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

Solution Validation and Customer Needs Understanding in the Early Phases of Product Platform Development; a Case Study in Digital Manufacturing Machines

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Abstract. We have observed in our company that the high-level specification of new products is difficult. The company works with legacy product platforms. Even with extensive knowledge about legacy products and applications, it can be difficult for engineers to understand if their proposed solutions for new products or features that will satisfy customers.

The goal of this study was to investigate why the company is having problems with specifying new products that eventually will constitute a new product platform. We show that relying on proxies and agile development is not sufficient to close the validation loop, how validation of solution concepts fails due to insufficient specifications of needs and that engineers must rely on indirect customer feedback, which they often receive late in the development process. We trace the problem to a sub-optimal definition of customer segments, causing a lack of validated needs and leading to challenges in calculating business cases

Introduction

Company and Context. The company is a global company with a product portfolio targeted at a variety of market segments within the packaging and signage industries. The company delivers solutions that support its customers in packaging management, 3D CAD, print prepress, flexo platemaking, 3D visualization of shops, workflow automation, palletization, digital converting and more.

The company employs the author of this paper as a Systems Engineer in one of its R&D departments. The R&D department focuses at the development and support of digital manufacturing equipment. There are currently two main product platforms. One of them a high-productivity platform, with multiple automation options serve the higher end of the market. The other platform, with lower productivity, lower price and cheaper technology serves the low-end, entry-level market. The product platforms consist of both hardware and software. Customers use the products for converting material into packaging products.

Being manufacturing systems, used in different contexts, the two product platforms incorporate many different qualities:

- *Performance*: The throughput or speed of the system whilst converting
- *Availability*: Uptime of the system
- *Quality*: The resulting quality of the converting performed on the product
- *Versatility*: The variety of applications the systems can be used for

- *Safety*: Safety of operators and other users
- *Usability*: Ease of use for the operator and other users
- *Connectivity*: Connections to 3rd party systems
- *Workflow management*: Planning and managing production workflow

Case. In this paper, we study the development of a next generation product platform (hereafter named the NextGen project). The NextGen project aims to develop the first product of a new product platform. This platform will eventually replace the two existing multipurpose product platforms. The first product will initially target only one customer segment. Later it is the intention to expand this product into a platform covering all the customer segments

Problem and Research Questions. "*Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. Systems Engineering considers both the business and the technical needs of all stakeholders with the goal of providing a quality product that meets the user needs"* (INCOSE, 2011). Most important of these stakeholders are the stakeholders belonging to the customer domain, the buyers and users. From the company's perspective, the customer group includes, amongst others, operators, designers, managers and owners. From the overall goal one can derive the two following problem statements; "*how do we know what the customers need?"* and "*how do we know that our proposed solution fits these needs?"*

The first step in any system development is to state clear goals and objectives based on perceived needs and business opportunities. Then, interpreting and translating these into product specifications. The needs must be validated and adapted to make sure that the right system will be developed. For companies working with legacy products, there is also a bottom-up process. Based on knowledge from these products, engineers already have ideas and solution proposals that can add value to existing or new products.

We have observed and experienced challenges concerning the early stages of new product development. In this study we therefore choose to focus on two defining aspects of this; the studying of solution concepts and the specification of new products. Typical challenges surrounding these aspects are unclear goals and criteria, inconclusive validation of needs and solution concepts, understanding of stakeholder needs and the translation of needs into clear system specifications. These struggles have in the past led to re-prioritization of projects, projects changing scope, projects shifting focus or projects being fully abandoned. All of which causes delays and increases development cost. As a result, the company does not release new products or features into the field as often as the organization demands it, or the customer needs it.

During a period of five months, we have investigated why the NextGen project is unable to conclude on a high-level specification for the first new platform product. We started the investigation with an initial research question (RQ) based on an idea of continuously improving the validation of solution concepts:

RQ1: How good is the NextGen project team at validating their solution concepts in the early lifecycle stages?

The initial investigation showed us that due to unclear needs and a failure to specify the product successfully, the NextGen project fails to validate their solution concepts. This led us to pose the two following research questions:

RQ2: How and when does the R&D department get customer feedback in their development process?

RQ3: How well does the NextGen project team understand the stakeholder needs?

The paper proceeds with state-of-the-art literature deemed relevant to the above research questions. We describe the research approach taken to study the problem before giving a contextual insight

about the case, stakeholders, and process. We present methods, results, and findings for each of the RQ's in separate sections before summarizing in a conclusion section.

State of the Art

Verification and Validation. (Boehm, 1984) defines verification and validation with two simple questions;

- *"Verification: Am I building the product right?"*
- *"Validation: Am I building the right product?"*

Both verification and validation are crucial to developing good systems. Validation and "building the right product" refer to the user's needs (Pesola, 2010) and is the focus in this paper.

Figure 1 illustrates the various system life-cycle stages in a V-model (Muller, 2017). Validation activities should be present in all lifecycle stages. Early validation refers to checking in the early life-cycle stages if the system under development is in fact the system the customer needs. For the earliest stage in the V-model below, this means validating, with the stakeholders, that the perceived needs are in fact the right needs. Do we understand the needs of our customers correctly? Are we able to translate this into product specifications that meet these needs?

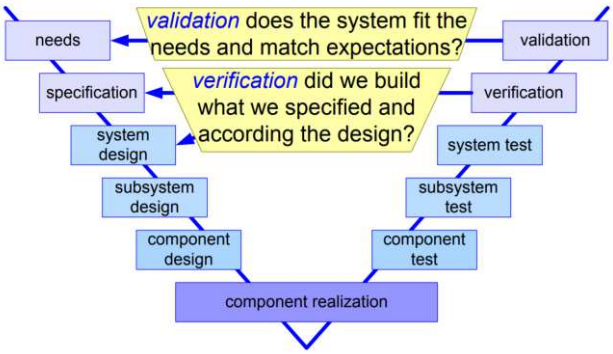

Figure 1. The V-model (Muller, 2017)

Customer Feedback. (Olsson & Bosch, 2015) consider the difference between qualitative and quantitative customer feedback. They define qualitative customer techniques as techniques that require active participation from customers, typically customer interviews, or surveys. The aim is often to collect information on how customers perceive products and what they need from future products. Further, they define quantitative customer observations as the observations a company can automatically collect from products in the field.

CAFCRL. The Customer, Application, Functional, Conceptual, Realization and Life cycle (CAFCRL) model in Figure 2 illustrates six views of an architectural decomposition (Muller, 2011). On the left one can see the Customer objectives and Application views; *what* does the customer want to achieve, and *how* does the customer realize his goals. Together these two views justify the high-level product specification; what does the customer need and why? The "Conceptual" and "Realization" views constitute the *how* of the product and the "Functional" view, the *what*. The "Functional" view represents the interface between the problem and solution domain. To create good products, these five views must be integrated. Muller states that this is the job of the architect (Muller, 2004). The sixth view illustrates the system life cycle. The life cycle represents the system from development start to system phase-out. All the internal stakeholders; sales, marketing, service, production, management and R&D are involved in the life cycle. These stakeholders also possess core knowledge within the five basic CAFCR views. The CAFCRL model is chosen as a reference framework in this study. Both to understand and provide explanations about the architecture and stakeholders within it.

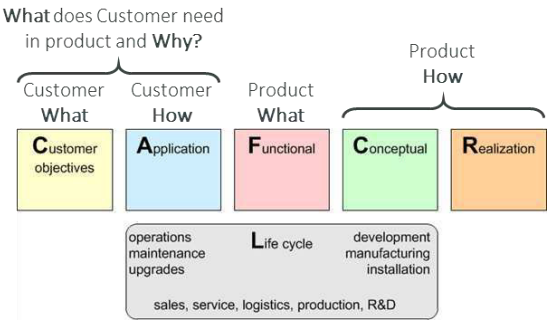

Figure 2: A combination of views on the CAFCRL model.

Agile System Development. The company studied uses agile development. According to (INCOSE, 2011), agile development recognizes that the development process may need more flexibility than what traditional methods offer. It provides a framework to tailor the process, allowing process steps in parallel or in an alternative sequence to develop good systems faster. Agile development is specially adapted to handle the validation activities. *"Agile development is in-process validation in action"* (INCOSE, 2011). The Agile Manifesto (The Agile Alliance, 2001) states the following principles for agile development:

- "*Our highest priority is to satisfy the customer through early and continuous delivery of valuable software*". Also applicable for other systems elements.
- *"Welcome changing requirements, even late in development. Agile process harness change for the customer's competitive advantage".*
- *"Business people and developers must work together daily throughout the project".*

SCRUM. SCRUM is an agile framework for managing product development (Green, 2016). The technique is particularly suited for software development, but more and more organizations are adapting to the agile approach with various hybrid development processes (Dabney & Arthur, 2017).

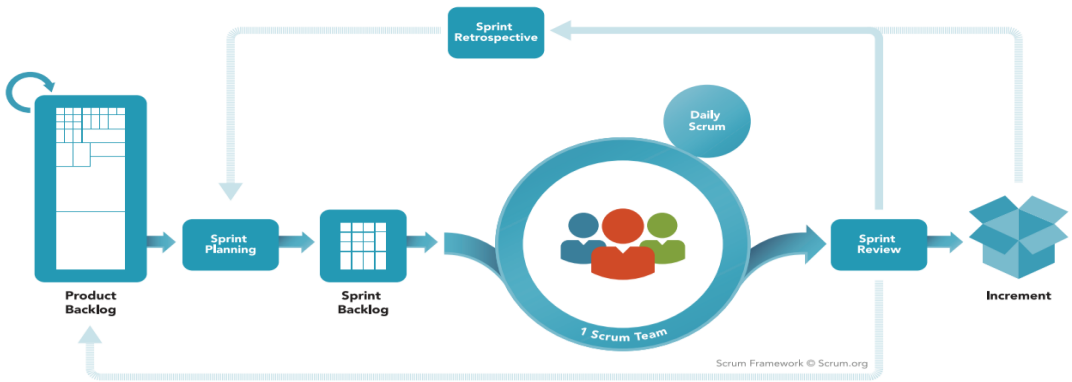

Figure 3. The SCRUM framework (scrum.org, 2018)

Figure 3 illustrates the SCRUM framework (scrum.org, 2018). The SCRUM team consists of a cross-functional development team. Engineers are responsible for the technical development. The product owner is responsible for prioritizing and maintaining the product backlog. In addition, it is the responsibility of the product owner to act as a proxy and represent the interests of everyone with a stake in the project (Schwaber, 2004). Refining the product backlog based on needs is one of the crucial validation activities in SCRUM; are we building the right features into our product? The team, guided by the SCRUM master, selects work from the product backlog and pulls it into a sprint backlog. A sprint is typically a period of two to four weeks. To adjust and modify the ongoing sprint, the SCRUM team holds daily stand-up meetings. The sprint review concludes the sprint. Here the development team demonstrates the finished work to the product owner and stakeholders. The product owner should update the product backlog based on the stakeholder feedback, to ensure that the team works on the correct features. Thus, the sprint review or demonstration is a crucial validation activity in the

SCRUM framework (scrum.org, 2018). To make SCRUM even more agile, each sprint is followed by a retrospective. In the retrospective the team discusses how well the process worked in the previous sprint and adjust where needed.

Research Approach

The method used in this study is action research. Simply speaking, action research is learning by doing (O'Brien, 2001). The characteristic of action research is that the researchers are part of the conducted research, not just looking from the outside and in.

We based our research on the multi-step approach seen in Figure 4. The approach is an interpretation of action research, adapted to the study in question. We started out with the idea of optimizing solution validation by SCRUM. Due to lack of a validated specification, we found that we had to adjust our research towards the understanding and validation of needs. We investigated customer input to the product development engineers to position the current situation. Further, we investigated actual customer needs by visiting representative customers in a few segments.

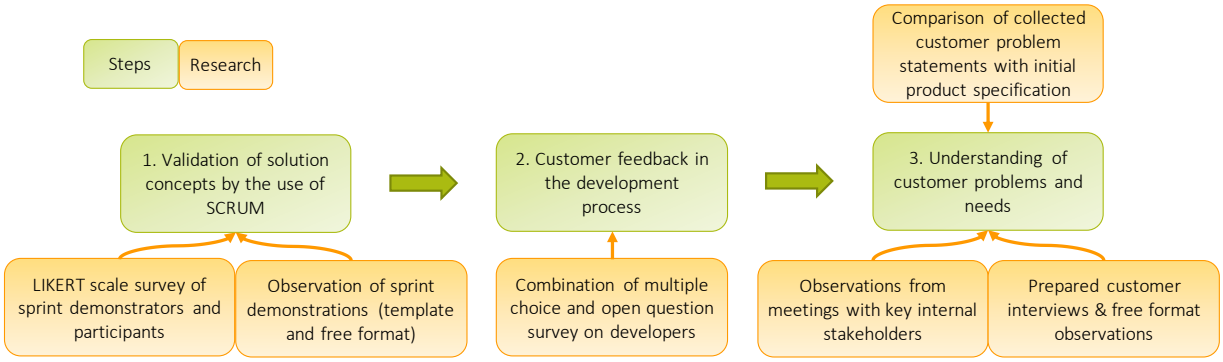

Figure 4. The multi-step research approach.

RQ1 Solution Validation. To investigate how good the NextGen team is at validating their solution concepts we studied the demonstration part of the SRCUM sprint review. The objective we set was to improve the use of sprint demonstrations for validation. We used surveys aimed at measuring the value of the demonstrations as perceived by the participating stakeholders and demonstrators. We posed questions about perceived importance, relevance of participants, level of understanding, and value of feedback. We used a ten-point Likert scale for most of the questions (Muller, 2013). To evaluate the satisfaction levels, we used the Net Promoter Score method (Reichheld, 2003). To observe the demonstrations in an effective way we created a simple observation template (Muller, 2013). We brought a printed version to the demonstrations to write down observations. In addition, we used free format observations (Muller, 2013) during and after the demonstrations.

RQ2 Customer Feedback and Design Changes. We studied the development through reviews and talking to project leaders and engineers. In a multiple-choice survey (Muller, 2013), we questioned the engineers about their experiences regarding customer feedback during development and after product launch. We questioned the engineers about design changes, and perceived product satisfaction in the past 3 years.

RQ3 Customer Needs Understanding. We performed a series of five customer visits together with product management. The number of customers was defined based on budget and scope of the research. The customers were selected as representative for the segment in question and were selected by application specialists. We observed each customers' workflow by participating in guided factory tours. During the observations, we were allowed to talk with and ask questions to operators and factory managers. We used free format observations and later logged our findings. We conducted prepared interviews (Muller, 2013) with the customers. We brought pre-defined problem statements that

we both discussed and ranked together with the customers. Before starting the interview exercise, we asked each of the customers to list their top three priorities concerning the digital converting process. We also asked how they would rate the current products in relation to these priorities. We compiled and translated the collected customer information, problems, and priorities into customer needs. Then, we analyzed and compared these needs to the initial product specification. The idea was that the comparison would tell us how well the NextGen project understood the customer's needs and map the gap between presumed and validated needs.

In the customer visits aftermath, we observed, in a free format, discussions about findings and methodologies used. We observed discussions with product managers, product owner, co-engineers, and representatives from the company management. We use the takeaways from these discussions to validate our perceptions.

Background

Platform development. Figure 5 illustrates the sequence of the platform and product developments. To make a multipurpose platform one should first explore the internal business needs and the needs of all the customer segments. Based on this, the development team can make an initial high-level platform specification. By targeting the needs of one segment, the development team can instantiate a first product specification. The first product instance does not need to cover a full set of needs or features within the segment. Automation features, such as automatic loading and unloading, are good examples of features that can follow as a later delivery. Developing the first product, results in a partial platform. Based on specific needs and problems of another customer segment, the team can then update the partial platform with a new product instantiation. They can also update it by adding new features belonging to the first segment. By continuing this approach, the company will eventually end up with a platform that is covering all the customer segments and intended features. It is also important to keep revisiting the exploration of needs, both in-between product steps and during development.

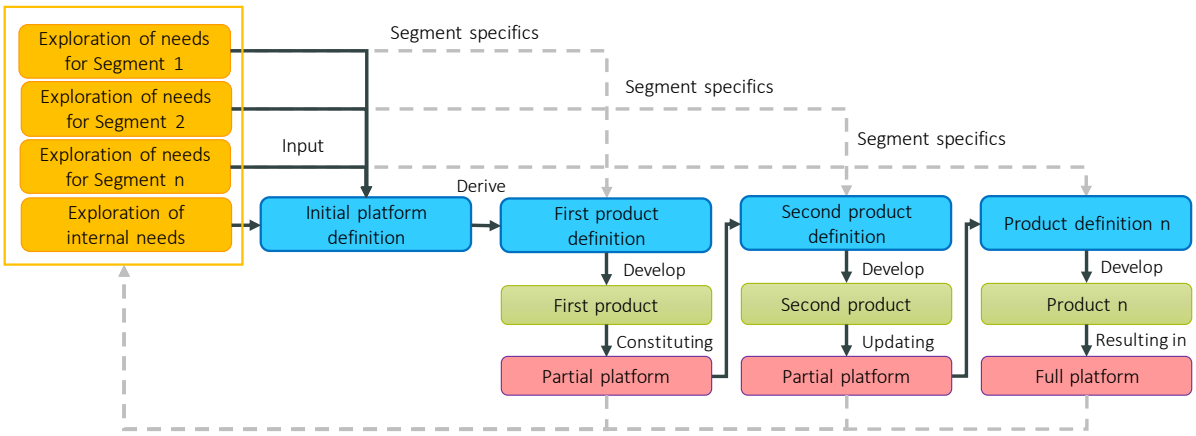

Figure 5. Platform and product sequence.

Case Context. Upon starting the NextGen project, the project team with systems engineers took it upon themselves to make the initial high-level platform specification. They did this based on knowledge of platform development principles, knowledge of current products and customer applications, input coming to the R&D department from various sources, and a list of user stories from previous collected customer feedback. The high-level platform specification resulted in a set of 93 stakeholder needs. The list of needs was communicated and reviewed by internal stakeholders only. Table 1 shows a summary of the platform stakeholder needs, the prioritization and what stakeholder group they are concerning. "Qualifier needs" are needs that the platform must meet, for it to be viable. Customer needs are needs originating from the customer domain. Internal needs are needs originating from within the company. The needs in the table are covering all the customer segments.

Table 1. Platform stakeholder needs

Priorities	Customer needs	Internal needs
Qualifier	17	13
High	27	19
Medium	9	4
Low	4	0
Total needs: 93	57	36

Based on the overall high-level platform specification, knowledge of the targeted segment, statements from the company management, and pain points of current products, the NextGen team attempted to specify the first product instantiation. Parallel to the specification phase, the NextGen development team also worked with solution concepts for the first product instance with the goal of meeting the stated needs.

Stakeholders in the CAFCRL. As mentioned in the description of Figure 2, different stakeholders in the system life-cycle possess knowledge in different views of the CAFCRL. The NextGen team members mostly work as engineers, their core knowledge is in the (F)CR views. They have an extensive knowledge about products, included technologies, and feasibility. Product management and application experts possesses more knowledge in the CA(F) views. One of their main responsibilities is to know the market and the customers: *what* does the customer need in products and *why*. The role of product management is to bring this knowledge to the product development teams, both when specifying, verifying and validating products. Marketing and sales also belong more to this side of CAFCR. In the company, it is the responsibility of the product owner to be the binding link between the views. The company management is mostly concerned with the L view or the business perspective; strategy, cost, margins, and business potential vs. risk.

Segments. The current product platforms serve multiple customer segments. The company defines the segments based on what application the customers are using the tables for. Within each of these segments, the production volume can range from sample-making to high-volume production. To serve the different segments the company offers two different product platforms, each with a range of tools. They can also configure some features, like possible material size and automation level, to better suit the customer's application. Table 2 shows an example overview of the various customer segment applications. Within each of the segments, there are different variations and typical materials. Customers within these segments do not necessarily stick to the application for which they bought the system. Our customers have customers of their own, and convert products based on what these customers require.

Table 2. Example of customer segments, sub-application and typical materials

Segments	Types	Typical materials
Packaging	Protective packaging, brown-boxes and carton boxes	Foam, corrugated, folding carton
Signage	Rigid signs and flexible signs	Wood, aluminum, forex, acrylics, textiles

Product Development Process. The company uses a hybrid development model. The model is part waterfall and part agile. The model is close to what (Dabney & Arthur, 2017) describes in their paper as a *Water-SCRUM-fall model.* Development projects in the company follow the tollgate-based (TG) model in Figure 6. The company names the process the accelerated product development process. For each tollgate, a set of objectives and tasks require approval before the project can transition into the next phase.

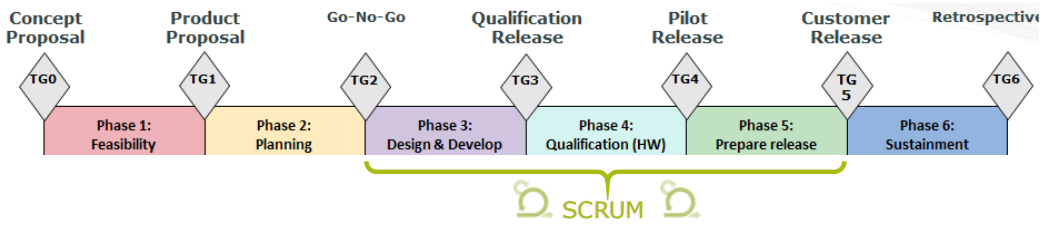

Figure 6. The company's hybrid development process with tollgates.

The work done in the early phases (pre-TG2) of a project should be a joint endeavor where product management, marketing, R&D, sales, etc. work together in the planning and specification of a project and product. The cross-functional endeavor should continue throughout the process but is critical in beginning as this is where the final outcome is mostly defined. Between TG2 and TG5, the R&D department uses SCRUM. The R&D department uses SCRUM for both hardware and software intensive projects.

In (ISO, 2010), Ergonomics for human-system interaction, it is stated that involving users throughout the development process might increase the chance that the developed system will meet the customer demands. The R&D department does not include actual customers, or users, in their SCRUM process normally. They use proxies to act on behalf of the large customer base of both existing and potential customers. The proxies are internal employees, often the product owners, product managers or application engineers with an extensive knowledge of customer applications. The stated reasons for not using actual customers in the process are amongst others complexity, budget, confidentiality and practical challenges.

The team perceives the sprint demonstration as the main arena for validation of solution concepts in the SCRUM process. Here they can involve relevant stakeholders and proxies. This means that they use SCRUM a bit earlier in the development process than usual.

RQ1: How good is the NextGen project team at validating their solution concepts in the early life-cycle stages?

Results

We questioned participants and demonstrators after a selected NextGen sprint demonstrations. Figure 7 shows the survey results to the most relevant survey questions. In general, the participants find the demonstrations valuable. Most participants perceive themselves as relevant attendees to the demonstration. The demonstrators answered that they were missing some stakeholders in the audience. They were not fully satisfied with the value of the feedback they got.

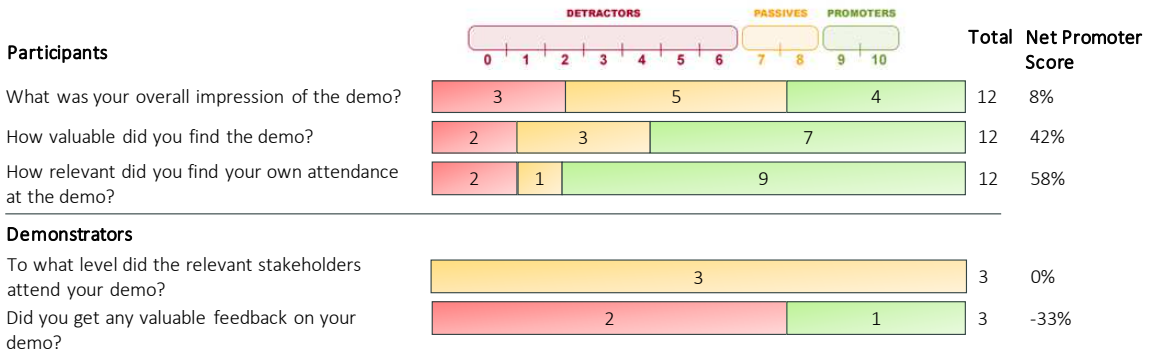

Figure 7. Survey showing perceived value of sprint demonstrations.

Normally, there were between 10 and 15 people participating in the demonstrations observed. Of these, only 1 to 4 participants were not engineers: the product owner, the project leader, and sometimes representatives from global support and product management. For the NextGen demonstrations, there were both comments and observations indicating that the demonstration turned more toward a technical review or brainstorming session than a sprint demonstration. We observed a clear attempt on validation of a user interface by the NextGen project team. However, none of the user proxies present could clearly validate that the solution would meet the need of the customers.

Evaluation

The study on validation in the NextGen SCRUM process indicates that both engineers and proxies find the sprint demonstrations valuable. Engineers appreciate the possibility to demonstrate and get feedback on their solution concepts. The proxies appreciate the possibility to get an insight into what the engineers are doing. Observations and answers from demonstrators indicate that some stakeholders were missing or not present. Customers are one of these stakeholders, meaning that their perspective is potentially lost, or in best case filtered through a proxy. There are also observations indicating that there is a lack of feedback upon if demonstrated solution concept is the right solution and if it will yield any value to the customers. Currently the format of the NextGen sprint demonstrations allows for brainstorming. When proxies are unable to provide the wanted feedback, they turn toward reviewing the solution concepts from a more technical standpoint.

The major takeaway from the study on the NextGen SCRUM process is that the team attempts to use the sprint demo for early validation of solution concepts but fails to do so. There are multiple causes to why this could be happening:

- The project participants and proxies do not really know what needs they are trying to meet
- Uncertainty about what segment is targeted
- Suboptimal segmentation, meaning that needs and priorities are not unambiguous within the segment, leading to difficulties regarding validation
- For the assumed list of needs, the NextGen project does not know which needs to prioritize
- Lack of customer input in the early development stages

The study indicates that the company's agile development process is not sufficient for closing the validation loop. Needs are not validated, specifications are not validated and thus, solution concepts cannot be validated.

Recommendations. To mitigate the solution validation issues, the NextGen project needs a validated specification to base its development on. Such a specification must also be based on a validated set of needs. The NextGen project should go back to solution validation by SCRUM sprint demonstrations, after a validated high-level specification is in place. However, they should consider including even more stakeholders, both internal and external (customers), if possible. If customers cannot be included in the process, proxies or systems engineers should continuously check with representative customers that development is on track. Further investigation is then necessary to check if the NextGen project is now successful in using the sprint demonstrations for validation, and thereby closing the validation loop.

Validity. In the survey, there are too few participants to reach any hard conclusions. The number of participants were decided by that was practically possible. Thus, we can only use the results as indicators. There is also the possibility of bias by the observer. However, the indications match our expectations and observations from previous projects.

RQ2: How and when does the R&D department get customer feedback in their development process?

Results

We evaluated customer feedback in the development process by questioning engineers in the R&D department. 17 of 21 applicable attendants answered the survey. We asked the engineers to consider the past three years when answering the questions.

Figure 8a illustrates when in the development process the engineers had direct contact with customers. Out of the 17 that answered the survey, 7 had not been in direct contact with a customer at all, during the past three years. The remaining 10 had on average been in direct contact with a customer between 2-5 times, in the same time-frame. From Figure 9a, we can see that the direct contact usually takes place in the later stages of the development process. The medium of the direct customer contact is equally as much e-mails, phone calls, and customer visits. We also asked when engineers receive indirect customer feedback. By indirect feedback, we mean feedback received through proxies, other internal stakeholders or colleagues, or through various channels that are part of the development process. 16 of the 17 engineers answered that they had received indirect customer feedback in the past three years. 8 of the engineers answered that they had received indirect customer feedback more than 20 times. We let the engineers map when in the development process they received indirect customer feedback. From 36 answers in Figure 9b, engineers received 69% of the indirect customer feedback during or after the pre-release of the product.

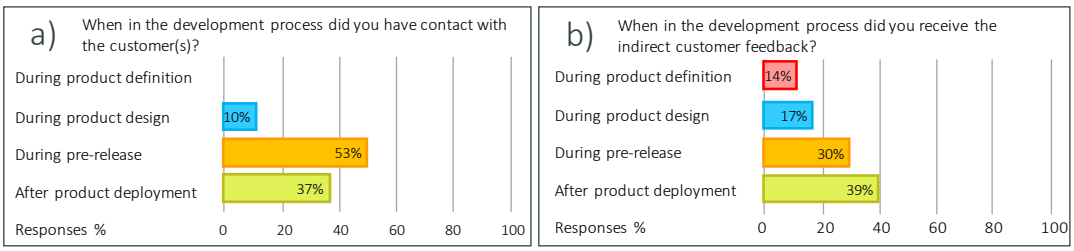

Figure 8. a) shows a graphical representation of when in the development process engineers are in direct contact with customers. b) shows indirect customer feedback in the development process.

Figure 9 illustrates the amount of design changes each engineer has been part of, and why. In these questions, we are referring to released or pre-released products. The two diagrams clearly indicate a difference between changes made due to product failures (a) and changes made due to a product not meeting customer needs (b).

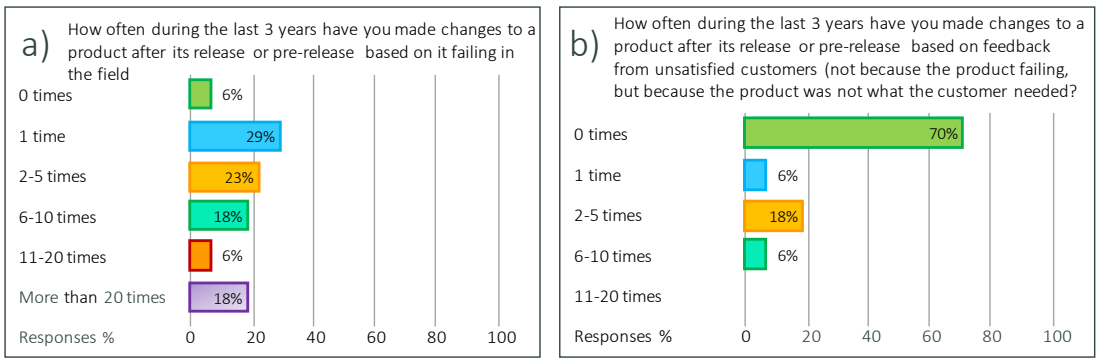

Figure 9. Graphical representation of late design changes due to product failures (a) and unsatisfactory products (b).

16 of the 17 engineers answered that they had been involved in the past three years in at least one project where they felt that the resulting product would satisfy the customer's needs. Of these 16, 11 answered that they had been involved in at least two such projects.

Evaluation

Customer Contact and Input. The results concerning direct customer contact in the development process indicate that R&D engineers are seldom directly part of any early validation activities. The occurring contacts tend to happen late in the development process, during or after the pre-release of a product. Observations also indicate that the nature of this direct contact does not concern validation, but verification, installation or repairs.

Engineers get more indirect customer feedback, through proxies, support or quality departments, or digital mediums like task management system or company newsletters. The results indicate that some of this indirect feedback takes place early in the development phase. However, engineers receive most of the indirect customer feedback during or after pre-release. It is critical that the intermediaries or proxies have an extensive knowledge of customers across the segments. The products developed at the R&D department are based heavily upon the input from the proxies. Not getting direct customer feedback into the development is a hiccup for validation and increases the risk for launching unsatisfactory products. There is a risk that proxies can bring their own bias or misinterpretation of the customer needs when communicating this to engineers.

The overall study tells us that the R&D department has a potential for improvement concerning direct and unfiltered customer input earlier in the development process. Both the level of early direct customer contact and indirect feedback is too low. This input is crucial for the engineers' understanding of what the customers' need, which in turn increases the probability for launching a successful product.

Recommendations. The company should consider to regularly letting the R&D department engineers visit customers to collect feedback and elicit needs. As a minimum, personnel with the roles of systems engineer, architect, or project manager should participate in these activities (here the practice may already differ from project to project). The R&D department should also investigate the nature of the early indirect feedback.

Product Changes. In the same survey, we asked the engineers to answer how many times they had been included in changing design of products, after the product had been released or pre-released. We did this to get an indication of how successful we are in developing good products. Late design changes are also quite costly, see (Boehm, 1984). The results concerning changes to products show that engineers have often been involved in product changes due to failure in the field. Typically, service and support departments collect information of quality issues or systems failing. This information reaches R&D and the responsible engineers through standard channel. 70% of the engineers answer that they have never been involved in product changes because of a product not meeting customer needs. There could be multiple explanations for this:

- Products are addressing the actual needs
- Feedback does not reach the R&D company, but is stuck in other departments
- The company uses the feedback to update product backlog, which the engineers do not recognize as a change, but a new development
- The engineer (respondent) has a role that is not related to design and the question is not relevant

If we also consider that the engineers generally perceive that the products they develop will satisfy the customers need we can draw the conclusion that engineers perceive that products are addressing the needs of customers.

30% of the engineers answered that they had been included in making changes to a product because it did not meet the need of the customers. In total, the R&D department has potentially made 10 or more changes to products in the past three years due to products not meeting needs. The magnitude of these changes is unknown. It could be a software feature, or it could be a hardware change. In total, this tells us that effort and resources are being used for fixing and changing products that should already be finished. In addition to quite costly changes, the R&D department must use resources on fixing existing products instead of new developments.

Validity. When conducting surveys there is always the possibility of poorly phrased questions, participants misinterpreting questions and analysts misinterpreting answers. However, the indications from this survey also match observations and experiences of the author in the past three years. The development process is set up to work so that engineers work towards proxies and proxies toward actual customers.

Recommendations. By including or involving the actual customer or end-user in the early development stages, some of the late design changes might be avoided. Both exploration of solution concepts and specification of products might heavily benefit from this. The topic of how to include the customer in the process is however out of scope for this study.

The company should investigate if products are in-fact satisfactory to the customers that are buying them. This can then be matched to the statistics of how often engineers are involved in design changes based on product failing to address customer needs. If customers are not satisfied with products, the company should investigate why.

RQ3: How well does the NextGen project team understand the stakeholder needs?

Methods

The customer visits were part of the first half of a problem to portfolio exercise. The goal of the first half of the exercise is to elicit, understand, and validate the needs and problems of the customer segments. The second half, concerning how to solve problems and add to product portfolio, is outside scope for this paper. Product management performs the exercise simultaneously across multiple customer segments. Figure 10 illustrates the flow of the first part of the exercise and included stakeholders. Product management accompanied by application sales managers performed a Value Stream Mapping of a typical workflow within each of the customer segments. Value Stream Mapping is used to map the product development process and identify value adding and non-value adding activities (Ali, 2015). They clustered problems, seen from a customer perspective, to the red flags in the value stream. They ranked all the problems in a frequency-frustration matrix before voting for the top three focus areas within each segment. The last part of the exercise part 1 is to validate the company's presumed list of problems with actual customers. Customers, participants from the R&D department, including the author, took part in the customer validation part. All the customers visited were using the digital manufacturing machines for production.

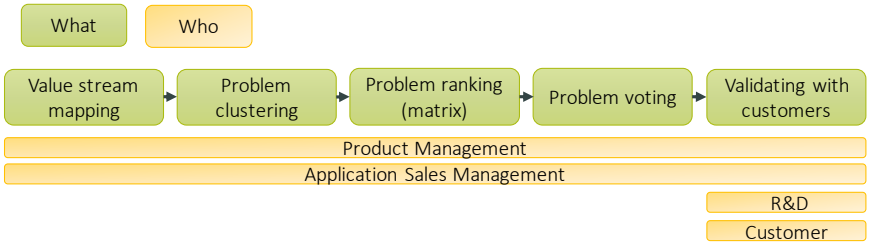

Figure 10. Flow of Product to Portfolio part 1.

To interview the customers, and validate the problem statements, we used the problem frequency-frustration matrix seen in Figure 11. We brought the pre-defined problem statements written on post-its. Then we asked the customer to rank the problem from low to high. Low frequency means that the problem occurs seldom, high frequency that it occurs often. High frustration means that the statement is a big problem for the customer, low frustration, that the customer does not perceive it as a significant problem.

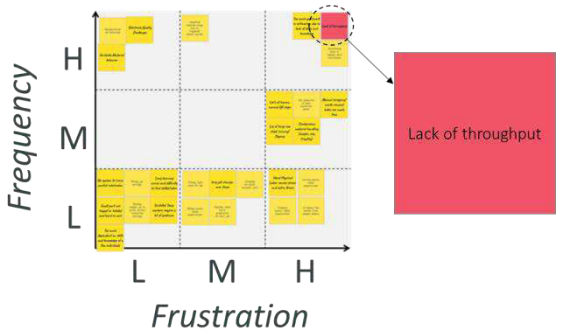

Figure 11. Example of the problem frequency-frustration matrix.

Results

Need Elicitation. When interviewing the customers, we asked about their top priorities concerning digital converting products. The customers answered with the same three priorities. We also asked the customers to rate the current products in relation to these priorities. Figure 12 illustrates what we found from this very simple exercise. Segment 1, the targeted segment, clearly needs solutions with better performance. This is not an issue for segment 2, as customers in this segment struggle with availability. The difference between the segments originates in application differences.

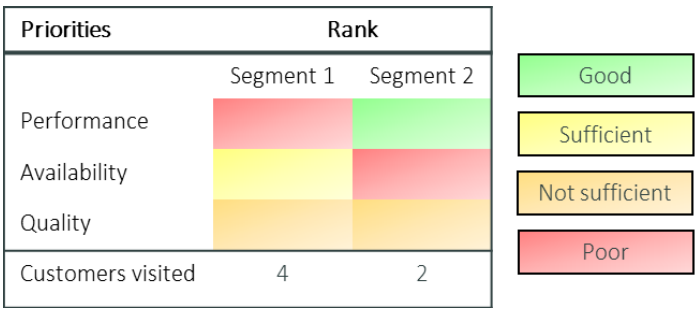

Figure 12. Ranked priorities in the visited segments.

From the interviews and factory workflow observations, we saw both similarities and differences between the two segments visited:

- The digital manufacturing devices are a bottleneck for both customer segments, but not for the same reasons
- We saw that customer using our equipment for high production volumes set the systems up for dedicated purposes. They do this since they need the full system capacity or cannot afford the time required for change-over between applications
- In both segments we saw application dependent quality issues
- We learned that the segments have different trends, e.g.
    - Segment 1: Business to business, bigger sheets, faster printers
    - Segment 2: More business to consumer, more unique jobs
- We learned that the two segments visited do not count equipment cost, but cost per unit produced

Figure 13 illustrates a ranking of problems for the two customer segments visited. We have here included grouped problem statements that are relevant for the NextGen project. That means that we have left out many of the statements concerning the rest of the workflow. The total score within each segment determines a ranking and the associated color of the problems. The right-hand side matrix illustrates the correlation between color and rank. Red color means medium to high frustration and frequency for the customer. Green color means low to medium frustration and frequency.

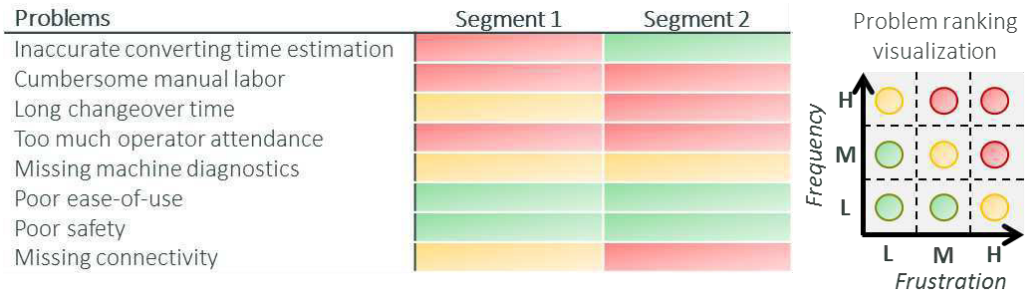

Figure 13. Problems ranked per customer segment.

Comparison to First Product Specification. To evaluate how well the NextGen team understands the stakeholder needs we compare the initial product specification to the findings from the customer visits. We limit ourselves to the findings from the targeted segment customers for the first product.

In Figure 14 we illustrate if and how the initial first product specification would meet the needs and problems of the visited customers in the targeted segment. Column 1 is a repetition of the two previous figures. In the second column, we have repeated the color ranked priorities and problems of the customers in the targeted segment. Column 3 shows if the first product, as initially defined, would address the problems perceived by these customers. "Partially" means that the first product specification to some extent would have met the need of the segment. "No" means that the product would not address the problem. "Yes" means that the product would have addressed the problem. Some of the listed items were indeed part of the total platform specification, but the NextGen team was unsure if they should include it in the first product. We have marked these with "not concluded" in the rationale column.

Problems	Target segment rank	Addressed by 1st product	Rationale
Performance		Partially	Some performance measures included
Availability		Yes	
Quality		Partially	Some quality measures included
Inaccurate converting time estimation		No	Not concluded
Cumbersome manual labor		Partially	One of many measures included
Long changeover times		Yes	
Too much operator attendance		Partially	Fully unmanned production not included
Missing machine diagnostics		Yes	
Poor ease-of-use		Yes	Too much focus on improving
Poor safety		Yes	Too much focus on improving
Missing connectivity		No	Not concluded

Figure 14. Comparison of initial first product specification and findings from customer visits.

Observations. From participating in meetings with participants from the company management, product owners, and senior engineers, we collected the following observations:

- The company does not fully know the difference (priorities/preferences/trends) of the various segments
- The company does not fully understand the value of proposed features that have not been validated by potential customers
- The company needs to improve the correlation between what product management is specifying and what R&D thinks to be feasible with the given timeline, amount of resources and available technology
- The company needs to know the reasoning behind customer needs coming from proxies or other internal stakeholders

Evaluation

Method. The problem to portfolio exercise gives a good insight into customer segment problems. The work done by product management before visiting customers builds a good foundation for the frequency-frustration matrix interview. The matrix exercise seemed to be an effective way to elicit customer problems and priorities. The customers seemed to like that the interview included an activity. Going directly to customers and interviewing them about their problems ensures the validity of the problems. Using the matrix exercise to do so also ensures a priority of those problems. When performing the exercise, the discussions evolving around a problem statement are as valuable as the final scoring. The drawbacks of the exercise:

- It is a time-consuming effort, with only a few customers visited
- It does not tell us about the segments market potential; how many customers with the same needs or how many products can we sell
- It does not tell us what segment to prioritize; should we satisfy this or that segment first

Validity of methodology and Customer Visit Findings. According to (Virzi, 1992), one can detect 80% of usability problems with four or five subjects, and that the most severe problems are likely to be detected with the first subjects. The customer visit findings are in general valid as they come directly from the source. One can argue that three customer visits within one segment and two within another is a relatively small number. It might also be that customers in a different region have different needs and priorities. Observation of meetings were the problem exercise was discussed also verifies both the pros and cons.

Customer Needs Understanding. The total high-level platform specification addresses many of the needs and problems of the two segments visited. However, the initial specification of the first product fails to answer several of the elicited needs from the targeted segment. The most critical problems perceived by the customers in the targeted segment, were the lack of performance, converting quality, lack of accurate converting time estimation, heavy manual labor and operator attendance. The initial product specification attempt does not properly address these. There were some measures of performance and operator attendance, but these would not have covered the needs of the customers visited. The initial product specification also prioritized some aspects of the product that the visited customers did not at all perceive as problems.

The high-volume production customers visited do not count equipment cost but cost per unit produced. They are more concerned with the return of investment and recurring cost. One of the initial statements, from the company internally, was that the first products should be cheaper than current products. This conflicts with the need of increased performance, as this is a cost-driving feature. Another finding was the fact that both segments use the systems for dedicated purposes. One of the core qualities of the current products are their versatility, or ability to be used for multiple purposes. It is obvious that this quality is not a priority for the customers visited. These customers are more concerned with optimization of performance and output quality. The current product is a bottleneck for customers in both segments for different reasons. For one segment, the machines are a bottleneck due to performance not keeping up with other parts of the workflow. For the other segment, the

machines are the bottleneck due lack of availability, e.g. long change-over times between jobs and no available automated material handling. Both are seeing problems with converting quality. By quality, we mean the quality of the product produced. Quality is one of the most challenging needs for the NextGen team to define and measure as it is different from segment to segment.

It is difficult to conclude upon if the first product, as initially specified, would fail. The product would be an upgrade compared to current products. Thus, it should be more competitive in the total market. However, the customers in the targeted segment are looking for a converting system that, at the end of the day, can deliver X times more converted products with a similar or improved quality compared with today. For these customers, the performance or speed of the current products is what limits their production capacity. The customers of segment 2 are looking for a system with more automation, better converting quality, and less changeover time. For them, the time the machine is not converting is what limits their production capacity.

We perceive that there is a suboptimal definition of customer segments. In general, the company and the NextGen team are aware of most of the customer needs but struggle in defining to what segment the needs belong; current segment needs are ambiguous or might even contradict each other. Thus, the company often fails to calculate, with reasonable confidence, the business case of introducing features or products not validated by customers. E.g., how many customers would be interested in automatic tool change or how much are customers willing to pay for X times the current performance. This slows down the decision-making process, which again slows down development.

Recommendations. By studying the product specification problem and participating in product management exercises, we perceive a gap between people with knowledge in the CA(F), people with knowledge in the (F)CR and people with mainly L-view knowledge (see Figure 2). People with knowledge on the left side struggle in giving valuable input to people with knowledge on the right side, and vice versa. In the meantime, the life-cycle view and business must be balanced. The mutual understanding and alignments between these people are crucial in the early development stages. The company should put some effort into investigating why they are having this internal gap in the organization. The R&D department and the NextGen team also need to know the reasoning of statements coming from internal sources. They should investigate if needs stated are based on real customer needs, and what the value to the customers is, or if the needs originate from internal stakeholder opinions. Too often needs or problems are presented to engineers in the form of a solution. This could lead to misinterpreting what the actual needs are, and the resulting product may not meet the expectations of the stakeholder.

To specify a new product successfully, the company and the NextGen project should review the customer segmentation. They should look at the synergy within the customer segments, where the customers have specific needs and how many shares those needs. To cope with the specific customer needs, the platform should incorporate variation points. The company should select a set of segments with sufficient synergy.

Validity. The author has performed both analysis and comparison of elicited customer needs and the initial first product specification. There is a possibility for errors or misunderstanding in such analyses.

Conclusion

In this paper, we study why the R&D department and the NextGen project team are struggling in the early stages of developing new products. We have investigated how good the NextGen project team is at validating their solution concepts, when in the product development process engineers get customer feedback, and how well the NextGen team understands the customer's needs.

We have observed that agile development and SCRUM is not sufficient to close the validation loop for the NextGen project team. As there is a lack of validated customer needs, the team is unable to rely on customer proxies for validation of solution concepts. Surveys indicate that R&D engineers have little or no direct customer contact early in the life-cycle stages. The direct customer contact often takes place in the later life-cycle stages and the study indicates that this is mostly for verification purposes. Surveys also indicate that engineers mostly receiver indirect customer feedback in the later stages of development. They receive the indirect feedback through proxies, other internal stakeholders, or various engineering processes.

In general, the NextGen team seems to understand customer needs. However, they are unable to estimate the business case of proposed features or products confidently. We perceive that this struggle comes from a sub-optimal segmentation. The customer needs within the current segments seem to be ambiguous, not necessarily shared amongst all customers within the segment, or even contradicting other needs within the segment. This sub-optimal segmentation leads to a lack of validation of the customer needs. This hampers the specification of new products, the prioritization of features to include, and which needs to meet. We have also identified an internal gap in the organization. People with knowledge in one view of the CAFCRL model sometimes struggle with understanding the people with knowledge in a different view.

Future Research.

All the conducted research focuses at one R&D department and the development of a first step in new product platform. For this research to be valid in other industrial context more research is needed on each of the major aspects; agile development and validation for product platforms, the use of proxies for validation and customer segmentation optimization for product platform development. The recommendations given in the specific chapters are subject to further research and validation; including more stakeholder in the SCRUM process, impact of early direct or indirect customer feedback, customer satisfaction levels, gap between people that possess knowledge in the different CAFCRL views, statements and needs posed by internal sources and not customers, and finally the sub-optimal segmentation. We need more data on the sprint demonstrations, as observing only one yields a shallow foundation. We planned a survey on customer knowledge amongst application sales managers, the survey fell out of scope for this research. A natural progression of this study is to investigate the company vision and strategy and how this affects the segmentation and estimation of business cases for proposed products, as this was kept out of scope for this study.

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