilization. However, the notion of the non-functional requirements is absent from the elicitation process

documentation. The case company has not acknowledged that non-functional exist as a style of the requirement but rather emphasize the translation of needs to the functional domain. Partly, this was due to that decision-making was described to be "very technical and cost-centric" restraining the employees to focus on other aspects. This does not mean that all non-functional requirements are missed, but rather that the ones included are done so thanks to their expressed importance by the management and corporate strategy. Apart from one ility mentioned explicitly in the requirement specification, the document is dominated by expressions of functional requirements. Looking at needs, it was found from both the interviews and observations that "non-functional needs" are collected and analyzed but the current process and support tools are not able to manage these efficiently. In relation to the first issue, the lack of support and an inclusive process stops the mitigation of needs from marketing to R&D.

#### 4.6. "Highest performance to lowest cost"-culture

The final issue affects the entire organization and all its processes, even though its main influence was deemed to be on the product development phases. The mantra of "highest performance to lowest cost" was mentioned at almost every interview and was visible in the daily work at the case company. Further, it was ever-present at the decision-making, both individual, group, and departmental. In Value-Driven Design, the goal for a designer is to create the maximum value by finding the design which gets the highest score (Collopy and Hollingsworth, 2011). This means that it is not necessary the highest performance to lowest cost that in reality provides the highest value but it is rather a challenge of optimizing the requirements to find the design with the best "design goodness" (Cheung et al., 2012). There is a risk of sub-optimization of the value when only looking at one dimension without a good understanding of the others. Pursuing functional requirements will only lead to partial fulfillment of the value potential. Taking the historical perspective, this culture was probably motivated by the fact that it is the functional requirements that are more critical in a product-centric enterprise, something which Gomez Sotelo et al. (2018) argue against. Additionally, servitization puts additional stress on the importance of meeting the non-functional requirements as added service contributes to value through the non-functional domain and thus shifting the ratio between value contribution from functional and non-functional fulfillment. For instance, the addition of a digital service for fleet management could lead to increased cost and slight reduction of functional requirement fulfillment (added weight and resource demand) but at an overall level it can increase the value and thus motivating a compromise. This style of reasoning was retained at the case company as they expressed a reluctance in compromising on performance and cost.

### 5. Discussion

For a pure product-based firm, it can be sufficient to compete on strictly functional requirements and cost. But as you start moving toward PSS solutions and a servitized business, the non-functional requirements become a critical aspect for enabling success. This paper aimed to track the issues existing for capturing and utilizing non-functional requirements in a traditional linear and product-centric organization starting its servitization journey. There is a plethora of research addressing requirement elicitation, but the majority looks at it from the market analyst standpoint and tries to find ways to improve the process to be more efficient and stable. In contrast, the target of this study was to take the designer's and the design process perspective in the requirement elicitation and look need and requirement management for value creation as the main goal, especially focusing on the non-functional domain. As the global competition and customer demands increase, companies have seen servitization as a strategy to enhance competitiveness. Non-functional requirements are a critical cornerstone in the success of this approach as the added services are contributing solely to this domain. However, the case company included in this study has little experience in working with non-functional requirements and how the development process should incorporate these efficiently. Therefore, a need for investigating the current issues in working with these requirements was desired. Going through the results of the qualitative single case study, multiple issues and obstacles were found that hinder the capturing and utilization of non-functional requirements for value maximization. Most of these affect the early phases of the product development process. This is somewhat reasonable as it

is where the elicitation and major decisions are made. A possible explanation for this can be the organizational structure of silos which results in a division of people working with capturing and people working with the utilization of requirements.

Onward, functional requirements are typically easy to translate from needs and express in a formal and quantifiable manner while non-functional are harder but the design team still has to ensure that both are met (Gomez Sotelo et al., 2018). A possible explanation for excluding non-functional requirements is the cultural heritage and a general perception that the functional aspects are the ones that matter in a product-oriented market. But as the market and company are becoming more servitized, they need to acknowledge that it is both domains of requirements that determined the value delivered. In the pursuit of maximizing value for a PSS, both functional and non-functional requirements need to be captured and utilized.

The six issues listed in Section 4 are not separate and standalone from one another. As previously mentioned, there are interlinks between them as well as possible cause and effect-relationships. For instance, the incompleteness of needs translation to non-functional requirements can partly be explained by the fact that non-functional requirements are not included/mentioned in the process itself. This further restricts the ability to validate these requirements at the later stages of the product development process. The culture of the case company also has a substantial effect on what happens and how things are perceived. Moreover, the first four issues are more straightforward and something which could probably be solved in a short time frame while the last two are more complex and thus could demand longer efforts. At the same time, the latter two will probably have a higher impact and generate a more sustainable change.

From a future perspective, it is valuable to investigate how these found issues can be tackled. This case study provides a good descriptive base for a prescriptive study, even though it is thus far limited to this specific case company. For this particular case company, it is important to remember that they have a linear organization meaning that the capturing and utilization of requirements are done by two separate departments. This restricts and hinders the implementation of approaches such as needfinding as these typically have a more seamless integration of work tasks (Patnaik and Becker, 2010). It is hard for an organization to succeed in needfinding with the traditional approach of working in silos (Faste, 1987). It is possible to make an organizational change, but those are typically hard and might give rise to new issues and obstacles and, therefore, might not be the best first action to take. A sounder approach is to look at what can be done while respecting the organizational boundaries.

On a positive note, the case company has good potential for tackling the found issues as they have a good baseline to start from, e.g., customer needs are collected today in both functional and non-functional domains, operational data is available, etc. This allows for any prescriptive research to focus more on the internal processes and limit the intervention to a narrower part of the elicitation process. Moreover, the available telemetrics enables data-driven approaches to be utilized and function as a complement to the traditional ethnographic methods. Some issues can be solved rather easily such as sending R&D personnel on field visits while others require a more holistic approach. Which interventions to go forward with is something that needs to be strategically discussed and is a part of future work.

The case company's ambition to servitize is representative of the general trend hopefully providing good cascading possibilities to other companies facing similar issues. This leads to them being a good pilot platform for investigating what interventions can be used for leveraging non-functional requirements in the design process. Afterward, both the descriptive case study presented in this paper, as well as future prescriptive study, can be replicated at other manufacturing firms in the midst of servitizing to validate the findings and provide a firmer scientific base.

Finally, the empirical study has been subjected to some limitations that are important to acknowledge. The first is that this is a single case study, which means that it is not guaranteed that the findings are transferrable to a generic level and applicable in other contexts even though single case studies are beneficial for more holistic and in-depth explorations (Yin, 2014). Blessing and Chakrabarti (2009) suggest using multiple case studies complemented with a mapping of relevant literature to be able to generalize the findings in a theoretical domain. Therefore, it is wise to expand this research and look at other contexts for validating and expanding the findings from this one. The second limitation is that

the case study to a large extent was dependent on interpretations and implicit data. The explicit data was sometimes poor and subject to confidentiality restricting the possibilities to utilize it.

## 6. Conclusions

In the pursuit of maximizing value in the design process, all requirements must be successfully captured and utilized. For functional requirements, this is commonly the case since they are easy to understand and quantify and are sufficient to fulfill for a product-based business model. However, when servitizing, the company can no longer ignore the non-functional requirements as they are a crucial part of the value delivery of PSS solutions. This paper looked at one of those firms to determine what issues and obstacles exist in capturing and utilizing non-functional requirements.

The qualitative case study showed a set of six issues that exist for the non-functional requirements to be properly captured and utilized in the design process and contribute to the designer's ability to maximize value. These issues were mapped on the product development process to visualize how and when they affect from a designer's perspective. At its core, it was found to be a lack of support in transforming needs into non-functional requirements and conveying these to the designers without losing the rationale. To summarize, it is no longer enough for servitizing firms to sub-optimize the functional requirements in favor of non-functional requirements. No, finding the highest value demands a holistic standpoint and recognition that in PSS, both functional and non-functional requirements are vital.

## Acknowledgments

The research leading to these results has received financial support from the Swedish Knowledge and Competence Development Foundation (Stiftelsen för kunskaps- och kompetensutveckling) through the Model Driven Development and Decision Support research profile at Blekinge Institute of Technology.

## References

- Adams, K.M. (2015), *Non-Functional Requirements in Systems Analysis and Design*, Springer.
- Blessing, L.T.M. and Chakrabarti, A. (2009), *DRM, a Design Research Methodology*, Springer London, London. <https://doi.org/10.1007/978-1-84882-587-1>
- Cheung, J., Scanlan, J., Wong, J., Forrester, J., Eres, H., Collopy, P., Hollingsworth, P., et al. (2012), "Application of Value-Driven Design to Commercial AeroEngine Systems", *Journal of Aircraft*, Vol. 49 No. 3, pp. 688–702. <https://doi.org/10.2514/1.C031319>
- Christel, M.G. and Kang, K.C. (1992), *Issues in Requirements Elicitation*, Carnegie-Mellon Univ Pittsburgh Pa Software Engineering Inst.
- Collopy, P.D. and Hollingsworth, P.M. (2011), "Value-Driven Design", *Journal of Aircraft*, Vol. 48 No. 3, pp. 749–759. <https://doi.org/10.2514/1.C000311>
- Cysneiros, L.M. and Yu, E. (2004), "Non-Functional Requirements Elicitation", *Perspectives on Software Requirements*, Vol. 753, Springer, Boston, MA.
- EN12973. (2020), *EN12973:2020: Value Management*, European Committee for Standardization, Brussels.
- Esterman, M., Zimmerman, R.F., Spano, J. and Pereda, D.A. (2008), "An Exploratory Study Into Process Failures During the Voice of Customer Process in Product Development", presented at the ASME 2008 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, ASMEDC, Brooklyn, New York, USA, pp. 181–190. <https://doi.org/10.1115/DETC2008-50055>
- Faisandier, A. (2012), *Systems Opportunities and Requirements*, Sinergy'Com.
- Faste, R.A. (1987), "Perceiving Needs", *SAE Transactions*, Vol. 96, pp. 419–423.
- Gomez Sotelo, K., Baron, C., Esteban, P., Estrada, C.Y.A.G. and Laredo Velázquez, L. de J. (2018), "How to find non-functional requirements in system developments", *IFAC-PapersOnLine*, Vol. 51 No. 11, pp. 1573–1578. <https://doi.org/10.1016/j.ifacol.2018.08.272>
- Griffin, A. and Hauser, J.R. (1993), "The voice of the customer", *Marketing Science*, INFORMS, Vol. 12 No. 1, pp. 1–27.
- Johansson, C. (2019), "Reverse Engineered Design Automation: Applying Knowledge Based Engineering Techniques to a Case of Automotive Fixtures Design Configuration", *Proceedings of the Design Society: International Conference on Engineering Design*, Vol. 1 No. 1, pp. 1583–1592. <https://doi.org/10.1017/dsi.2019.164>

- Kuijken, B., Gemser, G. and Wijnberg, N.M. (2017), “Effective product-service systems: A value-based framework”, *Industrial Marketing Management*, Vol. 60, pp. 33–41. <https://doi.org/10.1016/j.indmarman.2016.04.013>
- Machchhar, R.J., Toller, C.N.K., Bertoni, A. and Bertoni, M. (2022), “Data-driven value creation in Smart Product-Service System design: State-of-the-art and research directions”, *Computers in Industry*, Vol. 137, p. 103606. <https://doi.org/10.1016/j.compind.2022.103606>
- Matzler, K. and Hinterhuber, H.H. (1998), “How to make product development projects more successful by integrating Kano’s model of customer satisfaction into quality function deployment”, *Technovation*, Vol. 18 No. 1, pp. 25–38. [https://doi.org/10.1016/S0166-4972\(97\)00072-2](https://doi.org/10.1016/S0166-4972(97)00072-2)
- McDermid, J. (1989), “Requirements analysis: problems and the STARTS approach”, *IEE Colloquium on Requirements Capture and Specification for Critical Systems*, p. 4/1-4/4.
- Miles, L.D. (1972), *Techniques of Value Analysis and Engineering*, 2d ed., McGraw-Hill, New York.
- Miles, M.B. and Huberman, A.M. (1994), *Qualitative Data Analysis: An Expanded Sourcebook*, 2nd ed., Sage Publications, Thousand Oaks.
- Patnaik, D. and Becker, R. (2010), “Needfinding: The Why and How of Uncovering People’s Needs”, *Design Management Journal (Former Series)*, Vol. 10 No. 2, pp. 37–43. <https://doi.org/10.1111/j.1948-7169.1999.tb00250.x>
- Pohl, K. (2010), *Requirements Engineering: Fundamentals, Principles, and Techniques*, Springer, Heidelberg ; New York.
- Robertson, S. and Robertson, J. (2013), *Mastering the Requirements Process: Getting Requirements Right*, 3rd ed., Addison-Wesley, Upper Saddle River, NJ.
- Rondini, A., Bertoni, M. and Pezzotta, G. (2020), “At the origins of Product Service Systems: Supporting the concept assessment with the Engineering Value Assessment method”, *CIRP Journal of Manufacturing Science and Technology*, Vol. 29, pp. 157–175. <https://doi.org/10.1016/j.cirpj.2018.08.002>
- Ryan, M.J., Wheatcraft, L.S., Dick, J. and Zinni, R. (2015), “On the Definition of Terms in a Requirements Expression”, *INCOSE International Symposium*, Vol. 25 No. 1, pp. 169–181. <https://doi.org/10.1002/j.2334-5837.2015.00055.x>
- Savin-Baden, M. and Major, C.H. (2012), *Qualitative Research: The Essential Guide to Theory and Practice*, Routledge, Milton Park, Abingdon, Oxon ; New York.
- Toller, C.N.K. and Bertoni, M. (2021), “THE RESEARCH DOMAIN OF PRODUCT-SERVICE SYSTEMS AND VOICE OF THE CUSTOMER: A SYSTEMATIC MAPPING”, *Proceedings of the Design Society*, Vol. 1, pp. 3101–3110. <https://doi.org/10.1017/pds.2021.571>
- Ulrich, K.T. and Eppinger, S.D. (2012), *Product Design and Development*, 5th ed., McGraw-Hill/Irwin, New York.
- Yin, R.K. (2014), *Case Study Research: Design and Methods*, Fifth edition., SAGE, Los Angeles.