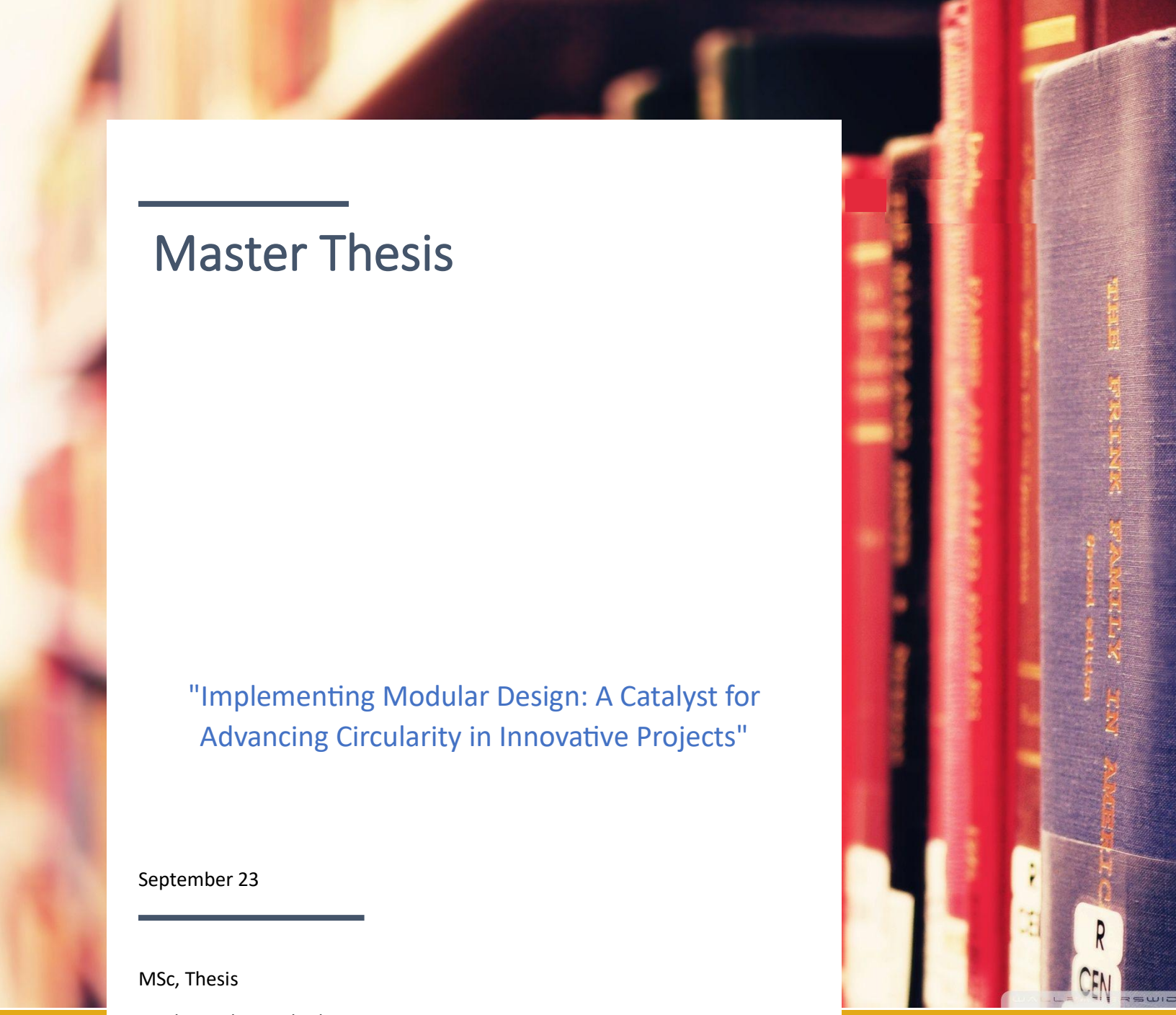

Master Thesis

"Implementing Modular Design: A Catalyst for Advancing Circularity in Innovative Projects"

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MSc, Thesis

Arad Namdarmoghadam

BILFINGER TEBODIN

TU Delft

MSc. Thesis

"Implementing Modular Design: A Catalyst for Advancing Circularity in Innovative Projects"

A qualitative study on the application of Modules and reusing them in innovative projects

By

Arad Namdarmoghadam

In partial fulfillment of the requirements for the degree of

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Preface

The complex interaction between innovation and circularity has become a crucial focus in a time of unheard-of technical developments, environmental awareness, and a desire for sustainable progress. This thesis explores the fascinating intersection of modular design and the circular economy, revealing the complex influences modular design has on the circularity of creative initiatives. This investigation was inspired by a keen interest in the dynamic interplay between design principles and their broader economic and environmental consequences. The need to develop goods, systems, and procedures that not only improve functioning but also uphold the circularity principles is more pressing than ever as we stand at the nexus of innovation and responsibility. When presented with the remarkable opportunity to delve into my thesis on circularity, I recognized it as an endeavor I could not pass up. The subject, which revolves around the assessment of how modular design influences the sustainability of innovative projects, holds the potential to offer a viable solution for enhancing industry circularity. This topic's congruence with the master's track in construction management and engineering was evident, positioning it as an ideal avenue for exploration. Moreover, it offered a unique opportunity to immerse myself in the realms of consultancy and engineering, an opportunity further enriched by my internship with Bilfinger Tebodin.

I would like to express my deepest appreciation to the individuals who have helped me navigate this complex academic journey. Your unwavering support, invaluable insights, and commitment to my development have profoundly influenced this thesis. I would like to express my deepest appreciation to my esteemed superiors, Marian Bosch-Rekveldt and Daniel Hall, whose collective guidance has been instrumental in shaping this complex academic journey. Throughout this investigation, your expertise, compassion, and consistent encouragement have been indispensable. Your perceptive observations, insightful feedback, and diverse perspectives have challenged me to broaden my horizons, refine my ideas, and expand the breadth and depth of this thesis. Your mentorship transcended academic advice, and for that, I am profoundly grateful. I am also extremely grateful for the guidance provided by Martijn Leijten. Your role as overseer of this thesis is greatly valued. The coherence and precision of this work would not have been possible without your insights and supervision. Your objective assessment has been a guiding light, and I appreciate your commitment to the academic process. My appreciation extends to my coworkers and mentors at Bilfinger Tebodin, especially my company supervisor, Wouter van Gerwen. Your real-world insights, pragmatic viewpoints, and hands-on experience have been invaluable. Your willingness to invest time and energy in advising me, despite your professional obligations, is greatly valued. Thank you all.

I am deeply appreciative to everyone who supported me throughout this journey and contributed to the successful completion of this thesis.

Executive summary

Introduction and Ideology

Significant shifts have taken place in the business sector over the past few decades, a time period that is commonly referred to as the "era of change." Companies need to be able to adjust to quick advances in technology, such as the expansion of the internet, in order to maintain their competitive edge in this dynamic environment. The volatile nature of the market, which is caused by altering demand, shifting tastes among consumers, and shifting conditions economically, makes it more difficult to prepare for the future. The adoption of modular thinking in business, such as the building of modular plants, has emerged as a solution that is both efficient and cost-effective. Concepts such as sustainability and the circular economy put an emphasis on the efficient management of resources and the minimization of waste.

Research objective & question

The objective of this research is to find possible suggestions in order to apply a modular approach to innovative projects driven by circularity. The research objective has translated to the following question:

“How can the modular design approach be utilized in innovative projects that are motivated by reusing the equipment to address circularity?”

Research Methodology

This research applied qualitative research methods and was conducted in several steps. The steps are a literature review, a workshop with parties, interviews, an expert meeting, and a conclusion and discussion. A literature review was used to extract data and learn about the fundamentals of innovative projects, modular design, and circularity. Three parties attended a workshop. The participants all discussed their desires and needs for modular approaches, and obstacles to modular design were argued. In the next phase, 10 interviews with 10 participants from different projects and at least 5 disciplines in the company were conducted. During these interviews, information regarding the shortcomings of the linear design method, modular design approaches, and how to address circularity and reuse the equipment was gathered. Then the interviews were analyzed, and based on the results of the interviews, some suggestions for change in the design method and how to implement the modular design in order to reuse the equipment were proposed to apply to innovative projects. For the evaluation of the proposed methods, an expert meeting was held. Six experts attended the meeting and evaluated and ranked the solutions provided in the last section. At last, the key findings of the research were discussed, and the sub-questions and main research question were answered.

Literature review results

Due to market shifts, especially post-COVID, companies are eager to adapt and compete in new markets. Innovations, whether in product creation or process improvement, face inherent challenges. Changes in project scope and development are common. New ventures often lack established market access, leading to discrepancies between reality and market predictions.

In this thesis, applying the modular method to innovative projects was explored, considering their unique traits. We've found various advantages, such as speed, safety, and ease of

implementation in modular construction. However, certain limitations exist, like the need for high-quality materials, experienced personnel, precise design, and transportation challenges.

Regarding project sustainability, industries have primarily concentrated on reducing CO2 emissions, minimizing raw material use, and occasionally recycling components. However, there's been little emphasis on recycling machinery and establishing a circular economy. In our research, we'll evaluate the feasibility of reusing modules, examining leasing and buy-back contracts to gauge their potential. Although there's potential for equipment reuse, it has rarely been practiced, except for a few rare instances.

Workshop results

During the workshop, three parties were present, the clients which were start-ups emerging an innovative plant, the skid builders that had a great connection with vendors, and also Tebodin Bilfinger as the consultant and engineering firm. All of the parties talked about their desire and demand regarding the modular design, they also mentioned how modular design is an option in this project and what are their concern for using this method. The needs of one end of this market are for shorter realization times, cheaper prices, and greater flexibility, while the demands of the other end are for interfaces with greater harmony, an efficient workload, and lower costs. The project's cost is the only factor brought up by either party, highlighting the significance of financial viability and demonstrating that, even in projects that are willing to explore new techniques and uncommon methods, lower costs are still the primary motivator for decision-making.

Interview results

Although nine out of ten interviewees agreed that modular design had potential, they believed that a number of obstacles would make its rapid deployment difficult. However, the study group came to the consensus conclusion that, in a perfect world, modular design represents an amazing method for setting up and running factories. The majority of interviewees (60%) favored a gradual switch to new approaches in order to remove obstacles and improve project circularity. Four participants, on the other hand, thought the current strategy was still effective and didn't need to be changed right away.

Analysis revealed that there was less excitement for using modular architecture for whole projects. Due to the difficulties in fully implementing the approach, the prevailing opinion underlined the need to concentrate on simpler and more universal procedures. This viewpoint was influenced by elements like simplicity of implementation, decreased dangers, and the efficacy of the current approach. Notably, given the success of the existing strategy, the interviews revealed a reluctance to adopt a new design technique in the absence of observable results. Another important finding was that collecting a sizable inventory of modules can result in the production of commodities for which there is no current market demand, which is judged unacceptable for profitable firms. Therefore, the general agreement suggested that businesses are likely to stick with their current processes unless other forces, like necessity or regulatory changes, force a change. During the interviews, the issue of equipment reuse came up frequently, producing a wide range of perspectives that made it difficult to decide on the best course of action. Nevertheless, despite the diversity of solutions, they may be categorized into two general strategies: either reusing the material in its present form or building a sizable storage facility while investigating a leasing model to increase circularity. The discussion's opening section focused mostly on the technical considerations involved in extending the

operating lifespan of equipment. This required actions like meticulously keeping up-to-date maintenance logs and creating regular plans for inspection and maintenance.

Proposed solutions to the practitioners

After analyzing the interviews and data gathered in previous phases, some solutions and suggestions were prepared to encourage using modules in order to reuse the equipment. The solutions for industry are divided into three main parts.

- Design approach changes
    - Data sharing between different parties
    - Multiple customers for a design
    - Being involved with clients in calculation for design
    - Easy accessibility for the maintenance
    - Compatibility of the automation units
- How to approach modular design
    - Increase the awareness of the advantages of modules
    - Including modules in the basic design level
    - Made to measure
    - Common process
    - Mass production
    - Demo plants
- How to address circularity
    - Data-driven maintenance
    - Consider future reuse
    - Make vendors sell refurbished equipment
    - Framing
    - Leasing contracts

Expert Evaluation

The evaluation meeting included participation from six specialists. They largely concurred with the solutions proposed. All the experts agreed that modular design should be considered in the early stages and from the beginning. Increased public awareness of the modular design and its benefits was given first priority, and then it was proposed that we start with standard operating procedures and leasing agreements to establish and grow the market. Framing, which would encourage participation in the modular approach from other businesses and parties involved in the industry and evaluate its viability, was given the second-highest priority. Overall, experts mentioned that to implement the modular design in order to reuse the equipment, first the awareness of all parties need to be increased, and then it should be started step by step and from parts and equipment which are more common and would create less risk for the projects. Framing the procedure and maintenance of the equipment are also in high importance in order to encourage companies to reuse their equipment.

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1. Introduction

The goal of efficiency, sustainability, and innovation continues to be of utmost importance in the dynamic world of construction management and engineering. The construction industry must balance quality, time, and resources as the demand for quick and affordable construction solutions grows (Chen, 2019). In this thesis, suggestions for using the modular approach to reuse the equipment in innovative projects is made and applicability of this method is evaluated.

The commercial and technological landscape has undergone a considerable upheaval during the last few decades, which Marinov and Marinova (2020) referred to as the "era of change" Businesses have had to adjust to the fast-paced, constantly changing technical landscape since the introduction of the internet and the ensuing rise in information technology if they want to remain competitive (Marinov & Marinova, 2020). The way businesses run, interact, and market their goods and services has been completely transformed by the growth of e-commerce, mobile devices, social media, and big data analytics. As a result, businesses now place a greater emphasis on digital innovation and transformation in order to achieve a competitive advantage (Liguori, 2020). Examples of these developing technologies include blockchain, artificial intelligence, and machine learning. Customers' expectations of seamless, personalized experiences across all touchpoints have changed with the times, forcing organizations to place a higher priority on customer-centricity in their strategy. The era of change has, in general, created enormous opportunities and difficulties for businesses and technology, and those who can adapt and innovate will be best positioned for success in the future (Kim, 2007).

Gummer (2001) suggests that Change is necessary for businesses to survive and prosper in a turbulent economy. In addition, rapid variations in supply and demand, shifting consumer tastes, and shifting economic situations are frequent characteristics of market volatility, making it difficult for businesses to forecast and plan for the future. Businesses that are adaptive and flexible will be able to react rapidly to shifting circumstances, modify their plans, and take advantage of opportunities as they present themselves in such an environment. By innovating and coming up with fresh methods to set themselves apart from the competition, businesses that embrace change may also stay ahead of the pack (Gummer, 2001). Change may also be a strong engine for corporate growth, allowing them to discover new markets, products, and revenue streams. Companies that struggle to stay relevant or take a long time to adapt, risk becoming obsolete. Thus, for firms to prosper in a turbulent market, change is not only crucial but also essential (Davenport, 1990).

Traditional techniques for product design that follow a straight line from concept creation to manufacturing are referred to as linear design methodologies (TA1: Designing Processes - Issuu, n.d.). This method is defined by a predetermined order of stages, where each stage builds on the one before it and is finished before proceeding to the next. Krajcovic and Grznár (2017) mention that although linear design methods have been used extensively for a long time, they have a number of shortcomings. They lack flexibility and make it difficult to readily make modifications during the design process, which is one of its biggest drawbacks. Changes may need to be made later in the process when it is more difficult and expensive to apply them, which can lead to delays and higher expenses. Additionally, because designers may be restricted by a predetermined set of needs and specifications, linear design processes can inhibit innovation and originality. Additionally, the quick-paced and dynamic nature of today's business world, where organizations must be able to quickly adjust to shifting client wants and market situations, may not be well-suited for linear design methodologies. Because of these

problems, and the severe need for change, in this master thesis, a modular design method is evaluated.

A knowledge gap exists in the field of innovative projects regarding the effective reusing of modular equipment. The practical application of module reuse frequently faces difficulties, despite the concept's promises of higher productivity, shorter development times, and enhanced safety. The goal of this study is to bridge the gap between the benefits of module reuse in theory and how hard it is to put into practice. This study aims to identify strategies, recommendations, and insights that can enable project teams to fully utilize modular techniques.

1.1. Innovative projects

There are extensive alternatives for defining innovative projects, Hölzl and Janger (2014) used this definition, “Innovative projects are initiatives and activities aimed at creating something new and different from existing products, services, and processes”. These projects emphasize creativity, experimentation, and risk-taking in order to bring about new and improved results. Innovative projects are often set up to solve a problem, create a new product, or improve an existing one. There are several studies regarding the risks in innovative projects, Garcia-Quevedo et al. (2018) concluded that the success rate of innovative projects varies greatly, depending on the level of creativity and risk-taking involved. Projects that are well-thought-out and have a solid foundation have a much higher chance of succeeding than those that are hastily thrown together. The key to success is to create a solid plan and strategy and to manage the project effectively. To increase the success rate, it is important to allocate resources appropriately, monitor progress and performance, and adjust the plan as needed. Regarding the high risk of this project, there are a lot of drawbacks in investments, and in case of failure, normally most of the equipment and process line lose its value. There are several cases of innovative projects that started to work but within the next two or three years they lost their customer and market and they had to close the business (Garcia-Quevedo et al., 2018).

Chen (2019) suggests that most creative projects can be divided into two distinct components: the innovative core and the supporting system. The majority of the other equipment is typically well-known, even though the cutting-edge core can be wholly unique and unheard-of technology

1.2. Modular thinking

There are several definitions for modular thinking and modular design. Smith (2010) suggests that creating components or modules that can be quickly put together or taken apart to produce a variety of different products is known as modular design. Modular design offers a high degree of flexibility and adaptability by utilizing standardized components that can be joined in numerous ways, allowing businesses to adapt swiftly and effectively to changing client needs and preferences. This strategy also has a number of advantages, including lower design and production costs, quicker manufacturing, and better product quality and dependability. In addition to promoting sustainability, modular design helps items last longer and produce less waste by making it simple to repair or replace them (Smith, 2010). Additionally, the modular design promotes creativity and innovation by allowing designers to experiment with various module combinations to produce one-of-a-kind items. In conclusion, modular design is becoming more and more significant in the modern economy as consumers demand more customized and adaptable products and organizations work to become more flexible, efficient, and sustainable (Gershenson, 2003).

Ma and Kremer (2016) indicate that modular plants are plants that are designed and built in sections or modules, which can be easily transported and installed on site. This is a cost-effective and efficient way to construct plants and is becoming increasingly popular in the industrial and manufacturing sectors. Modular plants offer a number of advantages over traditional plant building methods. First, modular plants are much faster to assemble than traditional plants and can be installed on-site in a fraction of the time. This reduces labor costs and reduces the amount of time required for construction. Additionally, modular plants can be customized and configured to meet specific needs and requirements, reducing the need for costly modifications (Ma & Kremer, 2016). In addition, Sutharshan et al. (2011) also mention that modular plants also offer improved safety and environmental protection. Because the modules can be easily moved and installed, they can be placed in locations with optimal safety and environmental conditions. Additionally, the modules can be easily monitored and maintained, resulting in improved safety and environmental performance. Finally, modular plants are more energy efficient than traditional plants, as the modules can be designed to be more efficient. Overall, modular plants offer a practical and affordable means of constructing plants. They may be customized and configured, are built more quickly than conventional facilities, and provide better environmental and safety protection.

Utilizing modules has a number of benefits, but for the purposes of this thesis, the reuse of modules is the primary quality that will be assessed in order to support the circular economy. It should be highlighted that in this thesis, modules are the pieces of plant machinery that can operate on their own. Such a facility may cost more to design, build, and invest in, but it should lower risk and break down Capex into numerous payments. We will weigh the benefits and drawbacks of the modular approach to determine whether Tebodin Bilfinger and its clients will benefit from using it.

1.3. Circular economy

There are several approaches to define sustainability and circularity, Schöggl et al. (2020) mentioned that sustainability is the practice of using resources in a way that meets the needs of the present without compromising the ability of future generations to meet their needs. It includes the concept of responsible and equitable use of resources that conserves both the environment and economic growth. A circular economy is a kind of business that prioritizes resource conservation and waste reduction (Korhonen et al., 2018). It functions by maximizing the value that can be extracted from resources while they are still in use, recovering and renewing goods and materials at the conclusion of their service life. This increases economic potential while minimizing waste and reducing resource consumption. Decoupling economic growth from resource usage is the core goal of a circular economy, which means that economic growth may be accomplished without increasing resource use. This is accomplished through creating goods and services that are effective, durable, simple to maintain and repair, and capable of being recycled or recovered at the end of their useful lives (Kuhlman & Farrington, 2010).

By minimizing waste and enhancing the value of resources, the circular economy seeks to develop a more efficient and sustainable economic system (Schöggl et al., 2020). The shortage of raw materials, which is a problem that becomes more urgent as the world population rises and consumption habits continue to change, is one of the fundamental forces behind the circular economy. Due to the fact that typical linear models of production and consumption result in the depletion of finite resources, the circular economy aims to prolong the useful life of materials by

using techniques like recycling, reuse, and repair (Korhonen, 2018). By doing this, it hopes to lessen the need for new raw materials, cut down on waste and emissions, and eventually develop a more robust and sustainable economy. The shift to a circular economy gives a great chance to solve the issue of resource scarcity and assure a more sustainable future for future generations, even though it is not without difficulties, such as removing obstacles to recycling and altering consumer behavior.

1.4. Plant design process

It would be helpful to look at the factory design process as we are talking about how modular design may be applied to factories and mechanical equipment. Harding and Popplewell (2000) indicate that the phases listed below are frequently used in the factory design process in an article about the simulation of the process.

- Ideation: During this stage, the factory design team generates concepts for a factory that will satisfy the demands of the business. This includes researching industrial layout options and rival strategies, as well as researching market trends and consumer demands.
- Planning: The design team prepares a strategy to construct the plant during this phase. This includes planning a schedule, a budget, and other practical aspects. Designing: The design team develops a thorough design for the factory at this stage. This involves making the physical layout, choosing the tools and supplies, and setting up a system for controlling the processes.
- Testing: The design team tests their plan for the factory during this phase to make sure it satisfies the demands of the business and adheres to safety regulations.
- Implementation: The design team puts its plan for the manufacturing into action during this phase. This includes acquiring the required supplies and tools, installing them, and instructing workers on how to utilize them.
- Evaluation: The design team assesses the factory's performance during this phase and makes any required modifications or improvements (Harding & Popplewell, 2000).

We can assume that the idea and the entire process have essentially the same phases, despite the fact that the design process is complex and may differ for each project. Furthermore, Tebodin Bilfinger has manuals, processes, and, in some situations, client-specific codes and rules that must be followed during the process.

1.5. Graduation company

Tebodin Bilfinger is a multifunctional engineering and consulting firm that focuses on offering cutting-edge, sustainable solutions for a variety of markets, including infrastructure, chemicals, energy, and pharmaceuticals. With more than 75 years of experience, the business has built a solid reputation for providing clients with high-quality projects that fulfill their needs and expectations. Project management, engineering design, procurement, construction management, and environmental and sustainability consulting are all services provided by Tebodin Bilfinger. The business is dedicated to sustainability and works to incorporate green practices into each and every one of its projects, fostering a circular economy and lowering waste and emissions. Tebodin Bilfinger is well-positioned to offer comprehensive and tailored

solutions that solve the complex difficulties facing today's industries thanks to its extensive global network of offices and staff of highly qualified individuals.

Bilfinger Tebodin as one of the pioneers of the design and planning of factories, has a huge potential to invest in modular design. In the current situation, several projects and clients are using Tebodin's services for designing and building new plants. By applying a modular approach and creating a design bank, there would be a noticeable reduction in the costs of the company. In this research first, we are evaluating the process and procedures of the company and how they are proceeding with the design now and next we are trying to introduce and develop a design method based on modular thinking in order to apply circular economy to the company.

1.6. Contribution of research

The present design methodology and its shortcomings will be evaluated, followed by the modular approach and the opinions of experts on it. Additionally, advice is given on how engineers and designers can better modify their design processes to take a modular approach. In the end, this study will point out some of the barriers to the industry's adoption of modular thinking and make suggestions for ways to persuade professionals to utilize modules to cope with circularity.

1.7. Structure of the report

Chapter 1 introduces the concept of innovative projects, their failure, and the risks of innovative projects, followed by a definition of circularity and modular design methods. The chapter also analyses the problem of the study and states the objective from which the research questions are framed.

Chapter 2 covers the research design which entails the different phases in which the research will be conducted.

Chapter 3 presents the findings of the literature study. First, the concept of innovative projects is introduced. Then the risks and failure of the projects are discussed. Circularity, reuse of equipment, and contracts are also included. The last part is about the modular design and factory plant design and development.

Chapter 4 discusses the data gathered from a workshop between the company, Skid providers, and two start-ups, during this chapter drivers for using modular approaches are discussed.

Chapter 5 covers the interview process of this research, it includes the interview questions and the interviewees. It is followed by a thematic analysis of the interviews and interview results.

Chapter 6 proposes solutions for changing linear design, encouraging the use of modular design, and creating the chance of reusing the equipment.

Chapter 7 covers the expert validation of the proposed ideas, it indicates which solutions are approved, and would create a ranking for the solution in each respective goal.

Chapter 8 covers the discussion of the findings and argues about the implementation of the solutions.

Chapter 9 covers the conclusion and recommendations for future research.

2. Research design

This study will employ qualitative research techniques and follow several steps. These steps will include a review of the literature, participating in Client, and provider workshops, interviews, drafting solutions, and an expert meeting. The literature review includes information on modular design and the circularity of innovative initiatives. Secondary information on the use of modules in industry will be gathered during the workshop, which will provide us with a more accurate picture of the needs of consumers and producers. During the interviews, corporate employees from various disciplines will provide information about the module and its relevance in light of their experience and line of work. Some recommendations will be made based on the results of a thematic analysis to enable the implementation of modules for tackling circularity in the industry. These ideas will be assessed in a meeting of experts to gauge their opinions. Finally, the conclusion and discussion will be reached using the information acquired.

2.1. Main research question

“How can the modular design approach be utilized in innovative projects that are motivated by reusing the equipment to address circularity?”

To answer the main question, the following sub-questions are defined:

1. What are the main challenges of innovative projects due to using a linear design process?

2. What are the main drivers/functions of the modular approach demanded by innovative projects and vendors?

3. What are the main criteria in the modular design process and what is a suitable framework in order to utilize this method?

4. What is the most suitable proposed method so reusing modular equipment can be applicable for innovative projects?

2.2. Methodology

Different ways will be utilized to answer these questions as well as the main research question. The first and second questions focus on the current state of issues, as well as the industry's design and decision-making processes. We need to know the methodologies and conclusions from academic studies and articles, in addition to Tebodin Bilfinger's approaches, in order to properly answer these questions. The most recent findings would be found through a literature study, and the company’s interactions with clients would be discovered through a workshop.

We will use interviews with various project participants to find the method's obstacles and will attempt to identify the most crucial design method components in order to address circularity. After gathering general knowledge about these topics, information regarding applying new methods to industry is required. We can offer a strategy to follow for using this approach with

the projects. This plan would be assessed via a company-wide expert meeting where a number of specialists in the field would be present, the plan would be presented, and their opinions would then be requested. Finally, their assessments and viewpoints are compiled and will be addressed.

2.3. Phases for the research

Phase 1: Literature review

Snyder (2019) suggests that a literature review is a good starting point in order to gather knowledge and create a base for further steps in qualitative research. A literature analysis has been done in order to develop a logical scope and discover crucial information regarding the current design methodologies and modular design. Innovative ideas, their failure, the significance of circularity in the absence of material, as well as modular design and its benefits and drawbacks, were all culled from previously published literature for this review. Additionally, details about the design process and the value of using the materials again rather than recycling them were scattered. Relevant search engines, including university research paper repositories and journal citation databases, were used to find terms like "Innovative projects," "innovative projects failure," "circular economy," "reusing or recycling," "Modular design," "Modular design in the industry," and "plant design in the industry". Sub-question 1 is answered by this literature review.

Phase 2: Workshop

Workshops offer a singular setting for interacting with participants, encouraging group discussions, and producing insightful information (Ørngreen & Levinsen, 2017). In order to gather a better understanding of the actual projects and opinions of each stakeholder, a workshop between different parties has been held by Tebodin Bilfinger. These workshops give participants the chance to bring together a variety of stakeholders, including specialists, practitioners, and even the project's intended beneficiaries, to collect a variety of viewpoints and explore challenging research problems. Sub-question 2 was answered based on the data gathered in this workshop.

Phase 3: Interviews

In order to gather rich and extensive information on the participant's experiences, beliefs, attitudes, and opinions, interviews entail posing a series of questions to them, either in person or via other techniques like video conferencing or phone calls. To encourage participants to give more thorough comments, the interviewer may ask open-ended questions, and then ask more questions to elucidate or expand on their responses (Choy, 2014).

Interview questions will be answered by several individuals from various departments of the organization in order to collect data and improve understanding. Having multiple people in our data gathering process provide a more comprehensive understanding of the modular design because there are currently no projects that completely fit the scope of this research but there are people who have experience with modules and modular activities. It should be noted that some of the primary themes of the literature study were brought up in the interviews, and the interviewees were asked their thoughts on that particular subject.

Finding the thematic analysis technique approach that is most suited for the sort of research was the first stage in the analysis process. Nowell et al. (2017) suggest using the deductive

approach to look for themes in the data transcripts because the literature study has given this activity a strong theoretical grounding. After conducting a thematic analysis, sub-question 3 was answered.

Phase 4: Proposing suggestions

In order to assist the company in adopting a modular strategy, suggestions will be made based on the information collected. The suggestions will include both technical and cultural modifications suitable for Tebodin Bilfinger.

Phase 5: Evaluating the proposed suggestions

The offered solutions will be evaluated by specialists from the company who have competence in the relevant areas, and the recommended solutions will be ranked according to their usefulness to the company. By using this setup, the evaluation is going to check if the proposed solution is useful or not and if it is useful how much impact it is going to have. The decision to conduct this phase in the form of a workshop was made in order to cut down on the amount of time necessary, as well as to encourage the experts to collaborate and actively participate with one another in the evaluation of the potential solutions. In order to avoid misunderstandings and inaccurate assessments, the people who take part in evaluation were not involved in the earlier interviews. Sub-question 4 was answered after the expert meeting based on their evaluation of the proposed suggestions.

3. Literature review

This literature review aims to set the stage for the subsequent chapters of the thesis, where empirical data will be gathered, analyzed, and interpreted to address the research objectives and contribute to the larger discussion on innovative construction methodologies. Key phrases from previously published literature, such as "innovative ideas," "their failure," "the significance of circularity in the absence of material," and "modular design" and its advantages and disadvantages, were all taken into consideration for this assessment. There were also mentions about the design process and the advantages of reusing the materials as opposed to recycling them. Searching for relevant articles has been done using relevant search engines, including university research paper repositories and journal citation databases like Scopus.

3.1. Innovative projects

Figure 1 displays the topics included in section 3.1.

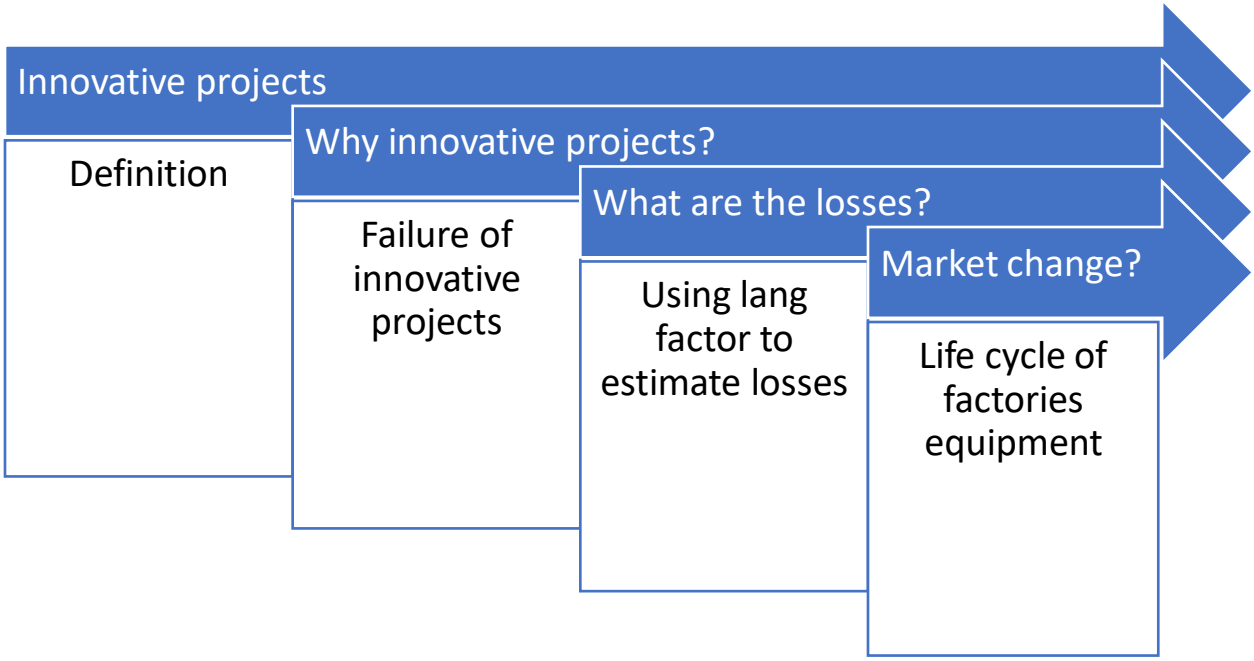

Figure 1: Innovative project literature review process

3.1.1. Definition

In order to define the scope of the project we need to have a definition for innovative projects, Innovation is a general word that could refer to different meanings, It should be noted that innovation is not something happening only in start-ups and new projects but several innovations are happening in existing plants. As Freeman and Engel (2007) separate innovation into two major categories, The process of innovation begins with the conception of a novel idea

and concludes with the introduction of a new product. The term "innovation" cannot simply be reduced to "invention." Because the process of innovation can take place in two distinct ways — the corporate model and the entrepreneurial model — we refer to established businesses that are older and often larger as "corporations" and businesses that have recently been formed by entrepreneurs as "startups." The reason for this distinction is that corporations are businesses that have been in operation for a longer period of time and are often larger.

In another article, Garcia-Quevedo et al. (2018) define innovation as, Innovative projects are initiatives and activities aimed at creating something new and different from existing products, services, and processes. These projects emphasize creativity, experimentation, and risk-taking in order to bring about new and improved results. Innovative projects are often set up to solve a problem, create a new product, or improve an existing one.

In recent times, the role that a relatively small group of high-tech startup companies played in stimulating innovation and economic growth has received widespread recognition and praise from a variety of different stakeholders. The high-risk, high-reward strategy that these businesses employ results in a high failure rate and a limited percentage of successful firms, even though their overall contribution is vital. As a result, it is interesting to note that the literature frequently ignores the multiple lessons that can be gained from looking at the experiences of businesses that failed in favor of focusing on successful firms and quantitative studies that seek success predictors (Cantamessa, 2018). Cantamessa et al. (2018) further emphasize that the most common reasons for a company's inability to succeed are a lack of business development as well as the utilization of an inappropriate business model. The management and founding team of this company are to blame for these issues because they put too much emphasis on the company's product or service and not enough on business development. In addition, it was reported that 21% of the startups had run out of money. This can be attributed to either misusing the funding that was received or failing to plan adequately (although it could also be interpreted as a sign that investors refrained from participating in additional financing rounds because they did not perceive enough factors supporting the decision). Insufficient compatibility between the product and the target market comes in at number five on the list of the most common reasons for failure.

3.1.2. Failure of Innovative Projects

As previously said, there are many distinct kinds of innovation taking place in business. Businesses are working to enhance results, cut waste, boost productivity, develop new processes, and even design entirely new goods. There is a considerable danger of failure, which would destroy a sizable investment and the raw materials used to make them, even though all of these actions are researched and intended to provide more effective and superior techniques. It's critical to be aware of some of these issues.

In a one-on-one conflict, the startup frequently possesses fewer scientists and engineers, fewer financial resources, a lower level of credibility or brand recognition, fewer strategic connections, shifting organizational structures, and incomplete or non-existent business procedures. Due to the disadvantages of their youth and small size, young enterprises fail more frequently than their larger and more established competitors. In organizational designs intended to maximize creativity, bureaucratic frameworks, well defined job assignments, and textual communications that are institutionalized in set filing systems are often emphasized. Conversely, it seems that creativity is enhanced in organizations that are built around teams, with job responsibilities developing to meet the needs of issues that never quite repeat (Freeman, 2007). Garcia-

Quevedo et al. (2018) show that the rate of failure is much higher in smaller firms and companies as they are not comfortable bearing losses and staying in business. Freeman further mentions that one distinctive quality is the alignment of incentives between the employer, investor, and employees. We refer to the social category of "professional entrepreneurs" as those entrepreneurs who are actively building businesses based on major discoveries. We refer to them as being "channeled" because the strategic problems they face greatly pressure them to grow swiftly, even when other business owners and well-established corporations threaten to overtake them because of their dominant market share. Repeated financial injections are necessary, some of which must come from institutional investors, especially venture capitalists.

In another study, Blasco et al. (2013) discuss the failure rate of innovative projects, The success rate of innovative projects varies greatly, depending on the level of creativity and risk-taking involved. Projects that are well thought out and have a solid foundation have a much higher chance of succeeding than those that are hastily thrown together. That being said, even the most innovative projects can fail if not properly managed. The key to success is to create a solid plan and strategy and to manage the project effectively. To increase the success rate, it is important to allocate resources appropriately, monitor progress and performance, and adjust the plan as needed. Regarding the high risk of these projects, there are a lot of drawbacks in investments, and in case of failure, normally most of the equipment and process line lose its value. There are several cases of innovative projects that started to work but within the next two or three years they lost their customer and market and they had to close the business.

Referring to a study by Cantamessa et al. (2018) we can mention the four most common reasons for failure below,

1. Wrong business model
2. Lack of business development
3. Run out of cash
4. No product/market fit

3.1.3. Using Lang factor to estimate losses

In this section, the amount of the project's initial investment that would be lost in the event of failure is assessed. Understanding the dire situation and the extent of the losses is crucial. Finding a means to measure or estimate the losses following a failure is crucial given the high rate of failure of innovative enterprises. Although there are numerous distinct estimation techniques, the Lang factor approach will be the focus of this study. The main purpose of it is to roughly estimate the project's costs and required expenditure.

The Lang Factor approach of cost estimating is used in project management. It is based on the Lang Factor equation, which calculates project costs based on historical data. This approach is particularly helpful when there is a solid data collection to draw from and the project is comparable to prior ones. To get an appropriate cost estimate, it considers variables including project size, complexity, and length. When comparing the predicted cost of a project to its actual cost, one of the most trustworthy cost-estimating techniques is known as the Lang Factor approach (Romero-Rodriguez, 2017).

The American Association of Cost Engineers (AACE) International recommends the Lang factor as one of the factored estimating methodologies for estimates. The formula used for this

strategy, which was first put forth by Hans J. Lang in the 1940s, is a series of factors multiplied by the Total Equipment Cost (TEC) to produce the Total Plant Cost (TPC). For solid plants, solid-fluid plants, and fluid plants, these variables are 3.10, 3.63, and 4.74, respectively (Wain, 2014).

It is important to mention that several different Lang factors depend on the industry and how the optimization has been done, but it is a good starting point to estimate the costs.

This estimate shows that around 25% of the investment goes into the equipment (Lang Factor=4), with the remaining 25% going toward connections, design and engineering, structure, support structures, control and safety, and pipes, all of which are worthless if the plant is unable to function. As it is used equipment, we may also assume that it will lose some of its original worth (Wolf, 2015). The fact that we would lose more than 75% of our investment in the event of failure makes it exceedingly difficult for investors to make investments, and start-ups and small businesses lack the funding to build the necessary facilities and manage the risks.

3.1.4. Life cycle of factories

There are some cases in the industry, in which the demand for the product decreases drastically, or the product is no longer appealing, but the equipment and process line still has a technical lifetime left. It is very important to know and study the life cycle of factory equipment and find out how they are evaluated. Changes in the factories are not always due to failure of the plan but it could happen to address some changes and improvements in the system. Nielsen et al. 2016 discuss the Life cycle of equipment as follows: to remain competitive in a volatile market, manufacturing organizations must understand and improve complicated production processes. Factory planning and operation provide issues due to the interconnected and converging life cycles of goods and physical factory components (such as machine tools, technical building services, and building shells). Garcia-Quevedo et al. (2018) suggest that Companies need their factories to be adaptable and flexible to actively design the necessary transformation processes if they hope to effectively compete in the market. As a result of more stringent regulations and consumer awareness, the industry must now take environmental and social goals into account in addition to economic ones. Nielsen et al. (2016) indicate that the fact that the life duration of factory structures as well as investment items like production machinery or technical building services (TBS) surpasses the period of product production presents a unique problem for factory planners. This leads to a variety of issues that need to be resolved throughout the development and operation of plants. It is necessary to view the factory as a sophisticated socio-technical system. This makes it inappropriate to evaluate the factory as a whole as a single entity. The factory as a whole has to be divided into its component factories and arranged in a hierarchical framework. All manufacturing components have previously been given a general description. Both a top-down and bottom-up method can be used to structure the factory pieces.

In another article, Favi et al. (2016) indicate that from design to disposal, the life cycle of industrial equipment is a continuous process that takes into account changes in technology, market needs, and environmental concerns. It starts with the design and engineering phase, where novel concepts are transformed into useful machinery while taking efficiency, safety, and scalability into account. As machinery moves into the production stage, it supports the manufacturing process and helps produce goods and services. The equipment's operating life is extended via maintenance and routine inspections, resulting in peak performance. However,

wear and tear accumulate over time and become unavoidable, necessitating eventual replacement or repair. As technology develops, newer, more effective equipment replaces outdated types. Responsible disposal or recycling is essential in the end to reduce the negative effects on the environment. As a result, the life cycle of production equipment represents an ongoing cycle of innovation, use, repair, and eventually, sustainable retirement.

3.2. Circular economy

Figure 2 depicts the topics encompassed within each segment of section 3.2 of the literature review.

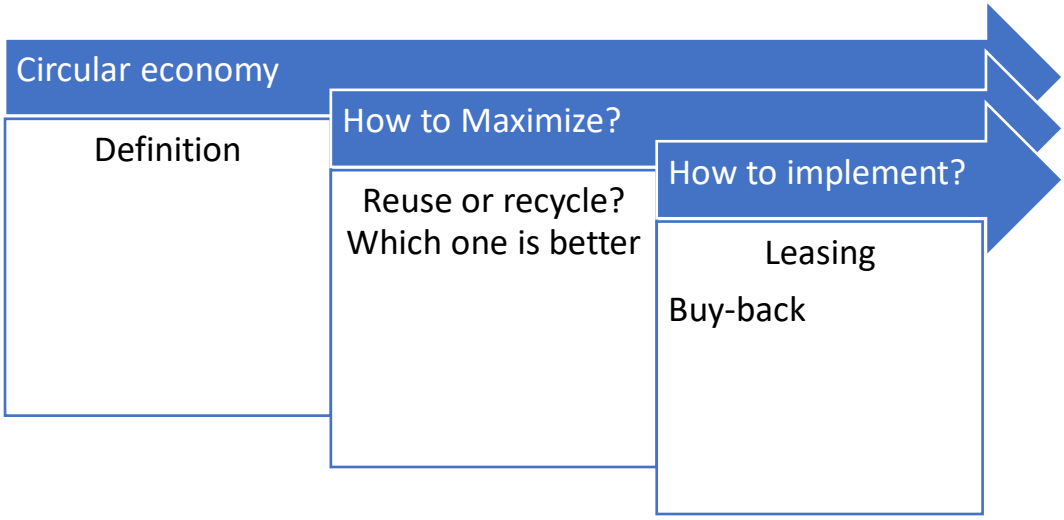

Figure 2: Circular economy literature review process

3.2.1. Definition

Both academics and practitioners are embracing the circular economy idea. Yet, adversaries believe that it might imply many different things to many individuals. A circular economy is an economic structure that is intended to be restorative and regenerative. It is a substitute for the conventional linear economy (make, use, discard), where resources are utilized in closed loops to reduce waste and pollution. A circular economy is founded on the ideas of designing out waste and pollution, keeping goods and resources in use, and renewing natural systems, according to the Ellen MacArthur Foundation. The objective is to develop a system that effectively uses resources while minimizing the harmful effects of production, use, and disposal on the environment. This is especially crucial in the modern world when resource scarcity and population expansion have exacerbated environmental strain (Chertow, 2019). Reusing, recycling, and upcycling are examples of circular economy techniques that may reduce the stress on resources and protect them for future generations. It is one of the most important concepts, yet it is not clear which is used. It is good to mention that (Kirchherr, 2017) also claims that reducing, reusing, recycling, and recovering would be the focus of CE, but "in actuality, most policy has been directed on encouraging the third.

Liu and Ramakrishna (2020) indicate that using resources as long as feasible is a key component of the circular economy, which aims to decrease waste and promote sustainability. Implementing the concepts of the circular economy entails creating durable goods and services that can be recycled, mended, and reused in order to limit the amount of waste produced over time. In order to limit the amount of energy and resources used, it also entails using renewable

energy sources, recycling items, and sharing resources. In order to increase the lifespan of their goods and services and lessen the need for new resources, companies might also collaborate with other organizations. Organizations should concentrate on using renewable energy and resources, upcycling materials, sharing resources, and collaborating with other organizations in order to implement the concepts of the circular economy (Rath & Roy, 2019).

It should be noted that there are several aspects related to circularity and every company and industry has its own way of improving and enhancing the circularity, but as mentioned in different papers, recycling is the main method in practice. While recycling is very helpful and reduces the severe environmental impacts, it is not the best way to eliminate them. In the next step, we are going to compare reusing and recycling the material to find out the differences.

3.2.2 Reuse or recycle

An innovative economic model known as the circular economy (CE) seeks to promote sustainable economic growth, raise the economic value added of businesses, enhance their competitiveness on a global scale, and fulfill the Sustainable Development Goals (SDG). Due to its industrial design and predetermined capabilities for disassembly and reuse, the modular structure has great potential to serve as a starting point for this transformation (Mackenbach, 2020).

It should be noted that there are several different types of recycling methods while reusing the modules is far more beneficial regarding the sustainability of projects. Minunno et al. (2020) suggest that reuse strategies, according to experts, may offer environmental advantages that far outweigh recycling in a building setting. To put this to the test, the environmental advantages of a prototype and specifically constructed, modular structure that was made to be disassembled and reused has been assessed. Then contrasted the findings of the life cycle evaluation with those of a modern building strategy with an emphasis on the recyclable nature of materials. Findings show that designing and manufacturing components for reuse cuts greenhouse gas emissions by 88% when compared to recycling, while also helping numerous other measured environmental indicators.

The environmental effects of recycling and reuse in the construction sector are extensive. Reusing materials reduces the number of resources required for new construction and can result in lower energy consumption, fewer carbon emissions, and less waste produced overall. Reusing materials reduces the energy and raw resources required to generate them. Reusing materials like steel and wood reduces the amount of waste produced, decreasing the need for landfills, and promoting environmental protection (Belleville, 2019).

Recycling in the building sector may be advantageous for the environment. Recycling resources like wood, metal, and plastic may assist in minimizing trash generation, which can lessen the need for landfill space. Recycling also lessens the demand for raw materials, which requires less energy to create and results in lower carbon emissions (Gangolells, 2014).

Generally, the building sector may benefit the environment by recycling and reusing resources. Reusing materials can cut down on the resources required for new construction and can aid in cutting down on waste. Recycling materials may also assist in decreasing trash generation and

the requirement for raw materials, which results in a reduction in the energy required to generate them.

3.2.3. Business model: leasing

Geissdoerfer et al. (2017) indicate that a flexible and adaptable method of purchasing assets and resources across numerous industries has emerged as the leasing business model. Contrary to traditional ownership, leasing gives businesses the chance to acquire machinery, automobiles, and even real estate without making a sizable upfront financial commitment. With this structure, organizations can carefully manage their financial resources, conserve resources, and maintain their agility in a market that is continually changing. The leasing business model offers adaptability to changing operational requirements, technical developments, and economic ups and downs. We shall examine the fundamental tenets, advantages, and factors of the leasing business model in this introduction, putting light on its significance as a cornerstone of contemporary commercial tactics.

The foundational areas of sustainability research, particularly industrial ecology, and cradle-to-cradle design have served as inspiration for the CE model. The key CE additions to the body of knowledge, according to Korhonen et al. (2018), are a change towards a sustainable production and consumption culture, the importance of material durability, and the relationship between the shared economy and sustainable production. There are several different CE definitions in the literature. According to the Ellen MacArthur Foundation (EMF), a circular economy CE is one that "aims to retain goods, components, and materials at their greatest usefulness and value at all times, differentiating between technological and biological cycles" and is "restorative and regenerative by design" (EMF, 2015). In an effort to describe CE, Geissdoerfer et al. (2017) described it as "a regenerative system in which resource input and waste, emission, and energy leakage are reduced by delaying, shutting, and narrowing material and energy loops. Through durable design, upkeep, repair, reuse, remanufacturing, refurbishment, and recycling, such a regenerative system may be realized. Kirchherr et al. (2017) highlighted that CE aspires to achieve sustainable development and is made possible by creative business strategies and responsible customers after analyzing 114 definitions. Although the CE model applies to all industries, its potential economic, environmental, and social benefits can be maximized by applying it to those with high material resource consumption, such as the design and construction industries, which are responsible for the built environment that surrounds us. Construction includes the planning and building of the things that are commonly referred to as the built environment (like structures, facilities, infrastructures, etc.), but it hasn't succeeded in coming up with ways to stop the demolition of structures, facilities, or infrastructures once they reach the end of their useful lives and the waste that results from that. It has been noted that the rate at which material resources are being used in building, along with trends in population growth and consumption throughout the world, will lead to a shortage of some commodities, such as steel and copper, which are widely used in the built environment. Steel and copper, however, are strong materials, suggesting that there may be a chance for their reuse. It is critical to be clear that the CE definition of reuse refers to the use of the product or component without recycling, whether that be in its current state, after refurbishment, or remanufacturing. Recycling is the act of turning used or discarded materials into new ones. It frequently necessitates using enormous amounts of water, and energy, and producing greenhouse gas emissions in the process. Recycling therefore helps save raw resources but has a greater

negative environmental impact than reusing or remanufacturing (including refurbishing) previously made goods. Recycling may also require very inefficient actions. For instance, it has been proven that leftovers (i.e., recyclable materials) are shipped abroad simply due to reduced production costs. In this situation, energy expenditure and greenhouse gas emissions from transit rendered recycling environmentally useless. Therefore, the CE model only considers recycling as a substitute when reuse or remanufacturing is not economically feasible (Stahel, 2016). Overall, the issue of resource scarcity calls for thinking beyond small adjustments to the linear economy. It necessitates a comprehensive, successful, and radical departure that successfully increases the lifespan of building materials and goods across several uses. In response to this issue, it is common to view the concurrent use of CE in the built environment as a synergistic combination that promises to encourage closed-loop cycles while efficiently addressing consumer and environmental demands (Merrill, 2020).

3.2.4. Business model: Buyback contracts

There are several contract models in the business but one of the famous ones is the buyback model. Wu (2013) suggests that remanufacturing is an industrial process that extends the functional life of discarded items. Remanufacturing differs from manufacturing in a few ways that make the production process and supply chain more challenging. For instance, a business must collect old goods from consumers, therefore the timeliness and caliber of the used goods are frequently unpredictable. Remanufacturing businesses depend on consumers returning old goods (cores). Wu (2013) further identifies the seven distinct forms of closed-loop interactions for collecting cores for remanufacturing. The ties that have been discovered include those based on ownership, service contracts, direct orders, deposits, credit, buy-backs, and voluntary agreements. In another article, Giri (2014) lists a number of drawbacks and benefits while developing a theory around these various kinds of interactions. Investigating these connections will help researchers better understand how to manage remanufacturing and the closed-loop supply chain.

Arshinder (2008) suggests that there are many different kinds of connections with customers and primary suppliers in the remanufacturing sector. Some relationships are very close, such as those where there is a lot of commitment, trust, and teamwork; in other relationships, the connection is not as strong.

- Ownership-based: This form of connection is typical when the manufacturer owns the product and the consumer uses it, as in a rental, lease, or product-service deal, for instance. Here, the installed base is tightly controlled and frequently subject to contracts.
- Service contract: This kind of connection is based on a service contract that involves remanufacturing between a manufacturer and a client.
- Direct order: The consumer returns the old item to the manufacturer, who then remanufactures it and sends it back to the client (if it is possible to perform a remanufacturing operation).
- Deposit-based: This kind of connection is typical in the car sector. Customers are required to return an identical used product when they purchase a remanufactured item, serving as both a supplier and a consumer of the remanufacturer.
- Credit-based: When customers return a used item, they are given a certain number of credits in exchange. When purchasing a remanufactured item, these credits are subsequently applied as a discount.

- Buy-back: In this process, the remanufacturer merely purchases the desired old items from a supplier, who might be the end user, a scrap yard or other comparable facility, or a core dealer.
- Based on voluntary exchange: The provider offers the remanufacturer the used product. The provider does not always have to be the customer.

The buy-back process is straightforward; the remanufacturer just pays money for the cores. A core or numerous cores may be sold by scrap yards, end users, or core brokers/dealers who specialize in the trade of cores. Most remanufacturing situations involve this kind of connection, which is utilized to complement another kind of relationship. The tough to locate cores are frequently acquired in this manner. If no other options are available, buy-back is frequently seen as the final resort. One technique to purchase cores, for instance, is on a spot market; other, more sophisticated mechanisms are also employed. One option is to use core brokers, who frequently have tight ties to their suppliers, who are scrap yards. They have their own routes for getting cores and are experts in what they do. Keeping good ties with the suppliers is a crucial strategic concern. In the toner and automobile sectors, these core brokers are relatively common; a drawback might be the higher price paid (Giri, 2014)

Automotive manufacturers and suppliers are learning that mastering IT is no longer sufficient to gain a competitive edge two decades after the introduction of JIT. Automotive manufacturers and suppliers are moving beyond JIT and reevaluating their respective supply chain activities and relationships in an effort to improve overall performance as a result of increased pressure to meet annual cost reduction targets and streamline operations. This involves reevaluating who performs the value-added work as well as where and how it is performed. Automobile manufacturers and suppliers must overcome new obstacles and seize new possibilities as the structure and dynamics of the automotive industry change. Serving new markets, improving partnerships, looking for shorter communication channels, and achieving quicker new product launches are a few of these. Automotive producers want to streamline the supply chain and boost productivity. To this purpose, automobile manufacturers are

- streamlining their supply chains,
- Establishing new supply needs (such as full-service supply, global sourcing, and design for manufacturing/design for assembly),
- and outsourcing operations that formerly fell under their purview (Chen, 2011).

In a modular consortium, the module supplier is in charge of assembling the module on the assembly line of the automobile manufacturer; suppliers and automotive manufacturers collaborate closely. The modular consortium is defined as a long-term contractual relationship between the automotive manufacturer and a small number of first-tier suppliers, where:

- The suppliers assume responsibility for modular assembly, the on-line final module assembly into the vehicle, an investment stake in the operation, and management of the module supplier chain.
- The automotive manufacturer provides the plant and assembly line and assumes responsibility for plant maintenance (Chen, 2011).

Previously, suppliers and vehicle manufacturers set out distinct domains; today, the lines are blurring. Suppliers are migrating in the direction of the manufacturing region of the automobile industry as a result of greater outsourcing to the supply base. Suppliers are migrating to the

right, assembling more made or sourced parts, making them crucial collaborators in the assembly of the car. The car industry, however, is increasingly concentrating on design, distribution, retail, and after-sales service. However, suppliers can only increase their "slice of the pie" at the expense of rival suppliers: two fundamental changes in the automotive supply base are being driven by the efforts of automotive manufacturers to rationalize their suppliers, as well as suppliers' desire to increase their proportion of value added: mergers and restructuring. The transition to modular supply was first justified on the grounds of cost savings. Manufacturers gain from less inventory, freed-up floor space, and streamlined transactions, while suppliers frequently pay cheaper salaries, have lower overhead, and achieve higher economies of scale. Today, this tendency may be driven by the demand for new company development and accelerated time to market (Esenduran, 2020).

3.3. Design method

Figure 3 presents an overview of the topics covered in sections 3.3 and 3.4 of the literature review.

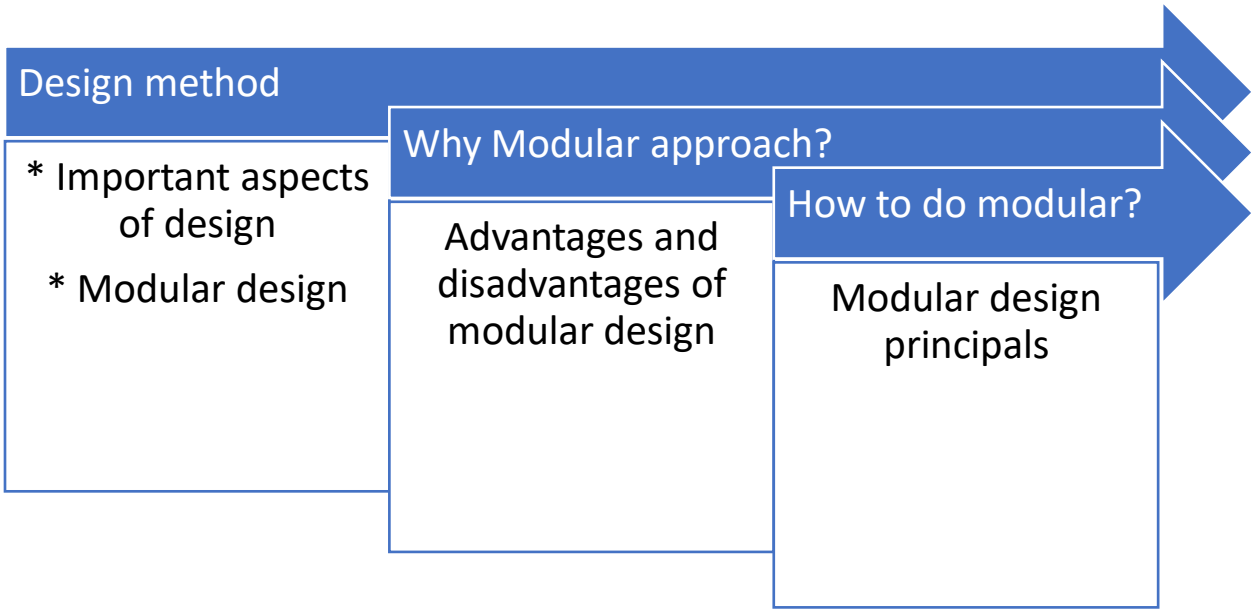

Figure 3: Design method literature review process

3.3.1. Definition

A thoroughly thought-out and well-structured process design technique is necessary for the efficient design of a sugar factory. The design process cannot be a straightforward "once-through" linear approach due to the many relationships between the various parts of a sugar refinery. Therefore, the process must be iterative in order to account for these interactions. This takes rigorous engineering judgment to make the proper assumptions and prevent overly frequent iterations of the design (Schorn et al.,2005).

A project must have a well-thought-out design that is finalized as early in the process as feasible to ensure that it satisfies the objectives for cost, performance, and timing.

Schorn et al. (2005) Further indicate that the planning and building of factories is a complicated process that calls for a diversified strategy. The kind of product being produced, the size of the facility, and the technology that will be used all influence the factory designs in different ways. Manufacturers must carefully plan and design their facility to guarantee it delivers high-quality items and satisfies client expectations. Defining the function and size of the factory is the first stage in the design process. The kinds of goods that will be produced, the size of the facility, and the workforce are all important considerations. After this decision, it is time to examine the current industrial layout and pinpoint any areas that may be improved. This can include boosting the workforce, adding more personnel, or expanding the number of machines (Iqbal, 2001).

The next stage is to create a thorough layout design for the plant. This involves drawing up a thorough floor design, selecting the required tools and technology, and choosing the ideal sites for the production and storage facilities. It's crucial to take into account any potential health and safety risks that can exist in the plant. After the completion of the plan, the factory's construction will start. This includes acquiring the required supplies, working with contractors, and setting up the required devices. It's crucial to make sure that all safety rules and guidelines are followed throughout this time. Before production can start, the factory must undergo testing and inspection to make sure it satisfies all requirements for performance and safety. A competent engineer is often needed for this procedure in order to see any possible problems and make sure the manufacturing is productive and safe (Saraswat, 2015)

Although the facility layout has been around for so many years, and different approaches have been used to make it as efficient as possible, there are still so many problems in the process and after finishing the design that need to be addressed. As the paper (Drira, 2007) mentions We have observed that the majority of published works concentrate on locating amenities. But, in reality, this issue is frequently taken into account with other design issues, such as selecting the best manufacturing or transportation resources, designing cells, figuring out resource capabilities, etc. These issues frequently don't exist in isolation (for example, the choice of a conveyor as a material handling device does not induce the same constraints as the choice of automated guided vehicles). Consequently, additional research is required to find a way to solve the various issues related to the workshop's design concurrently rather than sequentially. Such combinations, which are beginning to be handled, appear to be worthwhile and merit further development. This would encourage greater research on workshop design on a worldwide scale rather than just focusing on issues with facility layout.

Ultimately, designing factories is a complex process that calls for careful planning, research, and execution. Manufacturers may make sure their factories are effective, secure, and able to provide high-quality goods by following these procedures.

3.3.2. Important aspects of factory design

As Tisch et. Al. 2016 suggests, that to ensure that a factory is secure, effective, and functioning, it is necessary to consider a number of crucial factors. Among the most crucial factors to take into account are:

1. Workflow: Improving efficiency and cutting costs can be accomplished by designing a factory layout that maximizes throughput and minimizes the distance that supplies and employees must travel.

2. Equipment placement: To improve productivity and reduce the chance of accidents or injuries, equipment location within the plant should be carefully considered.

3. Safety: Proper lighting, ventilation, and emergency exits should all be included in factory designs to ensure the safety of both employees and tourists.

4. Sustainability: Reducing costs and environmental impact can be achieved by designing factories with sustainable materials, energy-efficient technologies, and renewable energy sources.

5. Flexibility: Since business requirements change over time, a flexible manufacturing design enables future alterations or expansions.

6. Compliance with rules: Manufacturers are required to abide by a number of local, state, and federal laws, including zoning laws, environmental restrictions, and construction codes.

7. Employee comfort and productivity can be increased by designing factories with elements like natural light, noise reduction, and comfortable work areas.

8. Maintenance and operations: While designing factories, keep in mind maintenance and operations to cut down on downtime and repair and replacement expenses.

Designers may construct factories that are useful, safe, and effective for workers and industrial processes by taking these crucial factors into account.

3.4. Modular thinking

Marinov and Marinova (2020) suggest that due to the intense market competition, businesses now produce a greater range of goods to satisfy consumer demand. Unfortunately, the installation and disassembly of components and modules are becoming more and more challenging due to the frequent variations in product requirements. So, the subject of product modular design is one that warrants attention.

In the cognitive process known as modular thinking, an issue is divided into more manageable chunks. It is a method of problem-solving that emphasizes disassembling complicated jobs into simpler parts so that they are simpler to comprehend and analyze. Recent scientific studies have revealed that modular thinking might boost overall performance and problem-solving abilities. This is so that people may break down problems into smaller, more manageable pieces using modular thinking, which makes problem-solving more effective and efficient. Additionally, research has shown that using modular thinking can inspire individuals to think creatively and innovatively by encouraging them to evaluate several options (Mutingi, 2017). Individuals are better able to comprehend the underlying structure of a problem and can develop original and innovative solutions by dissecting it into its component elements.

3.4.1. Modular advantages and drawbacks

Various characteristics and advantages of the modules have been detected. Kamali, (2017) mentions that due to the advantages offered, including shorter building times, lower prices, higher work quality, and less negative effects on the environment, modular or prefabricated construction is progressively replacing traditional on-site construction. More control over component quality and the security of the construction process is guaranteed by prefabricated construction. However, if a suitable procurement technique is not chosen, several additional issues, such as design considerations and coordination of factory and on-site operations, may be easily compromised. Kamali, (2017) also indicates that the precast members, for instance, need highly experienced laborers, more advanced processes, and a more sophisticated design in a precast concrete building. The intricate administrative labor may go unnoticed since the design experts must focus on improving the modular design. on the other hand, to guarantee that fabrication, shipping, storage, and installation happen quickly and cohesively, contractors or vendors should ideally be included throughout the design process. Only when the owner and his representatives are confident that the contractor is qualified to complete the task may service modules be employed. The ideal situation is to enter into contracts with vendors and installers who can construct and set up modules that incorporate plumbing, mechanical, and electrical components. Because of the contractor's experience, this will make project management for the service divisions simpler and increase trust in the project (Molavi, 2016).

In recent years, off-site modular construction has emerged as one of the most effective solutions for environmentally friendly buildings. The decision to choose an appropriate construction technique from among the available possibilities in a specific building project, however, is still decided largely on anecdotal information. Therefore, it is essential to assess the life cycle sustainability of various building techniques. The triple bottom line (TBL) sustainability categories, i.e., ecological, financial, and social, make up the sustainability evaluation criteria (SEC), and each category has a large number of sustainability performance indicators (SPI) connected to various building life cycle stages (Kamali, 2017).

The construction sector tends to change regularly, much like other industries. In terms of efficiency, economics, and sustainability—that is, minimizing the negative impacts on the environment—there is a rising need for the construction of new structures. Prefabrication can be used in this building to satisfy these standards. One of the prefabrication methods that is gaining popularity globally is modular building. The need for careful construction planning, the necessity for cooperation between manufacturing and construction, and the general public's and occasionally the professional public's resistance to this building technique are all described as drawbacks of modular construction (Hořínková, 2021).

Numerous benefits of modular construction, including its ability to complete projects quickly, for less money, with less waste, and so on, can significantly advance the field of sustainable building. However, there are certain difficulties with this kind of building as well, including transportation limitations, more difficult engineering and planning procedures, and the public's unfavorable attitudes toward innovative construction techniques. In order to compare the sustainability of modular and conventional buildings across their whole life cycles, an assessment methodology is necessary. It may also be used by researchers in other domains to measure the performance of a process or a product and for sustainability performance evaluation in other building techniques. This may be done by choosing appropriate criteria, assessing them, and setting the corresponding standards (Kamali, 2018).

3.4.2. Modular design principals

Innella (2019) suggests that there are various modular construction techniques, such as:

- Building entire rooms or portions of a structure off-site, replete with fixtures and finishes, then transporting and assembling them on-site is known as volumetric modular construction.
- Prefabricating walls, roof, and floor panels off-site, then transporting and putting them together on-site, is known as panelised modular construction.
- In hybrid modular construction, volumetric and panelised construction techniques are used to produce a unique solution that is tailored to the project's unique requirements.
- The use of pre-engineered, standardized components, such as structural steel frames or precast concrete columns, that are assembled off-site and then transported to the construction site for installation is known as component-based modular construction.

Guo (2004) suggests that the following details should be evaluated in the process of module development.

1. Separation of Concerns: Modular design requires breaking down complex problems into smaller, more manageable parts. This allows for easier maintenance and modification of the software.

2. Reusability: Modular design encourages the reuse of code by creating self-contained modules that can be easily reused in different applications.

3. Abstraction: Modular design involves abstracting the details of a module from its functionality. This allows for easier debugging and maintenance.

4. Encapsulation: Modular design requires encapsulating the details of a module within the module itself. This allows for better protection of data and easier debugging.

5. Loose Coupling: Modular design requires the modules to be loosely coupled. This allows for easier maintenance and modification of the software.

6. Flexibility: Modular design requires the modules to be flexible in order to support future changes and modifications. This allows for better scalability and extensibility.

The choice of approach will rely on aspects including the project scope, budget, timetable, and design needs. Each method has advantages and disadvantages of its own. Faster building timeframes, lower costs, and better quality control are just a few advantages of modular construction. There are some design limitations to take into account, just like with any building technique.

Boeri et al. (2016) indicate that working under standardized module sizes and transportation restrictions is one of the key design constraints of modular construction. To ensure their safe transportation on roadways, modules are often restricted to a maximum width and length, and the necessity to fit within these restrictions might limit the freedom of design. Additionally, the materials and construction methods that can be employed are constrained by the need for modules to resist the strains of shipping and installation. Gou (2004) points out that the requirement for meticulous planning and coordination between the design team, factory, and on-site personnel represents another design limitation of modular construction. This is so that any changes to the design during construction can be challenging and expensive to adopt as modules are normally manufactured off-site in a factory. So, compared to conventional construction techniques, modular construction needs more planning and coordination up front. Modular buildings can nevertheless offer a great deal of flexibility and can be tailored to match the unique needs of a project despite these design restrictions. It is feasible to design and construct modular constructions that are useful, long-lasting, and aesthetically beautiful by working with a knowledgeable modular construction team.

3.5. Overview

Based on the literature review and the structure of this report, the findings are presented in three main topics: Innovative projects, modular design, and circularity in the industry.

Market changes, especially due to COVID, have made companies eager to adapt and enter new markets. Innovation, as defined by Freeman and Engel (2007) involves creating new products or changing processes. Innovative projects often face challenges due to their nature, including scope changes. New ventures may struggle with market access and discrepancies between reality and predictions. Here are some key challenges faced by innovative projects using linear design methods:

- Change in scope (Blasco et al., 2013)
- Lack of prior market knowledge (Cantamessa, 2018)
- Investment problem (Cantamessa, 2018)

In many cases when the innovative project is running out of business and is considered a failure project, a big portion of the initial investment is going to be wasted. Romero-Rodriguez (2017) mentions that using the Lang factor to estimate the losses in case of failure shows that more than 75% of the investment is going to be eliminated and only equipment would have half price in the secondhand equipment market. Considering the fact that innovative projects are more prone to fail and the huge amount of waste in case of the failure, it shows the importance of finding a solution to reduce this waste. Using Circular equipment and also modular design could be a possible solution for this purpose.

Because of the mentioned characteristics of innovative projects, in this thesis, we are going to focus on applying the modular method to innovative projects. During this review, numerous benefits of modular design was mentioned, some of them are listed below:

- Shorter building time (Kamali, 2017)
- Lower costs (Kamali, 2017)
- Simpler Project management (Molavi, 2016)

Some of the disadvantages of the modular design is listed below:

- Need of highly skilled workers
- More advance process (Kamali, 2017)

Hořínková (2021) lists several drawbacks of modular construction, including the requirement for meticulous construction planning, the importance of collaboration between manufacturing and construction, and occasional resistance from both the general public and professionals toward this building technique. It shows that there is a potential for using this method, but it is not practiced in the industry yet.

In the realm of sustainability within businesses and industries, efforts have predominantly revolved around reducing CO2 emissions, optimizing raw material usage, and occasionally recycling certain components. However, there is a notable absence of initiatives aimed at recycling machinery and fostering a circular economy within this context. In the past, there have been instances where modular design principles were applied, but not with the explicit intent of reusing the equipment; rather, the emphasis was on leveraging modular thinking for various applications. This thesis takes a critical look at the applicability of modular equipment within the framework of a circular economy, aiming to bridge the gap in sustainable practices related to machinery and equipment reuse

The results of this part suggest that the industry should use modular design extensively, but this is not the practice case. As a result, in the following stages of this study, the obstacles that prevent businesses from adopting the modular approach are assessed. The possibility of reusing the modules and the reasons why it is not a common practice will be discussed in this research. Additionally, there are many different ways to reuse the material and equipment, both in contracts and the technical and engineering approaches, but in practice, there are not that many reuses in the industry.

4. Workshop

Researchers can get rich, in-the-moment insights from various stakeholders relevant to the thesis issue in a workshop setting since it provides a collaborative and participatory environment. Ørngreen and Levinsen (2017) suggest that workshops are increasingly acknowledged as a dynamic and interactive research approach, moving beyond their historical function as merely knowledge-sharing forums. Workshops encourage collaborative investigation of challenging research problems by including participants from various backgrounds, producing rich qualitative data that goes beyond conventional data-gathering techniques. Workshops offer an immersive setting that is favorable to discovering original insights, confirming hypotheses, and co-creating knowledge via interactive discussions, brainstorming sessions, and hands-on activities. Sub question 2 “What are the main drivers/functions of modular approach demanded by innovative projects and vendors?” will be discussed during this chapter.

4.1. Workshop set-up

The fact that Bilfinger Tebodin is a market leader makes it a top target for customers looking for engineering or consulting services. Numerous start-ups are attempting to employ the engineering design and recommendations of the organization due to the nature of the company and its strong reputation. Finding high-potential start-ups and actively participating in the process of concept development is one of the company's specializations. A modular approach was suggested to the possible clients during the initial stages of discussions, and two of them expressed interest. On the other hand, Bilfinger Tebodin has sister companies that are actively developing skids and modules for the pharmaceutical sector. After being apprised of the potential, a workshop was suggested in order to establish a starting point for negotiations and go forward with the business. The purpose of this workshop was to define what each party has to offer and what each of them wants in return. The idea of using the modular approach was proposed by Tebodin, so by using this opportunity, all the parties had the chance to find common ground and try to define their needs and strengths. The workshop had three main phases which will be explained in the next parts.

4.2. Participants

Tebodin Bilfinger, the event's organizer and key participant, served as the link between all of the participants. The Tebodin Bilfinger team consisted of five individuals, including two master's thesis candidates. The next participant was the German company Bilfinger Life Science, which has built and designed skids for pharmaceutical industries. There were two of them there. Then there were the two start-ups, one of which was attempting to build a pilot plant while the other was attempting to build a demo plant for their products. Both of these start-ups were working on food-related items and attempting to extract value from the waste streams of other food companies. It should be emphasized that while there are similarities between the food and pharmaceutical industries in terms of equipment and operations, there are differences in the corporate cultures and business philosophies. Bilfinger Life Science was selected due to the similarity since, although they may not be the experts on the topic, they have extensive knowledge of the procedures and practices in both industries.

Table 1 Workshop participants

Party	Background
Bilfinger Tebodin	Engineering & Consultancy
Bilfinger Life Science	Skid builder pharmaceutical
Start-up 1	Creating goods from food waste stream
Start up 2	Creating food supplies

Process engineers from both start-ups were present to discuss the potential for designing a plant for their companies, but because both businesses were still in the early stages of product development, there was a great deal of uncertainty surrounding the specifics, so everyone present decided to focus on the broad concepts and leave the specifics to later negotiations.

4.3. Workshop steps and findings

In order to create a modular design, each customer and supplier made an effort to identify and prioritize the variables that played a significant role in the success of their respective businesses. The parties were divided into two groups, the first group was the skid builders, and the other one was the users of modules which in this case are the start-ups. Then each group started to list the most crucial demands of the modular approach, At first each individual wrote down their perspective and then it was discussed in each respective group. Then in each group, the most important aspects were discussed and voted for. it should be noted that there was not any limit for these points and participants were free to choose the theme as they wanted. Then the parties sat together and talked about what they wanted out of the project, what they could offer to the table, and what they thought the other side would bring to the table. Simultaneously, each side considers the requisites of their respective organizations. Figure 4 displays the post-it notes employed for the purpose of referencing and assessing the mentioned points.

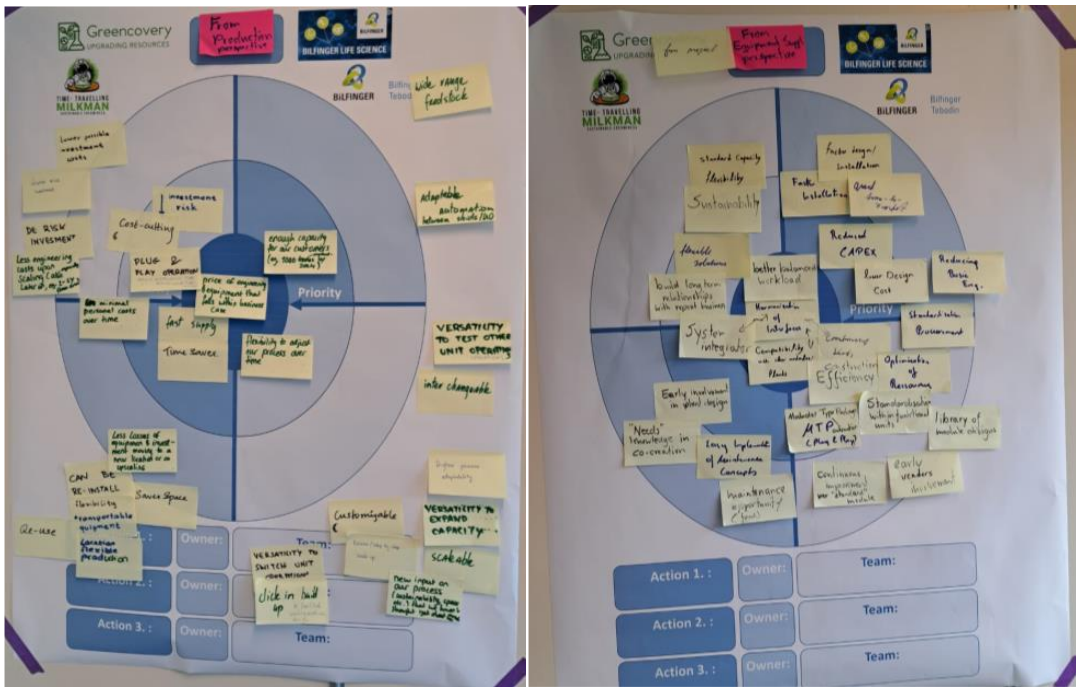

Figure 4: Each group writes down their demands in the workshop.

The top three crucial drivers anticipated from the modular approach for the Starts-ups are:

1. Time
2. Price
3. Flexibility(capacity)

The top three crucial characteristics anticipated from the modular approach for the Skid builders are:

1. Harmonizing the interfaces
2. Efficient workload
3. Lower costs

Time was the first and most significant driver that the startups mentioned. They are said to be in a highly competitive and volatile market, and time will play a crucial role in their plans. It was said that they would hope to shorten the length of the construction process by employing a modular strategy, or else they wouldn't find it as appealing. The price of the modules and how it would affect their functioning was the next crucial specification. The start-ups indicated that one of the primary factors in their project is the cost because they are unwilling to pay for new techniques without giving them value. The companies were still developing their products and unsure of the specific materials and capabilities, so they preferred to have some room for flexibility and modification in the future. The last consideration was the flexibility of the modules in case the product's capacity changed.

Skid builders had different ideas about modular design and its applications. The first factor mentioned was the harmonization of the interfaces. It was said that there are always difficulties in the creation and management of the interfaces in the factories because of the different standards, vendors, and client regulations. Skid builders saw the modular design approach as

an opportunity to create a more generic and standard interface for the control system and connections of the skids, which would make the design and preparation of the equipment much easier. The second point was the fact that it needed to decrease the workload. It was indicated that by designing a module, they would want to be able to use this design for several projects and keep the knowledge of it to themselves. It was also mentioned that in the pharmaceutical industry, they are using many skids and modules, but each firm wants to keep its own design, and it is not reducing the workload. The last point discussed was the lower costs, which are essential in order to compete in the market and would create competitive advantages over other companies.

The next step of the project was to assess the risks and challenges that may happen in the project in case of applying the modular approach. Each stakeholder listed their own risks, it was mainly the risks evolving the engineering and technical issues of the project. Then each of the individuals chose the risks that they thought had the highest impact or probability from the list that was created. By doing so the ones that were stated the most frequently were found and recognized as the main challenges of the project. Finally, a preliminary mitigation plant was suggested for each risk that was in the high impact/chance part of the diagram. Some of the main challenges that have been mentioned are as follows:

1. Incorrect cost estimation
2. Long lead time for equipment
3. Scale-up is not going to work
4. Change in market demand

These are some of the challenges that companies were afraid to face when starting the project. It is important to remember that the clients are innovative start-ups, which have their own risks and problems. Figure 5 shows the evaluation of the challenges, each one that is above the line needs to have a mitigation plan before the start of the project. (See Appendix B for additional information on this workshop)

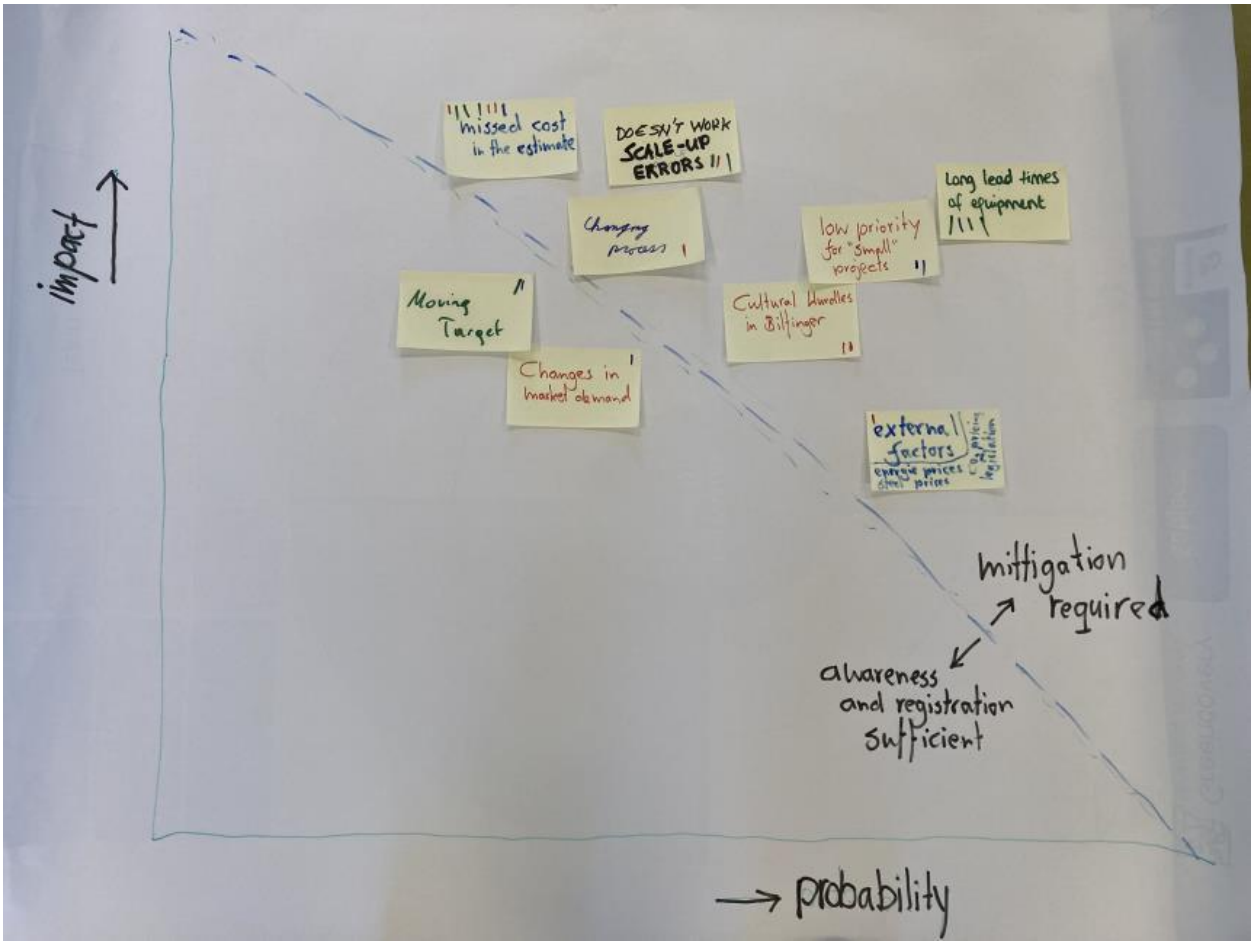

Figure 5: Position of each challenge on the impact probability diagram

4.4. Conclusions

The workshop offered a venue to consider a wide range of viewpoints by interacting with a diverse set of stakeholders, including engineers, contractors, facility managers, and process managers. These many points of view provide a more comprehensive understanding of the topic by shedding light on the subtleties and difficulties of applying modular design. Due to the workshop's participatory format, participants were able to freely express their first-hand knowledge, professional opinions, and open criticism.

One of the key takeaways from this workshop is the significant struggle that start-ups face when using the current design approach. Their primary issue revolves around the exceedingly high levels of uncertainty in their projects, making it nearly impossible to mitigate until the later stages of realization. Unfortunately, by this point, it becomes too late to make substantial changes within the confines of the traditional linear design process.

Fortunately, a potential solution to address this challenge has emerged during the workshop, proposed by other participants. Modular design is being put forth as a viable alternative. This approach has already garnered attention in the literature and has been discussed by both sides during the workshop. Thus, there exists a strong connection between industry practices and scholarly research. Some of the key points raised in both the workshop and the existing literature include:

1. Flexibility of the modules (Kamali 2017)

2. Reduction of realization time of the plant (Mutingi, 2017)

3. Harder coordination of the equipment (Molavi, 2016)

4. More sophisticated design (Guo, 2004)

5. Mobility of the plant

However, the following points were not mentioned in the literature, or the opposite was mentioned:

1. Longer lead time of the equipment, this component was not mentioned in the literature, probably because in all of the literature which was used, the scope of the project and focus of the research was on the process of modular design and modules itself, so procurement and how to manage the supply chain was not mentioned directly, however it was important for the start-ups to know that they would have access to their equipment as fast as possible because they are competing in a very fast and volatile market.

2. The higher cost of engineering and equipment was not calculated but the parties were not sure about it. Guo (2004) suggests that using a modular approach in the design would increase the challenges of design and probably would make it harder. Start-ups were concerned that this difficulty would force them to pay more for the equipment which is not appealing for them.

3. Easier workforce management, this was suggested by skid builders and was so appealing for the start-up projects but in the literature, it was suggested that handling the modules would need a more experienced and educated workforce.

The findings of this workshop help us answer sub-question 2 of this research.

What are the main drivers/functions of the modular approach demanded by innovative projects and vendors?

Shorter realization time, lower cost, and flexibility on one end, and more harmony in interfaces, efficient workload, and lower costs on the other, are the demands of the other end of this market. The project's cost is the sole subject that is raised by both parties, which depicts the importance of financial feasibility and shows that even in projects that are willing to go for new approaches and try nontraditional methods, lower costs are still the main incentive for decision-making.

5. Interviews

In this section, sub-question 3 is going to be answered.

Nine interviews with firm employees and one with a member of a start-up that required Bilfinger Tebodin to design a demo plant for them were conducted. It should be highlighted that the start-up was prepared to select the modular approach for their facility because they believed it would be simpler and faster and may allow them to develop the scale-up, so they were familiar with the subject, and they had some expectations in mind for the modular approach.

5.1. Interview questions

This interview starts with a small prerequisite, where the scope of the project and some definitions are reviewed with the interviewee Then it will follow with three main themes which (See appendix B for full list of questions).

1. Current design drawbacks (Linear design)

2. Modular design principles

3. Could Modular design contribute to circularity

5.2. Interviewees

Choy (2014) indicates that in order to obtain primary information and gain an understanding of particular study topics, interviews are an important tool. Selecting the right respondent helps to improve the research's overall quality by ensuring that the data gathered is accurate and reliable. A carefully chosen interviewee has experience, knowledge, and direct knowledge of the topic, which enables the researcher to gain insightful viewpoints and a thorough comprehension. Additionally, choosing an interviewee who is open to sharing their perspectives and is skilled at properly expressing their ideas improves the interview process and guarantees the researcher receives accurate and thorough responses. Researchers can access distinctive viewpoints, obtain important insights, and improve the authenticity and credibility of their master's thesis by carefully choosing the interviewee.

5.2.1. Possible interviewees

Gathering and taking into account every viewpoint is crucial because every stakeholder has a different viewpoint and set of interests.

Some of the suggestions for the interviewees would be as follows:

1. Bilfinger Tebodin as the engineering consultant
    1.1. Project managers
    1.2. Consultants
    1.3. Engineering staff from different specialization
    1.4. Procurement and vendors
2. Startups as probable buyers/users of the product.
3. Module designers and builders

5.2.2. Important characteristics of each interviewee

In order to select the most suitable interviewees for this research, careful consideration was given to the following characteristics of the interviewees. Abiding by these criteria, several individuals were invited to participate in the interview sessions, ultimately resulting in the completion of ten interviews. The following question were evaluated about each interviewee:

- Background of interviewees
- Work experience
- If they were involved in a related project
- What is their position in the discipline they are working
- Are they Part of the Tebodin or possible Client

The following are the expectations of the interviewees, candidates with more of these qualifications were more appealing for the interview and the project:

- Having experience related to modular design
- Being involved in a specific modular design project
- Having management experience with modular projects
- Being involved with circularity both as a consultant and as an engineer
- Having a strong overview of the process of design
- Being part of the project management and decision-making in the company
- Being part of the sales and procurement team, which has a good connection with different suppliers and clients
- Having experience with innovative projects and projects in which they need to adjust or shut down their plant and they are going to have difficulties with the investment.

5.3. List of interviewees

Table 1 provides a roster of participants involved in this research. The individuals are identified by numbers ranging from one to ten, as their names are not disclosed for confidentiality purposes. Each interviewee's profile is succinctly introduced within the table. Notably, the numbering sequence was conducted entirely at random and is unrelated to the interviewees' attributes or contributions.

Table 2: List of interviewees

Interview No	Company	Title	Level of experience	Experience with Modules	Experience with Circularity	Additional information
1	Start-up	Process Manager	Low	No	No	Developing a demo plant using modules Process development Scale-ups
2	Tebodin Bilfinger	Procurement management	High	No	Yes	Navy design experience Project decision making Vendor management
3	Tebodin Bilfinger	Process control	High	Yes	Yes	Work experience with different instruments Knowledge about wind turbines
4	Tebodin Bilfinger	Sales manager	High	Yes	Yes	Technical and Commercial roles Energy efficiency
5	Tebodin Bilfinger	Department manager Piping	High	Yes	No	Project management experience Pharmaceutical industry
6	Tebodin Bilfinger	Architect/Civil designer	High	No	Yes	Experience with site layouts Spatial planning
7	Tebodin Bilfinger	Asset management consultant	Medium	No	Yes	Estimating project expenses Prediction about projects
8	Tebodin Bilfinger	Process and energy group manager	Medium	Yes	Yes	Familiar with start-ups Work in several industries
9	Tebodin Bilfinger	Consultant for industrial sustainability	Medium	Yes	Yes	LCA and CO2 reduction projects Proposed Reusing the equipment
10	Tebodin Bilfinger	Process Engineer	Medium	Yes	No	Planning and execution experience Familiar with several industries

5.4. Thematic analysis

Nowell et al. (2017) indicate that thematic analysis, which involves meticulously identifying, evaluating, and interpreting patterns or themes in qualitative data, is a popular qualitative research approach. Castleberry and Nolen (2018) suggest that this type of analysis provides researchers with a flexible and systematic means to organize and understand challenging data sets, such as transcripts of interviews, discussions from focus groups, or written materials. Iterative steps in the process of doing a thematic analysis include familiarizing oneself with the data, developing rough codes, searching for themes, reviewing, and fine-tuning themes, and offering a final analysis. Due to the workshop, there was a strong awareness of the themes and general components of this research that would be discussed in the interviews. To make sure that all of the information is accurate and that all of the points have been made, the interview texts were reread and cleaned up in the first step.

5.4.1. Deductive approach

Furthermore, as the background context and the assumptions underpinning the data can be a rich source of information about the processes and approaches investigated in this master's thesis, it is preferable to look for the latent rather than solely semantic meaning in the data and quotations.

The four processes of thematic analysis, which were used to analyze the information gathered from interviews for this thesis project indicated by Nowell et al. (2017) and including some adjustments Castleberry and Nolen (2018) indicated, are as follows:

1. Familiarizing yourself with the data: The raw data was transcribed into a text file, and then it was cleaned and then re-read to gather all the information and important parts were marked in order to be used in the future.
2. General initial codes: After finding the whole idea of the interviews, then the most important codes in the interviews and the most observed points mentioned by different interviewees.
3. Searching for themes: In this step, themes that have been found in the interviews and themes that were anticipated because of the literature are compared and would help to create the final list of themes and sub-themes of the interviews.
4. Giving the report: Using the themes and the rate that different themes and sub-themes have been mentioned, a report of the interviews and its most important aspects are given.

The deductive approach in theme analysis is the process of using pre-existing theories, frameworks, or research questions to guide the interpretation of qualitative data. When a particular research problem needs to be solved or when an effort is made to test or validate pre-existing ideas or views, this technique is usually used (Pearse, 2019). There were numerous themes and broad phrases in this research that were inspired by literature or workshops. For this reason, a logical strategy has been used. The following were the primary themes that were intended to be looked for in the interviews:

1. Linear design drawbacks

2. Scope definition

3. Reliability of the current method

4. Modular design potentials

5. Technical obstacles of modules

6. Technical obstacles of circularity

Although these themes served as the primary focus of our interviews, there were some extremely significant additional characteristics that were discussed. The following are the major subjects that were raised:

1. Possible changes in the design method

2. Cultural obstacles of modular design

3. How and where to use modules

4. Usage of second-hand equipment

We could have added more sub-themes in this stage, but some of the observations and points made in the interviews, while still important, were outside of the scope of this study, so we won't go through them all.

Reflecting on the interview questions, three main themes have been chosen, and each of them has their own sub-themes. The main themes are as follows:

1. Current design method
2. Modular design
3. Circularity and reusing of equipment.

Table 2 shows the main themes and sub-themes of the thematic analysis.

Table 3: Main themes of thematic analysis

Theme	Sub-theme
Current design method	• Linear design drawbacks • Scope definition • Reliability of current method • Possible changes
Modular Design	• Modular design potentials • Technical obstacles • Cultural obstacles • How/where to start modules
Circularity and reuse	• Technical obstacles • Usage of second hand equipment

These themes were used to analyze and identify the key takeaways from the interviews.

5.5. Interview results

Based on the interview's questions and also the main themes from the thematic analysis, this section is also divided into three parts, The first would be the design approach changes, where the drawbacks and necessity of the change are evaluated, and what is needed to be changed. In the second part, there would be a modular design part, in which the applicability of modular design and how to address it in the industry is mentioned, and the last part would be about the circularity and if modules contribute to it and how it would be happening. During this section, we are mentioning some of the most important notes and quotes of interviewees as well.

5.5.1. Design approach changes

One of the inquiries during this investigation was about the need for an attitude toward change. Finding the flawed strategy and trying to develop a new, better technique would be one of the key elements in the transition to a circular world. The shortcomings of the existing design methodology have been discussed throughout these interviews. Some of the participants felt that it needed to be changed or at the very least rectified because of some flaws, while others felt that nothing needed to be changed because the current system is operating just fine. The following are some key points concerning the current design:

Interviewee No2. mentioned that the changes in the design are not always linear, which makes it a little bit hard for future expansions or changes in the future of the plant. He mentioned, "Extending the current situation by doubling the production for instance could not be linear as expected, so it's as much flow could be rapidly three times increases of pipeline systems". It shows that this method of design might be useful for a defined task, but it is not flexible regarding the changes or expansions in the future. Utilities and connections between equipment would face drastic changes. He also mentions the problem with new technologies evolving in the industry. He thought that fitting the new technologies in the plants, after the design is over would be hard and take so much effort and time, as probably the whole design should be done again and from scratch.

Interviewee No.3 also thought that there are some problems with the current method, he mentioned that in the current regime, the client would define the scope and then ask the company to develop and design a plant for them, however, there is always some problem with scope definition and also there is always changes in the scope throughout the design and realization phase, these changes are hard to address while we are going to design and build the plant using a linear approach. He said, "The drawbacks are currently that, it's very difficult to do a correct estimate for our work because what we see is, currently customers are having difficulties to predict very clearly, what the scope of the work is and what the scope of services are". He also mentioned that in some cases the client leaves the scope definition to Tebodin, which also has its disadvantages, as Tebodin is not an expert in the field that the client is working, and if there would be a change or misunderstanding, then they need to charge the client more. He suggested that you should not start a project when you do not know the scope of the project, but at the same time, he is aware of the changes in the market and the importance of starting as soon as possible in order to compete with others.

Interviewee No.9 talked about the importance of sharing in the process of design. She mentioned that there are some activities that are related or almost the same in different projects, but because it is done for each project Individually, then in the company two different teams are

going to do the same thing, without knowing that there is another team that is doing the same, and this is a huge waste of resources both for the client and for Tebodin. She mentioned that it should be in a way that we do the engineering and design as little as possible and then try to share the knowledge within the company in different projects and disciplines.

On the other hand, interviewee No.6 said that this process is seen as a linear approach but in reality, it is not a linear approach but, it is a feedback perspective approach, where in each step, Tebodin and clients are communicating about the scope and changes and needs and improve the design step by step to create a better outcome. He also mentioned that this method is working smoothly at the moment and has been working for many years in different companies and there is not a need to change it. He mentioned his experience with this method in different firms and that it is working just fine. Interviewee No.10 has the same Idea, he mentioned that there are no visible drawbacks at the moment, and the system is working fine so there is no need to change it.

Overall from the ten interviewees, six of them thought that the current method has some drawbacks whereas four of them thought that the system is okay and there is no need to change it. Of the six opposing the current design method, five of them mentioned that this method is not flexible enough and that this method cannot adapt to the changes in the future. Three of the participants also talked about the scope definition and its importance in the industry. Figure 6 shows the proportion of people who would like to see a change in the design method.

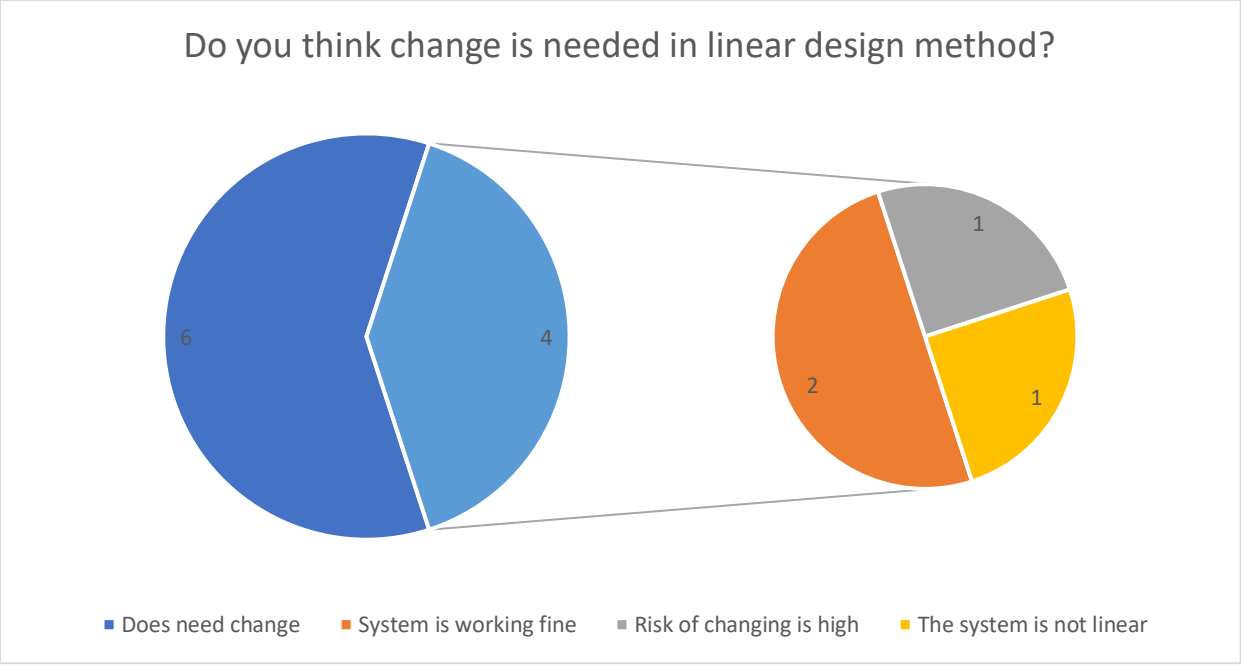

Figure 6: Responses regarding the change in the current design method

An additional noteworthy aspect within this section is that most of the opposing views said that you cannot change the design afterward, and you are prone to changes in the future, but there is one interviewee who mentioned we can design with the possibility of expansion in the future, and of course it is going to cost more for the client. As he is an architect, the contradiction here

is because he was mentioning different assets, We can design the building for the changes and expansion in the future, but for the mechanical equipment it would be hard, and we are unable to change the volumes and capacities easily. last important point to mention is that one of the interviewees mentioned that if you do the design with the traditional model, and finish everything and then the project is canceled for any reason, you are stuck with design, and if the realization happened and then the project is canceled, there is no other use for the design and the plant, and most of the resources if not all of them are going to be wasted. Figure 7 shows the most mentioned problems of the current design method.

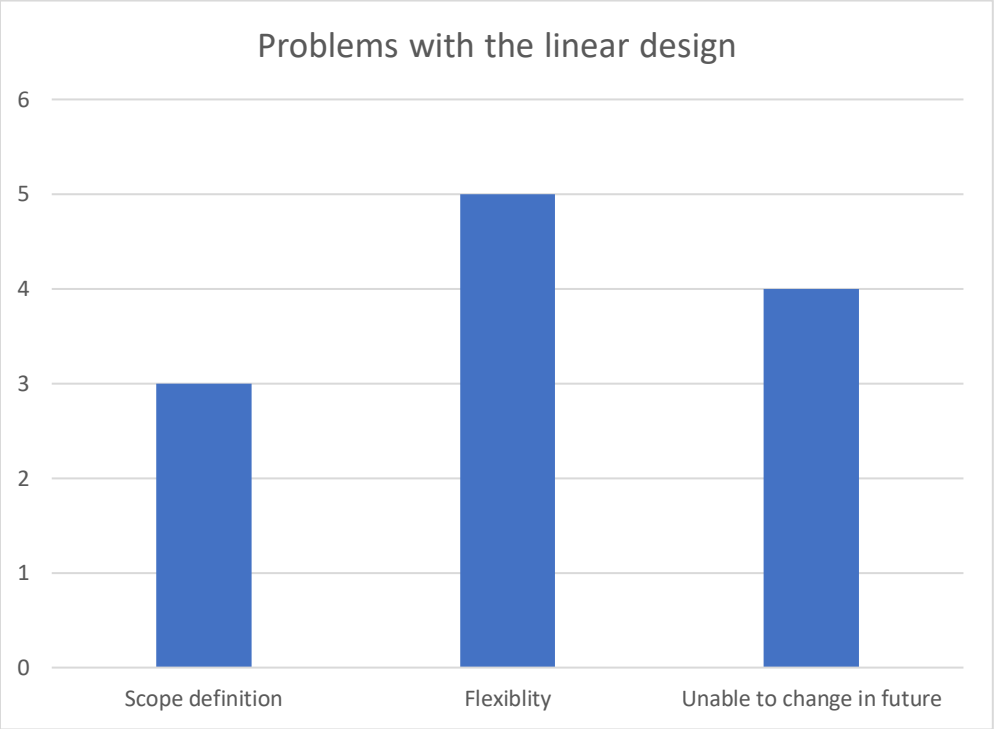

Figure 7: Problems with the current design method by the number of participants

Possible solutions were also asked during the interviews, of how to improve the current method or change it in a way that the outcome would be better. Some of the solutions are mainly focused on current problems and some are steps into new methods.

Interviewee No.1 mentioned that connections and automatization of the equipment play a very important role in the design of the plant, if we could improve the automatization then the equipment would be more useful in different scenarios. Also, in case of improvement of automatization, fewer workers are needed on site, which is a benefit for the client. Interviewee No.2 talked about the maintenance and mentioned the accessibility of the unit. He said “If you look into a container, then you can have a box container with only a door at the front. But if you have to remove something from out of the back side of the container, it takes a hell of a job. But if you can have an openable roof open-top container, then you can easily access it from above without destroying, or dismantling all the equipment in front of it”. while interviewee No.4 mentioned the possibility of finding new customers for the designs, which would be a big step toward reusing the engineering and design force.

Although there are some similarities in the solutions suggested by interviewees there is not a single solution that all of them mentioned or that they all somehow agree about, so some of these solutions are just mentioned here:

1. Automatization of machines
2. Accessibility of units
3. Getting involved in scope definition
4. Including environmental acts in big projects
5. Share details in different projects

Also, four out of the six people mentioning the changes, thought that it is necessary to convince people that change is necessary and to make them believe that there would be benefits for them in case of change. Otherwise, everyone is just going to repeat the tasks as they were doing and there would not be a change in the design methods.

5.5.2. Modular design

This section presents thoughts on modules and modular design as well as the key elements of the design. The first section discusses the benefits and values that the modules would offer to the projects, followed by a list of the top qualities that a module must possess to be considered as a design option. Then some of the obstacles that are keeping companies and engineers from using this method are discussed. The usability and availability of the modules in various projects as well as various project processes are also highlighted.

Interviewee No.1 mentioned costs as one of the main drivers of the decision-making, as he is working in a start-up, and expenses are so important for them. He mentioned that the reason that modules are considered as an option is that there would be a lower cost in the investments. On the other hand, Interviewee No.6 suggests that the modules and equipment should be demountable, so the option of changing and moving would come by using the modules. Interviewee No. 7 mentioned that by using modules one can use the same equipment and modules to create or build a factory in another country, although he also acknowledges the differences in the regulations and laws that may create some sort of problems.

Nine out of ten of the participants mentioned the technical difficulties regarding designing and using a module. Three of them mentioned that scope definition and the quantity in which the modules are going to be used are very important. Two of the interviewees mentioned that the size of the modules is very important as they should be transportable by truck, and also it should be In a way that you could move and install them on site. Interviewee No.5 said “The vision that we have is few boundaries, it must be transportable, fit on a big truck, 20 ft container, that is one of the limitations when you start designing. You have to make a decision in the automation part, where to put it, Will it be an automation cabinet per module, or for the whole plant, also Is the module going to be inside or outside, Is it going to be exposed to different chemicals, sea climate and especially when you look at the mechanical piping, and connection between modules there would be a problem, when you have big diameter for pipe, then your bends and valves and controls need to be reachable for maintenance so it is harder to build because you cannot make it too compact. When you have a big factory, you can have a good design easily in the space. Stress analysis could be difficult, there would be too much temperature difference and there would be expansion in the pipes that would create tension in

the pipes. and pressure, so there would be harder work to be done. It should be checked if it would be constructable". Figure 8 shows the overall opinion about the technical obstacles in creating a modular platform.

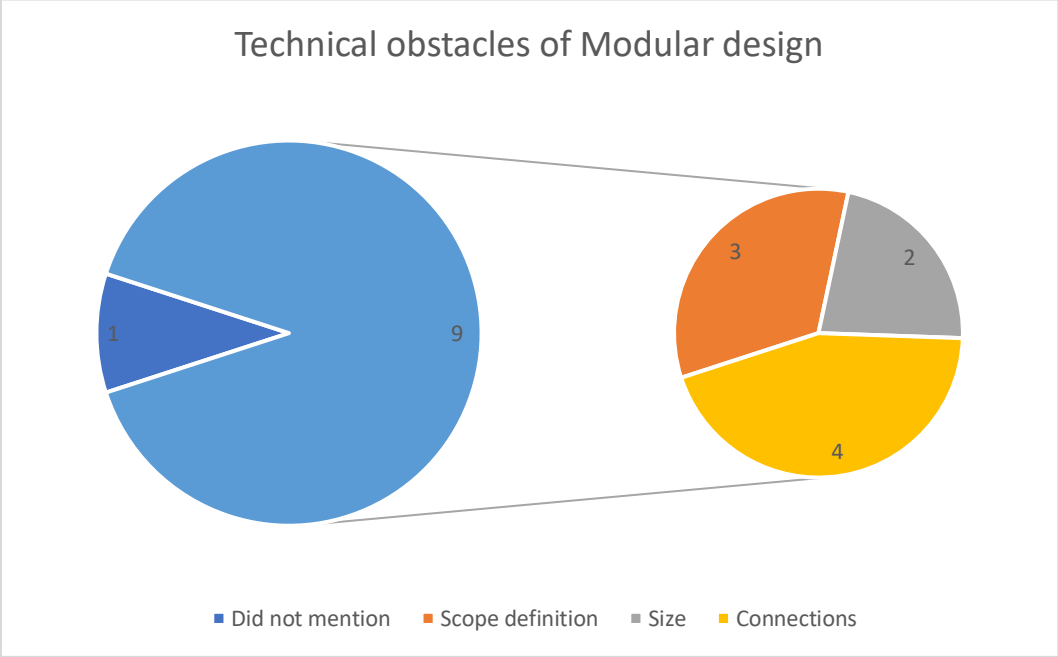

Figure 8: Technical and engineering obstacles of using modules

Interviewee No.8 mentioned that designing a module is the same as designing any equipment, but the boundaries and boundaries definition make the difference. How we are defining the module's borders and how we are going to connect them. 4 of the participants talked about the connections between modules and how it would be a very important aspect of the design. Also, three of the participants talked about the automation of the modules. This point is so important as it was one of the main aspects discussed during the workshop as well. Interviewee No.1 mentioned that ", in a plant, the more automatization the less labor intensive, and more stable process you have. In theory. So that you have separated pieces of equipment and of course you can control them independently, but they don't work as one".

One of the other obstacles to using the modular method is the organizational culture difficulties in the company or collaboration with the clients. Nine out of ten interviewees mentioned that the reason for not applying modular design or in general any new technique is the fact that people are reluctant to change. Five of the interviewees mentioned that it is going to be hard to convince the clients, and you should show them the value and also make them feel safe about using this new method. Interviewee No.4 suggests that "part of this the study would be what would be the impact on the customer, what would be the value of the customer because, without any value for the customer, it will be very difficult. So it could be for example, that global players like Shell or Huntsman or whatever company says, well, that's interesting because then that offers me a certain flexibility in assets around Europe, but it should not be always around the globe. But I think clients with multiple sites in let's say Europe or in the Middle East could benefit or similar sites could benefit from this approach". So we can see that it should be somehow valuable for each client, and because of the different advantages and specialties of modules, we could say that each client needs to be convinced by their own added value, and a single rule is

not going to work for every company. In addition to convincing the client, four of the people mentioned that engineers and project managers are now willing to risk implying a new method, while the old one is working and the client is happy with the result, so unless the client would come up with a modular design need, then nobody wants to change the paradigm. As interviewee No.10 mentioned that “They want the usual way of working, they go and talk, and they say why are you doing something different? And they need to check with supervisors. There would be a guy in the million-dollar company that there would be difficulties that there would be a new play. They don’t want to change anything by themselves so there would be some talks with higher-ups”. Figure 9 shows the opinions of participants about the cultural obstacles that are keeping companies from moving toward modular thinking.

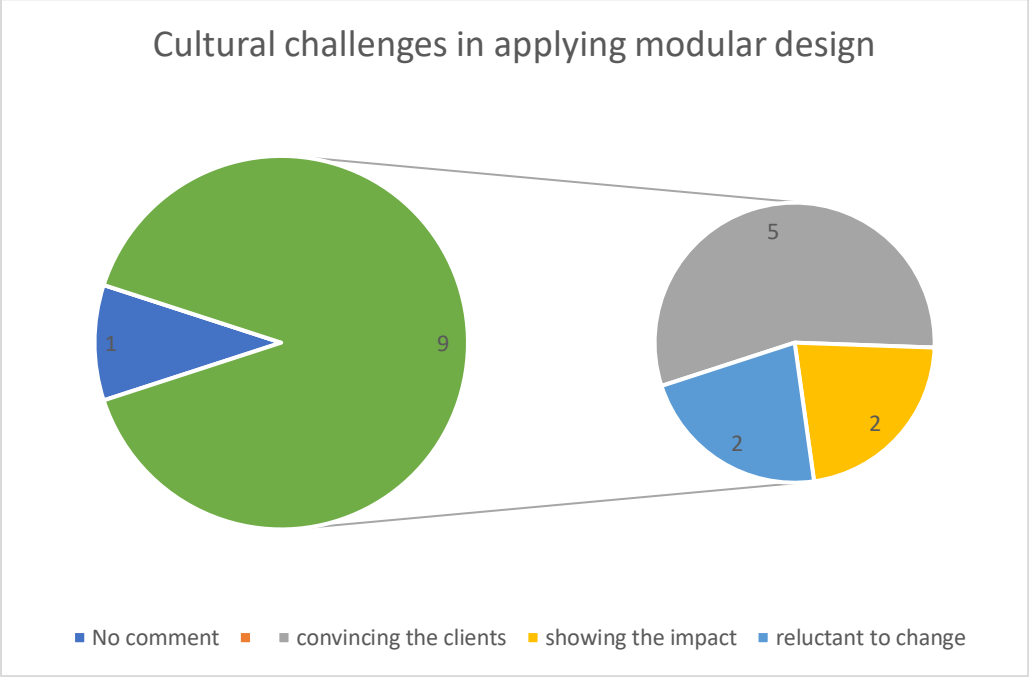

Figure 9: Cultural obstacles in using modules

Seven out of ten participants talked about the overestimation of the modules. It is one of the most important aspects in the design process as it would cost more for the customer to have overdesigns. Also, as a matter of fact, we know that when there is standard equipment there is always some level of overdesign and overestimation. All these seven interviewees talked about the importance of overestimation and how there should be always room for the adaptability of the equipment. Interviewee No.4 mentioned that “you want to take a certain level of flexibility regarding products and Volume of products produced into account and I think there comes the complexity of the modules. for example, if you talk about energy, which I have a background in energy installation, steam, boilers, cogeneration, and compressors are very suitable to put in a container and make some kind of module with it. Air treatment, water treatment, or pretreatment. So that is plug-in and okay. that is what you see already because if now we call some kind of rental company for Steam boilers, we could have perhaps tomorrow already 20-ton steam boilers on site. So perhaps it's not about eating the complete elephant now regarding modular design, but to start to see which systems or which parts of the plant could be modularized”. It shows some level of overdesign and overestimation is acceptable in the industry while it should be on processes that are less tailor-made and are more generic. Interviewee No.9 suggests that

you should include or at least try to include the level of uncertainty that the module would bring into the project. She said “Because if it's module there then one can enter parameters and get output. That's how I imagine that, if you change the input to be reasonable You can also see the output and you can see the difference in how much it changed so in the end the reality will be in between. If you choose the low range, it's going to be lower, and if you choose the high range, it's going to be higher, and the reality will fold. You know for sure it's somewhere in between. I mean, if there are not too many parameters to choose, they can see the comparison. Maybe that can help, but I don't know if there are a lot of them. You cannot see all the sensitivities on each other. They say there is one big item that is changing a lot. Let's say the biggest contributor, and then you can see that if you were assuming a lower range because you have to, then it adds 20% more to the cost if you know how much it is, is it 50%, is it 5%, is it 10%? Then people can keep in mind that this is the right one, but they're not small ones. Maybe the big ones? I'm thinking something that is some sort of indication because them, otherwise they say this is inaccurate instead of saying inaccurate or not inaccurate Just saying that this is the assumption and this is the more or less the impact of it It's in the 20% range, so they say, OK, we don't talk about 150%”. We can see that it is important to be specific about the level at which we are going to increase the costs with overdesign and also define to what level the modularity would cause overdesign. Figure 10 presents the numerical data reflecting participants' mentions of common challenges associated with module utilization.

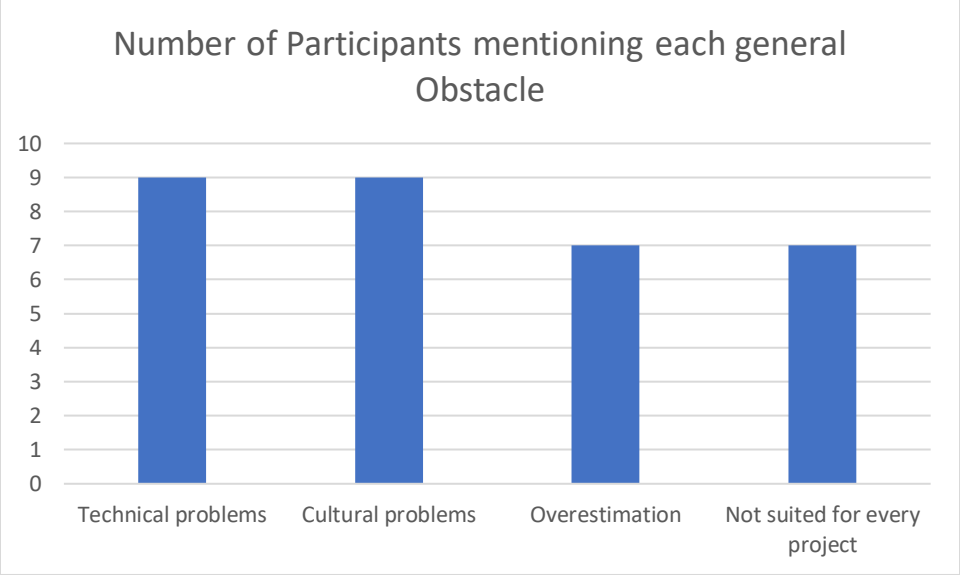

Figure 10: Percentage of participants who mentioned each type of obstacle

Seven out of ten of the interviewees have mentioned that modular design at the moment is not suited for every project and process and it needs to aim at a certain group of projects in order to be more successful. Three of the participants mentioned that a demo plant would be a perfect example of using modular design, as they are mainly smaller, and have a shorter lifetime, and it would be okay if demo plants are not tailor made or completely efficient. Interviewee No.8 suggests that “In that way, the only companies that I do see use it more would be like startup companies You're working on a pilot plant or demo plant because they're more open to taking risks”. Also, two of the participants suggested that using the modules in non-crucial parts of the projects would reduce the risk and would encourage companies to test the new model. One of

the other purposes for the modules is to use them in more generic pieces of the process like steam boilers or generators or equipment which are used frequently in different processes and projects, in this case, it would make It easier to design them in a generic way and a smaller amount of customization is needed. Also, Interviewee No.4 suggests that leasing the modules would be a helpful act in order to encourage companies to use modular design in their demo plants and to increase the lifetime of equipment which are used in demo and pilot plants.

5.5.3. Circularity

In this part, participants' opinions about the circularity and the contribution of the modules to the circularity are discussed. Eight out of the ten interviewees thought that using modules could be a method for reusing the equipment, however, they mentioned that only being modular is not enough to create the possibility of reusing the equipment but there needs to be some other criteria as well.

Interviewee No.1 mentioned that it is very important that the modules which are going to be used in a new plant, have the qualifications for the process. For instance, in the food industry, it is important that all of the equipment is food-grade, and do not have any chemical contamination. Interviewee No.5 added “But you need to be careful about the compatibility with the new plant. Especially in the chemical industry, they would not be used because of the contamination. It depends on the process. For pharma and food, it would be more expensive to get the certificates and hygienic design, so there is mostly new equipment used”. So from a financial standpoint, it would not be that easy to convince the clients to use second-hand equipment in these industries.

Five of the participants mentioned that in order to increase the life span of equipment, you need to change the design and maintenance, so in the design phase, using high-quality materials, and creating a more durable design, but that would not be enough, there is always a need for good maintenance. Two of the interviewees suggested that giving a guarantee or warranty to the client, that the equipment is going to work for a certain amount of time, would create a better chance of reusing the equipment. but to do so three of the interviewees recommended logging all of the data regarding the maintenance and overhaul of the equipment. interviewee No.8 mentioned “I think you need to have a good maintenance plan. Proper and good registration of the maintenance that has been done so you can show that the next user of the module that we checked every year, is the thing that we fixed. just almost like when you buy a second-hand car. You want to know what happened before”. Figure 11 shows what were the main concerns of the participants in order to use the modules again after it is no longer used in the first plant that had been designed for.

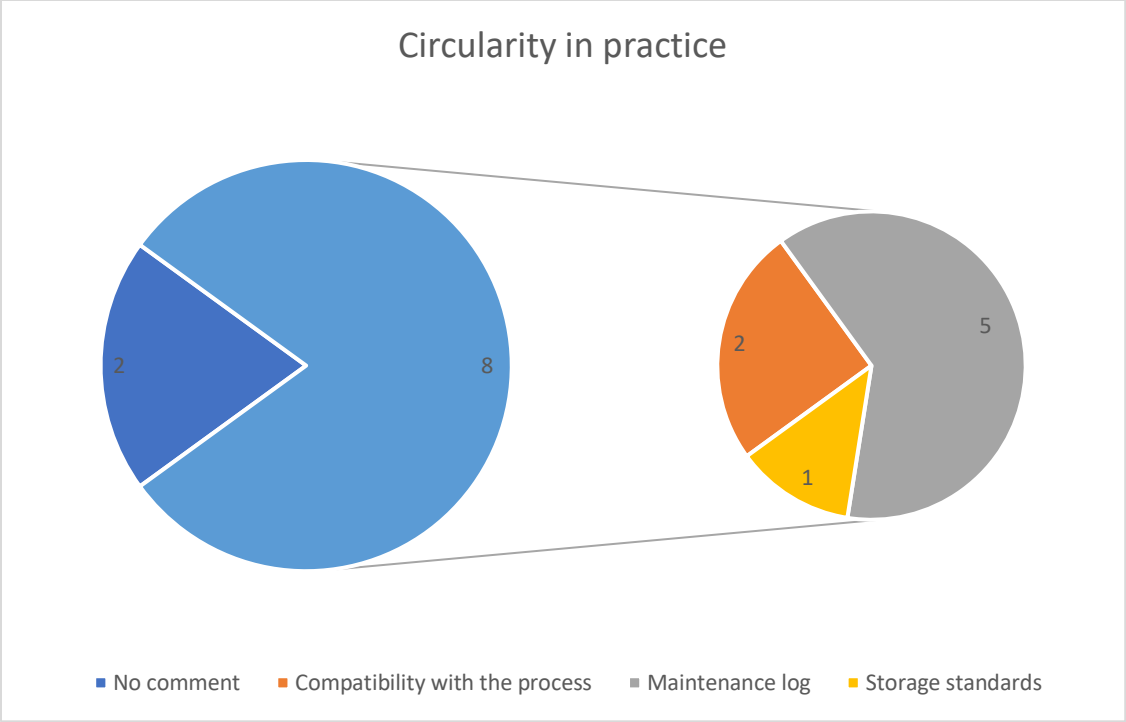

Figure 11: Participants opinion about the circularity in the industry

Although most of the interviewees agreed that modules could be reused in theory, some of them mentioned that it is not that easy to apply in reality. They mentioned that it would take so much money to maintain the equipment, it would be hard to use the connections and the control systems are not going to be compatible with the new process which would cost more to prepare and change. Interviewee No.6 suggests that designing the modules with the purpose of reusing them, would take much more time and would cost more for the companies, while there is not a potential buyer for it, so it would make it harder to commit to the companies. Interviewee No.3 added “That's of course by delivering quality and by Using materials that have a certain lifespan mostly that means that you're also going up in price, there should be a balance. And so yeah, you can make a Rolls Royce, but you will never sell it. So, you better go for the VW”. So it is important to keep the modules competitive and not to make them unable to sell. Interviewee No.2 suggests that there would be a system where you can rent a new module in the duration of maintenance of the faulty one, just like renting a car while your own car is getting repaired. By adding this option, companies are willing to use modules so they would fact much lower shutdown time in their plant and they would reduce the losses.

Interviewee No.9 had an interesting experience with reusing equipment, she mentioned that “What I remember from the previous discussion as an example for one company, for instance, management was trying to make a new project in a new plant and it was costing a lot of money because it was a new plant and then someone came up with an idea of we can reuse these three big equipment with another plant and it will suddenly reducing cost for a million or so. But they disagree with it. they said it’s not going to fit. You need to clean it. It's going to cost more. They think it's going to cost more and there will be a lot of hassle. And maybe it's not going to be as efficient.”. We can see that because it is not a common practice in the industry and the

storage and keeping situation of the old equipment is not that good, reusing them may cost the company and they are not willing to risk it.

One of the main importance of reusing the equipment is the fact that it is almost impossible to change the already built plant, so the aim of reusing the modules would be for the newly built plants that are suitable for this purpose. Interviewee No.8 suggests that we cannot change the linear plants as they are tightly built together, and all of the design is specific for that exact plant.

Some of the other points mentioned about the circularity and reuse of the material are listed below.

1. It should be noted that if modules are going to act as spare parts, then there is no advantage in using modules rather than the traditional way, so it should be in a way that reduces the maintenance costs and increases the efficiency of the plants.
2. Naming the procedure is also important, it would be appealing for some companies to be sustainable or address the circularity, but if it is presented as second-hand equipment then they are not willing to use the equipment.
3. One of the main goals of circularity should be the reduction in the engineering work of the firms, so it would be important to keep the designs and share the data and knowledge acquired between different projects. Although it would be a nice idea to share between projects, sometimes clients are not happy with doing so and want to keep the design as their Intellectual property.
4. The uptime of the equipment is far more important, rather the price, so the provider of modules should guarantee that the equipment is going to work for a reasonable duration and that there would not be higher than normal rates of failure.
5. Spatial planning and the weight of the modules are very important, most of the time the transportation is okay, but on the site, there are not enough tools or space to move and connect the module. In some cases, you may need to use the height of the building in order to fit the modules which is practical but may cause more safety and regulations cost. Also, the buildings should be compatible with modules, so equipment could get in and out easily.
6. It may help to involve every stakeholder in the process so that each of them sees the effects of reusing the modules and understands the environmental act behind using them.
7. At the moment the main focus of the companies is to control the CO2 emission of the projects and to reduce the LCA costs of it. so, in the current situation, it would be a little hard to persuade companies to include circularity in their design as well, However, if the regulations change, or some force from the third governmental parties is applied, then there could be a chance that companies start to evaluate this option as well.

5.6. Results overview

Sub-question 3 of this research is answered in this part. The first part of this question, "What are the criteria in the modular design?" is addressed in this chapter. Using the information, we are also able to provide some suggestions for applying the modular way of thinking to the projects that are discussed in the following chapter.

Some of the main characteristics of modules mentioned by interviewees are as follows:

1. Flexibility of modules
2. Unlinear relation of capacity and size
3. Size of the modules (both for transportation and realization on site)
4. Demountable connections and fixtures
5. Compatible connections
6. Their control unit

The overall findings of these interviews indicate that nine out of ten participants believed that employing the modules at this time was at least somewhat probable, but it was not practicable owing to various challenges. But everyone in our study group agreed that, in a perfect environment, modular design is one of the finest methods for creating and running a factory. Six of the ten interviewees said that we must gradually transition to new ways in order to both address the issues and boost the circularity of our projects. Four of the interviewees said that the current approach is totally functional and that there is no need for change at the moment.

When the interviews were analyzed, it became clear that nearly no one was interested in using the modular architecture for the entire project. The concept was that we needed to focus on more general and straightforward procedures and tasks in the project since we could not now apply this strategy to the entire plant. Participants may have had various justifications. It would be simpler to implement, and the risk would be decreased to a manageable level, making it practical. Another crucial aspect brought up in the interview was that there is now no reason to change, thus individuals are unwilling to take the risk of switching to a new design methodology. Companies, their engineers, and consultants are unwilling to incur the personal risk of implementing a new approach where they cannot see the results because the current method is effective. The last point made was that modularity and building a large bank of modules actually amounts to producing a good at a time when there is no market for it, which is currently unacceptable for any profitable organization. Therefore, even though it appears to be okay on paper, businesses won't change their behavior until a necessity arises or the law is altered.

The last part of the results covers the reuse of the equipment; here, the responses varied the greatest, making it challenging to determine the appropriate course of action. Nevertheless, it was conceivable to categorize the responses into two broad categories: reusing the material as is or building a sizable storage facility and attempting to use the leasing approach to address the circularity. The first part of the presentation focused primarily on the technical aspects of extending the technical life of the equipment, such as keeping maintenance logs and developing routine inspection and maintenance plans, while the second part focused primarily on how to change the industry's paradigm and culture. So that businesses would attempt to incorporate circularity into their designs.

6. Proposed Solutions

The answer to sub-question 3, "What are the main criteria in proposing a modular design?" will be given in this chapter. Several modifications and models based on the results of the interviews will be suggested in this chapter, and their viability will be examined in the following chapter.

Several solid and efficient solutions were found to solve the underlying difficulties after conducting in-depth interviews and carefully reviewing the data collected. The interview results have highlighted important areas for improvement, and the suggested solutions are crafted to address these particular problems head-on. The suggestions generated from the interview findings can hopefully open the door for a more effective, fruitful, and peaceful workplace as we move forward. In this chapter three parts of the problem will be discussed and for each part, solutions and suggestions are made.

6.1. Design approach changes

In this section, suggestions are made in order to solve the problems with the challenges of the design method. In this section, we do not merely present the words of excerpts from the interviews. Instead, we rely on the writer's interpretation of the insights gathered from the interviews, as well as insights derived from relevant literature and workshop, to formulate and propose solutions.

1. Share the information and design between different projects

Interviewees no.1, no.4, and no.9 suggested that there are similarities in the projects that teams and project managers are not sharing inside the companies or between different parties. According to the present linear technique, the information and experience that are acquired throughout the course of a project are typically retained within the project, and the majority of the time, various people who are working on different areas are not aware of the other groups and the issues and hurdles that they face. There is always the possibility that many teams will attempt to find a solution to the same problem for various projects on multiple occasions. It is recommended that a system be developed in which the data and expertise gained throughout the projects are shared, and various forms of collaboration across the teams are encouraged, in order to stop anything like that from happening.

2. Find new customers for the designs

Korhonen et al. (2018) indicate that the economic objective of a circular economy is to reduce the economic production-consumption with multiple approaches one of the approaches is having a cooperative and user group using the value, services, and functions. Interviewee No.4 also mentioned that there is a high chance of sharing some of the designs between multiple customers. Interviewee No.6 indicates that their similarities between designs in different projects. Having several clients who all use the same design is one of the most unique takes on how to go about utilizing the design that can be taken. At the moment, every company plans on developing its own design from the ground up and hopes to retain ownership of the intellectual property associated with the design. As a result of this framework, the intellectual property would be retained by the team that was responsible for the design, and the team could continue to develop the design while also utilizing it in new contexts. If this were done, then the additional value that the design brought to the project would be preserved, even in the event that the project was ultimately unsuccessful.

3. Getting involved in the capacities and calculations

Saraswat et al. (2015) suggest that an effective configuration of the design can lead to a significant decrease in the initial investment as well as in the ongoing operational costs. Interviewee No.5 suggests that if the consultant company gets involved in the design process it would be beneficial for all the parties, Interviewee No.7 indicates that the design method is not completely linear, but it is a responsive method which in each step would be redirected. There is no way for the consultant business to review and analyze the methods that are being used in the project because the existing method involves obtaining the information from the customer and then beginning the calculations based on the data that has been provided. The companies are not discussing the specifics; instead, they are only discussing the volumes and capacities they require. The designer team would have a better probability of appropriately influencing the outcome of the project if they participated in the calculations of the project. There are various use cases that have the potential to be optimized, but the industry as a whole does not achieve this due to the lack of communication and stringent design techniques. By utilizing this strategy, it may be possible to lessen the number of errors and produce a plant that functions more effectively.

4. Improving the accessibility of the units

Tisch et. Al. 2016 suggests that equipment placement and spatial planning are some of the aspects that change the productivity of the plants. Interviewee No. 2 indicates that spatial planning for easy access and easy maintenance is a key factor in the layout design. Interviewees no.6 and no.8 also indicate the importance of spatial planning and how the designers should foresee future usage and changes in the design process. It is of the utmost importance to construct and design the plants and equipment in such a way that they require a minimum amount of maintenance so the process of repairing may be completed quickly. Access to the equipment can be gained from the top side of the module or container that the equipment is housed in, which is one of the concepts that have been suggested for the development of a more effective plan for its maintenance. If a process line is equipped with this capability, it is possible to easily swap or overhaul any piece of equipment with a minimum amount of effort and without the need to remove any further pieces of equipment. It is important to keep in mind that providing adequate access to the equipment is not only necessary for the modules but also for each plant, and that failing to do so can sometimes result in extended periods of shutting down the process.

5. Compatibility of the automation system

According to Gou (2004), one of the design limitations of modular construction is that it requires thorough planning and coordination between the design team, the factory, and the on-site employees. This is a prerequisite of modular construction. Interviewee no.1 also mentioned that compatibility of the modules automation and control system is very important, as there would be changes in the products and modules in their plant. Interviewee No. 8 also mentioned the importance of control units and atomization of the modules in the factory layout. One of the most important things that the customers want is for the process to be automated; each piece of machinery has its control panel and is regulated just for the process that it is performing. A plant that utilized atomization would require fewer people overall and would offer a more secure working environment. We advise the creation of a general control plan for the various pieces of machinery that can be easily connected to the other modules. This would make it possible to

easily develop new processes and modify existing ones in the event that this becomes necessary. This kind of strategy would be very helpful in the food business, where the machinery is generally the same, but the feeder of the process may alter depending on the product being manufactured.

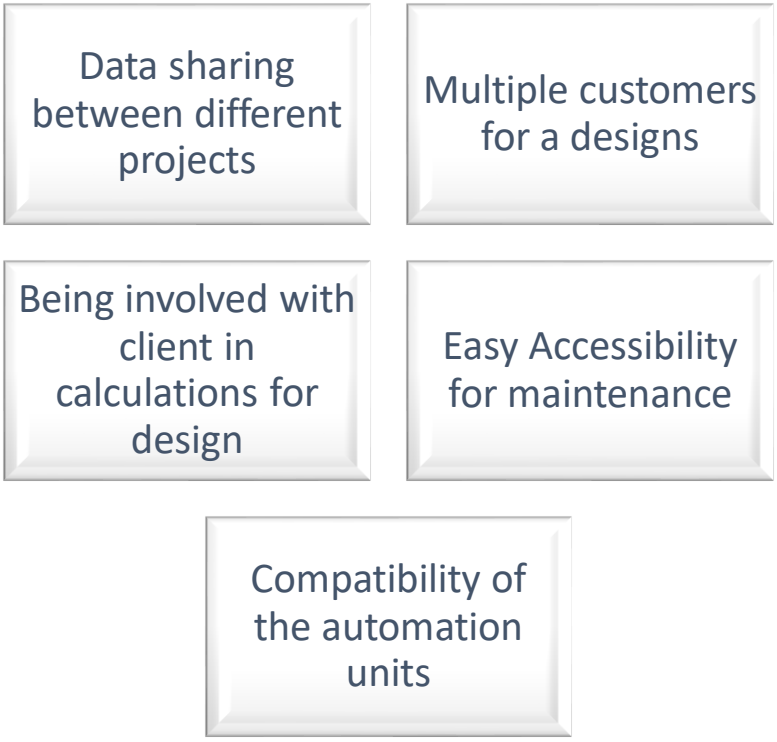

Figure 12: Suggestions for changes in the design method

6.2. How to approach modular design

In this section, suggestions are provided to enhance the likelihood of modular design, as well as to indicate where and when it would be a good idea to apply the modular method. hopefully, the chances of modular design are increased because of these remarks. These strategies involve not only modifications to the technical and design processes but also shifts in the paradigms and cultures of the organizations.

1. Increasing the awareness of customers of the advantages of modular design

According to a study conducted by Mutingi (2017), the use of modular thinking can encourage individuals to think creatively and innovatively by motivating them to consider a number of different choices. According to Marinov and Marinova (2020), fierce competition in the market has led to an increase in the variety of products that companies manufacture in order to fulfill the requirements of their target demographic. Unfortunately, due to the frequent modifications in product requirements, the process of installation and disassembly of components and modules is getting more and more difficult. This is because of the complexity of the products themselves. Therefore, the topic of the modular design of products is one that should receive attention. Interviewee no.2 and No. 5 also mentioned that it is very important to convince the customers about the added value of using this method. It is not possible for a single business to handle the

process of updating the design approach to a more recent version and including the modules; this endeavor requires the participation of various parties and stakeholders. It is of the utmost importance to raise people's awareness regarding this strategy, as well as to develop a concise portfolio that can be shown to prospective clients in order to persuade them to give the new approach a try. It is recommended that you begin on a small scale and that you strive to limit the application of the strategy to only certain aspects of certain projects. By doing so, after a few years, there would be actual practical data regarding the usage of the modules, which would assist the marketing and consultancy teams in giving the information to the clients and attracting the clients' trust. Taking these steps would be beneficial. It is necessary to place these instances in different processes and different components, but it is also important to keep them in low-risk and non-crucial portions so that testing may be completed more easily.

2. Using modules as a base in design

As a result of the numerous connections that exist between the several components that make up a sugar refinery, the design process cannot be a simple "once-through" linear method. Consequently, in order to properly take into account these interactions, the procedure in question needs to be iterative. According to Schorn et al. (2005), this requires a thorough engineering judgment in order to establish the appropriate assumptions and prevent an excessive number of iterations of the design. Interviewee No. 3 suggested including the modular approach in the basic design method. We may advise making use of the modules themselves as the foundation for the modular design in order to generate a beginning point for the modular design. Under this approach, designers would have access to some generic modules that have already been built by vendors or other suppliers. They would then work to improve upon and tailor these modules to the specific needs of the project in which they are participating. In this way, modules will make their way into large corporations as a new approach to design, and in the long run, it will be one of the needs that the customer is going to ask for. This may be accomplished by doing so slowly but steadily. If the customers are eager to receive the modular design, they are willing to share the risk with the firms, allowing the companies to give the modular design to the customers.

3. Create Modules Modify to Order

Gou (2014) mentions flexibility as one of the main details that need to be evaluated in the development of modules. Interviewee no. 2 mentioned that a little bit of overdesign would be acceptable if the added value is presented to the clients, and interviewee no.10 suggested making the modules and completing the preliminary design, and after there is a customer, it could be adjusted to their needs. It would be too costly for the skid builders and designers' company to give complete freedom to the customers and make everything tailor-made, and basically, that would be the same design method as it is right now. On the other hand, if they create generic modules, then the customers are not willing to buy and use them as they want some level of specification in their plant. In this case, a made-to-measure approach is suggested to design modules in a generic way and include some options to customize and create a better fit for the client. By using this method, companies could reduce their design expenses and not lose any clients.

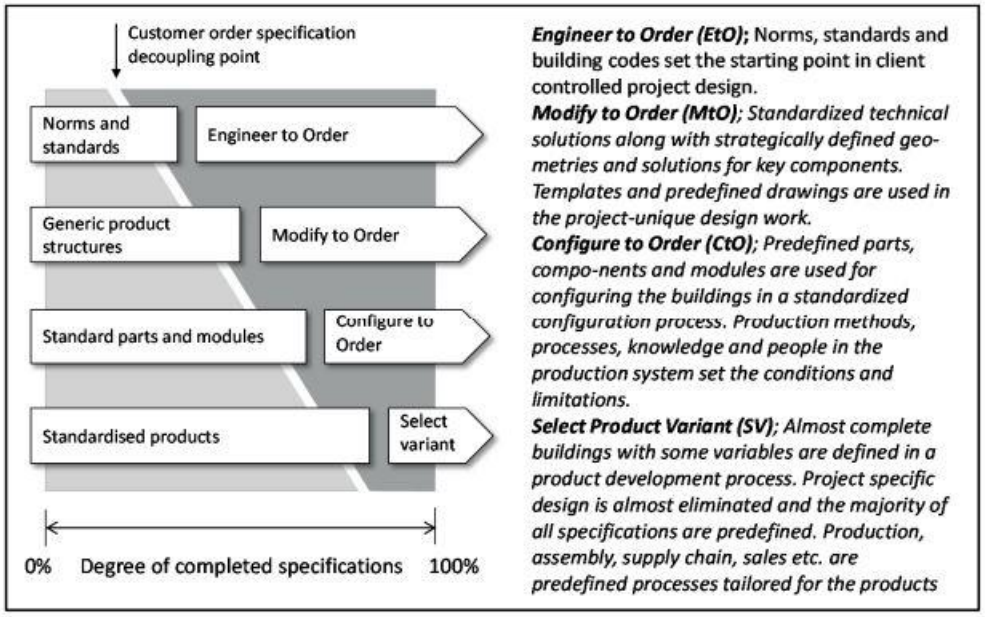

Figure 13: Four levels of product predefinition based on Hvam et al. (2008).

4. Use common process with multiple customers e.g., steam boilers

The move to a modular supply model was initially defended by citing cost reductions as the primary justification. The reduction of inventory, freeing up of floor space, and streamlining of transactions are all beneficial to manufacturers. On the other hand, suppliers usually pay lower salaries, have reduced overhead, and obtain greater economies of scale. It's possible that the demand for faster time to market and the creation of new companies is what's driving this trend in today's world (Esenduran, 2020). It is seen that in the automobile industry, they have been using this method at first to convert into modular design. Interviewee No. 5 suggests that starting from the common process would be beneficial for Tebodin. It would be crucial to begin the process with the equipment that is regularly used in different firms and is generally the same in different scenarios. Since the design and production of modules are costly, and corporations are not prepared to incur the risks involved, it would be important to begin the process with the equipment that is commonly used. If you follow this piece of advice, the risk will be reduced since there will be a greater number of clients for the items, and the costs associated with the design will be reduced because the processes that have been selected are more conventional and easier to design and calculate.

5. Mass production of the modules

Interviewee No. 1 from the food industry indicated that there are several similar pieces of equipment which with a very small adjustment different plants and factories are able to use them. During the workshop, it was mentioned by the skid builders that they saw the opportunity, but it is different in the pharmaceutical industry, and despite the similarities each company wants to have its own design and specification. It has been stated that if a single designer makes use of modules as well as employing generic ones, then they are engaging in overdesign, which would result in increased costs for the customer. The answer to this problem

is to save expenses by purchasing a greater amount of the things that are going to be used, which is the solution to the problem. Customers are going to use the equipment since it will be the same price or cheaper with a little bit more capacity at hand if this strategy is applied by firms, and companies are going to boost their use because they are going to develop and produce more generic equipment.

6. Using modules in demo plants

Interviewee no.1 mentioned that using modular design in their demo plant is appealing because of the financial status. Interviewees No. 4 and No. 8 also mentioned that demo plants could be a good starting point for approaching modular design. In the course of the interviews, one of the topics that came up most frequently was the possibility that a modular layout might be suitable for the demonstration plants. These facilities are almost certainly for the purpose of testing the process and the goods, and the vast majority of the time, they are going to be shut down in a few years or upgraded into scale-ups. Because the customer does not want to maintain everything and use it for a long time, these plants are an excellent beginning point for using modules because the customer merely wants to check if their idea would work. It is also useful that the companies that employ demo plants are typically start-ups with limited investment capital; these companies may find the modular method appealing due to their financial constraints. The fact that these plants are general and can be grown on a small scale makes them suited for use in modules.

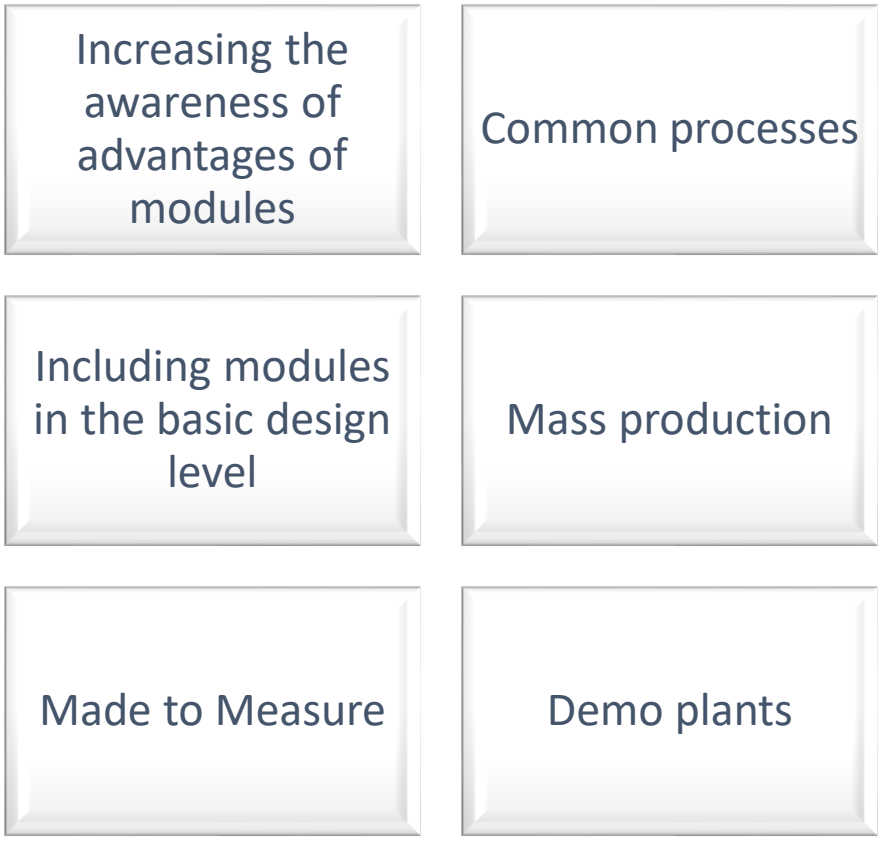

Figure 14: Suggestions to promote modular design

6.3. How to address circularity

Several recommendations concerning the multiple applications of the modules are discussed in this section. These recommendations are derived from the findings of interviews; some of them were brought up by a single participant in the interviews, while others were brought up by numerous participants. In this part of the article, we will address not only the engineering approaches but also the cultural modifications that are necessary in order to reuse the modules.

1. Data-driven maintenance in order to reuse

Chen (2011) suggests that the modular consortium is defined as a long-term contractual relationship between the automotive manufacturer and a small number of first-tier suppliers, wherein: • The suppliers assume responsibility for modular assembly, the online final module assembly into the vehicle, an investment stake in the operation, and management of the module supplier chain. • The automotive manufacturer provides the plant and assembly line and assumes responsibility for plant maintenance. • The suppliers assume responsibility for the management of the module supplier chain. Respecting the approach in the automotive industry and based on the information mentioned by interviewees no.2, no.8, and no.9 this suggestion is made. In order for any piece of equipment to be utilized more than once, it is necessary to keep an accurate maintenance journal and examine it, in addition to doing thorough checks and maintenance during its lifespan. It is vitally crucial to give customers enough information to make informed decisions. When the logs are available and routine maintenance has been done on the equipment, the risk of reusing the equipment will be smaller, and as a result, more businesses will experiment with it.

2. Predict the reuse of the equipment

Multiple interviewees mentioned that it is very important to guarantee that second-hand equipment is going to work in the plant and that the maintenance and storage quality is high. Interviewee no.3 suggests that equipment needs to be commercially attractive for the clients When a factory is not going to be used anymore or is shutting down, it can take a long time to locate a new prospective customer, and there may be certain legal processes that take time as well. In most cases, the plant will be demolished. Rust and oil would harm the equipment, rendering it technically unusable during this crucial period of time. If there is a strategy in place to reuse the equipment, then it is essential to store it in such a way as to minimize the risk of damage while still ensuring that it remains in good condition and is able to perform as intended. Before putting the apparatus away for storage, it is advised that you clean it thoroughly, removing any dust, oil, and other sources of contamination.

3. Make the vendors sell refurbished equipment

According to Arshinder (2008), the remanufacturing industry features a diverse range of linkages with primary suppliers and customers. These connections can take a variety of forms. One of the methods mentioned is a Service contract, which contains remanufacturing between the contractor and user. Interviewee no.2 and No. 10 mentioned that it is important that vendors guarantee future reuse or at least be involved with it. It is a standard practice in some other marketplaces and industries for the main producers to discover defective things, repair them, and then sell them again to the customers at a lower price. It would be a good idea to develop such a market in the industry as well; by doing so, the customers would have a more positive

attitude toward the pre-owned hardware and would use it more frequently because it had been validated and refurbished by the person who had initially designed and created it.

4. Change the presenting format

Interviewee no.2 suggests that it should be commercially attractive for the customers. Interviewee No. 9 added that Circularity and sustainability are already among the goals of the companies. Interviewee No. 4 mentioned that the aim of advertising and promoting should be companies that are interested in circularity and sustainability in the first place. It is possible that adopting the phrase "sustainable equipment or machinery" rather than "second-hand" or "used" equipment will prove to be more beneficial in the long run. In this scenario, it would attract businesses and organizations that are eager to demonstrate their regard for the natural world. Furthermore, it does not appear to be a technique designed to save costs; rather, it appears to be a practice designed to contribute to the future of mankind.

5. Leasing the equipment

According to Korhonen et al. (2018), the most important contributions that CE has made to the existing body of knowledge are a shift toward a culture of sustainable production and consumption, an emphasis on the importance of material durability, and a connection between the shared economy and sustainable production. Interviewees No. 4 and No. 6 also mentioned that a leasing contract seems like a useful tool for implementing the reuse of equipment. Leasing contracts are frequently utilized as one of the most popular techniques in the process of recycling items. Because of this, the companies will be able to utilize the equipment for as long as it is necessary to fulfill their demands and then return it to the supplier. The fact that customers desire to be in charge of their own plants presents a challenge for the fulfillment of this contract because it would be difficult to lease machines under those circumstances. Additionally, the issues that have surfaced as a result of the numerous bankruptcies need to be examined. Therefore, a robust contract is required in order to generate the potential of employing this contract model, but if it occurs, then it would contribute so much to reusing the equipment, and this would be a positive development.

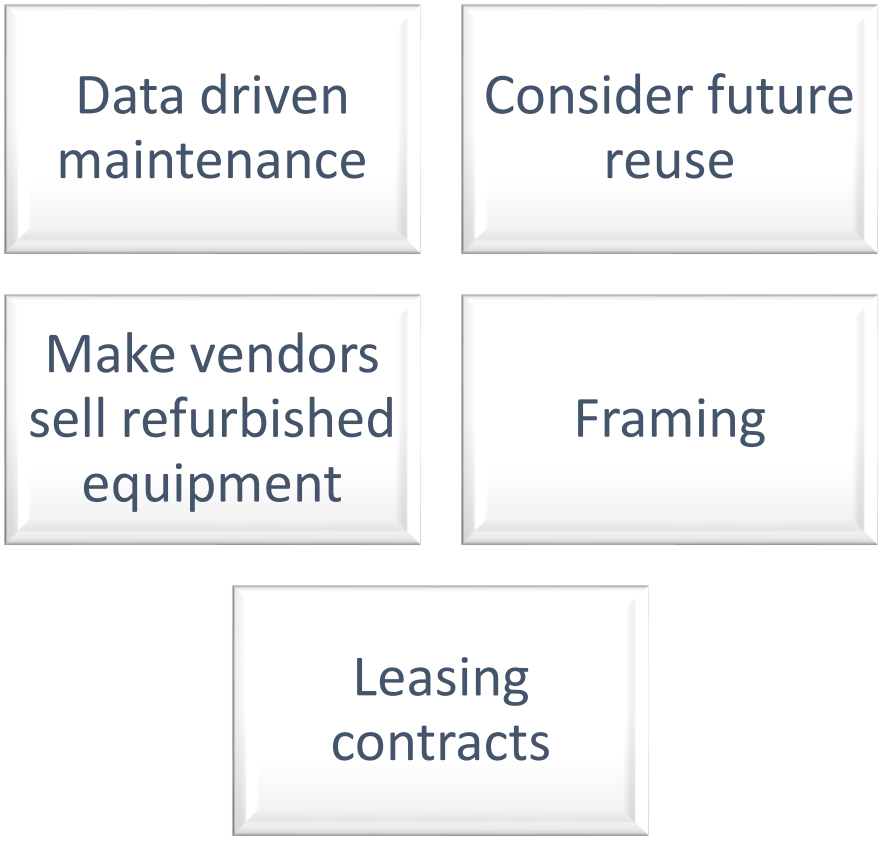

Figure 15: Activities to increase the circularity in the projects

7. Expert meeting

In an expert meeting, the proposed solutions were evaluated. The set-up of the meeting and an overview of the discussions and results of the meeting are presented in this chapter.

7.1. Expert meeting set up

This gathering of industry professionals was organized with the purpose of acquiring a deeper comprehension of the viability of the offered solutions from individuals who had actually carried out projects that were comparable to the ones being discussed. The selection of these specialists was based on their prior involvement in creative initiatives as well as their knowledge of the design procedure. In addition to this, each of them possesses a substantial amount of practical knowledge in their respective disciplines. The specialists who were present at this meeting were not the same ones whom the writer had interviewed earlier. Table 3 illustrates the roles and backgrounds of the experts present in the meeting.

Table 4: Expert meeting participants

#	Positions	Background
1	Process and project engineer	Food processing
2	Energy and mechanical project engineer	Electromechanical engineering
3	Manager engineer	Mechanical engineering
4	Mechanical equipment engineer	Mechanical engineering
5	Mechanical engineer	Project leader technology
6	Mechanical engineer	Mechanical engineering

It is important to point out that each of the specialists has worked on a variety of projects throughout the course of their careers. As a result, they are accustomed to working in a variety of markets, industries, and on a variety of scales of projects, including both large-scale projects and young enterprises.

7.2. Structure of the Workshop

The thesis project was presented to them during the workshop's second phase. The participants were given a brief explanation of the study's purpose, its methods, and steps. The presentation concluded with the delivery and explanation to the audience of the suggestions given in the previous chapter. For the remainder of the workshop, a list of bullet points for each solution will be displayed on the screen. In this part, the participants were enlightened about the purpose of the workshop for the master's thesis and understood how the data gathered from the workshop was going to be used. Some questions regarding the scope of the project and how the solutions are defined and details about the solutions were asked by the experts and after everything was clear for them, the next step started.

In the following step of the workshop, participants were divided into two groups; Because all of the participants had similar expertise and field of work, the group making was done on a random basis; Ørngreen and Levinsen (2017) suggest that group dynamics can be used constructively

to bring up the concerns by outlining scenarios, acting them out in a simulated and guided environment, and holding facilitated talks (although this can also, in some contexts or for some people, be counterproductive). The workshop co-creates a space for collaborative meaning negotiation between participants as well as between facilitators (the researchers) and participants, who adopt and adapt to what is being discussed, performed, and learned both during and after the workshop. Because of the time duration of the workshop and also to create a highly productive atmosphere, the participants were divided into two groups.

the first group contained the Experts number one, three, and four and the remaining participants were allocated to the second group. then each group would have time to discuss and evaluate the solutions with their members; during this process, posters shown in Figure 16 were presented to each group for each category. Using this poster would create a framework for the participants that would make it easier to process the workshop further and extract the information more sufficiently. Each poster has two parts: the first is the circular diagram that is divided into two parts that are separated by color; the blue parts are the advantages that are going to be mentioned, and the yellow parts are the drawbacks of the proposed methods. It should be noted that in this poster, the proximity of the points to the center shows their importance. The X-axis of the poster is not defined, so the members are going to name themselves and use them as they wish. In this process, all the experts will put the solutions based on their opinions in the respective parts. Each group would have one poster, making it two posters in total. For the last part of this step, groups are asked to write down their opinions and suggestions for practically applying these methods to the company and how they see it happening in the future. Using this method would help the writer manage the findings better and also would create a better opportunity for groups to discuss their opinions and in case of difference what was their idea for ranking or evaluating a certain solution.

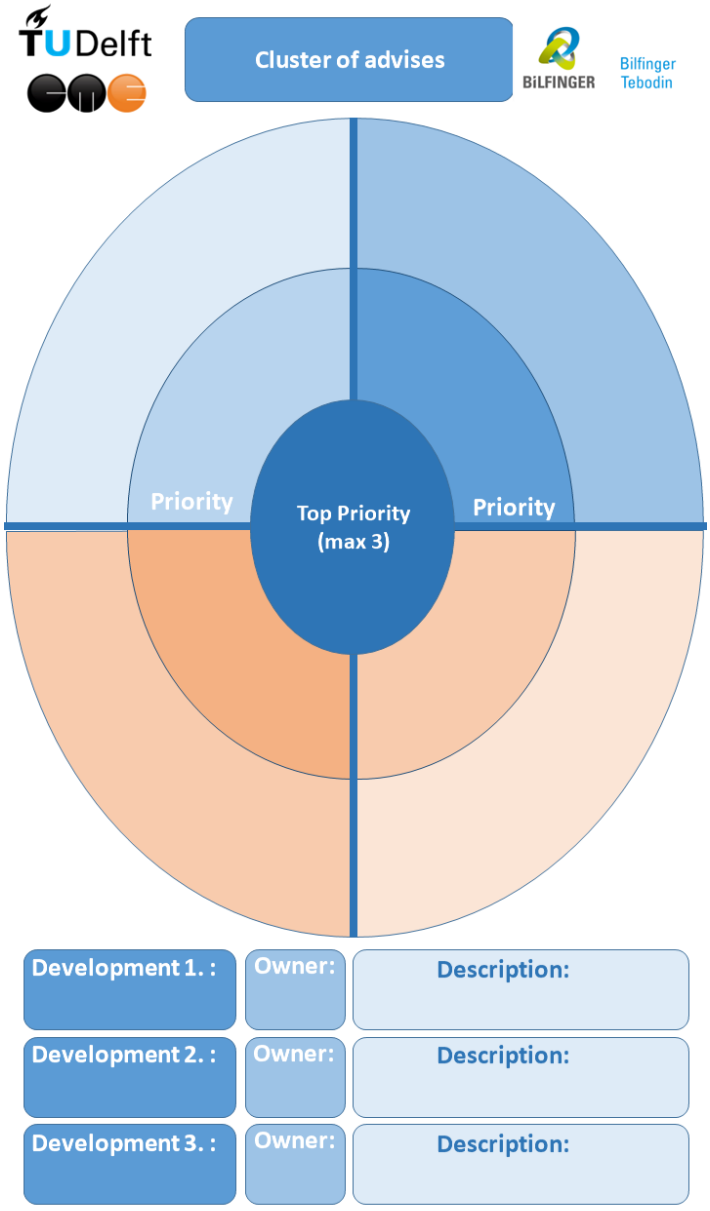

Figure 16: Poster used in the expert meeting workshop

The next step of the workshop is for groups to present their ideas to each other and discuss the differences in their opinions together. The result of internal group activities is presented in Figure X for Group One and Figure Y for Group 2. In this part, the writer was also involved and asked questions about the reasoning behind the evaluation and discussed how each group came up with their assessment. In this part, possible conflicts in the evaluation in the groups were also discussed with the individuals, and each expert would have the chance to express their personal opinions in addition to the parts mentioned on the poster because of the group activity.

The last part of the workshop was a brief evaluation of the process of the workshop and to check if the expectations of the workshop have been met. All of the experts were happy about the outcome of the workshop and found it useful to the company, They were interested in

sharing the data with other branches as well, and in the long term implementing some of the suggestions to the projects which are capable of modular approaches.

7.3. Discussion on proposed solutions

Group one found fifteen of the suggestions valid, they thought that they would all create a pass toward using modular design and increasing the circularity in the projects, however, they did not like to put the modular design in the basic design step but to include it in the earlier stages and also make it a trend in the company. Group one argued that there should be a set of actions to change the design paradigm and they mentioned the most important action to do so is to increase the awareness of all the parties. It was indicated that it is not only an engineering process but the tenders and regulatory parties should consider the usage of the modules.

Group two found 13 of the suggestions valid, the main one that they projected was again to not put the modular design in the basic design phase but include it sooner in the company. They also mentioned that they see mass production in contradiction with the reuse and leasing contract as they wanted to create a market based on leasing and not selling more items to the clients. Group two mentioned that regulatory parties can easily change the market and after the laws are changed, automatically a huge customer base is going to be available, which makes things more appealing for investors and parties involved. (See Appendix C for more information and details of the discussion in the workshop)

7.4. Interpretation of proposed solutions

Overall, all the experts were happy with most of the proposed solutions. After the presentation, both groups agreed that the main theme and most important aspect to be looked at was awareness of modular design and circularity. All of the experts agreed that there has been some usage of the modules, and individuals are aware of the modules, but they are not widely used or implemented because there is not enough collaboration and good framing for that. It was also mentioned by the experts that one cannot create a demand, but the demand exists, and companies need to find and address that. They mentioned that it is not the first priority of the companies to address circularity at the moment, and the main driver for the companies is the financial situation of the project. However, if the engineering team could come up with some plans that address the financial situation and, in addition, modularity and circularity, then probably companies would be willing to test and implement this approach for their clients.

It shows that all of the experts are familiar with and interested in the topic; they individually think about the matter and would like to create a platform for increasing the outcome of the projects that they are a part of, but they are not able to change the paradigm by themselves. At the end of the meeting, all of the experts were talking about the process that they need to do in order to create a better space for having such discussions and improve the company. They also suggested that they need to share the findings of the report with other branches of the company so the whole company can start to work and move towards modularity and reusing the equipment.

7.5. Chapter conclusion

The findings from the interviews led to several solutions, which captured the attention of all of the experts. They were in agreement with the majority of the proposed solutions, and for those with whom they were not in agreement, they indicated that it was not their inherent fault but rather the strategy that the organization ought to progress toward. The solutions need to be put

into action, at least the ones that are most essential in the upcoming circumstance for the organization, in order to evaluate their applicability and determine whether or not they would be successful in actuality.

The most relevant solution that a company needs to use in order to apply the modular method is to increase the awareness of the parties involved in projects and create a better understanding of the modular design for them. The second important solution is to consider future reuse from the start. It would change the overall actions and decisions that Tebodin and the client are going to make. Applying this method would create a higher chance of reuse and make everything easier in the future. All of the other suggestions are acting as tools to make these two most important solutions happen; they are either technical approaches that make it easier to implement the modules and start the modular design or cultural approaches that change people's perceptions about modular design and circularity and encourage them to use this method. Overall, it is possible to say that most obstacles are not technical, but the traditions and culture of the industry and companies are keeping them from using the new methods. It would be wise to make changes in this regard, either by increasing education or by creating a more creative working atmosphere.

8. Discussion

This chapter addresses our findings, provides an interpretation of the solutions, investigates the industry implications of our approaches, and recognizes the limitations of the study. It bridges the gap between empirical investigation and the application of learned knowledge in the real world.

8.1. Key findings

The results of this research indicate that innovative projects and start-ups are considered good candidates for a starting point for implementing the changes. It has been mentioned in the interviews that innovative projects are suffering mostly because of the difficulties of scope definition. Also, Cantamessa et al. (2018) suggest that some of the main reasons for failure in innovative projects are the wrong business model and a flawed market study. It shows that innovative projects could be a good option to implement circularity in order to reduce waste.

According to Favi et al. (2016), the life cycle of industrial equipment is a continuous process that takes into consideration changes in technology, the needs of the market, and environmental concerns. This process begins with the design phase and ends with the disposal phase. In this study, we found that not all equipment is reusable because of its nature and how the expenses would change in order to reuse equipment. Liu and Ramakrishna (2020) indicate that using resources as long as feasible is a key component of the circular economy, which aims to decrease waste and promote sustainability. Implementing the concepts of the circular economy entails creating durable goods and services that can be recycled, mended, and reused in order to limit the amount of waste produced over time. Interview results also indicate that there are several difficulties in the process of reusing the equipment, and it needs multiple activities beforehand.

Geissdoerfer et al. (2017) indicate that a flexible and adaptable method of purchasing assets and resources across numerous industries has emerged as the leasing business model. The leasing model is one of the best solutions in order to reuse equipment in the industry. Although reusing is not one of the main concerns of companies at the moment, engineers and participants of this research indicate that it only needs to be financially feasible, and the risks of the equipment should be discussed beforehand.

Schorn et al. (2005) Further indicate that the planning and building of factories are complicated processes that call for a diversified strategy. It has been discussed that designing the plants is very complicated, and multiple teams and people are going to be involved in the process. It was discussed that applying modularity to the whole process of the design is not applicable at the moment. One of the solutions proposed is to limit the changes to the demo plants and only the common processes. Using this method, the risks of change are mitigated because there would be a bigger customer pool and it would be easier to sell or lease the equipment.

Kamali, (2017) mentions that due to the advantages offered, including shorter building times, lower prices, higher work quality, and less negative effects on the environment, modular or prefabricated construction is progressively replacing traditional on-site construction. It suggests that modules are being used in different industries and different aspects, but they are not vastly used in the process and factory design. The result of this project shows that it is a viable option to include the modular design in the factories, and also to use the same modules in different plants, It is important to move step by step towards the modular design. one of the main steps is

to increase the awareness of the different parties involved in the process about the importance of the modules and what are the benefits of using this method.

Boeri et al. (2016) indicate that working under standardized module sizes and transportation restrictions is one of the key design constraints of modular construction. It would be very important that modules are designed in such a way that they are usable in different plants. Another one of the mentioned characteristics of modules that is suggested by this research is to make the control units of the equipment compatible with each other. Applying this would make it easier to change the modules and replace them in accordance with the demands of the factory layout.

Lack of flexibility during the design phase and difficulties regarding changes in the future were mentioned as problems with the linear design method. Innovative projects also face many changes because of their nature and the changes that they face during the preliminary steps of realization. This indicates that the linear design method is not suitable for start-ups and innovative projects. In order to change the design method to modular design, the obstacles to modular design have been studied. Connections and the size of the modules are two of the main important aspects that need to be taken into account in order to create an effective design for the factories.

Willingness to change is also very important; the linear design method has been implemented for years, and companies and clients are not willing to change to something new. It is important to convince everyone involved that the change is needed and how the changes need to be addressed. Framing the idea plays a big role in convincing the stakeholders to use the new method and design. Regulations and changes to the codes could also be a good starting point for the change.

It has been mentioned that the modular approach needs to be one of the concepts that is actively practiced in the company. By applying this change and giving modular design high priority, all the engineers and designers are going to be familiar with the design, and they will have a better chance of presenting and proposing this idea to the customers. It would also increase the chance of using this method in the following design steps. Common processes are one of the best starting points for this method, as they are available in many factories.

In order to create the possibility of reuse for the equipment, the results of this research could be summed up in these points: first, it is very important to have data-driven maintenance; it would provide so much important data and information for the next user and is essential to creating this market. The second is to consider future reuse from the start; by doing so, there would be a higher chance of having better maintenance, and the storage quality of the equipment would be higher. And the last point is to encourage leasing contracts. It would be a huge step toward reusing the equipment and also create a circular economy as this contract would create a market where the risks are shared, and the seller of the equipment is going to be in charge of the storage.

8.2. Interpretation of the results

During the literature review of this thesis, it was mentioned by multiple authors that modular design has many advantages, and overall, the advantages of the method outweigh the disadvantages. Despite the just-mentioned fact, the method has not been utilized in the industry except on very rare occasions. The main application of the process was also to reduce the lead

time and to create a safer atmosphere during the realignment. The results of this thesis indicate that the fact that companies and industries are not trying to implement modular design is not because of the method's shortcomings but because of a lack of awareness and willingness to change.

Many studies show that there is a need to change the usage of raw materials and contribute to sustainability, which is necessary for all industries, but it has not been addressed yet. The results of this project indicate that, in order to change the paradigm, there is a need to change the financial feasibility of reusing the equipment. It was mentioned that companies are paying attention to circularity, but it is not one of their main drivers, and the only actions that are needed for sustainability are mainly focused on CO2 emission reduction. So the driver needs to be financial, and engineers and consultants need to convince the stakeholders that changing the method and reusing the equipment would create higher values as well. The main concerns of the parties are the maintenance and the shutting down risk of the plants. It was proposed to use the leasing contract in order to create a better situation for the companies and vendors and encourage them to use this method. It was also mentioned by the experts that in many cases, the first steps are taken by the regulatory parties. If there is a regulation that makes it mandatory for companies to reuse some parts of their plants, then automatically a new market would emerge, and companies with higher knowledge would have a larger share of that market.

There are several engineering obstacles that are keeping companies from using the method, but the expert's opinion was that this is not the main reason that companies are not implementing it. But the main reason is the culture of the companies, vendors, and clients, or, to put it simply, the culture of the industry is lazy and does not want to change. Experts mentioned that a high level of collaboration would be needed in order to change this.

8.3. Implications of findings

Linear design method

This thesis research makes a number of recommendations for alterations and potential solutions, some of which can also be applied to the linear design. If a company is not interested in changing the design, however, it may still use the solutions that were discussed in order to lessen the obstacles that are presented by the design method. The primary application and approach of these solutions is to transform the design method into a modular approach. Not only would the exchange of data between different designs and the presence of many clients for each design contribute to an improvement in the overall quality of the design approach, but it would also generate financial value for the organization.

Modular approach

Tebodin, as one of the leading engineering firms, would have a huge impact on the trends and changes in the sector if it were to implement the solutions presented in this thesis. This would create an opportunity for the company to move towards the modular approach. It is important to note that Tebodin has a very deep relationship with start-ups and innovative projects; hence, in the event that this strategy is implemented and used in a variety of projects, there is a great probability that they may attract more start-ups.

Reusing the equipment

As was noted before, Tebodin has a positive relationship with start-ups; nonetheless, it might be challenging to collaborate with start-ups and innovative projects because these types of endeavors frequently do not have sufficient finance. Tebodin would be able to save expenses, assist more start-ups with less risk, and contribute to changes in the market if it used the leasing approach and created the market for it. It would also expand the overall size of the market and provide Tebodin with a better opportunity to operate as a link party between the customers and the sellers of goods and services.

8.4. Limitations of this research

This section addresses the limitations of this research which needs to be considered when reading and implementing the findings.

8.4.1. Limited data availability

- Due to the fact that reusing equipment is so rare in the industry, we did not have firsthand access to projects in which equipment has been reused.
- As modular approach is not vastly applied in the industry, finding projects which has been completely modular was impossible.

8.4.2. Interviews

- The sample size of those interviewed for this study was fairly limited because many people had busy work schedules. Just ten employees from various company departments and disciplines could be interviewed by the author. The findings' generalizability would increase with more interviews conducted.

- The examiner could only interview people from the Tebodin and only have one interview with the clients. Skid builders and vendors were completely uninterested and did not want to participate in this research. Including information from other sources and parties involved would have been a good practice to evaluate the findings.

8.4.3. Feasibility of the proposed solution

- Since the experts in the evaluation workshop all had engineering backgrounds and positions, all the engineering obstacles were mentioned, but the financial and management issues were not brought up fully. There may be some conflicts which are not seen in the process.
- Some of the proposed solutions mainly focus on the reuse of the equipment and only take into account the circularity of the project. The financial aspects of the solutions are not completely clear.

8.4.4. Results are perception of people

- The data gathered in the interviews showed the experiences and perception of people involved in the projects and it was not based on solid facts driven from projects.

9. Conclusion

The objective of this master thesis was to explore solutions in order to use modular design for reusing equipment in innovative projects. The conclusion is presented in this chapter by answering the sub-questions and then the main research question of this project. The last part of this chapter will be the recommendations for future research and recommendations for implementing the solutions.

9.1. Answering the sub-questions

This section would answer the four sub-questions which would lead to the answer to the main research question.

1. **What are the main challenges of innovative projects due to using a linear design process?**

The following mentioned in the literature about the challenges that innovative projects are usually facing:

- Change in the scope
- Lack of prior market access
- Changes in the process
- Investment problems

According to the findings of the literature review, it can be shown that innovative projects encounter obstacles and challenges and are at a significant risk of failing. This is due not only to the nature of the projects themselves but also to the employment of antiquated, linear methodologies. The approaches center on creating a sound strategy, adhering to it, and minimizing modifications. However, at the moment and due to the rapid changes in the market and technology, it is impossible to adhere to the same approach. In this project, innovative projects were evaluated since they had to deal with both this issue and their own internal difficulties. Additionally, because these projects are inventive and more adaptable, it would be more likely to adopt modifications to the design process and equipment reuse. It should be remembered that innovation includes changes to methods and processes as well as the development of new goods. Therefore, these innovative projects may also use the modular design method and make adjustments to the design process as part of their innovation.

2. **What are the main drivers/functions of the modular approach demanded by innovative projects and vendors?**

The following points about the modular approach were mentioned by the literature and also the parties involved in the workshop which were discussing the opportunity to use modular design:

- Flexibility
- Lower cost of the design
- Shorter realization time
- Lower workload for the provider
- Integrity of interfaces

Each of these points are considered one of the drivers that may encourage companies to use modular design and modular equipment for their projects. Flexibility is one of the most important ones and shows that innovative projects are dealing with changes and a volatile market and would appreciate room for change both in the design and capacity. Also, as a natural request both parties would like to reduce their costs, innovative projects especially are going to aim for lower prices in the initial phases as they are not sure about the market of their products.

Despite the similarities in the demands of the innovative projects and vendors and skid builders, there is one essential difference in their view. The innovative projects are looking to realize their project and create a demo plant with lowest cost and introduce their product to the market, the quality of work, workload, interfaces and big picture strategies of companies are not completely relevant for their stage of business, on the other hand Skid builders and vendors are well known in the market and already have their customers and share of the market, so it is important for them how to manage the changes, what would be workload and in future what are the consequences of the change for their firm and market in general. Because of this fundamental difference each party has their own understanding and needs in the projects.

3. What are the main criteria in the modular design process and what is a suitable framework in order to utilize this method?

The following approaches were mentioned by interviewees and also mentioned by literature in order to change the paradigm into a modular design driven by the circularity of the projects. The suggestions were divided into three main clusters,

1. Design approach changes
    a. Share the information and design between different projects
    b. Finding new customers for the design
    c. Getting involved in the calculations
    d. Improving the accessibility of the units
    e. Compatibility of the automation system
2. Approaching modular design
    a. Increasing the awareness of customers of the advantages of modular design
    b. Using modules as basic design phase
    c. Create modules Made to Measure
    d. Use common processes with multiple customers e.g., steam boilers
    e. Mass production of the modules
    f. Using modules in demonstration plants
3. Addressing the circularity
    a. Data-driven maintenance
    b. Predict reuse of the equipment
    c. Make the vendors sell the refurbished equipment
    d. Framing
    e. Leasing contracts

It is clear that the obstacles which are keeping companies from using the new method is not only the engineering difficulties and harder design approach, but it is based on industries culture and how it is very hard to change the method which is already working. Different participants mentioned that they know that modular design could be beneficial for the projects, and they see

it as one of the possible approaches in order to change into more efficient design method, but no one was willing to apply the change or convince others to accept the change. It shows that there needs to be more incentives and freedom for the engineers and project managers to include new method and test in order to create and invent better solutions. it is also worth to mention the power of rules and codes in the industry, for instance after the CO2 emissions has been mentioned in the codes, all of the firms are developing new approaches to reduce the CO2 emissions and somehow control it. Maybe having the same idea about the usage of raw materials would encourage companies to find new ways to reuse equipment.

4. **What is the most suitable proposed method so reusing modular equipment can be applicable for innovative projects?**

After proposing the suggestions to the experts and evaluating the proposed methods, the following three suggestions were found to be the most appropriate and the highest priority to apply.

1. Increasing the awareness of the advantages of modular design
2. Considering future reuse
3. Multiple customers for a rescan

It shows that most of the people involved think that implying a change is so difficult. Most of the individuals know about the modular design and how it works and what are the benefits that it may bring to the table, but they are not completely familiar with it, and they have not been using it actively but only in rare occasions and when the customer asked for something especial. So, the first step toward using modules and also making them reusable is to create a market in which everyone involved is familiar with modules and their benefits and actively evaluate this method as one of the main approaches.

9.2. Main research question answer

The main research question of this research is **“How can the modular design approach be utilized in innovative projects that are motivated by reusing the equipment to address circularity?”**

Despite the findings of literature about the advantages of modular design and the vast flexibility that it would bring to projects, it is not used in the industry. The only rare cases where the plant has been modular were to increase safety, create easier construction and realization, or reduce the duration of the plant. So by using the tools and solutions proposed in this method we are going to encourage companies and vendors to use modular design and reuse equipment.

The challenges that innovative projects are facing are due to scope definition and changes in the plan during the realization and testing of the product. These challenges may result in the failure of the innovative project and waste a huge portion of the investment. Thess findings show that innovative projects are a good place to start the change. In order to reduce the loss, reusing the modular equipment has been proposed. The findings of this study indicate that it would be possible to use this approach, but first, some tools need to be applied to make it easier to implement this method.

The first step to starting the change is to increase awareness about the modular design. It is suggested to have workshops and educational platforms in the companies and start to promote modular design to people. The second step would be predicting the reuse of equipment and

making a plan for it. Not having a plan would make everything harder; the contamination and rust on the equipment may make it impossible to reuse. It should be mentioned that in all of the steps, the financial feasibility of the method is important for both the client and the contractor. The third step is to find multiple customers for a single design. This is a huge step in the market and needs collaboration between different parties in order to create this market, but if the first two steps are taken correctly, then vendors and clients will be willing to test the new methods. The last point to be implemented is that modular design needs to be considered in the company as one of the valid methods and conceptual design steps. It should not be something niche that may arise only if there is a problem or the client wants it, but basically be one of the methods that are applied by the company.

9.3. Recommendations for Research

In this final chapter, we outline key recommendations for future research directions. Building upon the insights gained from our comprehensive analysis of the modular design of the factories, these suggestions address prominent gaps in current understanding and offer avenues for further exploration. By delving into these uncharted territories, researchers can deepen their comprehension of reusing modular equipment in the industry and contribute to the ongoing advancement of knowledge in the field.

- It is recommended to interview different people from different sectors of the market, not only specialists from engineering and consulting firms. These possible interviewees should include engineers and experts from vendors and skid-building companies. It would broaden the insight into the market, include important data about the involved parties, and highlight their priorities and difficulties.
- This research explored the difficulties of applying modular design to reuse equipment in innovative projects. The focus of this project was on the technical and cultural obstacles that are keeping companies from applying the method to existing or future designs. The financial aspect of this approach is still uncertain; it is recommended that comprehensive research be done about the financial status of the projects that are applying this method.
- In this research several participants mentioned that change in the industry is very hard and nobody is willing to change, it is recommended to conduct a research on the approaches toward change in the industry and evaluate its difficulties and how it would be easier to implement changes in big corporates.
- In this research, innovative projects were proposed as a good starting point to apply the change and implement reusable modular design, it is recommended to assess the financial status of such a change in this type of project, how it would change the investment and if this change could make the investors more willing to invest in the projects. So, research should be conducted on the relation between investors and start-ups and how reusing modules is going to affect that.
- The research was conducted using interviews with people in the company. It is recommended to apply research, find cases of reused equipment, and study the advantages and disadvantages of this method. Also, it is recommended to evaluate the market for second-hand equipment.
- Detail design changes and difficulties was not in the scope of this project, it is recommended to apply this method to an actual project and find if the mentioned difficulties and challenges are the same in practice and try to find some solutions for creating a better and more efficient design method.

- The study was conducted by a company from Europe, whose majority of projects and portfolio are from the European Union. It is recommended that the same research be conducted on diverse projects throughout developing countries such as India, the Middle East, and China. This is because these are the regions where many first-of-a-kind projects are being created, and the financial situation of the enterprises in these regions varies. In addition to this, it is essential to have regulations in place regarding the circularity and utilization of raw materials.
- Modular approaches and equipment have been developed and used in the electronic and computer hardware industry, maybe it would be useful to study their approach and try to implement the approaches that they took in advance to try and create a better understanding of the challenges in the application of modular method.

9.4. Recommendations for Company

- Lack of awareness about the modular design and how to implement it in the industry was mentioned by people involved in projects, it is recommended that Tebodin Bilfinger start an educational program about the modular design and its benefits and create a better understanding of the method. Afterward it is recommended to encourage project managers and engineers to consider and use this method at least in small scales so that company could create data and increase the usage in the future.
- In case of creating a market based on using and reusing modular equipment, A 3D bank of twin models of modules could be one of the tools to help and make the approach more feasible. It is recommended to study the application of this method and try to apply this to an existing project and evaluate the outcome of using digital twins in the design phase.
- It is recommended to encourage the regulatory parties to increase the circularity laws in the codes and make it mandatory to use at least some portion of the plants from reusable of used equipment. Implementing this change would create a very huge change in the market and all of a sudden everyone involved in the market would try to create and improve the reusing methods. Tebodin Bilfinger and other companies could use their power and connections to increase the chances of having such a law.
- It is recommended to conduct in-depth lifecycle assessments of equipment to determine the environmental, economic, and social impacts of modular reuse compared to traditional disposal and replacement. This can help companies make more informed decisions about the sustainability of their equipment management practices.
- It could be helpful to Develop standardized guidelines and best practices for designing equipment with modularity in mind. Investigate how modularity impacts the initial design phase and how it can enhance equipment adaptability and longevity.
- Investigate the integration of modular equipment reuse practices into the broader supply chain. Assess how companies can collaborate with suppliers and customers to facilitate the efficient exchange and refurbishment of modular equipment.

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Appendices

Appendix A

Interview Questions

Prerequisite

It is important to make the storyline visible for the interviewee, but not to lead them into saying the things which we would like to hear. Things to be shared before the start of the questions would be as follows:

1. The volatile situation of the market
2. Examples of different innovative projects that have been canceled.
3. The era of the change
4. Importance of adaptability
5. The current design method (we should be on the same page to discuss the drawbacks)

Design method changes and drawbacks

1. What are the drawbacks of current design methods? Please give an example.
2. What should change in order to improve the outcome of the design? How could it change?

What are the most important design principles of a modular concept?

1. How would you make a modular design?
2. What are the main limitations in the case of designing something modular? Regarding product & process.
3. How can you strike a balance between the requirements for adaptability and customization and those for compatibility and standardization among modular product components?
4. What is keeping companies away from using this method? Is It cultural or lack of experience?

Could modular concepts contribute to a circular economy?

1. How can we extend the technical life of a module/ economic life?
2. What are the possible obstacles? How to tackle these?
3. What should be added in order to address the circularity?
4. How can we maximize the contribution of modular design in the circular economy?
5. Regarding all of the benefits, why this method is not applied? How can we promote it?

Appendix B

Workshop findings

In order for everyone to have a better understanding of the other attendees and for the meeting to be managed more successfully, the first phase of the workshop that was conducted was to generate a list of everyone's expectations for the gathering. The moderator would therefore merely ask attendees what they hope to get out of the workshop and how they envision us handling it during the discussion. There was a common theme as well as the individual understanding and desire of each side. The following is a list of some of the key points that were raised by multiple speakers:

1. Finding links between parties
2. Finding added value from Bilfinger to the production.
3. Understanding the needs
4. Finding the drivers and setbacks in using a modular design
5. Adaptability of the modules

According to the responses, it appears that the clients are unfamiliar with modules' advantages and what would modular design bring into the projects, but they are also curious about its potential and the benefits it might offer their projects. The versatility of the modules was also emphasized frequently due to the start-ups' inventive character. Finally, it is evident that drives and setbacks are crucial for both parties in the negotiation process because they want to understand the risks and how to mitigate them.

Then, in order to construct a modular design, every possible customer and supplier attempted to list and rank the variables that contributed to their respective businesses' successes. The parties were divided into two groups, the first group was the skid builders, and the other one was the users of modules which in this case are the start-ups. Then each group started to list the most crucial demands of the modular approach, At first each individual wrote down their own perspective and then it was discussed in each respective group. Then in each group, the most important aspects were discussed and voted for. it should be noted that there was not any limit for these points and participants were free to choose the theme as they wanted. Then the parties sat together and talked about what they wanted out of the project, what they could offer to the table, and what they thought the other side would bring to the table. Simultaneously, each side considers the requisites of their respective organizations.

The top three crucial drivers anticipated from the modular approach for the Starts-ups are:

4. Time
5. Price
6. Flexibility(capacity)

The top three crucial characteristics anticipated from the modular approach for the Skid builders are:

4. Harmonizing the interfaces
5. Efficient workload
6. Lower costs

Time was the first and most significant driver that the startups mentioned. They are said to be in a highly competitive and volatile market, and time will play a crucial role in their plans. It was said that they would hope to shorten the length of the construction process by employing a modular strategy, or else they wouldn't find it as appealing. The price of the modules and how it would affect their functioning was the next crucial specification. The start-ups indicated that one of the primary factors in their project is the cost because they are unwilling to pay for new techniques without giving them value. The companies were still developing their products and unsure of the specific materials and capabilities, so they preferred to have some room for flexibility and modification in the future. The last consideration was the flexibility of the modules in case the product's capacity changed.

Skid builders had different ideas about modular design and its applications. The first factor mentioned was the harmonization of the interfaces. It was said that there are always difficulties in the creation and management of the interfaces in the factories because of the different standards, vendors, and client regulations. Skid builders saw the modular design approach as an opportunity to create a more generic and standard interface for the control system and connections of the skids, which would make the design and preparation of the equipment much easier. The second point was the fact that it needed to decrease the workload. It was indicated that by designing a module, they would want to be able to use this design for several projects and keep the knowledge of it to themselves. It was also mentioned that in the pharmaceutical industry, they are using many skids and modules, but each firm wants to keep its own design, and it is not reducing the workload. The last point discussed was the lower costs, which are essential in order to compete in the market and would create competitive advantages over other companies.

The following step in the workshop was to check the demands of the start-ups, including the types of equipment that they wanted and the probable capacities of the mentioned equipment. and to check the capabilities of the Tebodin and Tebodin life science in order to design, create, and sell the equipment. it was also necessary because there was some equipment that Skid builders were not able to supply and Tebodin Bilfinger needed to come up with some sort of plan in order to design and supply it for the clients. It was also a good opportunity for the start-ups to mention different parts of their process and then the providers come up with ideas of which type of equipment would be sufficient and suit it more. Through this practice, all of the parties get a good idea about the scope of the project and what they need to prepare for. The results of this step have a higher level of technical detail and are out of the scope of this thesis. Every start-up provided a list of their unique pieces of equipment, and the skid builders provided a list of the pieces of equipment they had available and wrote it down on paper. Table 4 shows some of the available equipment that Bilfinger Life Science and Bilfinger Tebodin can offer or have the ability to supply.

Table 5: Available equipment in Bilfinger Life Science and Tebodin Bilfinger

Bilfinger Life science	Bilfinger Tebodin
Aseptic filling	Skid based distillation
Flash drying	Screw feeders
Decanters	Solid handling in a liquid
Continuous soaking time	Size reduction units
	Continuous soaking time

The next step of the project was to assess the risks that may happen in the project in case of applying the modular approach. Each stakeholder listed their own risks, it was mainly the risks evolving the engineering and technical issues of the project. Then each of the individuals chose the risks that they thought had the highest impact or probability from the list that was created. By doing so the ones that were stated the most frequently were found and recognized as the main risks of the project. Finally, a preliminary mitigation plant was suggested for each risk that was in the high impact/chance part of the diagram. Some of the main risks that have been mentioned are as follows:

6. Incorrect cost estimation
7. Long lead time of equipment
8. Scale-up is not going to work
9. Change in market demand

These are some of the risks that companies were afraid to face when starting the project. It is important to remember that the clients are innovative start-ups, which have their own risks and problems, and this may not be relevant to every modular project.

Appendix C

Discussion about the proposed method

In this section, first, the evaluation of group one is presented, and then the suggestions and discussion with group two are mentioned. And at last, the discussion between groups about the evaluation of the solutions and differences in their approach is addressed.

Group one evaluated all of the solutions and ranked them, respectively. Group one mentioned that the ranking is based on the necessity of applying the suggestion in order to create a modular plant. They mentioned that the activities in the center of the circle are the essential ones that need to be done in order to start the modular approach. Overall, they approved fifteen of the solutions and found them all practical in the industry and in the companies, except for one. "Including the modules in the basic design level". Group one indicates that in order to create a modular approach and be able to suggest it to potential customers, starting with the basic design level is way too late, and the company needs to evaluate the modular design beforehand, so they are ready to propose a modular solution to the clients when it is applicable.

The most important and highest priority of the solutions mentioned by Group One is to "increase awareness of the advantages of the modules". They mentioned that it is necessary to create awareness not only within the company but also among vendors and clients. They mentioned that it should be a priority because unless there is a good understanding of the situation and what the modular design could bring to the projects, nobody is willing to change and try the new approach. They also mentioned that knowledge about the modules already exists, and some people are aware of the advantages, but it needs to be more common and formalized, so having workshops, presentations, and educational programs about the modules seems like a possibility for applying this suggestion.

The second priority chosen by group one is "considering future reuse". They argued that if the first step is done and everyone is aware of the changes, then they can implement this suggestion. They would recommend putting this consideration into all of the phases and teams involved in the project. The management team, the project control, the designers, and also the vendors and clients. by doing so, there would be a better chance of creating a probable plan for the future of the equipment. It was also said that by having a plan and presenting it to the parties, the chances that they would engage in the act and create a better outcome would be increased.

The third priority mentioned by group one was "multiple customers for a single design". They argued that, after all, in a competitive market, in order to survive, each company needs to have financial feasibility. They indicated that this solution would be a good approach to making it valid both for the company and for potential customers. They mentioned that in order to do this, they would either choose "mass production" or "leasing contracts" based on the type of equipment and process to which the modular approach is being applied. They mentioned that these two solutions would act as tools to create or find multiple users for a design in the industry. It was also mentioned that the vendor's activity and framing are important but are not priorities because it would be impossible for Tebodin to change the paradigm. They could propose ideas to them, but it would take a lot of time for the market to change. It was also mentioned that for creating this market it is important to implement data-driven maintenance, which is so necessary, especially for the leasing contract models. One of the other solutions illustrated by group one was “Common process” " They indicated that in order to achieve a good result for the

solutions in the center of the picture, it would be helpful to at least start in the common process, so there would be a bigger user pool and the chance of finding a client would be higher.

When the reason for giving demo plants such a low priority was asked, they indicated that demonstration plants could be a very good starting point for modular design and also circularity and reuse, but they are not necessarily the only available projects. They mentioned that it is possible to apply the approach to all the projects as long as they can get the attention of the vendor and the client. They also mentioned that demo plants may create a less appealing situation for the leasing companies, as they are famous for not having a good maintenance plan.

Except for the solution that was not approved, the least favorable suggestion was "easy accessibility for maintenance". Group one indicated that although this is necessary and important, it is not only for the modules and is something to keep in mind in any design method. Also, they mentioned that it would create a better outcome and reduce the hassles of maintenance, but it would not directly help to apply modular design or circularity to the projects.

In the end, group one suggested that it should be clear what this approach has for each party, so the Tebodin project team would start to increase awareness among different parties; this would start with the tendering process and business development teams. Then the engineering team needs to address the issue and include the modular design in the concept phase; by doing so, it would be more practical to offer it to potential customers. The last suggestion was for the skid builders and how Tebodin should encourage them about the system, ownership, networking, and the potential that would be available by using the modular design.

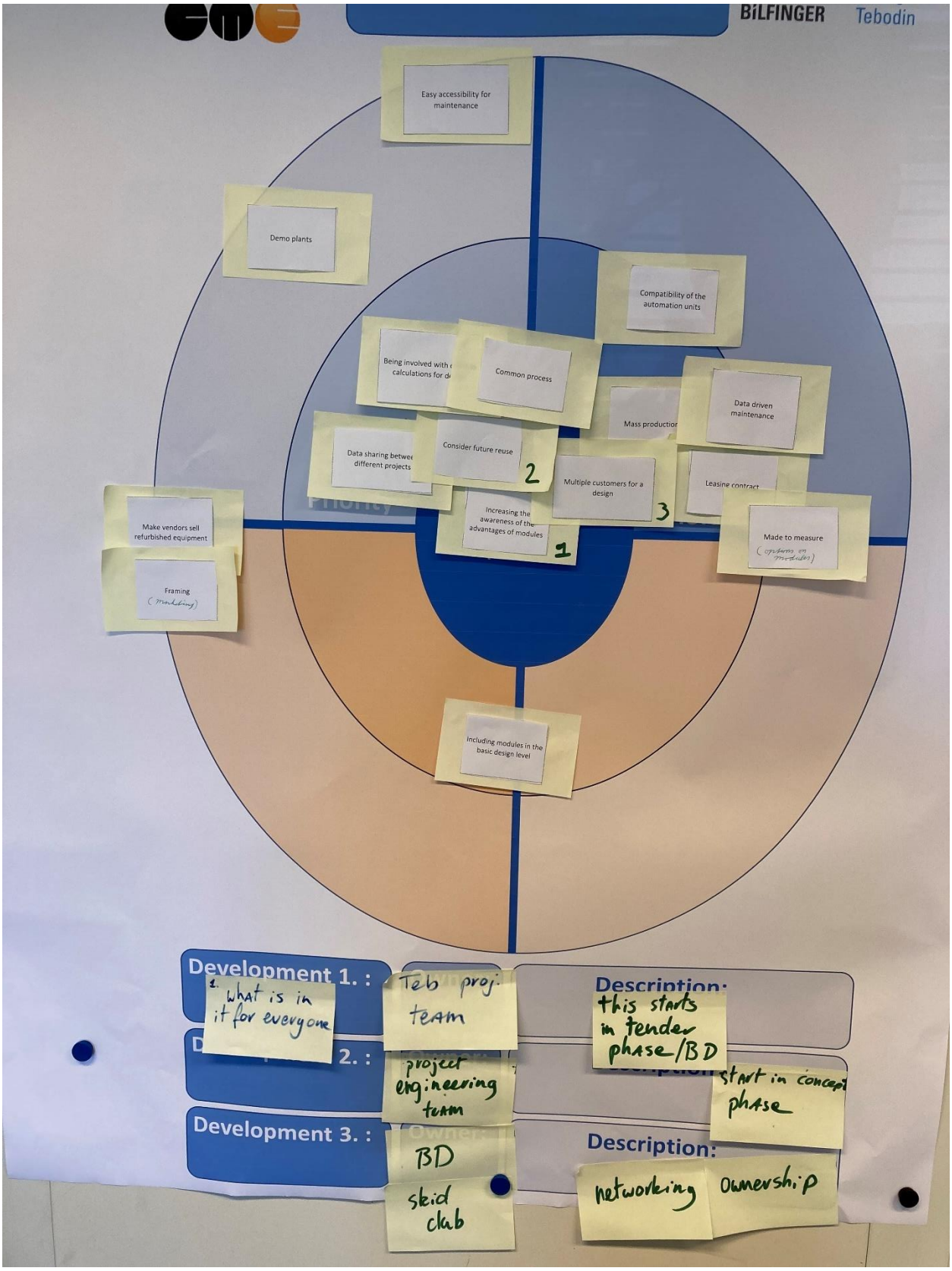

Figure 17: Workshop poster Group one

The second group sorted all of the solutions on the poster. They chose "framing" as the most important and number one priority that needs to be changed in order to influence the company and the market. They mentioned that it has a huge role in presenting ideas in the market, and better wording and presentation would make it easier for the marketing team to encourage customers to use this method. They also included the leasing contract as the second most important suggestion; they mentioned that using leasing contracts is very suitable for companies and could be used in order to start the modular approach. They mentioned that not only would Tebodin be able to use leasing contracts and start to own the modules, but they could also present it to the vendors that they are working with, and in the long term, they would create a whole market based on the leasing contract model. They argued that "mass production" is in fact in contrast to the leasing method, as in leasing you want to have a limited amount of assets that are always in use and move from client to client, while in mass production, there is no such thing, and every customer would buy their own equipment. So, they put mass production in the lower part of the diagram and would not agree with that.

One of the other important solutions, in the opinion of Group 2, was "common processes". They mentioned that it would be very nice to start applying this method and leasing contracts in the common processes as it would make it easier, and the bigger client base and more generic design would help the company reduce the risk and move towards this approach more easily. They also suggested that being involved in the calculation with other parties may help implement the modular design. The reason for that is that they would have the option to collaborate with the client and also suggest the usage of the modular approach with respect to the customer's plant and needs.

Group two mentioned "including modules in the basic design" and argued that it should not happen at that stage. Like group one, they indicated that it would be too late to start thinking about and applying the modular approach at that stage, but you could try and prepare the design team beforehand and use the modular approach as one of the practices that the company uses in order to get involved with the clients. The last point, which was in the lower part of the diagram, is "making vendors sell refurbished equipment", In this case, group two suggested that they do not want vendors to sell equipment, but they want them to stick with the leasing plan and try to create a market in which leasing is the main approach. They mentioned that there is a contradiction between these two approaches, but overall, they agreed that vendors are one of the main actors in this change and they need to be involved. They argued that if they could keep the intellectual property and vendors could keep the equipment, then together they could create a market based on leasing the equipment.

Group two mentioned that "being involved with the client in the calculations of design" and "easy accessibility for maintenance" are both important but not at a high level of priority for modular design. They argued that although both of these approaches are helpful in having a better design and a better outcome, they are not really helping the company move toward modular design at the moment. They also indicated that for solving maintenance problems, there are a lot of already studied approaches that designers and engineers could use in case of need, but the higher priorities are not easy to approach and apply and require creativity and new approaches. They also mentioned that "demo plants" are a good place to start the modular approach, but because they saw the problem as solvable by using leasing, they did not give it a high priority because leasing contracts are not limited to the demo plants and could be applied to different projects and plants.

The least priority was given to "multiple customers for a design" by group two. It was argued that it sounds nice and probably helps the approach, but it is not a priority to find multiple customers for a design; they mention that instead, they had the idea of creating a paradigm in the industry and backing it up with the help of vendors and also the data that they are gathering in other projects; in this case, they would attract the customers. So, to put it simply, they mentioned that instead of changing their design for the customers and making it fit for many customers, they should change the regime and make the customers approve and want what they are going to offer, which in this case is the reusable modules. It should be noted that it is and low priority because it is far away at the moment and almost impossible to do, but in the future, it would be a good plan to attract and change the demands of the customers. They mentioned that Tebodin, as one of the lead engineering companies, would have the power to influence and change the demands of the clients.

The suggestions and action plan that group two mentioned are a framing campaign and collaboration between vendor companies and engineering companies. By doing so, they would increase awareness about modular design and create an atmosphere in which it is possible to develop modularity. The second step would be to align manufacturers with end-users; this would be the main activity that Tebodin needs to do in order to create the market. Trying to find the potential to be modular and reuse and lastly, they mentioned standardization; they indicated that if the regulators emphasize some regulations about the reuse and less usage of raw materials, it would be part of the codes like DIN or ASME, then all the clients are obligated to use the method. They mentioned that this is not that far from reality with the situation and changes that are happening in different sectors and how governments and regulatory parties are trying to include environmental acts in their laws.

During the presentation of their thought process, neither of the groups mentioned the compatibility of the control units, but they both put it in the upper part of the diagram, so it was asked why they did not indicate the importance of the solution. They mentioned that it is an important aspect, and of course, it would reduce so many problems and create a better situation for the companies, but it has already been developed and there are so many methods and approaches to address this problem that they did not put it in as a priority.

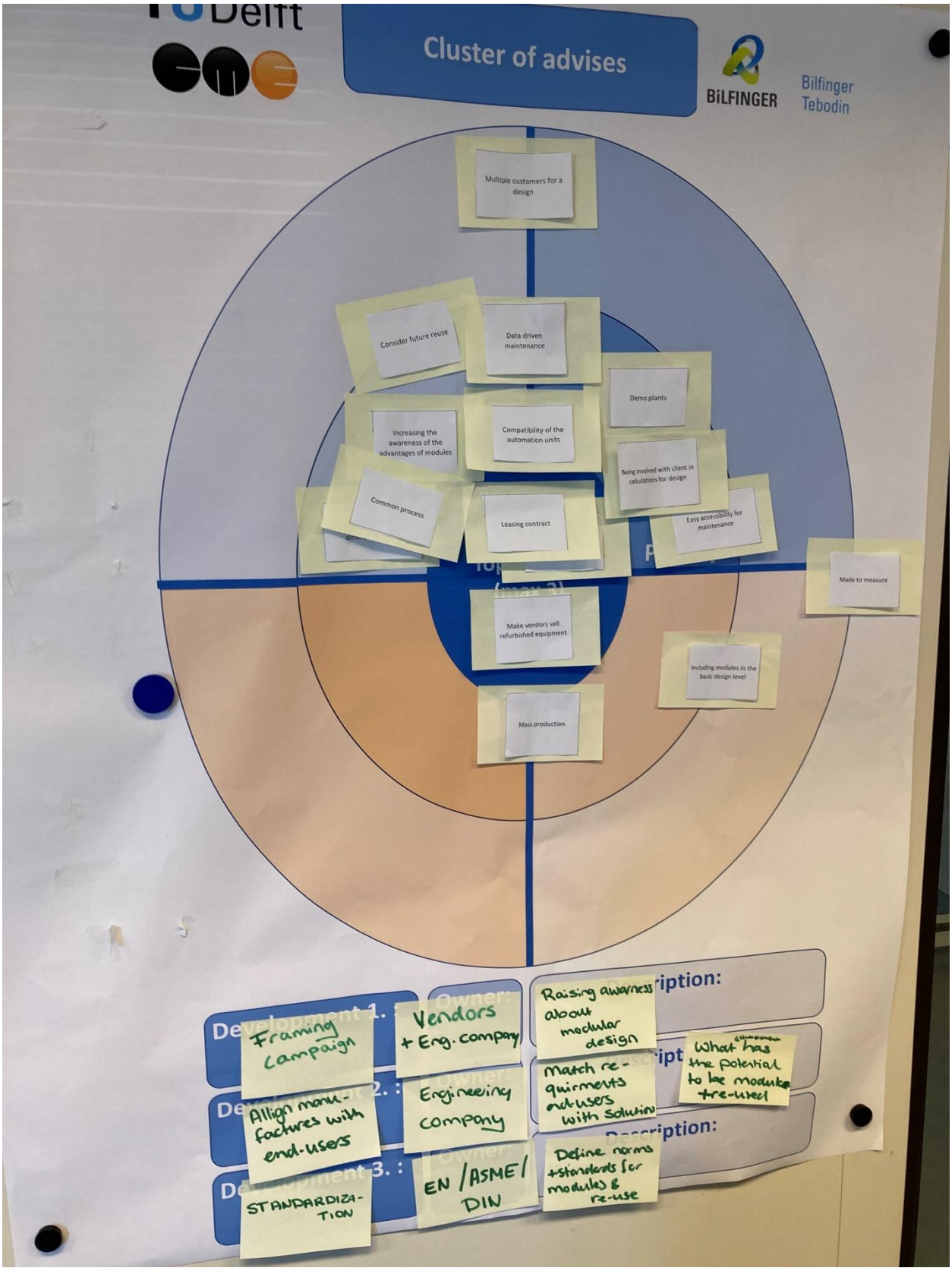

Figure 18: Workshop poster group two