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Procedia CIRP 109 (2022) 215–220

www.elsevier.com/locate/procedia

32nd CIRP Design Conference

Method for direct end customer integration into the agile product development

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Abstract

Agile product development methods help to reduce the product development time. The resulting shorter time-to-market ensures a company's competitiveness. For a time-reduced development process and product lifecycle, the response time to end customer requirements must be decreased as product complexity increases. This requires special methods and tools for customer integration into the agile product development process. Existing approaches do not meet these requirements and an analysis of tools and methods for customer integration and a new method for customer integration is needed.
The core of the work is developing a new *method for customer integration into the agile product development process* through customer surveys. The method includes two separate use cases for this purpose. Use case one considers customer integration regarding the overall product structure, whereas use case two considers customer integration in selecting specific development concepts. Both use cases include physical and virtual products. The connection of the method to agile product development identifies the results as new tasks. It is possible to run the 28-hour method several times within a sprint. In an exemplary case, the method is implemented in a software tool, tested with 130 end customers and verified by the requirements.

Keywords: Product-Service Systems design; direct customer integration; agile product development; Advanced Systems Engineering; Requirement management

1. Short product lifecycles request new methods

The globalization of competition is changing the demands of companies. A large number of companies must offer innovative products in a saturated market in order to position themselves successfully. To increase the productivity of market performance, product lifecycles and therefore the product development time are becoming shorter and shorter. Long product lifecycles of physical products are approaching the short ones of virtual products. [1] In this context, virtual products describe a software or application with a user interface to the end customer. Physical products, on the other hand, describe mechatronic products as a combination of the disciplines mechanics, electronics and embedded software with a complex system structure and a higher degree of networking as well as greater interactivity. The overall system consisting of physical and virtual product thus represents a Product-Service System as a smart device (e.g. a production machine with an application). The development of these products requires other approaches, such as Systems Engineering as the basis of the paper. [2]

Besides Systems Engineering other key drivers for a short product development time are, for example, new product development methods, such as frontloading or agile product development processes, which increase the flexibility of market performance and reduce the time-to-market. Agile product development methods are used for both virtual and physical products and partly take up the idea of involving the end customer, which takes up the second basic approach [3].

2212-8271
10.1016/j.procir.2022.05.239

Of great interest in this context is the integration of end customers into the agile product development process in the early stages of product development to be able to translate customer wishes into requirements. Early validation ensures that the final complex product or service meets the end customer's requirements.

The challenges of new and further developments – The end customers' requirements are important building blocks for the success of new and further developments of a product. The earlier each employee knows the current and future requirements of the end customers, the greater the certainty of success. Quick and pragmatic methods are still hardly available here, not even among German mechanical engineering companies [4].

The lack of fast and customer integration methods – Classic market research methods have been used for this purpose, usually require a long lead time and therefore cannot be integrated directly into the process on-demand [5]. There is a lack of faster methods for integrating end customers, which can be incorporated into new development processes and contribute to a compression of upstream development activities of new products. This is shown by an analysis of customer integration methods and the explanation of the Systems Engineering and agile product development approaches in this paper.
This leads to the need to design a new method, which is presented in this paper. The goal is to describe a specific method for integrating end customers into the agile product development process. Also important is the direct integration of the end customer, an interface to agile product development and fast implementation. As the basis of these goals are Systems Engineering (SE) and agile product development. In Chapter 3, previous methods and tools are analyzed. Chapter 4 describes the concept of the new method. Subsequently, the implementation is presented in Chapter 5. After a validation regarding the requirements follows the concluding chapter.

2. Systems Engineering and Agile Product Development as a Framework

The two topics Systems Engineering and agile product development are important regarding this paper. Systems Engineering aims to build the basis for the concept of Product-Service Systems and thus to enable the planning, development and operation of complex systems [2].
Product-Service Systems are characterized by a higher degree of networking, greater autonomy and end-to-end integration. This goes along with data-driven services and platforms with potential for new Product-Service Systems (PSS) and attractive business models [2].
Systems Engineering represents a more interdisciplinary and integrative approach of developing complex systems [6, 7].

Agile methods are used to further organize the development process and reduce the product development time. The basis of this paper's method is Axel Schröder's agile product development, since few approaches describe the development of physical and virtual products [3]. It is explained in advance that agile product development does not replace or exclude the reference model of the product development process (stage-gate process). Rather, the classic product development process provides an overarching framework supporting agile product development [8].

Within the agile product development, there are different meetings. Sprints are executed cyclically within the classic product development process. A Sprint covers a period of about two weeks. In a Sprint, a lot of tasks are processed. The tasks are defined before each Sprint in the Meeting Conclave of the Product Owner Team (POT) and discussed with the team in the meeting Sprint planning. The POT consists of three people representing technology, market and the project. Whereas the team consists of five to eight people and actively works on the tasks of the Sprint. After the Sprint, the results are presented to the POT in a meeting called demo. Then the Sprint is reflected and concluded by the team in the meeting Retro. Afterwards, a new Sprint can begin. The advantage of agile product development is that the definition of the time for a task is fixed by the sprints. However, the feasible effort must be realistically assessed by each team member. This requires practice. The greatest success of agility can be seen in projects with less time, a high degree of complexity and independence. In other words, projects with a high degree of unpredictability. Conversely, projects with a very clear structure and routine, an agile way of working is less likely to succeed. [3] With the description of the approaches SE and agile product development, the need for action for the agile development of complex products is addressed, on which the method of the paper is based.

3. Analysis of previous methods and tools

First, an analysis of already existing Methods of customer integration is carried out. This is to be divided into direct and indirect customer integration. Direct customer integration involves asking the customer directly. Indirect methods are characterized, for example, by an observation of the customer. Within the literature 23 methods are found for customer integration, for example a conjoint analysis or a concept test. Among the 23 methods analysed, also methods that specifically address the end customer were taken into account. Examples are co-development, co-creation or a focus group. Requirements are made on the method and these are evaluated afterwards. These result from the need for action, the objective, company interviews and conclusions from the literature. Requirements, like a small expenditure of time of the execution and preparation, are relevant. Table 1 shows the requirements on the method and if the requirement is mandatory (Fix (F)) or a Desire (D).

Table 1. Requirements of the new method.

No.	Requirement	Fix/Desire
1	The method must be applicable to the development of new products.	F
2	The method must support all phases of product development, but focus on the early phases.	F
3	The method must be implementable in agile product development within a sprint.	F
4	The time needed for preparation and implementation of the method should be less than two hours.	D
5	The method must ensure an interface to the end customer.	F
6	The method should be used for surveying large end customer groups with at least 100 end customers.	D
7	The method should use existing media from agile product development and the product development process.	D
8	The method must be implementable electronically with a software tool.	F
9	The method should take interfaces with other systems into account, such as the project management tool.	D
10	The method must be able to be used to query individual features.	F
11	The method must be implementable for virtual and physical products.	F

No method fulfills all requirements for the goal of this paper. Nevertheless, nine methods of customer integration have distinguished themselves from the other methods within an evaluation. Therefore, software tools are sought to implement the method of the paper. 26 software tools are evaluated against ten characteristics. Among other characteristics, an API interface and the availability of the results in real-time are relevant. The result of the evaluation is a software tool Qualtrics [9]. This tool is used to implement, test and validate the method.

4. Concept of the method

Based on the analysis and literature, a concept for integrating end customers into the agile product development process is described. Sprints are run in the overarching classic product development process. Since the method is used for both virtual and physical products, both use cases are classified for virtual products up to the gate process release, since a software structure is not associated with the production and planning of production. For physical products use case 1 is accomplished up to the gate requirement specification and use case 2 up to the gate of the design freeze. Use case 1 concerns the general product structure, which is defined at the beginning and can be changed until creating the functional specification. Use case 2 is interesting regarding the concept of one element of the product structure.

A decision between two concepts of one feature is realizable. The changeability of the general design is possible up to the gate design freeze. Changes are only possible after the corresponding gates with a change process. Agile product development moves within this framework of the classic product development process as an iterative process. The loop and the final event of the **demo** are shown in Figure 1.

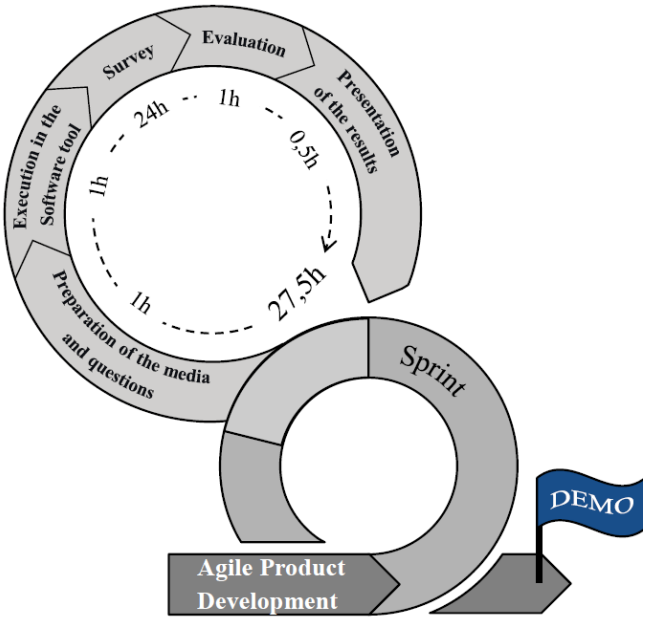

Fig. 1. Overview of the method

It provides an overview of the concept in chronological detail within the **Sprint**. Approximate values of time for the individual steps of the method are described and the total duration of the method comprises approximately **28 hours**.

In addition, Figure 2 provides an overview of the concept of the two use cases in an activity diagram. The legend defined by the Object Management Group shows the elements used, such as an **action** or an **object**. The start is defined by an **InitialNode**, while the end of the process is marked by a **FinalNode** [10]. This SysML diagram provides an overview of various actions of the concept [10]. Use cases 1 and 2 are grouped into one diagram to give an overview. The diagram is subdivided into four lanes. A **Data storage** that supports the **user**, a **software tool**, which is operated by the user and the **end customer**. If one **idea or concept** is **developed** by the user after the start, this refers to use case 1. Use case 2 is characterized by two or more concepts or ideas. In the following, the user checks whether the concept is **new**. If the concept or idea is new, a **patenting** per idea is **requested** or a **non-disclosure agreement** for use case each is created and precedes the questionnaire.

If a **patenting takes too long**, the end customers must accept a non-disclosure agreement before the survey. If the concept or idea is not new or a non-disclosure agreement is already in place with the end customer, the **preparation of the questions** starts. A **template** is to be used for the **non-disclosure agreement** and a **template** is used as a **question catalog** to prepare the questions. If this is done, the **preparation of the**

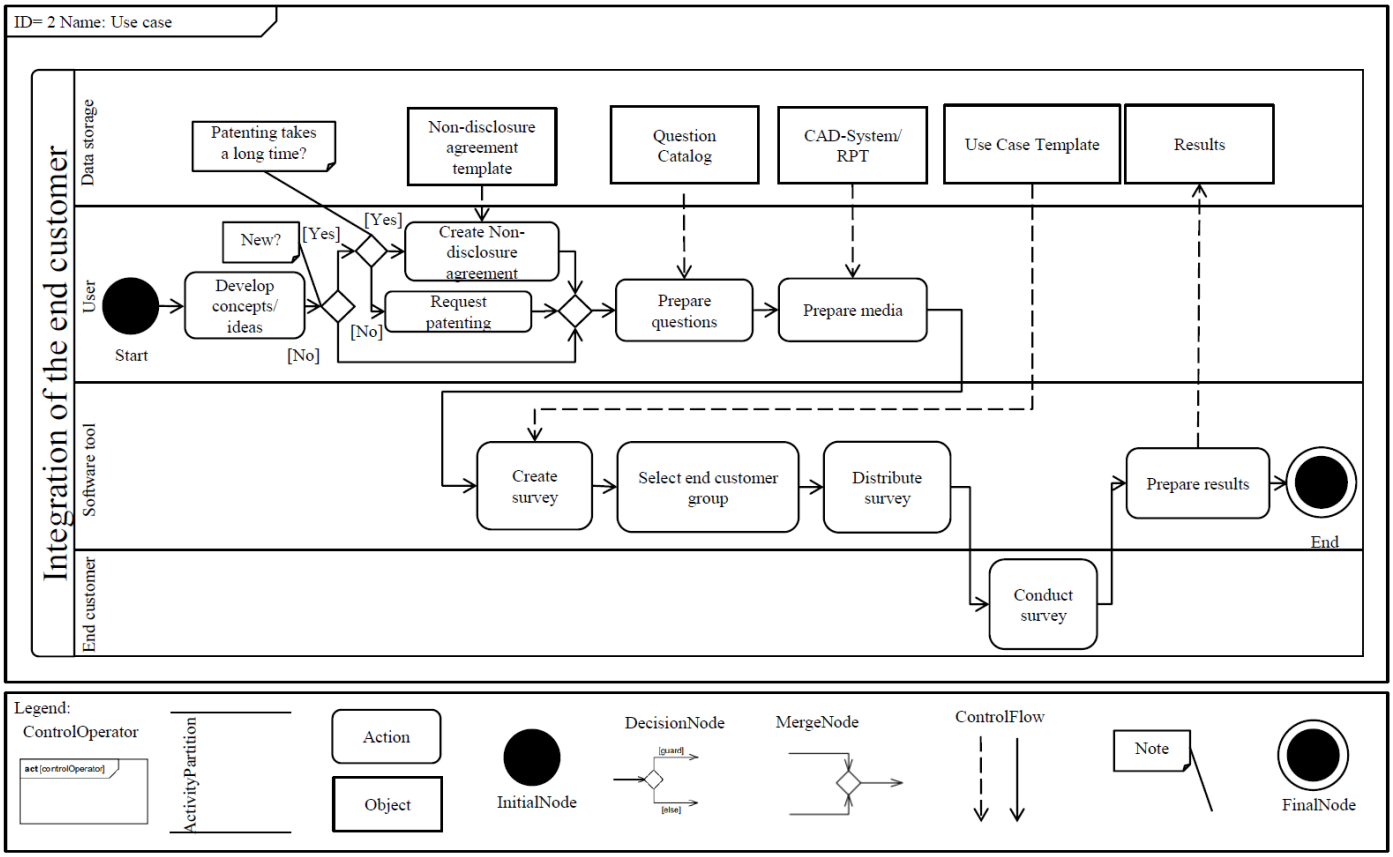

Fig. 2. SysML diagram of the method

media can begin. If possible, media from the company's internal **CAD systems** or photos of prototypes made by rapid prototyping and tooling (**RPT**) should be used. Once this preparation is done, the end-user works with the software tool.
The **creation of a survey** is done under consideration of higher productivity with a **template**. For example, questions and images built a framework to insert actual data and modified questions. After the **selection of the end customer group** the **survey is distributed** to the end customers. The end customers **conduct** the **survey**. Now the user can **prepare the results** in the software tool and export them to the data storage. This is the **end** of the process. The result can then be announced.

The classification of the **product structure**, shown in Figure 3, concerns the requirements of querying **features** from the end customer. A feature describes a characteristic or property of a product. This is divided into **design** and **function** in the context of the concept. The product structure consists of the **overall system**. The Product-Service System, which is subdivided into several **products**. Each product can also be subdivided into **assembly groups** and **individual parts**.

Ideally, the person applying the method as a user is the subject matter specialist for the use case working within agile product development in the team or POT and is also active in Systems Engineering in the sense of the system architect, since there is a particular proximity to the product here. This can be an engineer, an app developer or an employee of a design department. The focus here is on a development engineer who is responsible for the development of new products in the Business-to-Consumer (B2C) area and whose ideas or concepts are tested using this method.

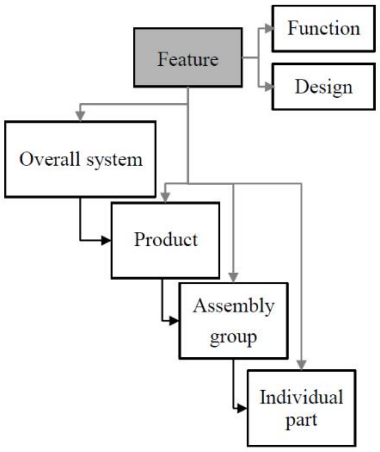

Fig. 3. Product structure

The method essentially involves two interfaces to the agile product development process. The first interface involves digital product development tools. The results can be used by an export and an API interface in other agile systems. For example, an interface to the project management system is possible to define new tasks for the current or the next Sprint. Based on the response of the end customers as a first impression, the product can be further developed and new tasks can be created for agile product development. The second interface is the

demo of agile product development. Here the results of the method can be shown and generate an idea in the team.

5. Example Implementation of a Product-Service System

In this chapter, the concept described in chapter 4 will be analogously implemented by means of an example. Within the validation scope, a company in the household sector could be involved and the method could thus be tested in realistic agile product development. Six Use cases are tested. Use cases 1 and 2 are implemented three times each in a survey. The implementation of the example is performed with the software tool Qualtrics [9]. A smart device as a PPS is used as the overall system. This overall system used in the following consists of a robot vacuum cleaner and an application (app) to validate the method for both physical and virtual products.

The survey is distributed to a pool of 500 end customers by e-mail. Of these, 130 end customers responded within 4 days and 94 end customers responded within the first 24 hours. The customer pool of the exemplary company could be used for this purpose. Demographic, quantitative and qualitative questions were asked to filter the end customer group and know the reason for the decision. For example, quantitative questions such as "Which concept do you like better?" or qualitatively "Why do you like the concept better?" are asked and pictures or videos are shown. Up to 30 text responses could be generated via qualitative questions per use case.

In one example, two concepts of a side brush of the robot vacuum cleaner are presented to the end customer. Accordingly, several concepts of an assembly group are requested. This corresponds to use case 2. Figure 4 clearly shows that the **end customer** favors **concept 1**, as around **80 percent** decide upon this **concept 1**. Answers are also generated within a quantitative question.

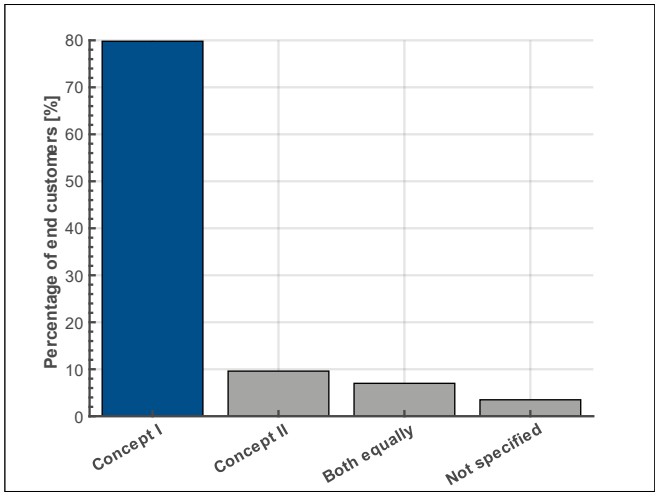

Fig. 4. Product structure

6. Validation on the requirements

The successful implementation with 130 end customers analogous to the concept shows the benefit of the method for practice. The requirements are checked regarding the degree of fulfillment with the concept of the specific method.

The comparison shows that a large part of the requirements (Table 1) is met. The time required for implementation and preparation has been assessed as partially fulfilled because a training in the method and the tool is needed to reach the target working time. As soon as the user knows the functions of the software tool the requirement is fulfilled. The limitation of the concept lies in the available number of participants and the fact that it is a quick impression of the end customers. To validate the content of the answers, 12 experts have carried out the method with a similar result. The concept and the method promise a high degree of fulfillment of all requirements, whereby the validation is successful.

7. Conclusion

Through agile product development and systems engineering, the basic approaches of the method are presented. Using the direct method of integrating end customers into the agile product development process is recommended as an impression of the end customer. Two use cases have been defined for physical and virtual products. The results are connected to the agile product development process as new tasks. The multiple uses of the 28-hour method within a sprint are given. A high number of text responses from the end customer leads to new ideas and decisions in agile product development. In terms of systems engineering, these can then be integrated as part of requirements management.

In addition, integration of the end customer through the query of detailed features is possible. The method presents itself as a quick impression as a complement to traditional methods of customer integration. Nevertheless, consideration must always be given to the interaction between function and design to make the right decisions.

Acknowledgements

This research and the MoSyS, CyberTech project are funded by the German Federal Ministry of Education and Research (BMBF) within the “Innovations for Tomorrow’s Production, Services, and Work” Program (02J198092, 02J19B012) and implemented by the Project Management Agency Karlsruhe (PTKA). The author is responsible for the content of this publication.

References

[1] Scheimann T. Produktlebenszyklen - Immer schneller neuer, Der Tagesspiegel, 2011.
[2] Dumitrescu R, Albert A, Riedel O, Stark R, Gausemeier J. Advanced Systems Engineering - Wertschöpfung im Wandel, acatech, 2021.
[3] A. Schröder. Agile Produktentwicklung: schneller zur Innovation - erfolgreicher am Markt, 2nd ed. München: Hanser, 2018.
[4] Stern T, Jaberg H. Erfolgreiches Innovationsmanagement: Erfolgsfaktoren, Grundmuster, Fallbeispiele, 3rd ed. Wiesbaden: Gabler, 2007.
[5] Landgraf R. Customer Integration: Meinungs-Communities als Instrument zur Gestaltung von Produkten: GRIN Verlag, 2005.
[6] Sillitto H, Martin J, McKinney D. Systems Engineering and System Definitions: INCOSE, 2019.
[7] Gausemeier J, Czaja A, Wiederkehr O, Dumitrescu R, Tschirner C, Steffen D. Studie: Systems Engineering in der industriellen Praxis, in Tag des Systems Engineering: Carl Hanser Verlag GmbH & Co. KG, 2013, pp. 113–122. Accessed: Mar. 16 2021.

[8] Cooper RG. What's Next?: After Stage-Gate. Research-Technology Management. vol. 57, no. 1, pp. 20–31, 2014
[9] Qualtrics, Umfragen - Allgemeine Übersicht. [Online]. Available: https://www.qualtrics.com/de/support/research-core/umfrage-reiter/umfragen-allgemeine-ubersicht/. Accessed: Nov. 24 2021
[10] Object Management Group. SysML 1.5. 2017 [Online]. Available: https://www.omg.org/spec/SysML/1.5/PDF. Accessed: Nov. 24 2021