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UTILISING DESIGN THINKING TO REFINE CUSTOMER REQUIREMENTS – A CASE STUDY USING THE CONCRETE SUPPLY CHAIN AS AN EXAMPLE

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ABSTRACT

The concrete supply and value chain in Germany is characterised by a large number of project participants and, as a result, numerous interfaces must be regulated continuously in every building project. The industry's high degree of fragmentation leads to a situation where information must be prepared and transferred from one system to another with a great deal of manual effort. However, initial attempts to establish a continuous information chain using digital technologies did not bring the desired success. It became clear that the past attempts placed an excessive emphasis on technological aspects and neglected the needs of the actual users. This paper describes a human-centred research methodology that puts the human being and therefore the ultimate customer more in the foreground and actively involves the person in the development of solution concepts. The aim is to reduce waste as well as repetitive and unnecessary activities for those involved in the concrete supply chain. For this purpose, the Design Thinking method is used and adapted to the current context. Summarized this paper contributes an exemplary procedure on how to use Design Thinking to refine customer requirements using the concrete supply chain as an example.

KEYWORDS

Collaboration, customisation, logistics, Design Thinking, concrete supply chain.

INTRODUCTION

The German construction industry is highly fragmented. According to the Federal Statistical Office (2020), 99.9 % of the companies in this country have fewer than 250 employees and 90 % of the companies have fewer than ten employees. In addition, the German construction industry is characterised by a high degree of complexity, which is increased, among other things, by a large number of project participants from different disciplines. This constellation leads to a heterogeneous use of software and hardware and thus to insufficiently interlinked knowledge silos, with many media and information breaks. (Shen et al., 2010)

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This paper deals with a specific area within the German construction industry, namely the concrete supply and value chain. Like the construction industry, this sub-sector is also highly fragmented. According to the annual report of the Federal Association of the German Ready-Mixed Concrete Industry (BTB, 2020b) the German ready-mixed concrete industry consists of 535 companies with 10,590 employees and a total of 1,880 ready-mixed concrete plants.

This situation is particularly problematic for the flow of information between the process participants. In the supply and value chain of concrete, information must be collected at different process steps and permanently documented (cf. DIN EN 206 , DIN 1045-2). This process is currently carried out manually and need to be connected and documented afterwards in a complex manner. For example, the delivery of concrete from the mixing plant and its arrival at the construction site must be documented. The risk of information errors due to the "human factor" is particularly high here (Lanko et al., 2018). At the same time, the communication channels in the supply chain of building products are often limited to conventional telephone calls, emails or faxes (Li et al., 2015). This circumstance makes an automatic exchange of information and easy traceability very difficult.

Various organisations have already attempted to develop a solution to this problem in the past (BTB, 2020a; edr software GmbH, 2019). However, the systems developed were only used in closed ecosystems limited to a few project participants. A large-scale application failed not because of a faulty system, but because of the acceptance of the users. A closer look at the systems reveals that the focus in the development of the solutions was on the technology and not on the customer. In a round of interviews with experts from the concrete industry, the system failure was identified as the result of incomplete collection of user/customer requirements and its lack of incorporation into the solution design (SDaC, 2022).

The aim of this paper is to examines the problem more closely and focusses on the customer requirements with the help of a human-centred research approach. For this purpose, a human-centred research method was selected and used, adapted, and extended to the present situation.

In the further course of the paper, the literature review to human-centric Design is presented. Afterwards the basics of the Design Thinking method are first discussed, before the actual procedure is presented. This section forms the main part of the paper. The individual steps in the process are explained in detail and examples of interim results are given. Finally, an outlook and a critical appraisal of the results are provided.

LITERATURE REVIEW

System development used to be based on predefined process steps that did not involve the user much, if at all. In the 1980s, the cost of computer hardware dropped significantly, giving many people access to computers. The problem, however, was that computers were difficult to operate. Therefore, with the involvement of users, new systems were developed that were simple and easy for everyone to use. This laid the foundation for the involvement of users in the development of systems and products.(Cockton et al., 2016)

User-centered design puts the user and their relationship to technology at the forefront of an application's development process (Zhang et al., 2020). Understanding the characteristics and needs of people leads to technologies that create added value for them. Additionally, understanding the customer results in a more usable product, financial savings by avoiding bad investments, and safer systems. A method to achieve an understanding of the user is, for example, to ask the following questions of Ritter et al. (2014).

- What do people do? Methods for gaining knowledge from data are used for this purpose.
- Why do people do what they do? Insights are gained into people's unconscious and conscious motivations.
- When are people likely to do something? Patterns of human behavior are identified.

- How do people decide to do things the way they do? An understanding is built up about people's possibilities for action, limitations, and resources.

While user-centered design examines the interaction of the user with a system, human-centered design focuses more on the abilities and characteristics of the people who are influenced by the system. The human being is considered the central element of the system (Spitler & Talbot, 2017). Nowadays, more and more systems are being created in which humans no longer interact with technology only as users but in a mixed human-machine interaction. Nevertheless, this can be influenced by new technologies. This makes it necessary to consider humans and their effects on development. Human-centered design takes into account both immediate and long-term points of contact between the human and the system. (Ritter et al., 2014)

To create user-centric design, there are several methods and approaches that designers can use. Personas are fictional representations of users based on research that help guide design decisions by providing a clear understanding of users' needs and goals (KSRI, 2020). User journey mapping is another method that involves visualizing the steps a user takes to accomplish a task, which can identify pain points and opportunities for improvement (Lewrick, 2018). Wireframing is another technique where low-fidelity visual representations of a user interface are created to explore different design options (KSRI, 2020). Prototyping is a critical step in the design process, where high-fidelity mockups of a product or service are created to test with users and refine the design (Uebernickel et al., 2015). Usability testing is another essential step to evaluating the usability of a product or service by testing it with representative users (KSRI, 2020). Co-creation is an approach that involves engaging users and other stakeholders in the design process to ensure their needs and ideas are incorporated (Schallmo & Lang, 2020). Design thinking is a problem-solving approach that emphasizes empathizing with users, defining the problem, ideating potential solutions, prototyping, and testing (Schallmo & Lang, 2020; Uebernickel et al., 2015). This approach ensures that the design is centered around user needs and goals. Agile development is a methodology that emphasizes collaboration, flexibility, and continuous improvement (Lewrick, 2018). This allows designers to iterate on the design based on feedback and new information, leading to a more user-centric design. Overall, these methods and approaches help designers create solutions that are centered around the needs of the users (Uebernickel et al., 2015).

For this study, the design thinking method was chosen to investigate the problem described in the introduction. Among other methodologies, design thinking is very customer-centered and has already been successfully applied in the past in various studies in the construction industry (Spitler & Talbot, 2017; Zhang et al., 2020). In addition, other methods, such as developing personas and forming hypotheses, can be included in the process. In the next chapter, the methodology is presented and the essential features are discussed.

METHOD

Design Thinking is used to create customer-oriented products, services, and processes, and to align them in the most customer-centric way feasible (Schallmo & Lang, 2020). Instead of developing solutions for which suitable areas of application still need to be found, Design Thinking offers a method for examining the problems and developing human-centred solutions. According to Erbeldinger et al. (2015) Design Thinking focuses on inventive thinking with a radical customer or user orientation. The methodology requires several iterations that serve to successively gather user feedback and consequently generate new knowledge and develop more appropriate solutions (Schallmo & Lang, 2020). In addition, an interdisciplinary team is used, which deals intensively with the issue over a period of time (Plattner et al.; Schallmo & Lang, 2020).

In the context of this work, the Design Thinking Microcycle according to Uebernickel et al. (2015) was chosen and combined with the procedure according to Schallmo and Lang (2020). The Design Thinking Microcycle consists of the following five steps (Figure 1):

1. **Step 1: Problem definition**
   Initially, it is important to look at and examine the problem as neutrally as possible and with a broad field of vision. In particular, a common understanding and a common perspective should be created within the team working on the problem. In this phase, it is important to deal intensively with the user and to understand the needs. This can be achieved through a lot of personal contact in the form of discussions or workshops. It is also very helpful to take on the role of the user for a few days and, for example, to carry out the work yourself. This approach gradually increases the knowledge about the user and his problems.
2. **Step 2: Need finding**
   The relevant conclusions are then collected, analysed, and interpreted. This procedure makes it possible to develop a user profile that demonstrates characteristics, needs and problems.
3. **Step 3: Ideating**
   The next step is to gather possible ideas for solutions based on the knowledge already collected. The ideas aim to fulfil the identified needs of the user. Relevant ideas are identified through a selection process.
4. **Step 4: Prototyping**
   Afterwards the collected ideas need to be transformed into testable prototypes as quickly as possible. The level of detail of the prototypes increases with each iteration loop. The aim is to identify the best properties of the prototypes quickly and without much development effort, and to improve them continuously in the following iteration loops.
5. **Step 5: Testing**
   In a test phase, the prototype is presented to its future users and checked for practicality. Prototypes that are not suitable are already dropped in early iteration loops. This allows the development team to concentrate on particularly promising prototypes or functions.

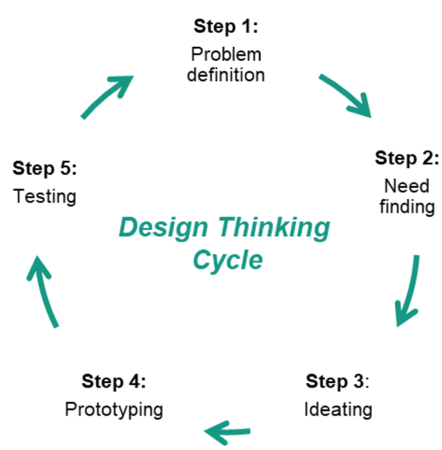

Figure 1: Design Thinking Microcycle according to Uebernickel et al. (2015)

As already mentioned, the Design Thinking Microcycle takes place in several iterations. Once an iteration has been completed, the cycle starts again from the beginning by revising the problem definition and adapting it based on the findings. This procedure makes it possible to quickly produce presentable results and to further concretise them after each iteration loop. In the next chapter, the Design Thinking Microcycle is applied to the concrete supply chain. The actual procedure and the methods used are described. In addition, exemplary results are shown.

RESULT

PROBLEM INVESTIGATION (STEP 1-2)

The case study started with arranging ***a panel of* experts**. As part of the Smart Design and Construction (SDaC) research project and in cooperation with the German Concrete and Construction Technology Association (in German: Deutschen Beton- und Bautechnik-Verein E.V. - DBV) and the Community for supervision in construction (in German: Gemeinschaft für Überwachung im Bauwesen E.V. - GÜB), a working group was initiated. The SDaC project is a research project funded by the Federal Ministry of Economics and Climate Protection of the Federal Republic of Germany, with the aim of developing a platform for Artificial Intelligence (AI) applications in the construction industry. The interdisciplinary consortium with numerous partners is led by the Institute for Technology and Management in Construction at the Karlsruhe Institute of Technology (KIT). DBV and GÜB are domain experts and active in the field of concrete construction for several decades. The expert panel is in turn composed of representatives of the concrete value and supply chain and most recently consisted of 28 people from 20 different organisations. The expert panel forms the group of people in which ideas and approaches were later presented and discussed. For this purpose, the current state of development was presented to this group at short intervals. The form and methods used will be explained further below.

To learn more about the participants in the supply and value chain, ***personas*** representative of each user group were developed. The identified relevant user groups are: concrete distributor, concrete mixer driver, shell construction manager and quality supervisor. Creating a persona is a method used to represent a fictitious user as authentically and realistically as possible. The persona represents a member of a real focus group. In the representation of the persona, individual characteristics, wishes and tasks of a user are considered. For example, it represents the age, gender, possible family relationships, personality, desires ("gains") and frustration ("pains") as well as tasks ("job-to-be-done"). The information on the persona is based on conclusions drawn from recordings, experiences and our subjective perception and thus represents how the user would behave from our point of view. (Lewrick, 2018) A persona from the concrete supply and value chain is, for example, the shell construction site manager. The persona of the shell construction foreman developed in the case study is shown in Figure 2.

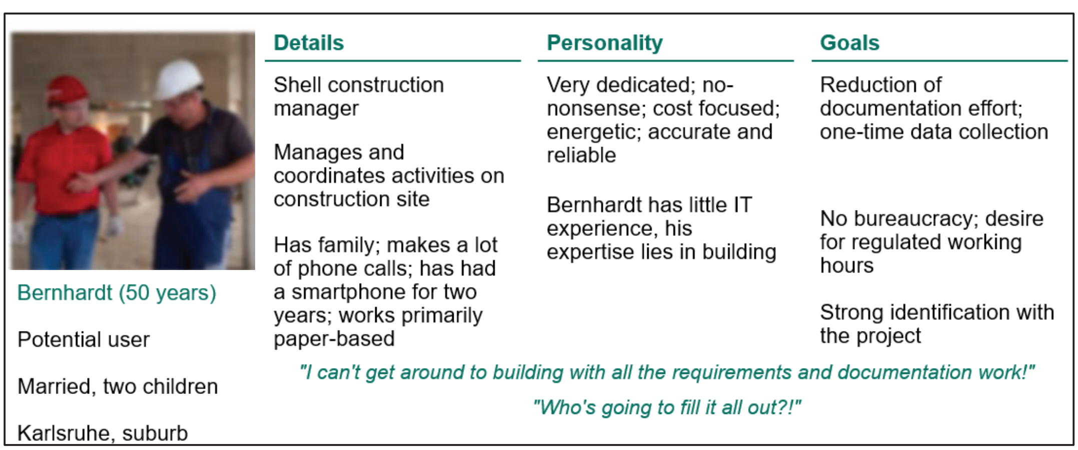

Figure 2: Persona shell construction manager

The developed personas were regularly reviewed and adapted within the Design Thinking cycle. For this purpose, expert interviews and on-site observations were used. This procedure successively sharpens the image of the potential users with each iteration loop and thus leads to regular insights into the behaviour of the users.

In addition to the personas, hypotheses were formed to add information. The hypotheses serve to make the knowledge gained tangible. The development and verification of hypotheses is oriented towards the three steps according to Kornmeier (2018). The three steps can be iteratively repeated as often as desired according to the Design Thinking cycle.

1. A hypothesis is formed about a causal relationship that requires explanation. The hypotheses describe a problem or a situation but can also represent a proposed solution at the same time. In relation to the shell construction manager, for example, a hypothesis is: "The site manager does not have enough time to carry out careful documentation. A simple, quick process is necessary".
2. The hypothesis is tested against reality through conversations or observations and falsified if necessary.
3. This process of constantly forming and testing hypotheses is repeated regularly until statements are found that best represent reality.

Figure 3 shows examples of hypotheses for the persona of the site manager. In addition to the actual hypothesis, the figure also describes how the hypothesis can be tested.

Hypothesis	Assumption	Measurement
Hypothesis 1	The construction manager does not have enough time to carry out careful documentation: A simple, fast process is needed.	Required time, number of errors
Hypothesis 2	The user has little prior knowledge of the requirements for the delivery. This results in insufficient / incorrect testing.	Years of professional experience of the tester, number of errors
Hypothesis 3	The matching of delivery bill to order form is insufficient. A daily updated and supporting digitalisation would be ideal.	degree of documentation, interviewing persons concerned
Hypothesis 4	External data (e.g., weather data) are not considered during the ordering process: Integration can optimize or facilitate ordering and documentation.	Data reconciliation
Hypothesis 4	Documents for documentation (individual documents) are not linked to each other: The same information must be entered in several places.	Number of multiple accesses to information, single documents with the same information

Figure 3: Hypotheses on the persona of the shell construction manager

The development of personas and hypothesis has created a sharper picture of the actual clients of a later solution. In particular, the problems and difficulties of each group of people have been addressed. One conclusion from this process was, for example, that the site manager is not averse to using digital technologies in principle, but that he hardly has time to deal with them during his working day. The development team was not previously aware of this connection in this much detail, and it was only highlighted through the development and validation of the personas.

SOLUTION DEVELOPMENT (STEP 3-5)

With a deeper understanding of the customer requirements (compare step 1-2), it is now possible ***to develop ideas and suitable solutions (step 3)***. One idea that quickly emerged from the intensive examination of the problem situation is the two-step approach. The two-step approach is particularly interesting because it quickly improves the current situation. The quick improvement of the current situation was one of the customer requirements identified earlier.

The two-step procedure is illustrated in Figure 4. The first stage is using an Artificial Intelligence-based scan function to extract machine-readable data from the delivery notes as quickly as possible and therefore at short notice, to circumvent the digital-analogue media breaks. The necessity for this first stage is the high fragmentation of the concrete supply and value chain. The high number of different companies makes a direct standardisation of a digital exchange format extremely time-consuming due to the necessary agreements. The Design Thinking Microcycle in connection with the presentations of personas and hypothesis have confirmed this fact. For this reason, the development of a digital interface is not planned in the long term until stage 2.

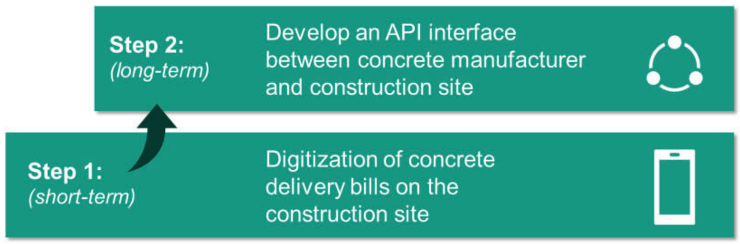

Figure 4: Graduated implementation model for a continuous information chain

After a suitable idea was identified, the team started with ***prototyping (step 4).*** The aim was to design a technical concept for each stage as quickly as possible for the software development later. To this end, conceivable technical approaches were quickly converted into testable prototypes using ***Mock-Ups.*** A Mock-Up gives the user an overall impression of the planned system without necessarily actually functioning (Lewrick, 2018). The future customer of the software application is placed at the centre of the development. Mock-Ups are ideal for expert interviews to convey ideas and approaches to the interviewer, visually and in a way that is easy to understand. For the presentation of the Mock-Ups, three levels of presentation were chosen: low, medium and high resolution (KSRI, 2020). Each level was ***tested through several iterations (step 5)*** in user interviews. The difference between the individual stages is the increasing level of detail of the prototype. By doing so the interviewer automatically focuses on the feedback of the viewer. Too specific content or a high-quality design can distract the viewer and therefore influence the feedback. For example, in an early phase of the Mock-Up development, it is not necessary to gather feedback about design aspects such as the button size or the colour scheme, but rather on the actual functionalities. The three levels are exemplarily shown in Figure 5.

Figure 5: Three levels of Mock-Ups according to KSRI (2020)

1. ***Low Resolution:*** This level shows the ultimate user flow in the application. Individual pages in black and white represent the necessary steps that a user must go through to achieve the desired result. The user flow thereby determines the number of pages and the click sequence in the later software.
2. ***Medium Resolution:*** At this stage, the first basic elements within the pages are defined and mapped. The resulting wireframes are already clickable but still in black and white. The focus of the feedback at this stage is on the completeness of the required functions. The design and layout do not play a role at this stage.
3. ***High Resolution:*** This third level already shows all details of the later application. This impression is created by a graphically appealing design with a high level of detail. The viewer may not be able to tell the difference between the Mock-Up and the final application.

After finishing the third level of the Mock-Up development, the final software development had to be carried out and the Artificial Intelligence-based scanning software and the API interface had to be created. The respective Mock-Ups provide a clickable prototype for this, which only needs to be technically replicated. Due to the short-cycle and the human-centred Design Thinking approach, the ***agile software development method is*** used for the development. Unlike, for example, the waterfall model or the Rational Unified Process (RUP), which tend to be considered less effective, heavyweight and unable to deal with short-term changes. The goals set were readjusted or completely redefined in each sprint by means of evaluated feedback (Martin, 2020). The four guiding principles and the twelve principles from the Agile Manifesto were used for orientation (Beedle et al., 2001) which according to Bergsmann (2018) form the cornerstones of practically all agile approaches.

DISCUSSION

The primary goal of any business is to satisfy its customers by providing products and services that meet their needs and requirements. However, determining what customers want and need is not always a straightforward process. Customer requirements can be complex and multifaceted, and understanding them requires a structured approach. In recent years, Design Thinking has emerged as a popular approach for solving complex problems, including those related to customer requirements. This paper discusses the use of design thinking to refine customer requirements, using a case study of the concrete supply chain as an example.

The concrete supply chain is a complex and multifaceted system that involves many stakeholders, including contractors, suppliers, and customers. To better understand the customer requirements in this supply chain, a Design Thinking approach was used. The process involved several steps, including the development of personas, hypothesis, and mock-ups. Design Thinking is a human-centered approach to problem-solving that highlights empathy, experimentation, and iteration. At its core, Design Thinking is about understanding the needs and wants of users and using that understanding to create innovative solutions that meet their needs. When it comes to customer requirements, Design Thinking can be a valuable tool for businesses. By using Design Thinking, businesses can gain a deeper understanding of their customers' needs and use that understanding to develop products and services that better meet those needs.

The Design Thinking process used in the case study resulted in several insights and improvements for the concrete supply chain. For example, the process revealed that customers in the supply chain were concerned about the quality of the concrete they received and the reliability of the delivery process. As a result, the developed system was reorganized to improve quality control and delivery scheduling. Additionally, new services were added to the process to help customers track their orders and communicate with suppliers.

The implications of these findings extend beyond the concrete supply chain. By using Design Thinking to refine customer requirements, businesses can gain a deeper understanding of their customers' needs and develop more effective solutions to meet those needs. This can lead to increased customer satisfaction, improved products and services, and ultimately, a more successful business.

CONCLUSION

The supply and value chains examined in this case study demonstrate significant possibilities for digitalisation. The application of the Design Thinking method within the framework of the research methodology proved to be very beneficial. Particularly during the phase of the problem investigation, the approach enabled an in-depth examination of the problem. Instead of focusing directly on a solution and working it out with the participants, a significant amount of time was spent in an early phase, analysing the problem in depth. Leading by this procedure, a two-stage solution implementation approach was formed. The use of Mock-Ups in the phase of the solution development also proved to be very helpful. The visualisations increased user understanding by giving the user a general understanding of the solution that have been presented. In comparison, it would have been much more difficult to present concepts to the future user only through explanations, text documents or similar. The three stages of Mock-Up development ensured that the focus of the feedback was targeted.

This article provides, for the first time, a customer-centric approach to analyse system requirements. The requirements obtained in this way can then be transferred into a type of requirements specification. Due to the fixed implementation time, only a limited number of methods could be tested and applied. Within the framework of the Design Thinking approach, however, there are many other methods (cf. job-to-be-done, stakeholder map, data canvas or similar) that can be integrated into the procedure as desired. For future work, it is recommended to also test these methods. Furthermore, the procedure presented in this paper has so far only been applied in the supply and value chain of concrete. For this reason, this case study doesn’t create a representative sample size and should be applied to other disciplines and industries.

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