Coping with uncertainty through Human-centered Design in engineering projects – Developing a Septic system for Wavin company within this process

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For the Degree of Master of Science in Innovation and Design

Master's thesis, advanced level, 30 credits
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2023-11-15

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Contents

Abstract:

This study explores how designers feel when working on a product in different ways. This research wants to understand a designer's experience in the design field. Designing is a problem-solving process, and not knowing possible results makes a situation uncertain for designers. This research examines this uncertainty and how it changes while creating a product.

To empirically explore this phenomenon, a project has been done for a company called Wavin, focusing on developing and modernizing a septic tank. The research design included the implementation of two divergent methods to elaborate the chosen approach's impact on the designer's uncertainty landscape. The first method was doing the project through the lens of the company's conventional product design methodology, providing a baseline for comparison. And then, the Human-Centered Design (HCD) approach was used, introducing a shift in perspective towards a more user-centric approach.

While working on both methods, a self-report was written at different stages. This self-reporting serves as a valuable qualitative lens, offering insights into the uncertainty experienced by designers when navigating the uncertainties inherent in product development.

The key findings in the uncertainty experienced from the self-report were categorized and analyzed with an "uncertainty triangle." This analytical framework serves as a tool to distinguish the varying degrees of uncertainty encountered in each distinct product development approach.

Based on these findings, the research proposes a strategic framework for dealing with and managing uncertainty in product development. Overall, this research talks about how designers feel uncertain and gives practical advice for dealing with uncertainty in the product development process.

Keywords: Product development process, Human-centered Design, uncertainty, Designer’s feeling, Uncertainty Triangle.

1. Introduction

"Every human being is a designer" (Potter, 1980, p. 10). This sentence is a broad definition of being a designer. More specifically, the definition of the designer as a profession is a person with deep knowledge and understanding of aesthetical subjects, such as knowledge of "gestaltning" – a Swedish word which describes the work of giving form - of the concepts for human use also for research (Hjelm, 2005). Designers experience feelings and emotional changes during the design process (Hutchinson, 2018). During product designing, designers often face wicked problems (Buchanan, 1992). They experience a wide range of emotions to handle the objective in focus. Also, they face various phases in the creative design process, which they need to investigate and define (Howard, 2009). For example, in a design process, they can feel positive, like interested, curious, inspired, and stimulated, or negative, like anxious, nervous, hesitant, or doubtful (Kumar, 2021). However, these feelings could affect the results of decision-making and problem-solving (Csikszentmihalyi & Rochberg-Halton, 1981). The result of a design process could be an artifact at the end. While it is unclear for designers during the design process to predict precisely about the results. This situation would bring some uncertainty for designers, who need to deal with that to have the result (Wigum, 2021).

1.1. Problematization

Problem definition:

This research aims to design and develop a product for Wavin company to meet their needs. At the same time, understanding and dealing with the uncertainty that happens for designers who work in different types of product design processes. In this research, I used HCD and the Engineering Product Design (EPD) process - which was given by the company and included 1. data gathering, 2. Ideation, 3. Assembly drawings, 4. 3D modeling, and 5. Presentation revision, and iteration - for doing the project and comparisons. All in all, this research would collaborate between the Human-Centered Design approach, Product Development, Innovation and Design, and Uncertainty concept (Figure 1).

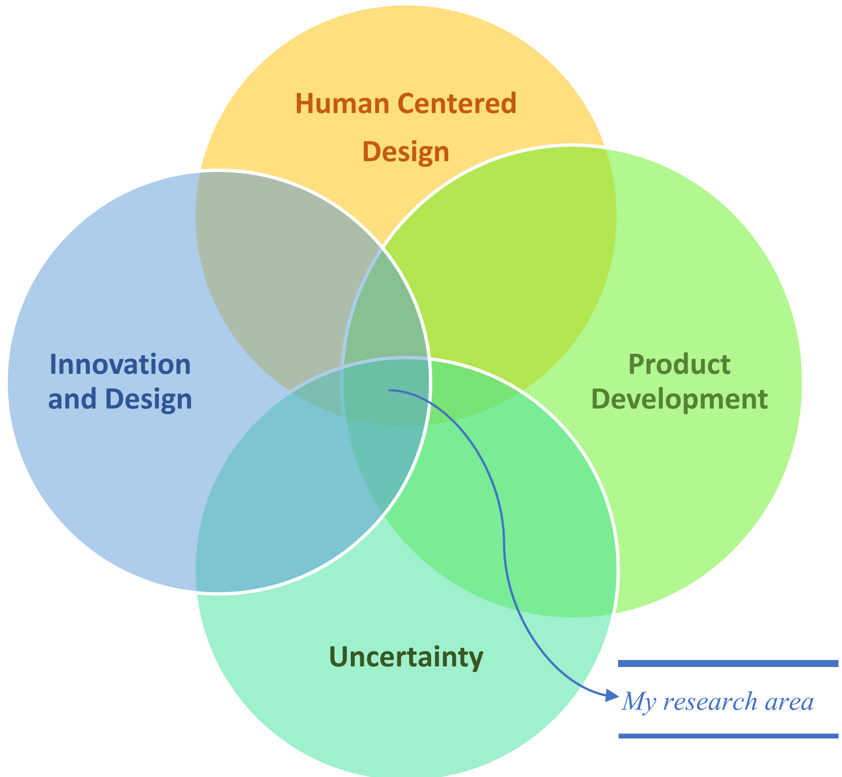


Figure 1. The research area collaboration

1.2 Uncertainty

The general definition of "uncertainty" based on the Oxford Dictionary is "the state of being uncertain." Uncertainty is broadly defined as an insufficient understanding of events that might happen in the future, or that might have already happened but are not yet known to the individual (Rosen, Ivanova, & Knäuper, 2014). However, there is a more precise definition of uncertainty that can happen in the present ambiguity and the unclear situation that might happen in future uncertainty (Tracey & Hutchinson, 2016). This research elaborates on this concept of uncertainty that may happen in the future. In the whole report, the uncertainty means the unclear situation concerning what might happen in the future.

Since uncertainty is a broad area, a narrowed-down concept for this research is chosen. This concept is the uncertainty that happens to designers during their design process.

Design is the center of innovation, and while embarking on innovation projects, designers must navigate the uncertainties that come with complexity. In addition, since the outcome of the innovation is supposed to be new, designers cannot predict precisely what the results will be, so one of the fundamental subjects in innovation is uncertainty (Tracey & Hutchinson, 2016). Moreover, the Designers need to deal with that to solve the problems and have the results.

Turtola and Määttä (2023), in "Competence of a successful designer," say that to be a successful designer, several characteristics need to have the ability to cope with uncertainty also since the design is an interactive process that relies on the ability to work well with others and excel in a co-design environment that fosters collective creativity. A designer's positive emotions, attitudes, and enthusiasm support design thinking, problem-solving, and innovation. In addition, designers need to accept uncertainty as an inseparable part of creativity and innovation to cope with that.

Wigum (2021), in "The Gift of Uncertainty," discusses the role of uncertainty in design education and practice. In the end, the article discusses how design education can play a role in preparing future designers to navigate the complexity of uncertainty. However, some interesting results of the article are that uncertainty shares a direct correlation with control, where an elevation in control corresponds to an increase in uncertainty, and with communication and interactions with others, uncertainty would decrease. **This research tests and analyzes this statement and the relation between uncertainty and using the HCD approach compared to the traditional design approach.**

1.3. Uncertainty in the design process

Kumar et al. (2021) have done research that primarily focuses on the product generated by the designers and the emotional experience felt by the users while using the product. It attempts to understand the emotional experience of designers during the design process with supporting empirical evidence. They also claimed that designers experienced high emotional levels when they reached the ideas during the creative ideation processes. These emotions could positively affect the results.

In their study, twenty-five designers were asked to complete a design task for a limited period. The data was analyzed to establish the dynamics of the emotions during the design process based on the observation (video and audio recordings of the task). The study found a primarily positive effect throughout the design process with associated high entropy scores and high outcomes, where the affective states varied between different time intervals and at different phases of the design process. Their research contributes to the understanding of the complex phenomenon of the design process, where designers often deal with wicked and ill-defined problems, which generate a complex set of emotions to deal with the goals of the process. These emotions could vary based on the cognitive and behavioral aspects and differences between senior and junior designers. Also, they mentioned that the designer's emotions could be measured by self-reporting their moment-to-moment experiences. **Even though their research elaborates on the emotions of designers in the design process, they do not investigate the positive emotions that happen in a user-centered design process or the typical design process. This is one of the points that this research elaborates on and tests more about to compare these two**

processes of product designing in terms of the emotional feelings of designers.

Wigum (2021), in the research “The Gift of Uncertainty,” discusses the challenges and opportunities that arise from the inherent uncertainty in the design process. They argued that the illusion of a designer’s ability to predict the future is often present in current design practices. Also, the need for control has the impact of an unpredictable future. This illusion is considered a skill to survive within the local systems of practice and thus reassure the existence of business and design practice by economic and environmental risk prevention through design. The authors suggested that the uncertainty of the human future may orient designers into a new role in society and business practice. They propose a design understanding that builds on systems theory and cybernetics, focusing on the design of new structures and, thus, the emergence of subsystems that produce new growth and systems goals. The authors posed the research question: "How can design education play a role in future designers' piloting development in the complexity of the uncertain?". They argued that design education is slowly bringing in systemic design thinking in order to be able to design for complex uncertainty.

Wigum (2021) revolved around the unique approach to managing a design project if there was a specific toolbox, in addition to a standard one, for comprehending, tracking, modifying, and adjusting the stages of the design process. This approach would involve sharing the knowledge acquired, facilitating dialogues and decision-making, and aiding the advancement of the development process.

In addition, Wigum argued that the gifts of uncertainty can be used to guide the design process and help designers navigate the complex and unpredictable nature of their work with system-oriented frameworks for design processes. In this research, they are not explaining whether their systematic design processes are in a participatory approach or not. **Their research goes through this subject to find differences in dealing with uncertainty between the HCD approach and the traditional design process.**

Tracey (2016), in “Uncertainty, reflection, and Designer Identity Development,” describes the definition of uncertainty, which is explained in chapter 1.2. They are also talking about the concept of the unclear situation in the present moment, which is called “ambiguity,” and for future “uncertainty.” In addition, the article discusses the role of uncertainty in the design process and its impact on the identity development of designers. The authors argue that uncertainty is a defining quality of the design space and that designers’ attitudes toward uncertainty may influence design processes and outcomes via cognitive, affective, and behavioral channels. Individual attitudes and behavior patterns related to uncertainty may constitute a critical element of designer identity, representing the synthesis of knowledge, action, and being. The study examined how graduate students in an instructional design course reflected on their experiences and beliefs regarding uncertainty. The participants were more reflective when discussing a general experience with uncertainty than their current attitudes toward uncertainty in design. The findings support the use of narrated reflection in design education related to uncertainty and identity. The study also discusses the implications for design education interventions and design. It also says the designer should try to reduce uncertainty with the co-evolution concept, emphasizing adaptability, responsiveness, and a continuous feedback loop. It encourages designers to evolve with the needs of users.

Designers' emotions are affected by the design methods they use. This statement is the main result of Chulvi's (2016) research. This research presents the results of an experiment carried out on subjects with an engineering background. The experiment aimed to determine the influence of the designer's attitude on the design process and the finished design. The participants were asked to solve various design problems using different methods while a non-invasive neuroheadset registered their emotional response parameters. The recorded data was used firstly to compare the different reactions of the subjects when using different design methods. A second analysis was carried out to determine whether the variations in the emotional parameters directly related to the outcomes' creativity. The results indicate a relation between emotional parameters, individuals, and the design method. However, there does not appear to be any direct association between emotional parameters and the creativity of the results.

The main result of another very recent research, "The competence of a successful designer" (Turtola & Määttä, 2023), says that, even though the designer's characteristic has some effects on the results, the working environment that the designer does the design duties and the team atmosphere are in great importance. This research discusses the competencies required for a successful designer in the context of contemporary design practice's increasing demands and complexities. The authors argue that a designer's competence requires continuous renewal and realignment, yet it contains several permanent qualities. They aim to create a holistic picture of the competence of a successful designer. According to the authors, a designer's competence comprises four factors: cognitive, social, emotional, and functional.

Cognitive factors: These include several characteristics required for design thinking, especially creativity, the ability to produce new insights, and the ability to cope with uncertainty.

Social factors: Design is a social process where interaction skills and collaboration are crucial in a co-design approach to collective creativity.

Emotional factors: The designer’s positive feelings, attitudes, and enthusiasm promote design thinking, problem-solving, and innovation.

Functional factors: Good knowledge and skills are essential for developing the design. These promote the designer’s work satisfaction and well-being.

The authors emphasize that the success of a designer requires multi-faceted competence, and success does not only depend on personal characteristics. Success is also influenced by the environment in which the designer works. A good atmosphere of the work community, support, and encouragement promotes success for all parties involved in the design process. So, in this research, they are finding that design should be a social process, and they are talking about the ability of designers to communicate with others to share ideas. However, Turtola and Määttä (2023) do not mention the relationship between this communication and dealing with uncertainty as an essential part of the design process.

In the above research, they discuss the ability of designers to communicate and involve users in the process, which is the king of the process of participatory design, such as the HCD process of product development (Simonsen and Robertson, 2012).

The benefits and Challenges of HCD in Engineering are numerous. HCD can improve engineering solutions' usability and user experience, leading to increased user satisfaction and adoption rates (Kujala, 2003). HCD can also lead to more innovative solutions that meet the needs and preferences of users. However, there are also challenges associated with HCD in engineering, such as the cost and time required to conduct user research and the difficulty of involving users in the design process (Simonsen and Robertson, 2012). On the other side, recent research shows that the HCD approach saves time in the design process (Hass & Edmunds, 2019). **Comparing the duration of different design processes is one of the subjects of this thesis' research. It aims to explore and test whether the Human-Centered Design (HCD) approach takes longer than traditional product development methods.**

The research area consists of two parts: one part is about the theoretical content of the thesis research about uncertainty and how to deal with it in the design process. The second component is a practical application of these theories through a case study project conducted with Wavin company in Sweden. This project involved the development of a septic system product.

1.4. Research aims and question

Aim

This research aims to explore and comprehend the uncertainty within two distinct design processes, namely the Human-Centered Design (HCD) process and the Engineering Product Design (EPD) process. The primary objective is to delve into the unique challenges and uncertainties that arise during these design processes. Additionally, the research aims to propose practical recommendations and develop a framework that designers can employ to navigate and manage uncertainty encountered in the HCD and EPD effectively.

The practical purpose of project is to development a product and find the solutions for the Wavin company to develop their product.

Research Gap

The trend in research that invites problematization within existing literature (Alvesson and Sandberg, 2013). Recent studies have highlighted the benefits of the Human-Centered Design (HCD) approach, such as the ability of designers to communicate and involve others in the design process. These studies also discuss how designers manage and reduce uncertainty through communication (Wigum & Gulden, 2021; Kumar et al., 2021; Tracey & Hutchinson, 2016; Turtola & Määttä, 2023).

However, these studies do not delve into the differences between uncertainty in the HCD process and traditional design methods. Furthermore, they do not propose a practical framework for managing uncertainty in design processes. This gap presents an opportunity for further research to bridge and contribute to the existing body of knowledge.

Research question

Having a research question is essential to problematizing and conducting research. A research question is the starting point for all theory development, although not all questions qualify as research questions, according to White (2009). In addition to being researchable, a good research question should be specific and yield relevant knowledge. The primary standard for a suitable research question is its ability to generate knowledge that makes a substantial theoretical contribution, as indicated by Alvesson and Sandberg (2013). The first step in creating a research question is identifying a domain or topic that piques our interest. From there, we can formulate a research question related to our chosen subject, followed by defining the study's aim to clarify its purpose. Developing a set of research questions is needed to guide research in a focused direction. Researching trendy topics increases the likelihood of discovering issues of societal importance or areas with growth potential. (Alvesson and Sandberg, 2013, pp. 19-21).

The research question of this study is based on the gap-spotting in the literatures (Creswell and Creswell, 2017) mentioned below.

Questions:

The main research question:

How might designers experience uncertainty in the HCD process compared to traditional design method, and how could they deal with uncertainty?

1.5. Target group

The Target group of this research is the engineers and experts in Wavin company who need to propose septic system customers. Another user and target group of the project would be users and owners of households whose houses are not connected or, for any reason, they do not have accessibility to the sewage system and they want to use some septic systems.

Wavin: This company is the partner for this project. One of their missions is to increase sustainability and use wastewater to tackle water problems worldwide. Wavin company and, on a bigger scale, Orbia company, they could use the final concept as a product for manufacturing.

MDU: The university is one of my partners. The MDU is the other stakeholder that I should work with, and to be more specific, the information and design department and product development department are the stakeholders of this research at the university.

The other stakeholders for this research are the **households** living in the areas without connection to the municipal sewage system.

The **engineers** in Wavin company can use the final concept to prepare the proposal for the customers and do some calculations with the final concept.

Project Team:

The team is considered Erik Bjurström (Thesis supervisor), David Jirout (Company contact person), and Mohammadhasan Yazdani (Master's student).

2. Theory

The uncertainty triangle (Eriksson, 2005) is used as the theoretical framework for this thesis research.

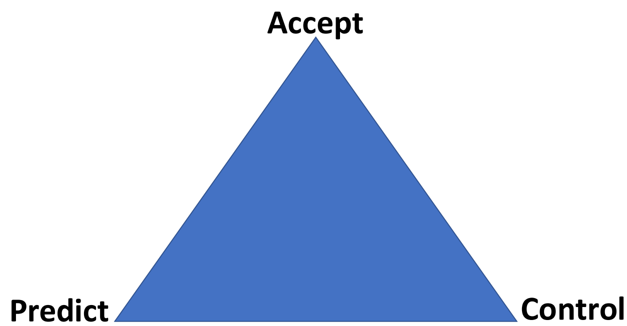


Figure 2: 'The uncertainty triangle' (Eriksson, E. A., p.169)

There are three vertexes in the uncertainty triangle, each indicating a primitive attitude toward uncertainty. Standing at each point would be the exact uncertainty. As a result, to reduce the uncertainty level, providing a balance between these three primitive attitudes and standing around the centroid point of the triangle would be recommended. "Accept," "Predict," and "Control" are the attitudes considered as the end of each edge (Figure 3).

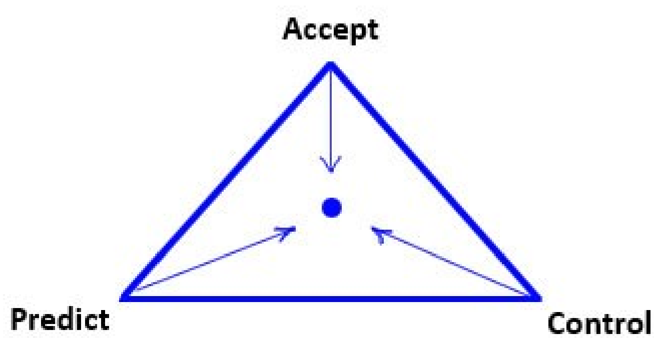


Figure 3. The balance between three main point of uncertainty

This framework has three dimensions, and three dimensions, "Emotional," "Practical," and "Intellectual," provide a comprehensive approach to understanding and addressing uncertainty. This uncertainty triangle allows individuals to identify their position within these dimensions and understand the level of uncertainty they are dealing with.

In a similar vein, Wigum & Gulden's (2021) research supports this concept, suggesting that relinquishing control over every aspect of the design process and fostering communication and collaboration with users can reduce uncertainty. They also highlight the importance of managing the impact of future unpredictability. This aligns with the uncertainty triangle's premise that balancing control and prediction can enhance uncertainty handling. However, this does not imply precise prediction of outcomes but instead designs through organization, decision-making, and action and adapts to situations and environmental factors (Bjurström & Bakken, 2022).

Tracey (2016) further supports this by stating that uncertainty levels are lower in interactive and communicative design process environments. While uncertainty can stem from a lack of future knowledge (intellectual aspect), it also impacts feelings and emotions (emotional aspect). Therefore, addressing uncertainty requires considering all three dimensions: practical, emotional, and intellectual (Dreborg et al., 1994).

In summary, this theory suggests that it is not just about predicting potential outcomes in uncertain situations. Effective uncertainty management involves a balance between the following:

- Taking control of the situation.
- Having some predictions about the result.
- Accepting others' ideas and communicating with them.

3. Method

3.1. Data gathering for this study

1. Self-reporting

Throughout the project for the company, a diary was maintained to express feelings during the product development process. The self-report documented technical issues, problems faced, and the corresponding emotional experiences.

2. Literature review

In this case, a literature review was conducted within recent and relevant subjects related to the topic. The focus encompassed uncertainty, designers' emotions, the Human-Centered Design (HCD) process, and the intersection of feelings and uncertainty in the HCD process for designers. Gap spotting, as outlined by Alvesson and Sandberg (2011), served as the methodology for identifying research question.

3. Interview:

Face-to-face and online interviews were conducted with project users and engineers at Wavin company.

4. Observation:

Planned a workshop for three engineers from Wavin, inviting them to the university. Requested their collaboration in designing a process for handling design projects at their company using the Human-Centered Design (HCD) approach. During their discussions and interactions, notes were taken, including explanations of their reactions and the keywords they used.

The research approach employed in this study is qualitative, as outlined by Bhattacherjee (2012). The data gathering methods are also qualitative, involving in-person and online interviews, as well as a co-creating workshop with three engineers from Wavin company.

During the workshop, observations were made, and notes were taken on the needs, keywords, and reactions expressed by the participants. This research utilizes qualitative methods, incorporating observation and personal interviews for data collection, following the guidelines of Creswell and Creswell (2018).

3.2. Human-Centered Design approach

Improvement projects for global communities should be a joint effort involving the very individuals for whom the projects are designed. These individuals should be equipped with resources and guidance from a diverse array of experts across various disciplines. The design community needs to transition from creating for people without their involvement or influencing their desires to serving as enablers and resources for the communities (Norman, 2023). Also, In the face of rapid and numerous changes, understanding the human viewpoint has become increasingly crucial. Human-centered design is an effective method to comprehend changing behaviors, preferences, and challenges and to direct efforts appropriately and effectively. By tapping into the user's viewpoint, designers can create solutions that function well and cater to a broad audience in our evolving reality—whatever that may eventually be (MacDonald et al., 2020).

Human-centered design (HCD) is an approach to developing products and services oriented to people's requirements and experiences. Understanding the environment in which a product or service will be used and incorporating consumers in the design process is required to guarantee that the finished product or service satisfies their requirements and preferences. In recent years, HCD has grown in popularity due to its potential to improve the usability, accessibility, and overall user experience of goods and services. Human-centered design is a more iterative approach with three main phases: inspiration, ideation, and implementation (Design Kit, 2016). Also, the main focus of HCD is in two areas: addressing the correct problem and doing so in a manner that aligns with human needs and abilities (Norman, 2013). According to the International Design Foundation, HCD "puts people first, above all else, and focuses on designing solutions that meet their needs, goals, and aspirations." HCD emphasizes empathy with consumers and aims to engage them in the design phase so that their opinions are represented in the final product. HCD prioritizes the involvement of all relevant stakeholders, including end-users, at the heart of the interactive systems' design and development process (Adikari, Sarbazhosseini, & Sawetrattanasatian, 2023).

The three major elements of the HCD approach could serve as an innovative tool for producing new goods (Petersen, 2017). The definitions of these three phases are explained (IDEO, 2016) in the following:

The initial stage of the design process is called the inspiration phase, which aims to comprehend the user and their requirements deeply. This phase necessitates empathy, observation, input, and stakeholder insights to identify the key issues that must be addressed and create a clear problem statement.

In the ideation phase, designers utilize the knowledge and input acquired in the inspiration phase to create various potential solutions. This includes brainstorming, prototyping, and testing ideas to determine the most effective approach. This phase aims to generate numerous ideas and a diverse range of solutions to choose from.

Finally, the implementation phase involves bringing the selected solution to life. This entails refining the design, testing it with users, and making necessary adjustments. The goal of this phase is to develop a solution that fulfills the user's needs while being practical to implement.

Post-World War II marked the birth of contemporary industrial design, driven by a growing consumer culture that demanded practical and user-friendly everyday products. However, these product designs were often created and produced with little end-user input. The design process was predominantly led by renowned designers, engineers, and influential design movements (such as Bauhaus, Art Deco, Modernism, and Postmodernism) that emerged in the late 19th century and continued until the early 2000s. Then, the modern product design methodologies use the HCD approach in contrast with the industrial age approach (Philips, 2021).

HCD has been applied to various engineering domains, including software engineering, product design, and systems engineering. In software engineering, HCD has been used to improve software applications' usability and user experience (Kujala, 2003). HCD techniques such as user research, prototyping, and usability testing effectively identify and address usability issues in software applications.

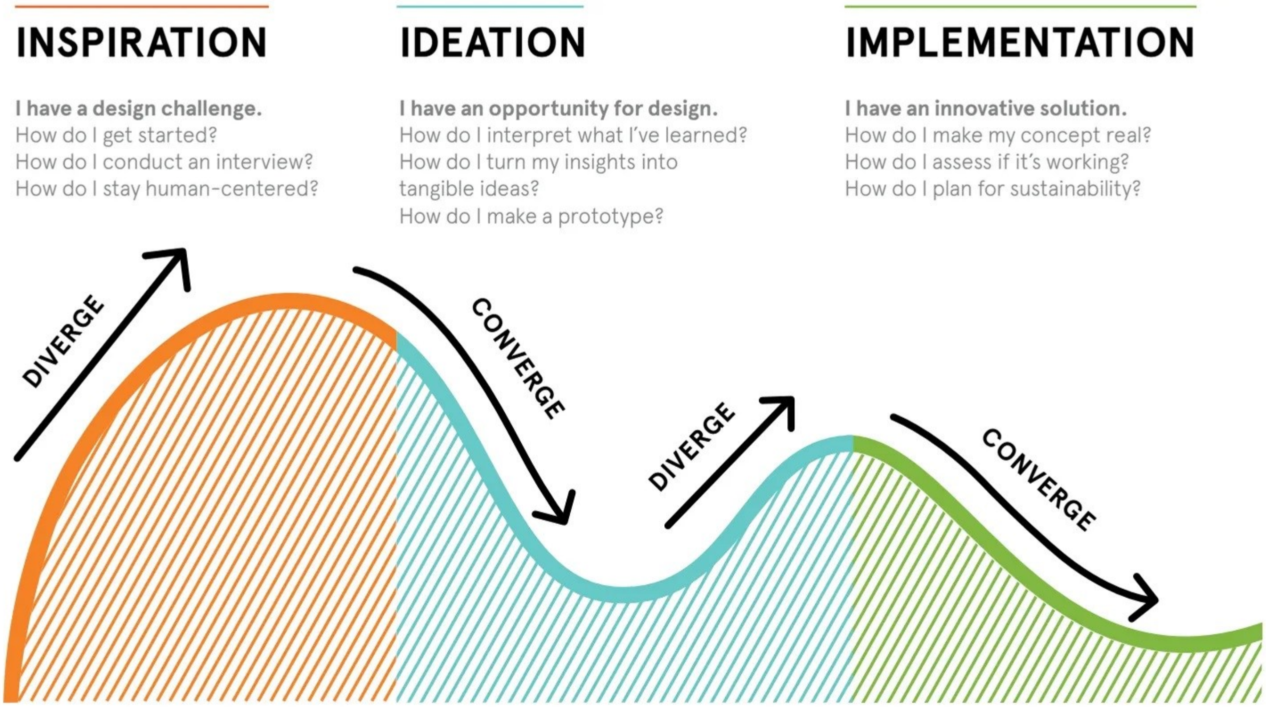


Figure 4. IDEO HCD process (2016)

In product design, HCD has been used to develop products that meet the needs and preferences of users. For example, HCD has been used to design assistive technologies for people with disabilities, such as prosthetics and mobility aids (Steen and Manschot, 2011). HCD techniques such as user research and co-design have been used to involve users in the design process and ensure that the end products meet their needs (Norman, 2023).

HCD has been used in systems engineering to develop complex engineering systems that meet users' needs. HCD techniques such as scenario-based and participatory design have been used to involve users in the design process and ensure that the resulting systems are effective and user-friendly (Simonsen and Robertson, 2012).

Also based on the ISO 9241-110 Principles of the Human-Centered Approach (National Institute of Standards and Technology, 2022), the key factors are:

- The design is founded on clearly comprehending users, tasks, and surroundings.
- Users partake in design and development.
- User-focused evaluation guides and improves the design.
- The process is iterative, allowing for ongoing refinement.
- The design takes into account the complete user experience.
- The design team comprises individuals with diverse skills and perspectives.

4. Case study –A septic system

Septic systems:

The statistics elaborate that more than nine million people in Sweden have access to main sewage systems and municipal wastewater treatment systems, and around 900,000 households who are not connected to the main sewage system have domestic treatment systems (Swedish EPA, 2022).

Many rural and suburban communities not connected to municipal sewage systems rely on septic systems for wastewater treatment. These systems clean and dispose of domestic wastewater from houses and other structures using a combination of natural processes and technology.

Here are the different types of septic systems (U.S. Environmental Protection Agency, n.d.):

Conventional Systems:

1. Septic Tank
2. Conventional System
3. Chamber System

Alternative systems:

- Drip Distribution System
- Aerobic Treatment Unit
- Mound Systems
- Recirculating Sand Filter System
- Evapotranspiration System
- Constructed Wetland System
- Cluster/ Community System

Septic Tank:
A septic tank is a waterproof, buried tank designed and built to accept and partially treat raw residential sanitary wastewater. Heavy sediments sink to the tank's bottom, while oils and lighter solids float to the top. As the solids remain in the tank, the wastewater is discharged to the drainfield for further treatment and dispersal (Figure 5).
Main characteristics briefly:

- Buried
- Water tank
- Made by concrete
- Heavy solids settle to the bottom
- Discharge wastewater

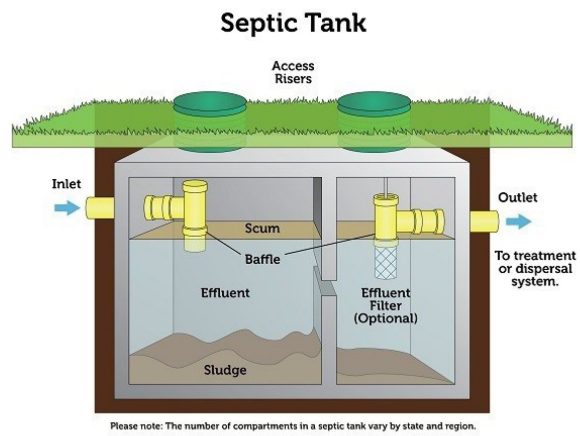


Figure 5. Septic tank (Environmental Protection Agency, 2018).

Conventional Septic System:
A conventional localized wastewater treatment system is built by a septic tank and a drainfield, which is a trench or bed subsurface wastewater infiltration system. This system is suitable for a single-family house or small business. The wastewater is directed from the septic tank to a deep underground stone or gravel trench.
The trench is subsequently covered with a geofabric or similar material to prevent sand, dirt, and other pollutants from entering the clean stone (Figure 6).
Main characteristics briefly:

- Consists of a septic tank and Infiltration system (Drainfield)
- Single-family home or small business.
- Gravel bellow the Drainfield
- Not be suitable for all residential sites

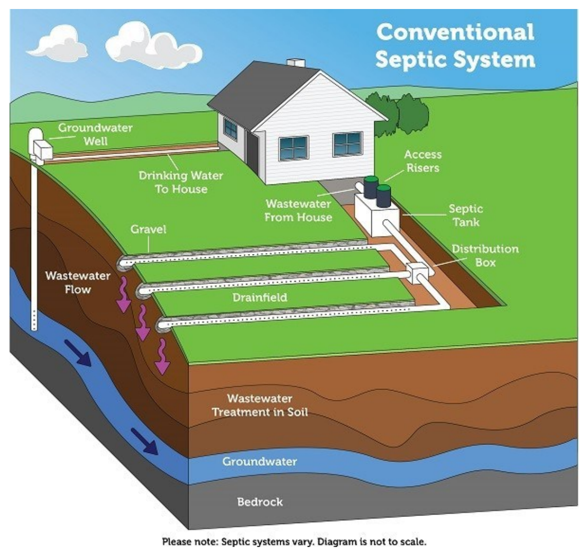


Figure 6. Conventional Septic System (Environmental Protection Agency, 2018).

Chamber Septic System:
They are in a variety of shapes and sizes, including open-bottom chambers, fabric-wrapped tubing, and synthetic materials like expanded polystyrene media.
Gravelless systems may be built with recycled materials, resulting in considerable carbon savings (Figure 7).
Main characteristics briefly:

- Consists of a septic tank and Infiltration system (Drainfield)
- Single-family home or small business.
- Gravelless Drainfields
- Not be suitable for all residential sites

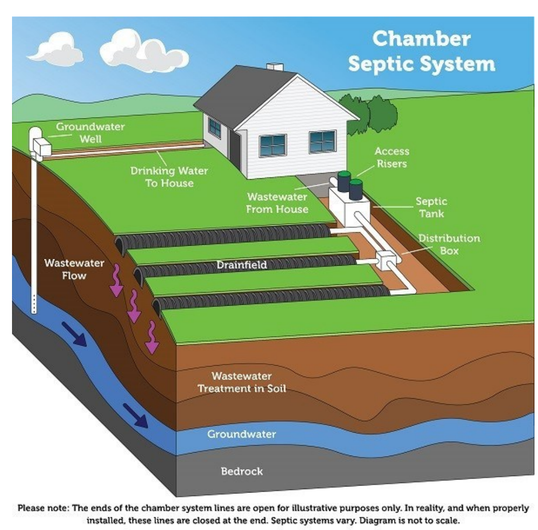


Figure 7. Chamber Septic System (Environmental Protection Agency, 2018).

Drip Distribution System:

Drip distribution systems are a sort of wastewater distribution system that may be utilized in a variety of drainfields (Figure 8).

Main characteristics briefly:

- Consists of a septic tank and Infiltration system (Drainfield)
- Need Electrical power
- Not be suitable for all residential sites
- Requires a large dose tank after the septic tank

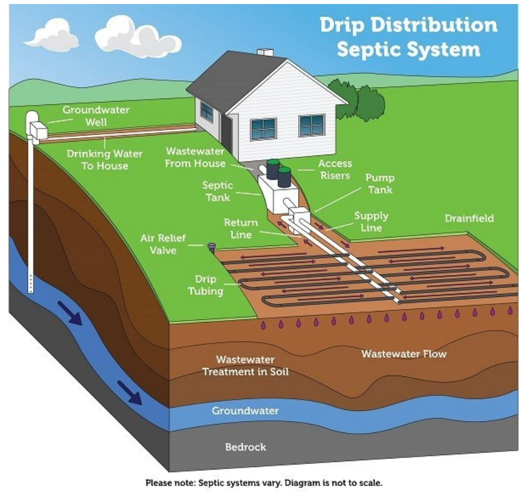


Figure 8. Drip Distribution System (Environmental Protection Agency, 2018).

Aerobic Treatment Unit:

Aerobic Treatment Units (ATUs) could have been defining municipal sewage treatment plants on a smaller scale. The treatment tank is oxygenated using an aerobic system.

The extra oxygen boosts natural bacterial load within the system, which offers further purification for nutrients in the wastewater. To further minimize infection levels, certain aerobic systems may include a prep tank and a secondary treatment tank with disinfection (Figure 9).

Main characteristics briefly:

- Injects oxygen
- Small scale of Municipal Sewage Plant
- Increases natural bacterial activity
- Need Electrical power
- Suitable for small home
- Suitable for houses near to surface water sensitive to contamination

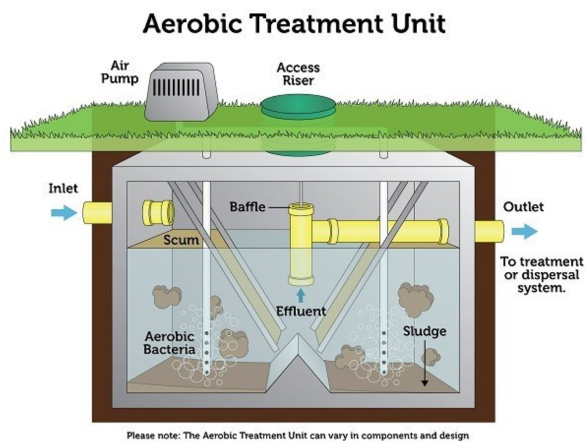


Figure 9. Aerobic Treatment Unit: (Environmental Protection Agency, 2018).

Mound Systems:
In areas with low depth of soil, high groundwater, or thin bedrock, mound systems are a possibility.
A drainfield trench is built into the sand mound.
The septic tank wastewater runs to a pump chamber, where it is piped in specified quantities to the mound.
The wastewater is treated as it flows into the trench, filters through the sand, and finally spreads into the soil (Figure 10).
Main characteristics briefly:

- High groundwater
- Need Electrical power
- Drainfield trench
- Filters through the sand

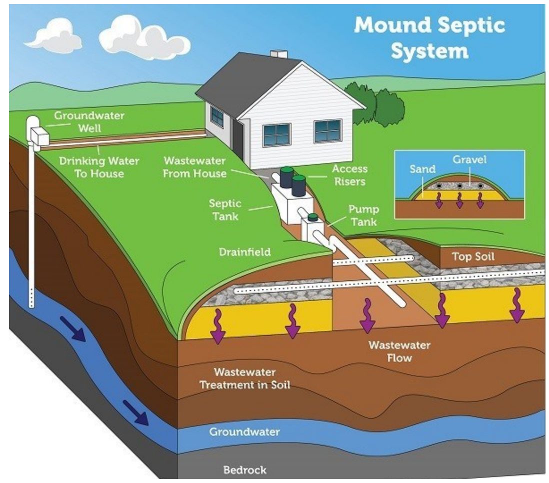
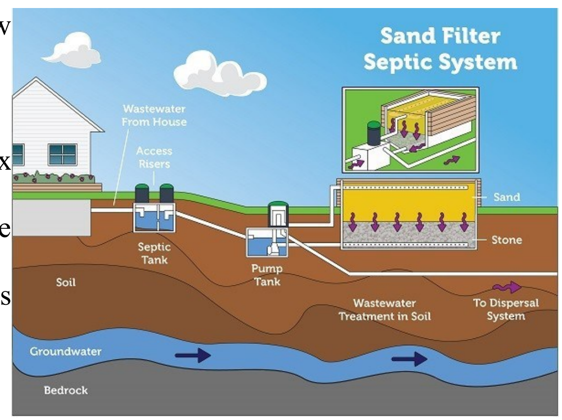


Figure 10. Mound System: (Environmental Protection Agency, 2018).

Recirculating Sand Filter System:
Sand filtration systems are able to be constructed on or below ground.
The septic tank discharges wastewater into a pump chamber.
The water is then sent to a sand filter.
The sand filter is frequently PVC-lined or a concrete box containing sand.
Wastewaters is pushed through into the pipes at the top of the filter at low pressure.
The wastewater exits the pipelines and is purified as it passes through the sand filters (Figure 11).
After that, the treated wastewater is released to the drainfield.
Main characteristics briefly:

- Septic tank to a pump chamber and a sand filter
- PVC-lined or a concrete box filled with sand
- High level of treatment
- Good for sites with high water tables
- Expensive than the Conventional Septic System



Please note: Septic systems vary. Diagram is not to scale.

Figure 11. Recirculating Sand Filter System: (Environmental Protection Agency, 2018).

Evapotranspiration System:
The drainfield of the evapotranspiration system is lined with a waterproof material (Figure 12).
Once entering the drainfield, the wastewater evaporates into the air.
In contrast to other types of septic systems, the wastewater never filters into the soil and never enters groundwater.
Main characteristics briefly:

- Septic tank and waterproof drainfield
- Never releasee water to the soil
- Suitable for dried weather
- Work well in shallow soil
- Risk of failure in case of raining or snowing too much

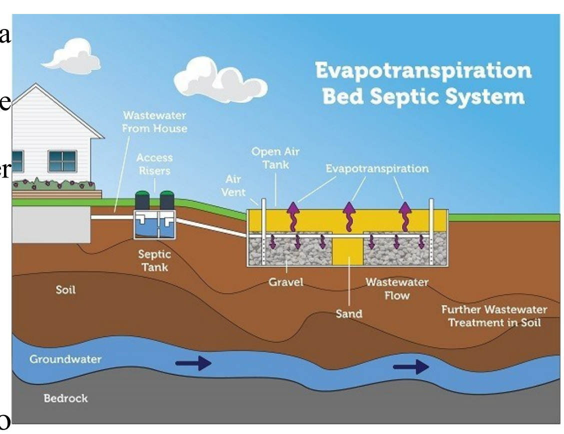


Figure 12. Evapotranspiration System: (Environmental Protection Agency, 2018).

Constructed Wetland System:

A manufactured wetland replicates the treatment procedures that exist in natural wetlands.
Wastewater passes from the septic tank into the wetland area.
The wastewater is then transported through the medium and cleaned by bacteria, plants, and other microorganisms that remove pathogens and nutrients (Figure 13).
The wetland cell is normally made up of a waterproof cover, gravel and sand fill, and the proper wetland plants, that need to be capable of functioning in a continuously saturated environment.
Main characteristics briefly:

- Septic tank and a waterproof wetland cell
- Treated water by microbes and plants

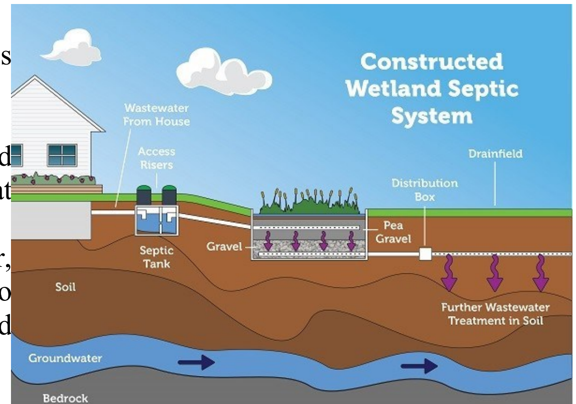


Figure 13. Constructed Wetland system: (Environmental Protection Agency, 2018).

Cluster / Community System:
A cluster (or community) decentralized wastewater treatment system gathers wastewater from two or more houses or buildings and is owned by a group of people (Figure 14).
It transports wastewater to a treatment and distribution system positioned near the residences or structures.
Cluster systems are widespread in regions such as rural subdivisions.
Main characteristics briefly:

- Shared Septic tank
- Distributing system system
- Suitabe for rural comunities

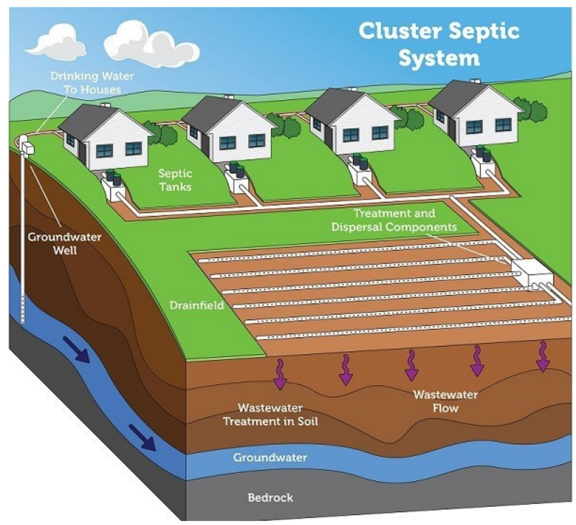


Figure 14. Cluster / Community System: (Environmental Protection Agency, 2018).

4.1 Process description

For the process of this research, I am going to design a HCD method based one the engineer's participation. One of the aims of this research is designing HCD Method for engineers so the users here are engineers, also since HCD is a user centered design process I decided to participate engineers for designing a process for themselves.

For three parts of HCD inspiration, Design, Implementation (Design Kit, 2016) the research process will be explained here:
Inspiration: In this phase the data gathered from literatures about HCD and the relation of that in engineering processes. Then, I have done interviews with the engineers about what they are doing in the company and how they are doing they projects. Observation was another method which I used for documenting the engineering

process for developing a product at the Wavin company.

Design:

I held a workshop for engineers and I asked them to Co-designing the HCD model for themselves. First, they did not have any interest to do that, and they said that: “you (Mohammadhasan) are responsible for designing so we do not want to do your work” but after a while when I explained the whole process for them, they accepted to do the co-designing process to design the process not the product. The whole process illustrated here in the Figure 15.

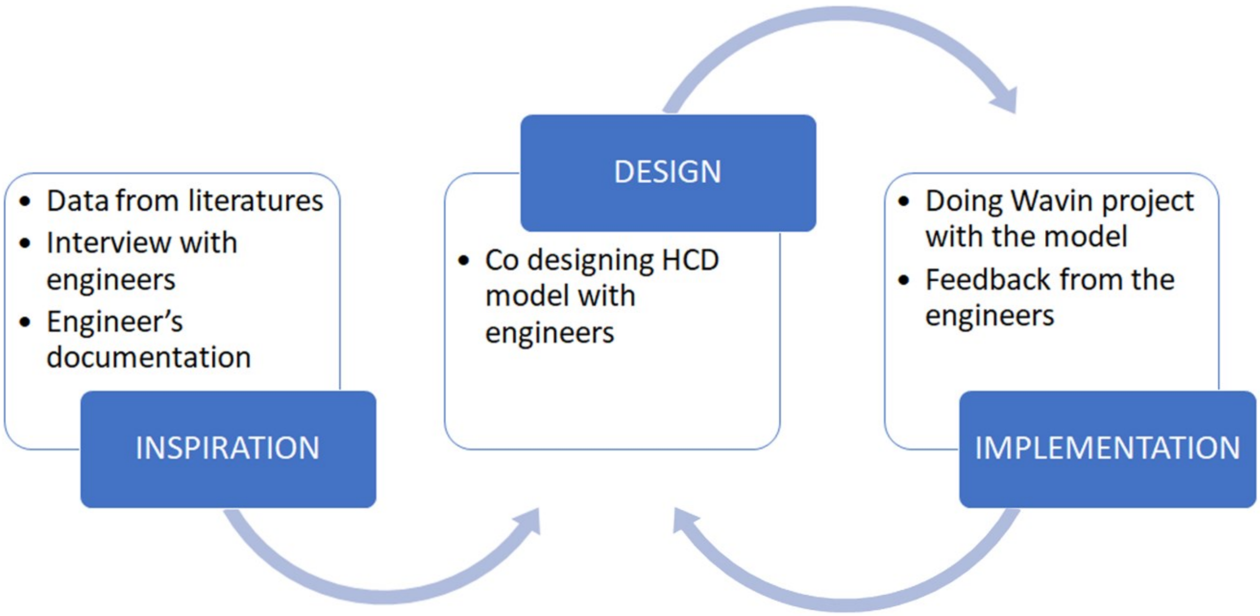


Figure 15. Designing a process for co-creating HCD process for product development.

4.2 Product Development Process

Wavin is an international company which originally from Netherland also they have some branches in other countries. In Sweden they have a production line and manufacturing company in Eskilstuna.

In this company they are producing plastic pipes and instruments for water systems. Their projects more about using water in sustainable manner like directing, gathering, and storing the rainwater in rainy seasons for dry seasons. They have some innovative other projects in the field of water filtration, pipe connectors, using pipes with different material for drinking water and waste water.

The Wavin company has a septic system similar to other existing septic systems. They want to improve this product to be pioneer in this area.

They are going to use IoT in their companies' sections and their product as a result this would be a merit for this product to be compatible with IoT.

They aim to be more sustainable until 2025 so this product could improve in term of being more sustainable.

To develop the product in this project, Human-Centered Design (HCD) approach was opted, which places people and their needs at the core of the design process. Picture (Figure 16) effectively illustrates the stages involved in this approach. The entire process comprises three distinct stages: Inspiration, Design, and Implementation.

During the Design stage, we employed two different methods to bring our product to life. The first method employed was the conventional engineering process (labeled as 2.1), a tried-and-true approach for product development. The second method, marked as 2.2, was the HCD approach specifically used for designing.

These two approaches were set in motion to create the final product. However, the journey doesn't end there; we undertook a critical step. We compared the outcomes of these two distinct methods – the products they yielded. The goal is finding the differences, both advantages and disadvantages, between utilizing the traditional engineering process used in Wavin company, and the Human-Centered Design approach for designing. This comparative analysis helps us gain insights into which method proves more effective for our project, to clarify the strengths and weaknesses of each approach. Ultimately, this evaluation aids us in making informed decisions regarding our product's development and design strategies.

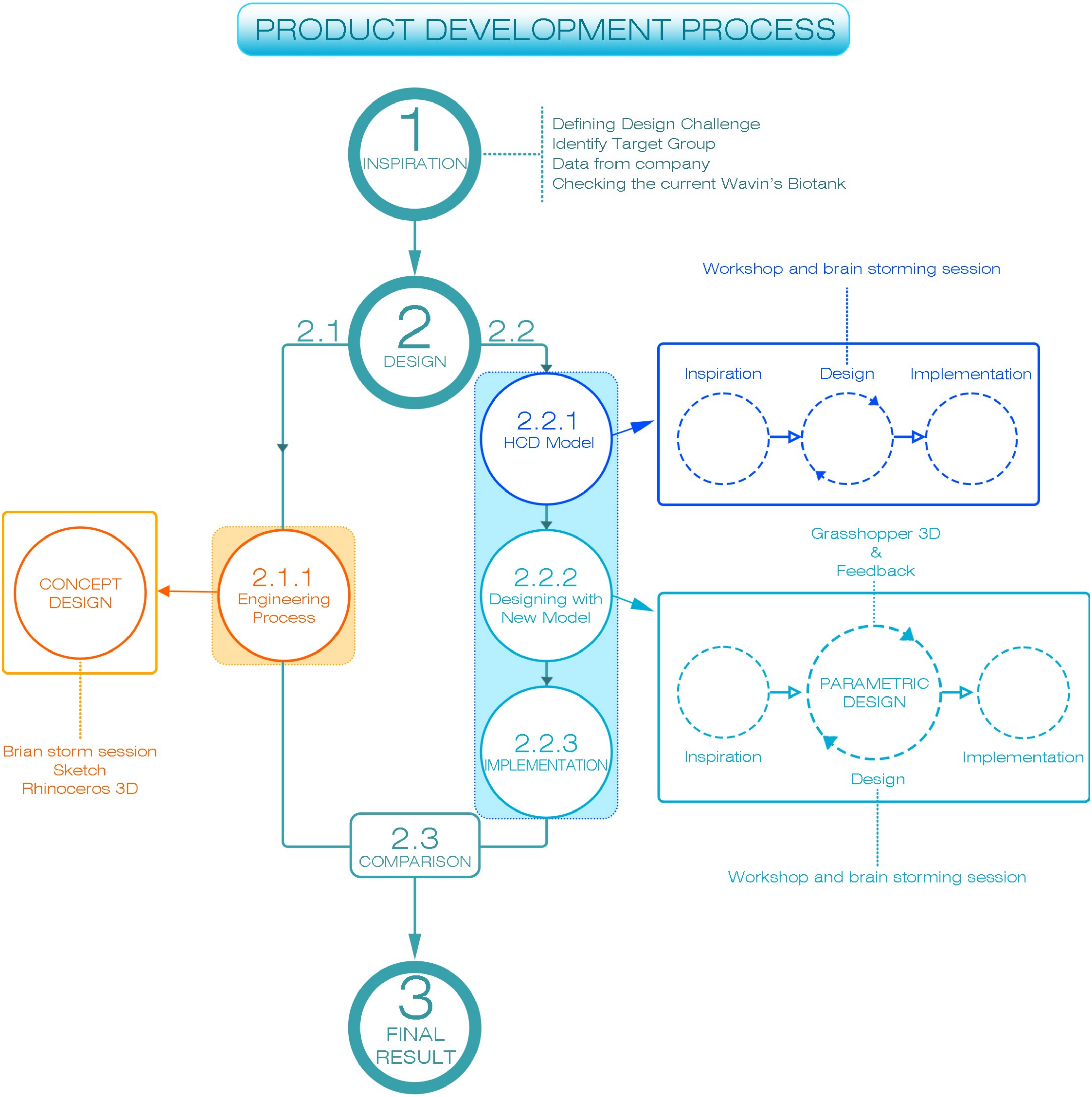


Figure 16. The whole process of product development.

4.3 Designing A Septic System

Due to the confidentiality agreement in my contract with Wavin, I am unable to share any images or specifications of the final products from this project.

In the following I will explain each stage:

1. Inspiration:

   In the inspiration phase, I started defining this project's design challenge. The challenge that needs to be met in this project is to design a Biotank system for the houses that do not have accessibility to the main urban sewage systems. The main challenge is to have a modern and brand-new product for customers to customize for their residential area.

   Target group: In the inspiration stage, there is a need to identify the target group for the project. The target group in this project is the people who have houses without connection to the main sewage system.

   Data from the company: Wavin provides some data about their current customers and the current Biotank they are using. However, for the sake of a competitive market, these data are confidential, and I do not have permission to release them in my thesis report. I used these data to design the new product for Wavin and develop the old version of Biotank in Wavin.

2. Design:

   For design phase I used two methods for designing the product for Wavin to have a comparison between them for finding and investigating the differences. The first method is: product designing with the normal process in engineering project at Wavin company. And the second method for designing is: using Human-Centered Design approach to design product for this project. In the following is the explanation in detail about the design phase.

   2.1. Normal method of designing product at Wavin company: For designing the product at Wavin after understanding the needs and inspiration phase I started to designing the product.

      2.1.1. I have held several brain storming sessions with my company's supervisor – David Jirout – and other colleagues at Wavin I have reached to several ideas and sketches. The ideas explained to my company's supervisor and he admitted one of them. Then, the chosen concept was modeled in 3D software Rhinoceros 3D. The designed model was presented to the company and after gathering feedback from them I have modified that with some changes.

   2.2. The second way of designing:

   This step is about the way of designing the same project for company - Septic System - with using HCD approach. First, I asked them to think and talk about their ideas that how the company could have a process for designing products with focusing on the users' needs. The result is that a process for product designing in this company (2.2.1).

2.2.1. I have held a workshop for some engineers in Wavin company and I explained them about the Human-Centered Design approach for designing, within this workshop I asked them to design a process for product designing and the result was used to design a septic system for Wavin (2.2.2).

The result process is: designing and modeling the product with some parametric design software, because within parametric software it is possible to define some variables as inputs for the model for example in this project one of the variables could be number of water storage banks. As a result, users easily can change these variables by putting some numbers and customize the model for themselves.

In addition, parametric design model has some benefits for the project executers and managers in company, before implementing the project in the designated place, they can have better insight about the costs of the project and different tasks that they are supposed to do.

2.2.2. In this stage the septic system has been designed with the model from 2.2.1 with Grasshopper 3D module in Rhinoceros 3D software. The Grasshopper modeling provides a parametric design for the company which customers and engineers can change several items in the model based on their needs. Based on the 2.2.1 process for iteration in designing part there is a need to gathering feedback from the sections mentioned in 2.2.1 and implementing that feedback on the product to have a better result (2.2.3).

When the operator or user change the “Number Slider” in grasshopper they can immediately see the change in the final 3D model.

I scripted a model in grasshopper 3D for the company for calculation of the amount of digging they need to do. This model is adjustable, it means when they change the numbers or the height of putting filters and septic tank, the script immediately calculate how much they need to dig. As a result, it helps them to prepare and estimate the cost of the project.

The end result of the 3D adjustable model was accepted by the company and was uploaded for them. This model would be a based model for future development of the septic system at Wavin.

5. Empirical data

To have the best results and valuable data at the end of this research project it is of great importance for implementing and doing all project phases in the right ways. For doing this project I needed to collaborate with the company to involve engineers. These collaborations were in the forms of in-person meetings, online meetings, co-design sessions, and a workshop for introducing HCD to the participant of co-designing session. The collaborations happened often based on the schedule of the engineers and the participants.

SELF-REPORT on the experience of the design process:

For analysing the emprical data which I found, I analyses my self-report to finding what are the main results and what are the main differences which make differences in comparison of these two processes.

Analysis of my self-report

Here I am going to analysis my diary based the time, different stages and number of sequences, and objectives and deliverables of each stage for both engineering process and HCD process of product development.

Comparison two processes Based on the time spent:

The time that I spend for inspiration and gathering data for the project:

05-09-2022 till 23-01-2023 apart from 20-09-2022 to 20-10-2022 - Three and a half months.

Time for designing engineering process:

- months – 1 month pipe cover project – 2 months AquaCell project = 4 months\

  Time spending for this part is around 300 hours

HCD process:

- one and a half month

  Time spending is around 140 hours

The number and sequence of stages involved in each process:

Engineering process:

1. Data gathering (inspiration/Documentation Manuals).
2. Ideation – Brainstorming -Sketching.

3. Choosing an idea and develop it.
4. 3D modeling.
5. Presentation, revision and iteration.

Human-centered Design process:

1. Inspiration and gathering Data.
2. Workshop for explaining HCD process and Customizing HCD for Wavin.
3. Ideation, concept designing
4. Start parametric 3D modeling (with Grasshopper 3D)
5. Meeting with the department
6. Iteration for concepts

The objectives and deliverables of each stage:

Engineering process:

1- Data gathering (inspiration/Documentation Manuals).

Objectives:

Define the problem that I want to address with Biotank2.0.

Identify the target users: The users identified in this stage as households which they do not have accessibility to main sewage system.

Needs: Based on the interview people need a product that they could adjust it for their house also the price is an important content for them. Also, Wavin's needs are producing a modern product that could be affordable for people. Wavin's expert could estimate the price and adjust product for each specific customer.

Explore the existing solutions and competitors in the market.

Generating as many ideas as possible to solve this problem.

Deliverables:

A clear problem statement that summarizes the user needs and the value proposition the BioTank.

A list of user personas that represent the different types of users and their characteristics.

A list of user scenarios that describe how users would use your product in different contexts.

A list of user requirements that specify the features and functions that the BioTanks should have.

A list of design criteria that define the constraints and specifications of the BioTank.

A list of potential solutions that address the problem or opportunity in different ways.

Conclusion: The initial stage of product development achieved its objectives by defining the problem, identifying the target users, creating user personas and scenarios, exploring existing solutions and competitors, and generating user requirements, design criteria, and potential solutions for BioTank2.0. This stage provided a solid foundation and essential parameters for designing a BioTank that meets user needs and market expectations.

2- Ideation – Brainstorming -Sketching.

Objectives:

Project Understanding:

Gain a comprehensive understanding of the projects at Wavin through collaborative workshops. I have done brainstorming with team members (David and Gladwin), presenting project data, and sharing gathered information.

Ideation and Conceptualization:

Generate creative ideas and concepts for the septic tank project. I sketched different concepts, particularly focusing on the aesthetic features of the septic tank.

External Input and Collaboration:

Seek external input and diverse perspectives to enhance ideation. I Collaborated with an MDU teacher for a full day of brainstorming, gathering additional ideas.

Feedback Integration:

Incorporate feedback from internal stakeholders (boss in Wavin) to refine and improve the ideation. Also, Present sketches to the boss, gather feedback, and iterate the design process based on received input.

Shift in Ideation Focus:

Adjust the ideation approach based on company feedback, shifting from a facelift to adding useful features. Modify the conceptualization strategy based on the feedback to align with the company's vision.

Deliverables:

Project Presentation:

Presentation materials for the workshop with David and Gladwin. A presentation summarizing project data and information gathered until that point.

Sketches and Conceptual Designs:

Series of sketches showcasing different aesthetic features and conceptual designs for the septic tank. For this stage, visual representations of various ideas generated during the ideation stage.

Brainstorming Output:

Documented outcomes from the brainstorming session with the MDU teacher. Also, summary of additional ideas and concepts generated during the session.

Feedback Integration Report:

Report on feedback received from the boss at Wavin and changes made in response. Documentation of feedback, how it influenced the design process, and the subsequent iterations.

Ideation Adjustment Plan:

Plan or document outlining the shift in ideation focus based on company feedback. Explanation of changes made in the ideation approach, aligning it with the company's expectations.

Conclusion: The design process benefits from these objectives and deliverables, as they help to shape the ideation stage with input from both internal and external sources, and a clear grasp of the user's problems and situations.

3- Choosing an idea and develop it.

Objectives:

Project Acceptance and Alignment:

Ensure acceptance and alignment of the project idea with stakeholders, especially with David my supervisor at Wavin to understand he gives me the permission to continue on this track. Conduct a meeting with David to discuss the project and seek approval.

Functionality Focus:

Shift the design focus from aesthetics to functionality, aligning with the feedback from the meeting with David. For this stage I reevaluated the project goals and redefined the design direction to prioritize functional features.

Clarity and Understanding:

Gain clarity and a deeper understanding of the project's requirements and expectations. Reflect on the work done so far, acknowledging the need for a shift in approach, and identify areas of confusion.

Reevaluation and Brainstorming:

Reevaluate the project concept and brainstorm new ideas to address the identified issues. Engage in a brainstorming session to generate fresh ideas and potential solutions.

Concept Development:

Develop a new project concept that aligns with the functional focus and meets the company's expectations. Develop a concept that involves using water after filtration for different usages, considering the filtration process and potential applications.

Deliverables:

Meeting Report:

Document summarizing the outcomes of the meeting with David. I made a report on discussions, feedback received, and decisions made regarding the project direction.

Design Shift Documentation:

Document outlining the shift in design focus from aesthetics to functionality. Also, I have done an explanation of the decision to concentrate on functional features and how it aligns with stakeholder expectations.

Brainstorming Session Output:

Record of ideas generated during the brainstorming session. And, documentation of new ideas considered for the project and potential directions explored.

Revised Concept Development:

Detailed concept development for the new idea of using water after filtration for different usages. Description of the concept, its functionality, potential applications, and how it addresses the company's requirements.

Conclusion: These objectives and deliverables contribute to the transition from a potentially misaligned project concept to a more focused and functional idea that better meets the company's expectations. The documentation helps in maintaining transparency, clarifying decisions made, and providing a clear path for the next stages of development.

4- 3D modeling.

Objectives:

Having a 3D model to present for the company and give them the better insight about the concept that I suggest for the development of the product.

Deliverables:

A 3D model on Rhinoceros as an artifact to present it for the company and show them we have a solution for their need.

Conclusion: This 3D model stands as a practical and illustrative tool, showcasing the envisioned product and demonstrating a thoughtful and viable solution for further development.

5- Presentation, revision and iteration.

Objectives:

Concept Visualization:

Transform the conceptual idea into a tangible representation through sketches and 3D modeling. With Initiating the sketched and 3D models to visually represent the new concept involving water reservoirs and a filtration process.

Model Completion:

Complete the 3D model, ensuring that it accurately reflects the envisioned concept. And, finalizing the modeling process, addressing details related to water reservoirs, filtration mechanisms, and overall design.

Iterative Improvement:

Incorporate feedback received during the verification process and iterate on the design for improvements. With analyzing David's feedback and make necessary revisions to enhance the design.

Final Concept Confirmation:

Confirm the finality of the concept after incorporating revisions and ensuring alignment with stakeholder expectations.

Review the revised 3D model with David to confirm that it aligns with the project goals and requirements.

Deliverables:

Sketches and 3D Models:

Compilation of sketches and 3D models representing the new concept.

Visual representations that communicate the design idea, including water reservoirs and the filtration process.

Completed 3D Model:

The finalized 3D model of the product design. With detailed and accurate digital representation of the product, including all specified features.

Revised 3D Model:

Updated 3D model reflecting the iterative improvements based on feedback. Also, a revised digital model that incorporates changes to enhance functionality, aesthetics, or any other relevant aspects.

Conclusion: These objectives and deliverables contribute to the refinement of the design, ensuring that it aligns with stakeholder expectations, incorporates feedback, and is ready for further development or implementation in subsequent stages of the product design process.

Human-centered design process of product development:

1- *Inspiration and gathering Data.*

The objectives and deliverables of this stage is the same with engineering process since I have used inspiration and data gathering for the both processes in a same time.

2- *Workshop for explaining HCD process and Customizing HCD for Wavin.*

Objectives:

Knowledge Acquisition:

Gain a thorough understanding of Human-Centered Design (HCD) principles and methodologies. With reading the HCD approach sources and literatures to obtain proper knowledge for the presentation.

Workshop Preparation:

Develop materials and resources to facilitate a workshop on HCD for the company.

And, creating informative slides outlining key concepts, processes, and applications of HCD.

Knowledge Dissemination:

Share knowledge about HCD with the company, emphasizing its relevance and benefits in the product design process.

Present the prepared slides during the workshop to explain the principles and methodologies of HCD.

Co-Creation Process:

Engage participants in a collaborative and creative process to adapt HCD for product design within Wavin.

Facilitate a workshop where participants suggest and discuss HCD approaches tailored to engineering projects at Wavin, doing co-creation.

Deliverables:

Educational Materials:

Informative slides on HCD principles, methodologies, and applications.

A comprehensive set of materials to communicate the key aspects of HCD for the workshop.

Workshop Execution:

Conducted workshop session on HCD for three participants at MDU university.

A documented session where HCD concepts were presented, discussed, and explored with the participants.

Co-Creation Process Output:

Suggestions and ideas from participants on how to apply HCD in engineering projects at Wavin.

A compiled record of the co-creation process, highlighting insights and potential adaptations of HCD for Wavin's product design.

Recommendations for HCD Integration:

A set of recommendations or proposed processes for integrating HCD into Wavin's engineering projects.

A document summarizing the collaborative ideas generated during the workshop, tailored to the specific needs of Wavin.

Conclusion: during this stage, the goal is to share information about HCD and work together to come up with practical ideas on how to use HCD specifically for Wavin's projects. The things we create, like documents and suggestions, will be important tools to help HCD become a more significant part of how Wavin designs its products.

3- Ideation, concept designing

Using the same ideas that we have reached on the previous process of product development. As a result, the objectives and deliverables of this stage is the same with engineering process of product development.

4- Start parametric 3D modeling (with Grasshopper 3D)

Objectives:

Skill Acquisition:

Acquire proficiency in using Grasshopper 3D for parametric modeling. With Initiating the learning process of Grasshopper 3D, recognizing its potential for parametric design.

Implementation of Wavin-HCD Model:

Apply the knowledge gained from the HCD workshop and integrate it into the product development process at Wavin, emphasizing parametric design for adaptability. Also, begin the product development phase using the new Wavin-HCD model, incorporating parametric design principles.

3D Modeling with Grasshopper:

Create a 3D model of the product concept using Grasshopper 3D, ensuring adjustability based on user needs and feedback from various departments.

Initiate and complete the 3D modeling process with Grasshopper, aiming for a dynamic and customizable product representation.

Presentation to Leadership:

Share the Grasshopper 3D model with key stakeholders, including the boss and chief of the company, to gather feedback and insights. With presenting the completed model, highlighting its features and obtain feedback from leadership.

Feedback Analysis and Model Refinement:

Evaluate feedback received from the leadership and identify areas for improvement in the Grasshopper 3D model.

Analyze feedback, recognize errors and problems in the model, and commence the refinement process.

Deliverables:

Wavin-HCD Model Implementation Report:

Report outlining the integration of the HCD approach into Wavin's product development, emphasizing parametric design.

A document detailing the application of HCD principles, specifically parametric design, in the product development phase.

Grasshopper 3D Model:

Completed 3D model of the product concept using Grasshopper 3D.

A dynamic and adjustable digital representation of the product, showcasing its adaptability.

Leadership Presentation:

Presentation of the Grasshopper 3D model to the boss and chief of the company. With a session where the model is showcased, and feedback is gathered from key stakeholders.

Feedback Analysis Report:

Report summarizing the feedback received from leadership and outlining areas for model refinement.

An analysis of feedback, including identified errors and problems, and a plan for refining the Grasshopper 3D model.

Conclusion: This stage focuses on the practical application of parametric 3D modeling using Grasshopper, aligning with the HCD principles previously introduced. The deliverables serve to document progress, demonstrate the application of new skills, and gather valuable feedback for further refinement.

5- Meeting with the department

Objectives:

Leadership Presentation:

Showcase the Grasshopper 3D model to key stakeholders, including the boss and chief of the company.

Present the model, highlighting its features and design concepts, seeking feedback and approval.

Feedback Collection and Initial Revision:

Receive feedback from the boss and chief on the presented model, noting areas, identify initial errors or problems that require improvement or correction.

Model Refinement:

Address identified errors and problems in the Grasshopper 3D model, ensuring it aligns with the expectations and requirements. Conduct necessary revisions to improve the model, considering feedback received during the initial presentation.

Submission for Company Feedback:

Share the improved model with the organization, encouraging input and suggestions for additional enhancements, feedback and iteration.

Positive Feedback Acknowledgment:

Acknowledge the positive comments made by the boss during the meeting with the Swedish Wavin organization.

Deliverables:

Revised Grasshopper 3D Model:

Updated and refined version of the Grasshopper 3D model.

A model that addresses errors and problems identified during the initial presentation, demonstrating improvements.

Feedback Documentation:

Document summarizing the feedback received from the leadership. With a record outlining comments, suggestions, and areas for improvement provided by the boss and chief.

Company Feedback Compilation:

Compilation of feedback received from the company after submitting the refined model.

Acknowledgment of Positive Feedback:

Response expressing gratitude for positive comments from the boss. With a message acknowledging and appreciating positive remarks, fostering positive relationships within the company.

Conclusion: This stage focuses on refining the model based on initial feedback, submitting it for broader company feedback, and ultimately acknowledging positive impressions from the organization. The deliverables serve as documentation of progress, improvements, and responses to feedback received.

6- Iteration for concepts

Objectives:

Feedback Integration:

Integrate feedback received from the meeting with the whole Swedish Wavin organization into the product design. Then, review and understand the feedback, identifying areas for improvement and enhancement.

Concept Revision with AquaCell Integration:

Revise the project by incorporating AquaCell features into the design concept. Ans explore and integrate AquaCell features to enhance the functionality and adaptability of the product.

Iteration for Improvement:

Conduct another round of iteration based on the AquaCell integration, refining the design for optimal performance. Also, implement changes and improvements identified during the revision process, ensuring alignment with AquaCell features.

Modularity Assessment:

Assess how AquaCells can be modularly adjusted based on customer needs, ensuring flexibility in the product.

3D Realistic Render Creation:

Develop a 3D realistic render of the revised concept for presentation. For this manner I used rendering tools to create a visual representation of the updated design, showcasing its features and adaptability.

Deliverables:

Integrated Concept Design:

Updated product design that incorporates feedback and integrates AquaCell features, with refining concept that reflects improvements based on the feedback received and the inclusion of AquaCell functionalities.

AquaCell Modularity Assessment Report:

Report evaluating the modularity advantages of using Wavin's AquaCells. Based on the documentation highlighting from feedback of how AquaCells can be adjusted modularly to meet varying customer requirements.

Iteration Documentation:

Document outlining the changes and iterations made during the revision process. A record of the improvements made to the design, capturing the evolution of the concept.

3D Realistic Render:

Visual representation of the revised concept through a 3D realistic render. This is a high-quality render showcasing the design enhancements and AquaCell integration for presentation purposes.

Conclusion: This stage is about making the design better by using feedback, adding AquaCell features, and getting ready to show the improved idea. The things that are made during this stage show how much progress has been made and what has been improved.

6. Analysis

Analysis self-reposts' results with uncertainty triangle

First, analyze the findings with three dimensions from the uncertainty triangle: Practically, Intellectually, and Emotionally. Analyzing these three dimensions helps individuals to find where they are standing in the uncertainty triangle. Then, analyze the results based on three angles of the uncertainty triangle: Accept, Control, and Predict

1. Practical:

In terms of practical differences between the two processes, it is noteworthy that in the Engineering Product Design (EPD) process recommended by the company, five steps were employed: 1) Data gathering (documentation manuals), 2) Ideation (production drawings), 3) Assembly drawings, 4) 3D modeling, and 5) Presentation, revision, and iteration. In the Human-Centered Design (HCD) process, six steps were utilized: 1) Inspiration and data gathering, 2) Workshop for explaining the HCD process and customizing HCD for Wavin, 3) Ideation, concept designing, 4) Parametric 3D modeling, 5) Meeting with the department, and 6) Iteration for concepts.

The initial phase of both processes involves inspiration through data gathering, and this stage is consistent across the two processes. For data collection, I gathered information from the company through:

- Interview:

Engaged in interviews with engineers, individuals responsible for product development, and the project manager to understand project requirements.

- Observation:

Visited the company and observed the section dedicated to customizing products. This involved witnessing their work processes, exploring available customization options, and understanding the methods employed.

- Manual Documents:

Accessed the company's portal, where comprehensive manuals for their products are available. Additionally, I utilized specific manuals sent by my manager pertaining to the products.

As a result, the data gathered for both processes remained the same, indicating no practical differences in terms of data collection between the two processes.

One practical distinction between EPD process and HCD processes is the stage of "customizing a process of product designing" for the company in the HCD process. While EPD process employs a standard product design process commonly implemented across many companies, in the HCD process, a process specialized for the company is reached through a co-creation workshop.

In the ideation phase, another difference is clear. In EPD process, ideation is typically the designer's responsibility, individually or in brainstorming sessions with peers. However, if the ideas are not aligned with the company's objectives, needs, and thoughts, potential mistakes or misunderstandings might not be detected and corrected in this phase. In contrast, in the HCD process, ideation is iterative and directly based on the feedback and needs of the company. Therefore, the ideas and results would probably be more acceptable to the company, and the designer would be more on track in designing valuable products. This occurred in the designer's experience in this phase. Designing and ideating with EPD process initially led to results that were not what the company wanted in the end, necessitating a repetition of this phase from the beginning. As a result, uncertainty in practical terms would decrease in this phase with the HCD process.

Another practical difference is in the 3D modeling. In EPD process, 3D modeling simulates the product in 3D software, which I did in Rhinoceros 3D. However, in the end, the model cannot be changed based on the company's or market users' different needs. Also, different aspects that the company needs for their proposal cannot be calculated. The inability to adapt it based on varying company or market user needs poses limitations. However, in the HCD process, parametric design was done with Grasshopper 3D, allowing the ability to change and modify the final model by adjusting parameters. This method also facilitates the automatic calculation of different parameters based on changes for the company. To see the differences in uncertainty, the first result from EPD process would be uncertain for the company and the designer if they want to change some aspects of the product. Also, they do not have any information and calculations from this end model in EPD process. However, the final product in the HCD process would be certain with different inputs, enabling the company to modify inputs and immediately have corresponding results, with calculations available for future tasks.

In the Human-Centered Design (HCD) process, there is a step where we check our model with specific parts of the company, a recommendation originating from the HCD co-creation workshop. So, the 3D model was again checked with that section, and I could gain some insights and feedback for my product. However, the EPD process lacks clear instructions for designers to conduct a systematic verification process with designated sections. This can make it uncertain for designers because they may not know which department or section of the company to get feedback from.

Practically, the iteration in EPD process in my project was radical at the beginning since I had to change the concept entirely for the first time due to the company’s feedback, and after that, the changes were incremental based on the user's feedback. I involved the engineers (the project users) in coming up with ideas, checking with different departments, and making changes to the concept. I also made a 3D model that could be adjusted. Except for the data-gathering phase, I considered the users in every step of the HCD process. Consequently, user feedback was used and integrated incrementally across all phases, contributing to a more cohesive and user-aligned design evolution.

To conclude, the differences in practical aspect that make some differences are using different tools for concept modeling also using different way of designing in terms of process of designing which make the whole process and model more adjustable and user-centered. So, practically choosing different software and customize product design process make differences to have a more human-centered result.

2. Intellectual:

From the intellectual perspective, in EDDP, I thought about the ideation by myself and used my interpretation of the company's needs. So, I relied on my experiences to design some concepts for the company. However, in the HCD process, the most essential part of my thinking was engaging and involving the users (engineers in the company). So, the main difference in this perspective is putting users at the center of focus. In EDDP, the main area for thinking and concentrating is to design concepts for the company based on my experiences and interpretations as a designer from the data gathered. However, in the HCD process, the central area of focus is how I should involve users in the processes and not think about the result.
In other words, the EDDP thinking is like making food for friends with some ingredients - data from the company - and a recipe (design priniciple from company). The food is prepared, and when it's ready, friends are invited to help themselves. In the end, feedback from friends can be observed. If there's enough experience in cooking, initially, there is confidence in making a nice meal; like me as an experienced designer, the expectation was to design a fantastic concept for the company. However, when observing the feedback, it could create complete uncertainty. Since, this uncertain situation is happening in that moment it could be ambiguity.

On the other hand, the HCD thinking process is akin to cooking with the same ingredients but inviting friends to help make the food and guiding them to create a nice meal. From the start, certainty the end result is not certain, but with effective leadership and guidance, there's a higher likelihood of achieving a satisfactory outcome as the food preparation progresses.

At first glance, it might seem that uncertainty in intellectual aspects would be less in EPD process. The designers may believe they know what the company wants and can start sketching and ideating. However, in the end, there is uncertainty about whether the company will accept it. So, initially, there is a sense of complete certainty, but as one gets closer to the end, the uncertainty level decreases. In this case, the uncertainty level in the intellectual aspect decreases over time.

Nevertheless, in the HCD process, the result is unpredictable and completely uncertain. Even after several iterations, it's not precisely known what the result will look like. Intentionally increasing uncertainty at the beginning by using the HCD process aims to have a more user-centered concept at the end. In this process, the intellectual uncertainty increases initially, and with each iteration and feedback gathering, the designer feels closer to an acceptable result for the company. As a result, the designers' thoughts would be less uncertain when they are close to the end of the HCD process.

3. Emotional:

Here, there is an elaboration on the emotional aspects and emotional differences between the HCD process and the EPD process.

In the EPD process, my emotional journey started with stress when I started brainstorming and generating ideas. The uncertainty about what to design for the company weighed on me. However, as I had some brainstorming sessions and ideation phases, I gradually gained confidence that I was on the path to creating something valuable. This confidence, however, did not last long when I received feedback from the company after sharing my initial concept. Their desire for a product vastly different from my design left me feeling lost and confused. At that moment, regarding the emotional aspect, I experienced confusion and felt that I had done something entirely far from the company's expectations.

Throughout the iterative process, with each round of gathering feedback and revisiting the ideation phase, the emotions fluctuated from understanding to confusion and uncertainty. Doubts about whether the new product would be accepted stayed with me for the process. The feeling during the process was uncertain; I was unsure if they would accept what I had made. EPD process's emotional conclusion was uncertain, which made doubt regarding the eventual acceptance of the results.

In contrast, the HCD process presented a different emotional landscape. From the beginning, the stress was noticeably less pronounced because I knew that the users - engineers from the company - were active participants in the design process. This collaborative approach allowed the pressure and stress to be shared among team members, resulting in a collective sense of responsibility. The emotional aspect of this process played a crucial role in improving my overall outlook and experience.

The critical emotional difference between these two processes is the distribution of responsibility for the result. In EPD process, the burden of responsibility was more on my shoulders, contributing to heightened stress and uncertainty. Conversely, the HCD process, with its shared responsibility and collaborative nature, relieved a significant portion of the stress. Consequently, the emotional environment in the HCD process played a vital role in raising a sense of clarity and reducing uncertainty, ultimately influencing the outcome positively.

Personal experiences in product designing in comparison with the finding from the analysis:

I have been working as a product and industrial designer for almost eight years in several companies and projects, so I have experience with product designing processes. The way that I always used for product designing was like the EPD process in gathering data, idea generation, sketching, 3D modeling, and, finally, gathering client feedback. This project with the company was the first time I used the HCD process in an actual project for a customer. So, my reflection upon comparing these two processes would be like for the EPD process that I always did: having some ideas based on client needs, being confident and relying on my knowledge and experiences, and starting sketching and modeling the best concepts based on my thoughts. In this way, I always think that I should ideate from my imagination and creativity, and if the client is intervein at this stage, it would ruin my creativity, and I could not have original and innovative ideas. In this way, when I am doing ideation, I always feel I will have something interesting for the client at the end, and this would be my ability to convince the client that one of these concepts would be the best option for them. While it happened to me several times that, in the end, the client liked the concept very much, and they were satisfied with the result. Also, it is possible that they did not like the final concepts, but I could convince them to choose between them, and they could choose one closer to their expectation. Sometimes, I needed to change the concepts entirely since I was not even close to their needs. Here is the moment that I became confused. At the end of the EPD process, no matter which scenario happens and when I present my concept, there are feelings of uncertainty because you cannot predict the customer's feedback correctly. On the side, when I was doing the HCD process, I increased the uncertainty at the beginning by engaging users in my designing process and the rest of the process, but when I went through the process and got closer, this uncertainty became less because I knew the feedback and thoughts of the users about the concepts also the idea was the result of their activities, thoughts, and feedback.

Uncertainty Triangle:

Regarding the triangle of uncertainty, when you are closer to each vertex, the uncertainty level is higher. To deal with this uncertainty, there is a need to balance between the vertexes. In the case of EPD process, the whole process controlled the ideas and situation, and I, as a designer, tried to control the ideation process. Initially, I thought I was confident, which is certain for me, but based on this triangle, the situation was uncertain. In HCD, I tried to reduce controlling processes and get closer to accepting others' ideas. Meanwhile, when I made progress, the situation also became closer to prediction. That was a move from controlling to accepting, and the result would be more predictable. As a result, in the end, I stand somehow in the middle of the triangle and the uncertainty handled with this HCD process.

The key findings of my analyses are:

1. Practically choosing the right and advanced software could have a more human-centered results.

2. Emotional positive Feeling I had in HCD approach.
3. HCD uncertainty level in intellectual aspect for me was downward (Figure 27) and in EPD process was upward (Figure 28).

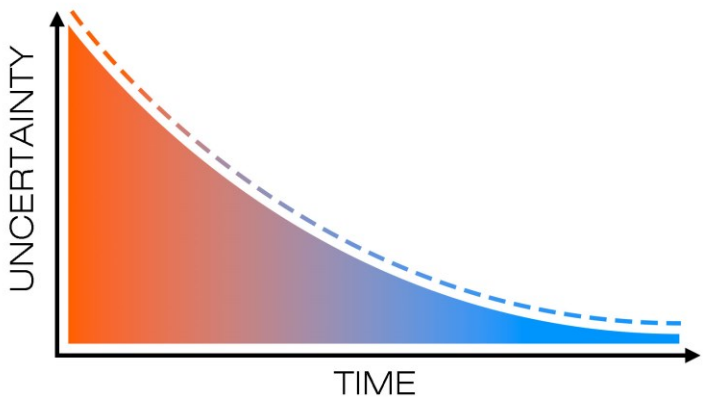


Figure 17. Uncertainty level in HCD

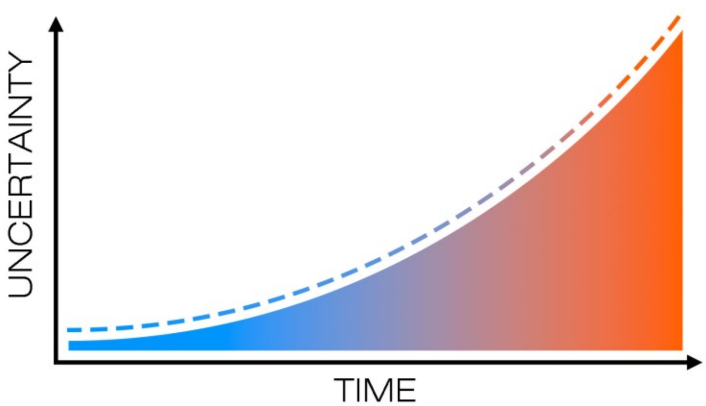


Figure 18. Uncertainty level in engineering process of product development.

4. The emotional environment in the HCD process is reducing uncertainty, and helped me to have better outcome.
5. Moving from controlling everything in design process to accepting others ideas, communicating, and interaction with others reduce the uncertainty in design process.
6. Time spending for HCD process was less than EPD process.
7. In EPD process I have one failure concept but in HCD I did not face with concept failure

7. Discussion

7.1 Findings in relation to recent studies

Here, a comparison is made between the findings of the research and existing literature in related areas. In this thesis research, the software - Grasshopper 3D - utilized for modeling with the HCD approach proved more adjustable and user-oriented. Using the right software aligns with Boy's (2017) research, which emphasizes the need for the HCD approach to employ advanced techniques, software, and tools.
While several studies explore users' emotions during product use and their emotional experiences (Norman, 2004), there is limited research on the personal emotion's designers experience during design processes. Designers undergo various emotions, especially when generating ideas (Kumar et al., 2021), and Csikszentmihalyi et al. (1981) argue that these emotions can significantly impact the final results. Measuring emotions often involves designer self-reporting (Mauss & Robinson, 2009), and positive emotions have been linked to increased creativity in the design process (Ho & Siu, 2012).
Based on the self-reporting, the moment-to-moment experiences indicate positive emotions during the HCD process. The shared responsibility with others through communication contributed to positive feelings, and the engagement in communication resulted in a decrease in uncertainty levels, aligning with the findings of Wigum and Gulden (2021).
Kumar et al. (2021) found that in the process that was not user-oriented at the beginning, designers feel confident, curious, and inspired to solve the problem. However, as time passes and they get closer to the end of the designing process, there is a tendency to feel more nervous. Similar to the result from the analysis when approaching the end stage of designing in EPD process, there was a feeling of stress, coupled with an increase in uncertainty for the end result.
In a process of designing for a project, complexity introduces uncertainty, emphasizing the importance of transitioning from a traditional design approach to a participatory approach. This involves encouraging others to share their ideas and accepting those ideas to reduce uncertainty (Krippendorff, 2007). Based on the results from the analysis and combining this idea that Krippendorff (2007) mentioned with the Uncertainty Triangle theory, accepting others' ideas can lead to a reduction in the amount of uncertainty in a designing process.
Additionally, in research by Wigum & Gulden (2021), the idea that putting control solely in the hands of the designer has negative effects on the predictability of end results is established. According to the Uncertainty Triangle, control and prediction are at the vertices of the triangle. Therefore, exerting more control in a design process leads to less predictable end results and an overall increase in uncertainty. The results from the two processes align with this notion: when using EPD process, thoughts about the end were more unpredictable and uncertain, as all control of the designing process was taken. However, when

incorporating elements of observation, acceptance, and using others' ideas, the end results became more certain and predictable.

When an unclear issue happens and exists at the present moment, it is ambiguity, and when it is in the future, it is uncertainty (Bors, Gruman, & Shukla, 2010). The issue experienced in this thesis research was uncertainty since the focus was on the project's end result during the process. Therefore, all the results and analyses conducted are about uncertainty. The analysis of ambiguous situations in design processes could be a topic for future research.

Complexity brings uncertainty, and both can be handled in participatory design, such as the human-centered design approach, which benefits society and not just financial subjects (Turtola & Määttä, 2023). Based on the findings, HCD provides a positive environment. Turtola and Määttä (2023) mentioned that in interactive design processes like HCD, the positive feeling of designers brings problem-solving and innovation. Redström (2017) says that the Scandinavian way of designing is "form" and "user," and design is about having concepts for users. The claim is "Form follows user," inspired by the famous statement of Sullivan (1896), "Form ever follows function," understanding the benefits of user-centered approaches in the present design processes.

To the answer the research question based on empirical findings: *How might designers experience uncertainty in the HCD process compared to traditional design method, and how could they deal with uncertainty?*

Based on the result of this study, in human-centered design, in the beginning, the designer feels more uncertainty. However, going further in the HCD process, the uncertainty level decreases since the designer in the HCD approach starts to communicate and accept the others' opinions, also in this project designer do not need to take all control. The HCD approach is more predictable in the end; all in all, it can reduce uncertainty.

Furthermore, a framework based on the Uncertainty Triangle was recommended for designers to address the research question in more detail regarding how designers could effectively deal with uncertainty.

7.2 Results based on Uncertainty Triangle

In a product development process, when designers face uncertainty, they can deal with it based on this structure:

They need to understand where they stand between these three main points: control, accept, or predict.

The designer can distinguish at which point they are standing by explaining their interpretations of the situation in these three dimensions: their emotional response at this stage, practical actions, and intellectual subjects they are considering.

Control: If standing in the control point, accepting and communicating more with others in the project is necessary. Also, having some insight and predictions for the results is essential. One clear example of being in the control point is using the EPD process. In this kind of design process, the designer takes control of everything. So, to deal with uncertainty in this case, the designer should accept others' ideas and have some predictions for the possible results. Within these actions, the designer would be closer to the center of the triangle, which would be a certainty (Figure 29).

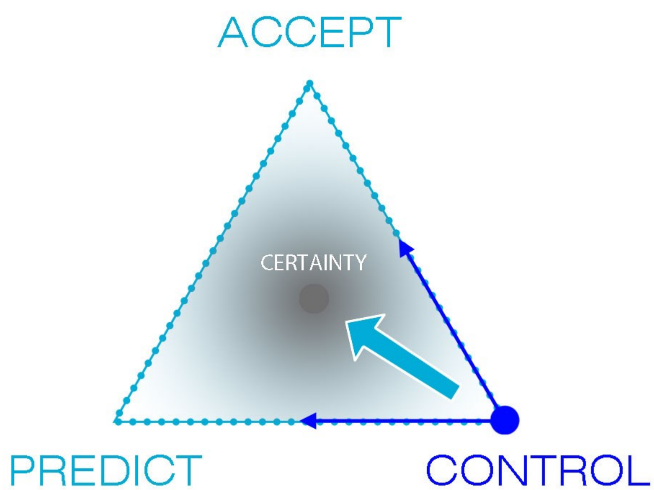


Figure 19. Coping with uncertainty from Control point.

Predict: A designer may be at the prediction point and, instead of doing something, predicts the end results. In this case, the designer needs to control some actions and also communicate with others to have a certain view in the end (Figure 30).

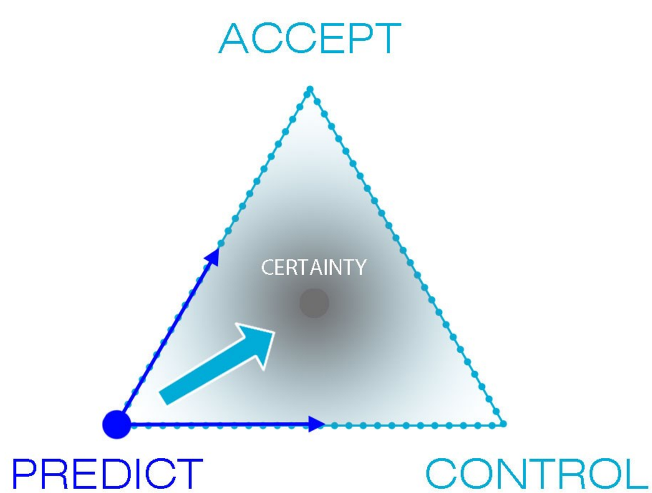


Figure 20. Coping with uncertainty from Predict point.

Accept: The final scenario involves becoming stuck at the acceptance point. If a designer simply accepts all ideas without controlling the design process or making predictions about the end results to guide the process in that direction, they face uncertainty. In this situation, the designer needs to take control of specific design actions and make predictions about possible outcomes. The designer needs to take control of some actions (Figure 31).

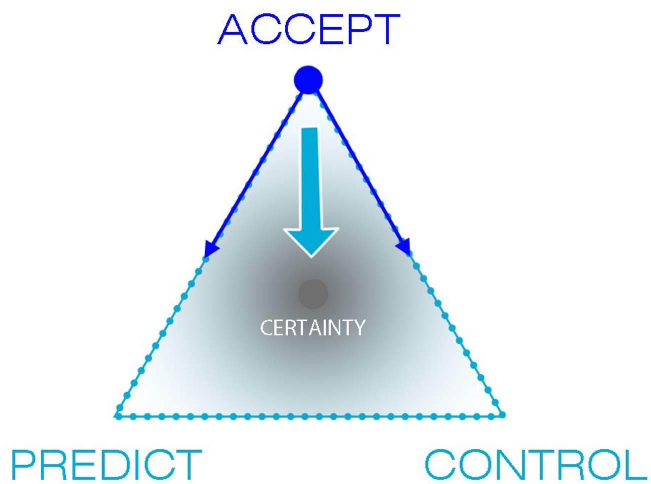


Figure 21. Coping with uncertainty from Accept point.

It is also possible that the designers do not stand at a point but rather on the edge. For instance, the designers could accept and communicate with others and take control, but they might not have any predictions for the possible result. In this case, the designers face uncertainty, and to deal with it, they need to make some predictions for the results.

The crucial idea is to maintain a balance among these three points and avoid leaning too closely towards any one point. To determine whether a designer is too close to a point, the interpretation of three dimensions - emotional, practical, and intellectual - can be helpful.

7.3 Future research

To contribute to this research, it is recommended that a study based on the proposed framework be conducted. As studied in this research, the framework relies on the introspective analysis of a designer's experiences during two distinct design processes. However, expanding the scope to include more designers could have valuable insights.

By applying this framework to a more extensive group of designers, researchers could potentially quantify the degree of uncertainty experienced across diverse design contexts. Subsequent research could adopt a quantitative approach, employing surveys for designers throughout their design processes to document their uncertainty level. This research would facilitate the systematic calculation of the levels of uncertainty they encounter.

Furthermore, how designers deal with uncertainty and ambiguity could be related to their personalities (Tracey & Hutchinson, 2016). However, Turtola and Määttä (2023) claim that it is not only about the personality; the environment is also essential. In terms of personality, what kind of designers could deal better with uncertainty in the same or different environment? This also could be a future research topic in this manner.

Furthermore, exploring the efficacy of this framework across multiple designers could provide a richer understanding of its impact. Checking how well the method reduces uncertainty in different design situations would make the framework stronger and more functional.

In simple terms, if we study this with a more extensive and more varied group of designers and use numbers to understand things, it will not only show that the framework works for many situations but also help us better understand how it helps in dealing with uncertainty in the ever-changing field of design.

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