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The Future is living in a cube

Building sustainable modular constructions through contributing to a circular economy – the case of Acondo & Containerwerk

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Abstract

Waste is becoming an increasing issue globally while the concept of a circular economy as a sustainable solution to it has gained attention in the past years among governments, researchers and businesses. As the construction industry accounts for 40% of waste in Europe, this study particularly showcases this industry's challenges and outlines how modular construction can tackle them by shifting a major part of the construction process off-site. Exemplary, the case of the general contractor for modular buildings Acondo and its collaboration with the modular constructor Containerwerk are introduced to highlight their contribution to a circular economy through Containerwerk's business model of converting used sea-freight containers into sustainable living modules.

The two questions analysed within this study examine Containerwerk's economic, environmental and social objectives and how the company can generate a competitive advantage through contributing to a circular economy. As a theoretical basis, literature on sustainability, the Triple Bottom Line, circular economy, hybrid organizations and Porter's Generic Strategies are reviewed. For the first question, the Triple Bottom Line aligned with the concept of a circular economy is applied, showing that Containerwerk fulfils all elements of the economic and environmental dimension but only partly the social one. Thus, this study questions whether an achievement of all three objectives to the same extent is required to contribute to a circular economy. The analysis of the second question based on Porter's Generic Strategies highlights that Containerwerk generates a competitive advantage in the narrow segment of tiny houses but not in the entire industry.

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Sumário Executivo

Os resíduos estão a tornar-se um problema crescente a nível mundial, enquanto o conceito de economia circular como solução sustentável tem ganhado atenção nos últimos anos entre governos, investigadores e empresas. Sendo a indústria da construção responsável por 40% dos resíduos na Europa, este estudo apresenta seus desafios e delineia como a construção modular pode enfrentá-los ao deslocar parte do processo de construção para outros sítios. Para exemplificar, é apresentado o estudo de caso da colaboração entre as construtoras modulares Acondo e Containerwerk, com objetivo de realçar a sua contribuição para a economia circular através do modelo empresarial da Containerwerk, que converte contêineres de frete marítimo em módulos de vida sustentável.

As duas questões analisadas neste estudo examinam os objectivos económicos, ambientais e sociais da Containerwerk e como a empresa pode gerar vantagem competitiva. Como base factual, é revista a literatura sobre sustentabilidade, o Triple Bottom Line, economia circular, organizações híbridas e as Estratégias Genéricas de Porter. Para a primeira questão, aplica-se o Triple Bottom Line alinhado ao conceito de economia circular, evidenciando que a Containerwerk está a contribuir para todos os elementos do objectivo económico e ambiental, mas apenas parcialmente para o social. Este estudo questiona se é necessária uma integração dos três objectivos nas operações de uma empresa, na mesma medida, para contribuir para a economia circular. A análise da segunda questão, baseada nas estratégias de Porter, salienta que a Containerwerk gera vantagem competitiva no nicho das casas minúsculas, mas não em toda a indústria.

Título da dissertação: O futuro é Viver num Cubo: Construir construções modulares sustentáveis para contribuir para uma economia circular - o caso da Acondo & Containerwerk
Autor: Alice Isabella Müller
Palavras-chave: Sustentabilidade - Economia Circular - Triple Bottom Line – Estratégias Genéricas de Porter - Organizações Híbridas - Indústria da Construção - Construção Modular - Acondo – Containerwerk

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List of Abbreviations

Acondo	ACONDO GmbH & Co. KG
CE	Circular Economy
Containerwerk	CONTAINERWERK eins GmbH
EU	European Union
HO	Hybrid Organization
R&D	Research and Development
SD	Sustainable Development
SDGs	U.N. Sustainable Development Goals
TBL	Triple Bottom Line

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1. Introduction

In 2016, the European Union (EU) produced 2.5 billion tons of waste whereas the huge consumption of resources burdens the planet (European Parliament, 2021). In total, only 9.1% of the resources and materials are reused globally (CGRi, 2020). Therefore, the EU, several national governments and businesses worldwide are promoting the concept of a circular economy (CE), defined as "keeping materials available instead of disposing them" (Ritzén & Sandstörm, 2017, p. 7). By doing so, the loop of materials within the product lifecycle can be closed to reduce resource waste (Korhonen et al., 2018; Rajput & Singh, 2019; Ritzén & Sandstörm, 2017).

The concept of a CE is aligned with the UN Sustainable Development Goals (SDGs) which aim for prosperity while protecting people and the planet (Friant et al., 2021; SDGs, 2021). Almost all huge globally active corporates are contributing to these goals (SDGs, 2021). From a managerial perspective, CE is outlined as a possibility to increase productivity of resources and decrease resource dependency to foster growth (Murphy & Rosenfield, 2016). Accordingly, CE enables the European economy to grow resource productivity by up to 3% per year, resulting in a primary resource benefit of 600 billion € annually by 2030 (MacArthur, 2015).

In academic research, sustainability and CE have received increasing attention from practitioners and policymakers with a steep increase in published articles and journals in the last decade (Geissdoerfer et al., 2017; Ghisellini et al. 2016). Both, sustainability, and CE, are essentially global in their nature, sharing concerns regarding industrial production and consumption while presenting sources of competitive advantage (Geissdoerfer et al., 2017). Thereby, especially the importance of integrating environmental and social aspects within economic processes have been outlined (Geissdoerfer et al., 2017). One type of organizations that generates social and/or environmental impact while aiming for financial sustainability are Hybrid Organizations (HO)s (Doherty et al., 2014; McMullen & Warnick, 2016). Nevertheless, CE is a new area of research, and its concept is rarely and fragmented applied in practice yet (Friant et al., 2021; Geissdoerfer et al., 2017; Ritzén & Sandstörm, 2017).

This thesis strives to understand how companies can apply the concept of a CE to overcome the issue of waste in a sustainable way while generating profit. As almost 40% of the waste in Europe in 2016 was generated in the construction industry while this industry is considered as

a key market in Germany with almost 5% of the overall gross value added in 2013, two German companies in the construction industry will be analysed (BAuA, 2014; European Parliament, 2021). For this purpose, *ACONDO GmbH & Co. KG* (Acondo) as a general contractor for sustainable modular construction projects is introduced. One of these projects that will be focused on in this thesis is the partnership with the HO *CONTAINERWERK eins GmbH* (Containerwerk). By transforming used sea-freight containers into sustainable living apartments, they aim to generate environmental, social and economic value while contributing to a CE.

To evaluate the case, the following teaching questions will be analysed:

1. What are the objectives for Containerwerk to contribute to a CE?
2. How can Containerwerk achieve a competitive advantage through its contribution to a CE?

To answer these questions, qualitative data has been conducted as this type of data is sensitive and flexible to social relations and the case study is highly based on social interactions of Acondo and Containerwerk (Hox & Boeije, 2005). Overall, both primary and secondary data were collected with a clear focus on primary data.

This thesis is divided into six chapters. After this introduction, a comprehensive literature review of sustainability and the triple bottom line (TBL) as a framework that depicts the key elements of sustainability are outlined. Moreover, the concept of a CE aligned with the TBL is demonstrated. The literature review closes with a classification of HOs and an introduction of Porter's Generic Strategies as a framework to analyse a firm's competitive advantage. In the third chapter, the methodology of this thesis is described with a specific focus on the interaction between Acondo and Containerwerk. Chapter four covers the case study on challenges in the construction industry and the introduction of modular constructions as a sustainable solution. The example of Acondo and Containerwerk will enable students to further understand the practical dimensions of the topic. In the subsequent chapter, teaching notes are provided as a guideline for the instructor to analyse the case study and to answer the two teaching questions. The last chapter sums up the case, its analytical results and discusses managerial contributions for the two companies. The thesis is finalised by a conclusion with limitations and an outlook for future research.

2. Literature Review

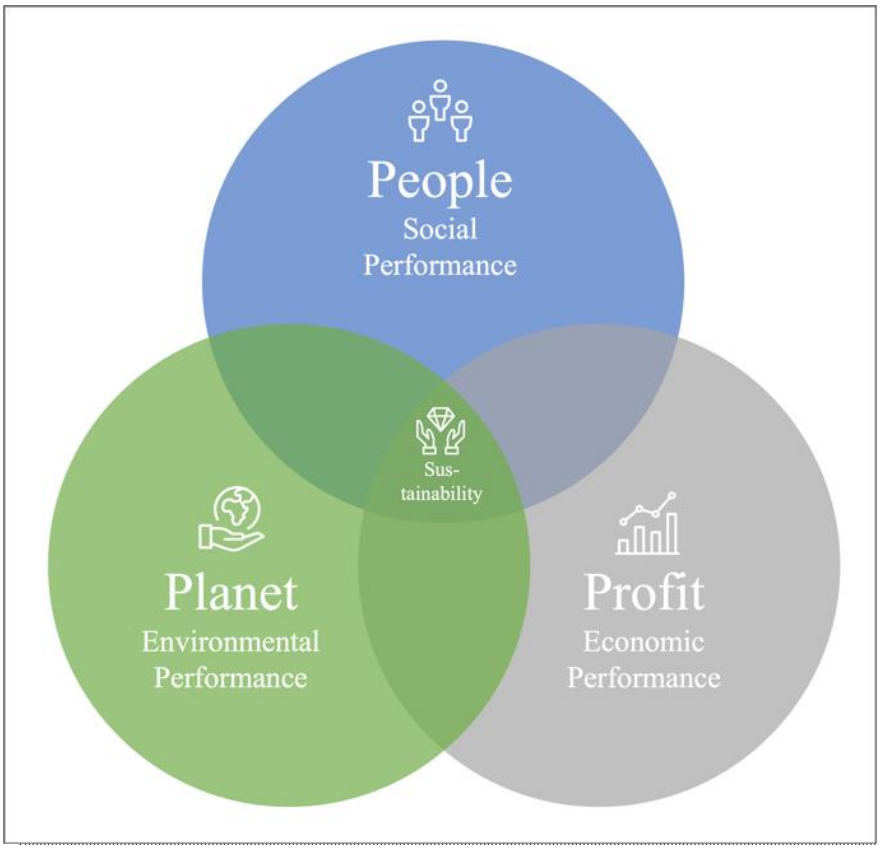
2.1. Sustainability and the Triple Bottom Line

Sustainability and sustainable development (SD) are getting increasing attention from all types of stakeholders and are becoming a strategic priority for corporates (Hengst et al., 2020; Olawumi & Chan, 2018). Globally, the sustainable sector generates 1 billion $ revenue annually while the SDGs forecast the growth of the sector with market opportunities of 12 trillion $ a year by 2030 (Elkington, 2018).

SD can be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Based on the definition of Kleindorfer et al. (2005), sustainability consists of environmental management, closed-loop supply chains and TBL thinking which includes profit, people and the planet into a firms' culture, strategy and operations. Following the approach of Norton (2005), sustainability and SD can be considered as synonyms and are used interchangeably in this thesis.

The TBL has been developed by Elkington (1997) as a sustainability framework to reflect a company's economic, social and environmental dimensions (i.e., "profit, people, planet") as illustrated in Figure 1 (Elkington, 1997; Goebel et al., 2018). These dimensions constitute the TBL with the objective to meet resource needs of the current and future population without harming the environment (Elkington, 1997; Khan et al., 2021). Elkington (2018) highlights that the TBL is not only an accounting tool but is supposed to revaluate capitalism and fundamentally change the thinking about the future towards SD. Among the literature, many researchers agree that sustainability integrates and balances these three objectives (Gimenez et al., 2012; Goebel et al., 2018; Khan et al., 2021; Korhonen et al., 2018).

Figure 1: The Triple Bottom Line



Source: *adapted from* Coşkun & Kısacık (2017); Evans et al. (2017).

The TBL implies that a companies' responsibilities go beyond those related to economic aspects of providing profitable products and services at regulatory standards demanded by customers (Hubbard, 2009). Besides a firm's economic sustainability which targets to secure liquidity, generate profit and improve productivity, the framework consists of two more objectives: planet and people (Braccini & Margherita, 2019; Elkington, 1997; Schulz & Flanigan, 2016). At a planet level, environmental sustainability refers to the number of resources a company utilizes in its operations, e.g., energy, land, water and its resulting by-products, such as waste and air emissions (Hubbard, 2009). The third objective is the social performance which can be described as a firm's contribution to the development of human and societal capital and its own as well as its suppliers' impact on the communities in which they operate (Hubbard, 2009; Khan et al., 2021).

2.2. Circular Economy

One of the main challenges of global SD is the one-way flow of materials and energy which leads to resource losses in several ways, e.g., waste in the production chain and end-of-life

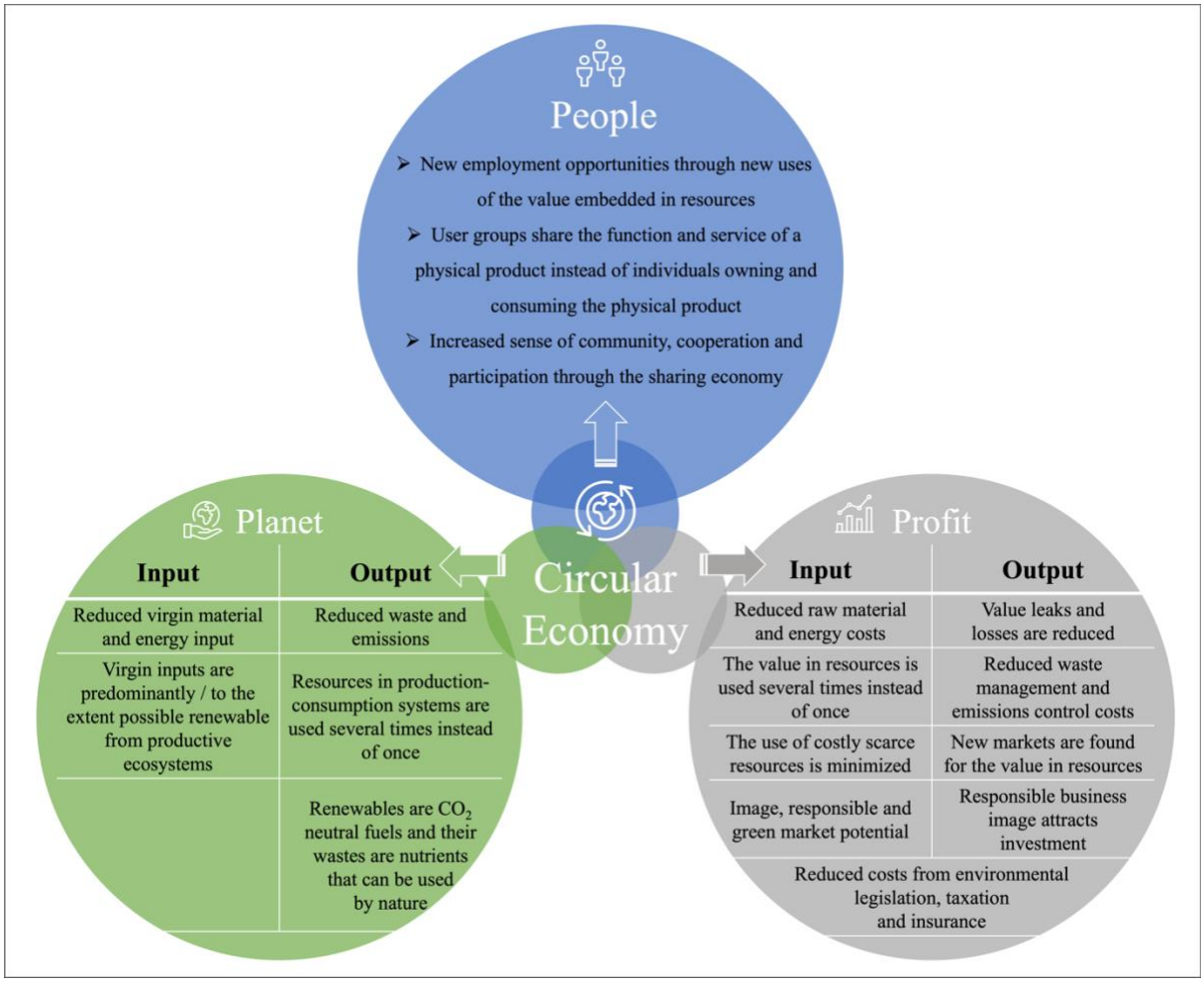
waste (Korhonen et al., 2018; MacArthur, 2013). Therefore, the EU economy leaves significant amounts of resources behind which could be potentially reused as secondary raw materials (Tomić & Schneider, 2020). This one-way conversion of natural resources into waste through its production can be defined as linear economy (Murray et al., 2017). The generated waste impacts environment and economy negatively while the system of a linear "take make dispose" economy is reaching its physical limits (European Parliament, 2021; Tomić & Schneider, 2020; Tura et al., 2019). As a response, the concept of a CE as a reversion of the linear model has been developed (Korhonen et al., 2018).

The origins of the concept of the CE are debated in literature (Murray et al., 2017). Pearce and Turner (1990) introduced CE as a concept invented by nature, elaborating how natural resources influence the economy by providing incentives for production, consumption as well as waste management to shift the traditional open-ended economic system to a circular one. McDonough and Braungart's (2002) cradle-to-cradle concept outlines the infinite circulation of materials and is considered as one of the most influential background concepts of CE. Korhonen et al. (2018) state that all types of products at the end of their life cycles can be either recycled as biological nutrients or persist in closed-loop industrial cycles as technical nutrients. The most renowned definition has been framed by the *Ellen MacArthur Foundation* which was founded in 2010 to promote the concept of a CE and defines CE as "an industrial economy that is restorative or regenerative by intention and design" (MacArthur, 2013, p. 7).

In the previous years, CE received increasing attention worldwide as a possibility to overcome the current linear model based on continuous growth and increasing resource reuse (Ghisellini et al., 2016). Its purpose is to shift the focus on renewable sources of energy and precise management of waste through a cyclical flow of materials and energy (Korhonen et al., 2018; Mavi & Mavi, 2019). Thus, the maximum reuse and recycling of materials are promoted to decrease waste to the largest possible extent (Ghisellini et al., 2018).

By taking a circular closed-loop perspective on resources and concentrating on their value regeneration, CE aims to contribute to all three objectives of the TBL (Geissdoerfer et al., 2017). Figure 2 illustrates how CE and the TBL are linked, and which element of the CE can be assigned to which objective of the TBL. According to Korhonen et al. (2018), a successful CE contributes to all three dimensions.

Figure 2: CE aligned with the TBL



Source: Own illustration *adapted from* Korhonen et al. (2018).

At a planet level, the environmental objective of a CE is to reduce virgin material and energy input and to ensure that these inputs are predominantly renewables from productive ecosystems (Korhonen et al., 2018). Considering that, a method to contribute to a CE is upcycling which can be defined as a process of transforming materials into new materials with higher quality and increased functionality (MacArthur, 2013). In the construction industry, grey energy can be defined as the primary type of energy necessary to construct a building (Staiger, 2021). It includes energy that is used to extract materials, to manufacture and process components, to transport people, machines and resources to construction sites as well as to install components and to dispose them (Staiger, 2021). According to the concept of a CE, grey energy should be minimalized (Korhonen et al., 2018; Staiger, 2021). Regarding environmental output, waste and emission reduction should be targeted by applying resource cycles and utilizing renewable-based fuels and energies (Korhonen et al., 2018). Moreover, resources in production-consumption systems should be used more than once (Korhonen et al., 2018).

The economic objective of a CE is to reduce costs regarding raw materials, energy, waste management, emissions control as well as costs that arise from environmental legislation or taxation. In addition to cost reduction, value leaks and losses should be reduced, and resources should be used several times to increase their value. Moreover, the use of costly scarce resources should be kept at a minimum and new markets should be found for resources. Thus, a public green market image of a responsible business can be created to attract investments (Korhonen et al., 2018).

The social objective of a CE refers to employment opportunities due to potential new usage of resources and/or more efficient use of the existing physical material capacity (Korhonen et al., 2018). This could be achieved through a cooperative and community user culture called sharing economy (Korhonen et al., 2018). Thus, sharing economy can be defined as a market pattern which is characterized by collaboratively fee-based sharing of materials, services and underutilized inventory (Zervas et al., 2017). However, Murray et al. (2017) describes CE as a concept of economic and environmental activities in a sustainable way which it is not depending on social objectives. Among literature, the social dimension of a CE is the least expanded and can result in tension with one of the other objectives (Murray et al., 2017).

2.3. Hybrid Organizations

In the past decade, research on HOs has intensified as the number of these organizations is growing and the term is gaining traction internationally (Haigh et al., 2015; Holt & Littlewood, 2015). Nonetheless, the landscape of these firms is heterogeneous, complex and the understanding is embryonic (Holt & Littlewood, 2015).

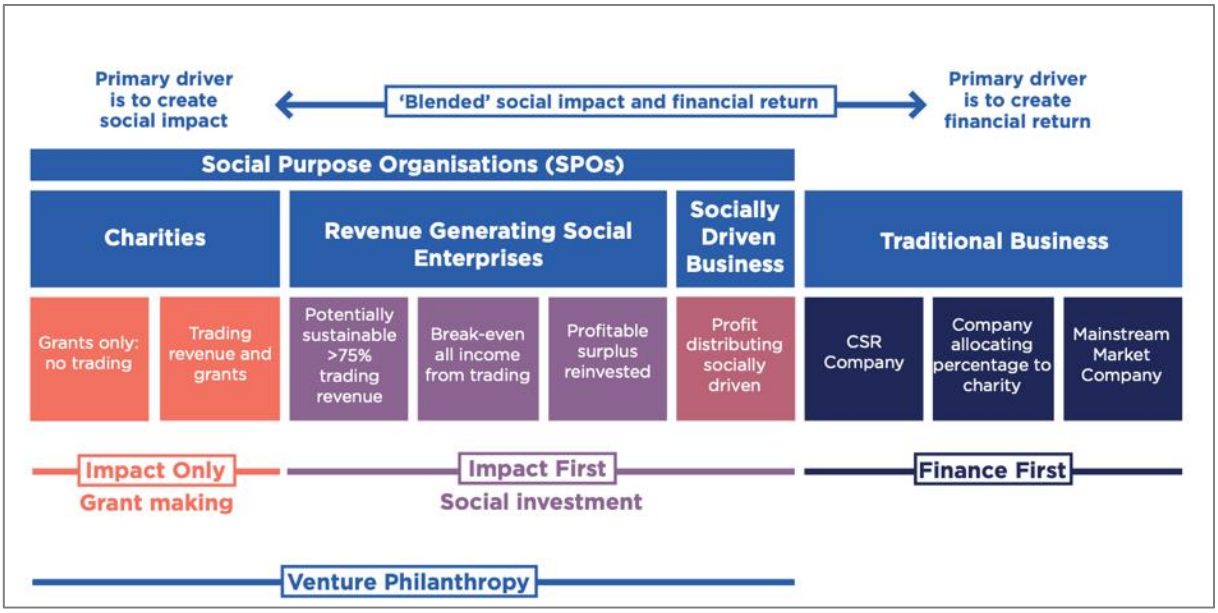
HOs aim to create economic, social and environmental value which aligns their objective with the TBL (Haigh et al., 2015; McMullen & Warnick, 2016). By integrating all three perspectives into their missions, HOs seek to shift the focus from financial value creation exclusively to the importance of integrating social and environmental value (Battilana & Lee, 2014). Therefore, it can be outlined that HOs blend traditionally for-profit practices with non-profit ones (Haigh, 2015).

The way HOs generate income and attract capital can be applicable for both for-profit and non-profit organizations (Haigh, 2015). They can be either identified as non-profits that receive most or all of their revenue through donations, or for-profits with a very strong social mission

(Haigh, 2015). In addition, HOs are represented in all sectors, they can be small- to large-sized organizations and are located in developed as well as developing countries (Holt & Littlewood, 2015).

The origins of the impact they seek to create as well as the institutional forces that shape them can vary across HOs (Holt & Littlewood, 2015). Therefore, it can be distinguished between different types as demonstrated in Figure 3.

Figure 3: Types of Hybrid Organizations



Source: Gianoncelli & Boiardi (2018).

According to the *European Venture Philanthropy Association*, it can be differentiated between charities that are financed through grant making, *Revenue Generating Social Enterprises* and *Socially Driven Businesses* which prioritize impact over financial return and are depending on social investments as well as traditional businesses that are mainly driven by financial return (Gianoncelli & Boiardi, 2018).

HOs are serving a growing market segment called *LOHAS* (Lifestyles of Health and Sustainability), which focuses on health, the environment, social justice and sustainable living and has been worth 209 billion $ in 2015 (Haigh, 2015). Especially partnerships between companies and HOs offer mutual benefits as it can be an effective way for HOs to scale as well as an opportunity for traditional firms to move beyond corporate social responsibility goals and use hybrid structures and strategies to strengthen their commitment to social and environmental

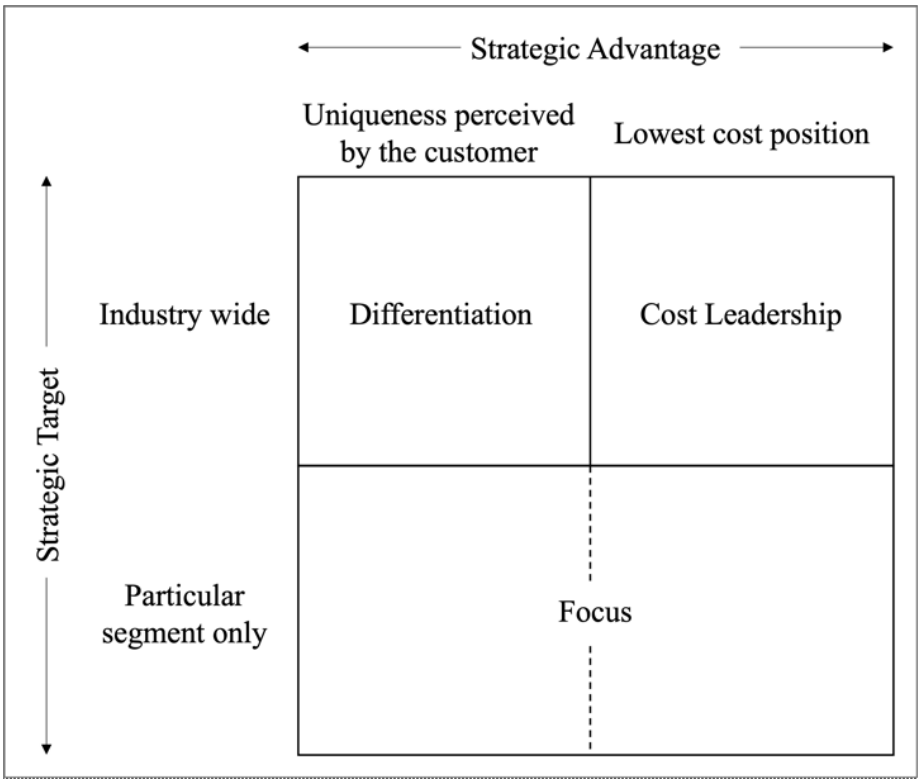
goals (Haigh, 2015; Haigh et al., 2015). Holt & Littlewood (2015) highlight that an increasing number of traditional for-profit firms is cooperating with HOs.

2.4. Competitive Advantage according to Porter's Generic Strategies

To gain a competitive advantage, companies need to differentiate themselves from others within their industry through a various set of activities to create a unique value (Murray, 1988; Porter, 1996). Therefore, it is crucial to understand the industry's structure, competitors as well as customers and to analyse its own relative cost position (Porter, 1986).

According to Porter (1996), "a company can outperform rivals only if it can establish a difference that it can preserve" (Porter, 1996, p. 62). This can be achieved by either delivering greater value to customers compared to competitors through differentiation, by providing value at lowest cost or by developing a unique product within a narrow segment (Porter, 1996). Thus, Porter's Generic Strategies to gain a competitive advantage can be divided into three strategies: differentiation, cost leadership and the focus strategy, all depending on a firm's strategic advantage and strategic target as illustrated in Figure 4 (Hambrick, 1983).

Figure 4: Porter's Generic Strategies



Source: *adapted from* Hambrick (1983).

Cost leaders can gain a competitive advantage through products or services that cost less than equivalents of their competitors (Hambrick, 1983). Their strategic advantage is their lowest cost position which targets the entire industry as depicted in Figure 4 (Hambrick, 1983). To achieve cost leadership, they focus on efficiency in all their business operations while avoiding unprofitable customer accounts and minimising costs (Porter, 1997). For this strategy, it is crucial to maintain the price differential even if competitors reduce their costs through product or technology imitations (Porter, 1997).

Differentiation requires significant value creation of a product that is perceived as unique by customers of various industries in the market (Hambrick, 1983; Porter, 1997). This added value can take on many forms, including brand image and loyalty, a specific product function, technology or feature, service, distribution or quality (Hambrick, 1983; Porter, 1997). The strategy might require a high investment in research and development (R&D) or high-quality materials which could be compensated by increased profit margins (Porter, 1997). However, whilst the differentiation strategy is still costs-sensitive, the reduction of costs is not the main target of it (Hambrick, 1983).

The third one of Porter's Generic Strategies, the focus strategy, can be achieved through an advantage in a narrow segment, e.g., in a specific buyer group, product line or geographic market (Hambrick, 1983; Murray, 1988; Porter, 1986). According to Porter (1997), this focus strategy allows for both, a differentiated and low-cost product or service. It is significant for the strategy that the competitive advantage is only generated in a particular segment (Hambrick, 1983).

3. Methodology

Within this thesis, primary and secondary data have been collected. However, the case study is mostly based on primary data as this type of data allows to specifically target its methods to the research problem, i.e., the teaching questions. Thus, the data collection strategy can be tailored to the teaching questions to ensure that the study is coherent and that the conducted information is sufficient to answer them. In addition, secondary data has been collected through articles, official reports, journals and press releases to validate the primary data (Hox & Boejie, 2005).

Moreover, qualitative data has been evaluated as the most appropriate to answer the teaching questions as they are highly based on the interactions of Acondo and Containerwerk and qualitative data is sensitive to those social relations (Hox & Boejie, 2005). A primary method of qualitative data collection are semi-structured interviews based on prepared open-ended, non-judgmental questions which are not fixed, allow for flexibility and maximize the variety of answers (Braun & Clarke, 2013). Furthermore, they can be controlled by the interviewer as questions can be changed or mixed regarding the course of the interview to vary the degree of details (Braun & Clarke, 2013). Therefore, this case study is mainly based on interviews which can be found in Appendix II.

Throughout the process of the thesis, close communication with both companies was established through E-Mail, phone and several semi-structured interviews. In addition, a semi-structured interview with Carsten Leopold, CEO of *CHS Container Group,* has been conducted to get a perspective of another container modules constructor. An overview of the types of sources and their objectives are summarized in Table 1.

Table 1: Data Collection

Type of source			Objectives
Acondo	**Primary**	• First semi-structured interview with Heinrich Laumen, CEO & owner and Michael Krátký, founder & owner (22nd of February 2021) • Second semi-structured interview with Michael Krátký (03rd of August 2021) • Exchange via E-Mail (Michael Krátký)	Detailed understanding of the company's structure, mission and strategy. Deeper analysis of the modular construction industry and the partnership with Containerwerk.
	Secondary	• Internal documents and reports • Website	
Containerwerk	**Primary**	• Company visit (08th of April 2021) • First semi-structured interview with co-founder & partner Markus Goldmann (via phone, 09th of April 2021) • Second semi-structured interview with Markus Goldmann (via phone, 1st of August 2021) • Exchange via E-Mail (Markus Goldmann & Christine Schaal, responsible for marketing and communications)	In-depth discovery of the company's product, production process, vision, structure and goals.
	Secondary	• Internal documents and reports • Website • Press releases	
	Primary	Semi-structured interview with Carsten Leopold, CEO of *CHS Container Group* (via phone, 17th of August 2021)	Understanding the firm's strategy and structural incentives.
	Secondary	Official reports and journals	Capturing data published by researchers, institutions and governments.
		Webpage articles and newspapers	Gathering relevant information about the companies and the construction industry.

Source: Own illustration.

4. Case Study

4.1. Challenges in the construction industry

The linear production model incurs resource losses and material waste: In 2016, 2.5 billion tonnes of waste were generated in Europe while 60% of the wasted materials were neither reused, recycled nor composted (MacArthur, 2013; European Parliament, 2021). Almost 40% of the waste was generated in the construction industry (European Parliament, 2021). In Germany, construction and demolition waste accounted for 223 million tonnes in 2016 which is an increase of 6.6% compared to the previous year (DGNB, 2021b).

With substantial resource consumption, limited resources and increasing environmental concern, the construction industry is one of the priority industries that requires actions in terms of resource efficiency (Hossain et al., 2020; Kirchherr et al., 2017). Especially traditional buildings are not designed or built to be transformed into recyclable or reusable components which leads to significant losses of valuable materials (MacArthur, 2013). In addition, some resources are exhausted, e.g., gravel pits are starting to groan which are essential for concrete constructions.

A shift of the linear economy to sustainable construction through a CE enables to protect resources and to incentivize their efficient use (Hossain et al., 2020). Felix Jansen, Director of PR and Communication at *DGNB* (German Sustainable Building Council), a non-profit organization which promotes sustainable building, highlights that

> "*there needs to be a change of thinking. We need to dispel the idea that sustainable construction means additional effort and added costs, instead it needs to be seen as a necessary maxim and as a guideline for future-oriented planning and construction*" (Containerwerk, 2019).

Working conditions on construction sites can be outlined as another challenge in the industry: They are rated poor to average based on a survey conducted among 14 large general contractor members of the registered employer cooperation *ECMBA* (East Cape Master Building Association) (Abrey & Smallwood, 2014; ECMBA, 2021). Influencing variables are particularly weather, organisational factors, health, safety and the workers' mindset while poor conditions cause confrontations, health and security issues and have a negative effect on productivity (Abrey & Smallwood, 2014; Panas & Pantouvakis, 2010).

Especially the influence of weather occurs significantly more often in construction than in other industries. The *German Federal Institute of Occupational Safety and Health* (BAuA) conducted a survey in 2012 on working conditions in the construction sector with 422 construction employees and 10,605 employees of other occupations. While 79% of employees in the construction industry reported distractions due to climate, e.g., cold, heat, wetness, humidity or draught, it was only reported by 23% of employees in other occupations (BAuA, 2014).

One way to adapt elements of CE (environmental), to provide better working conditions (social) and to realize financial benefits (economic) can be achieved through modular construction which will be focused on in this case and further analysed in the next chapter.

4.2. Modular construction as a sustainable solution

Modular construction can be defined as the production of standardized components in an off-site factory while these components are assembled on-site afterwards (Bertram et al., 2019). By shifting activities from traditional construction sites towards factories with off-site, manufacturing-style production, modularity holds several economic benefits as enabling to speed up constructions by 50% and cut costs by 20% (Bertram et al., 2019). This can be achieved as the risk of delays due to vandalism and site theft is minimized, material exposure caused by weather extremes is reduced and standardization of design and higher energy efficiency is enabled (Kamali & Hewage, 2016). Thereby, modular construction could enable annual savings of 22 billion $ and claim up to 130 billion $ of the market in U.S. and Europe by 2030 at moderate penetration (Bertram et al., 2019).

As around 85–90% of the modules can be prefabricated in off-site facilities, employees are less exposed to weather extremes and working conditions can be improved (Kamali & Hewage, 2016). In addition, safety and health of workers are increased due to less work under severe weather, at height and congestion and reportable accidents can be reduced by 80% compared to on-site construction (Kamali & Hewage, 2016; Lawson et al., 2012).

Regarding the environmental impact, it can be referred to a report by McGraw Hill Construction (2011) based on data that has been collected by 800 architectures, engineering and contracting professionals. The report states that modularity can reduce construction waste by 76% as an off-site factory makes it is easier to control, reuse, recycle and dispose generated waste (Kamali & Hewage, 2016; McGraw Hill Construction, 2011). Furthermore, the prefabrication allows

for less construction site disturbance regarding noise, dust, congestion, pollution, energy consumption, emission and waste as the construction site time is four to five times shorter than for conventional projects (Kamali & Hewage, 2016; Lawson et al., 2012).

Thus, it can be claimed that modular construction provides environmental, economic and social benefits in terms of SD (Nahmens & Ikuma, 2012). Acondo is an example for a construction company fostering sustainable projects solely in the modular construction industry. Based on the example of Acondo and its collaboration with Containerwerk, the topic of sustainability and the movement towards CE in the industry will be further analysed.

4.3. Acondo

Acondo is a general contractor for housing renovations and modular buildings. As a general contractor, Acondo provides a range of services for modular constructors such as location, competition and demand analyses, design planning, organisation of permit procedures, financing and marketing (Acondo, 2021). The company is a 100% holding of the private limited partnership entity *Grizzly KG* which is owned by Acondo's CEO Heinrich Laumen and Acondo's founder Michael Krátký who divided his shares between his family members and him. A detailed description of the organizational chart can be found in Appendix I.

Michael Krátký gained experience in the real estate and construction industry for over 35 years. Thus, he brings expertise to the company and has observed a change in the sector: While projects were solely driven by return and location a decade ago, the factor of sustainability becomes increasingly important for site managers and investors. The German government is further encouraging this development: On the one hand, restrictions regarding duration, transport quantities as well as dust, light and noise emissions tighten construction-site regulations (Bertram et al., 2019). On the other hand, energy-efficient construction projects are subsidized in accordance with a law adopted by the German government in 2021 (federal funding for efficient buildings, BEG) (BMWI, 2020). The funding depends on a project's KfW Efficiency House Standard (Credit Institute for Reconstruction), a benchmark for the energy efficiency of buildings (BMWI, 2020). In general, a construction has to fulfil a minimum KfW Standard of 100 by law while a lower number than 100 results in a higher subsidy (BMWI, 2020). Acondo's projects reach a KfW Standard of at least 55, meaning that the annual primary energy requirement of the building requires 55 % of the energy of a comparable new building and resulting in a subsidy of 15% (KWF, 2021).

The trend towards sustainability in construction is embedded in Acondo's mission to develop, design and establish professional, solution-oriented modularity projects in a mobile, sustainable and flexible way (Acondo, 2021; Salmon Capital, 2020). The modules consist either of wood, concrete, containers or used sea-freight containers and are built in cooperation with companies whose values are aligned with Acondo's mission. Currently, Acondo has eight of those collaborations. Exemplary, Acondo is working with a company that processes wood panels which are collected from the forest ground and would rotten otherwise. Therefore, a contribution to a CE is made as no trees need to be fell. Another type of modular constructions that fulfils the criteria of a CE is based on used sea-freight containers and will be the focus of this case study.

4.4. The partnership of Acondo and Containerwerk

In the sea-freight container segment, Acondo is solely working with Containerwerk as according to Michael Krátký,

> "*Containerwerk is the only company worldwide which provides sustainable, high-quality container solutions based on used sea-freight containers. Their technology is their unique selling point which makes the product unbeatable, and I would not work with another provider in this segment.*"

Michael Krátký and Containerwerk's founder and CEO Ivan Mallinowski started converting used sea-freight containers into modules with the goal to create simple affordable apartments that combine low-cost and sustainability. As they realized that R&D and the product itself are much more complex and expensive than expected, they switched the focus to prioritize quality, mobility and sustainability over production at lowest cost which is the target until today. One of the projects they both constituted to in collaboration with other companies is the boarding house complex "*My Home Wertheim*" which is described in Appendix III. The key facts of the companies as well as the main elements of their partnership are opposed in Table 2.

Table 2: Company profiles of Acondo and Containerwerk

	Acondo	Containerwerk
Year of foundation	2009	2017
CEO	Heinrich Laumen	Ivan Mallinowski & Micheal Haiser (Figure 15)
Number of employees	11	50
Locations	Bad Vilbel, Hesse, Germany	Wassenberg, North Rhine-Westphalia, Germany and Stuttgart, Baden-Wuerttemberg, Germany
DGNB	Both members of DGNB	
Beginning of the project	Both founders travelled together to Canada in 2009 and got inspired by containers as apartment modules	
Goal of product	Combine quality, sustainability and mobility in the product	

Source: Own illustration *adapted from* Containerwerk (2021e).

In the next chapter, Containerwerk and its housing concepts are further elaborated and its objectives to contribute to a CE will be outlined.

4.5. Containerwerk

According to the German federal government, around 400,000 apartments have to be built in Germany annually while living space is becoming an increasingly scarce commodity worldwide (Bertram et al., 2019). A solution for sufficient, payable living space provided in a short time is modular, serial construction (Bertram et al., 2019; Containerwerk, 2020a). Containerwerk developed a product which fills the growing need for small but flexible residential units and offers opportunities for architects and investors (Containerwerk, 2020a). Aligned with the three objectives of the concept of a CE, Containerwerk's mission is to purchase used sea-freight containers to upcycle them into high quality, affordable living space (Containerwerk, 2019).

The company is certified member of the DGNB which provides a certificate that is internationally renowned as "Global Benchmark for Sustainability" (DGNB, 2021a). DGNB focuses particularly on the increasing importance of the concept of a CE in the construction industry and understands the concept as to maintain a high quality of resources and to reuse them as long as possible, aligned with Containerwerk's mission (DGNB, 2021b). According to Ivan Mallinowski:

> "*The service life of a shipping container is on average less than 20 years. During this time, it will have transported millions of tons of freight and circled the globe multiple times. But its journey must not end there. Freight space can be turned into valuable and sustainable living space*" (Containerwerk, 2019).

Containerwerk is part of the consortium for sustainable modular constructions which continuously assesses the sustainability of modules according to the SDGs (Containerwerk, 2021c). The SDGs act as guiding principles for Containerwerk with a particular focus on ensuring sustainable consumption and production patterns (Goal 12) and combating climate change (Goal 13) (SDGs, 2021).

4.5.1. Hybridity

Besides creating environmental impact as aligned with the SDGs, Containerwerk supports social projects which shifts its purpose from financial value creation only to a blended model of generating impact and financial return (Battilana & Lee, 2014). Thus, Containerwerk aims to create environmental, social and economic value and can be defined as a HO (Battilana & Lee, 2014). Within the continuum in Figure 3 (chapter 2.3., page 8), Containerwerk can be classified as a *Revenue Generating Social Enterprise* which puts "Impact First" and is depending on investments. Its first investment was financed through equity, the second is covered by one of the federal states of the German government. In a long term, the company targets to become a *Socially Driven Business* that is by definition profitable and impact driven (Gianoncelli & Boiardi, 2018). Acondo can be identified as a *Traditional Business,* cooperating with a HO to strengthen their commitment to sustainability. In the following chapters, Containerwerk's contribution to the three objectives will be further clarified.

4.5.2. Environmental Objective

Aligned with its mission, the company aims to design its production process as sustainable as possible. Containerwerk is awarded among others as the winner of the *"Green Product Award 2018"*, an annual international competition for innovative, sustainable products and services as well as the winner of the award *"Germany - Land of Ideas"* in 2018, a joint initiative of the Federal Government and the German industry (Containerwerk, 2021b; Figure 16). Containerwerk gained these awards through the resource of used sea-freight containers, its unique insulation technique and its sustainable construction process.

Resource Container

Containerwerk uses 40-foot-high cube sea-freight containers which can be stacked and combined as needed as illustrated in Figure 5. Due to the low weight and the variability of the facade design, container modules are suitable for integration into existing housing structures.

Figure 5: Four container modules combined in Stuttgart, Germany

Source: Hohloch (2019a).

A 40-foot-high cube container weighs 3.5t when it is empty, around 10t if its fully furnished and it can carry 26.5t (Containerwerk, 2021g). The shell consists of Corten steel which cannot rust through. Containers have international standard dimensions which allow for high mobility as Ivan Mallinowski elaborates:

> "*The special thing about Containerwerk is that it is sustainable and that we are fully mobile with our containers. Because unlike other providers, our containers can be transported by all standard logistics systems. That means with our containers, customers can in a few years' time move to another city. Nothing has to be dismantled and no special transport is required – everything is so straight forward with us*" (Containerwerk, 2019).

Around 38 million containers exist worldwide while additional six million 40-foot-high cube containers are produced every year. Since all production facilities are located in South Asia, containers need to be transported to Europe. While not every container has a follow-up order and it is expensive to ship an empty container, the number of imported containers in Europe is higher than exported ones. Exemplary, purchasing a used container costs 2,000€ to 3,000€ while shipping it from Hamburg, Germany, to Lisbon, Portugal, costs minimum three times as much. Containerwerk purchases used containers that are no longer shipped and converts them into living spaces. As every container has a CSC (Container Safety Convention) plate which documents its carried materials, it can be ensured that the container did not transport toxic pollutants. For Ivan Mallinowski,

> "*the best and most fascinating thing about the whole concept is that it is completely sustainable. We use shipping containers that would otherwise be scrapped – there are no new, specially made components. Our actions are putting something that is no longer required back into practical use*" (Containerwerk, 2019).

The composition of the container grants a life of 50 to 80 years which is similar to traditionally constructed buildings such as student flats or hotels (Containerwerk, 2021a). Not only the independence in terms of location, but also the possibility of reassembling the container modules to create different building layouts and heights, and thus adapting to changing property and usage requirements, makes a further contribution to increasing the economic service life of a module. Moreover, flexibility exists in the use itself. The planned extension of the container modules can be used as tiny house, hotel room or office space. In general, other forms of living also seem possible (Albeck & March, 2017).

Insulation technique

In an off-site factory in Wassenberg, Germany, the modules are modified virtually on the assembly line and converted through a semiautomatic process into apartments (Containerwerk, 2019). It takes two hours to install slim high-tech insulation including sound decoupling in a container (Containerwerk, 2020a). In accordance with the *Fraunhofer Institute for systems and innovations research* and the university RWTH Aachen, Ivan Mallinowski developed a multi-patented unique technology for monolithic, i.e., thermal-bridge-free and compact full insulation (Containerwerk, 2020a). This energy efficiency is achieved by a liquid foam which is pushed under high pressure on the inside of the trapezoidal exterior walls and the ceiling of the container. The company chose the foam over other methods for insulation as it is a renewable

raw material which consists of 99.9% vegetable oil and can be upcycled and reused. The insulation is executed by a machine which allows for a process that is unrivalled in terms of speed and is depicted in Figure 6 (Containerwerk, 2020a). It fulfils the requirements of the German Energy Saving Ordinance[1] and enables energy-efficient heating and cooling (Containerwerk, 2021a). Through this worldwide unique procedure, Containerwerk will be able to start serial production.

Figure 6: The insulation machine in Wassenberg, Germany

Source: Hohloch (2019b).

As only Containerwerk holds the patent to this insulation technique, competitors have to use other methods for insulation, e.g., putting insulation panels in front of the trapezoidal exterior walls in the inside of the container which results in loss of space. An insulated container has a length of 11.80m inside and a height of 2.50m. While the width of Containerwerk's modules is 2.20m, containers insulated by competitors without the technique have a maximum width of 2.00m. Thus, the technology enables a floor space and rentable area of 26m^2 (11.80 * 2.20)

[1] German Energy Saving Ordinance: Regulations to protect energy and climate, ensure that the targets of the German government's energy policies are achieved (Dena, 2018).

compared to a maximum of 23.6m^2 (11.80 * 2.00) with other techniques. In a tiny house like a container, the additional width of 0.20m makes a noticeable difference (Containerwerk, 2021d).

Sustainable construction

On the roof of its 13,000m^2 production facility, solar panels are installed which compensate Containerwerk's total electricity supply with an investment that will pay off after 10 years. Moreover, natural resources and energy are saved by upcycling and repurposing used sea-freight containers (Containerwerk, 2021a). As they can be processed without welding or melting elements, no grey energy is released. The only type of waste that arises from the converting process is the Corten steel which is cut off for the windows. Containerwerk passes these parts to recycling companies which reuse them due to their high resistance.

During the insulation process, no waste is produced as well: Machines that press the renewable foam into containers are equipped with sensors, enabling to use the exact amount of foam needed. Besides that, all materials of the insulation process can be 100% recycled (Containerwerk, 2020a). Containerwerk tested and verified that the entire container can be dismantled into carriable parts which can be reused at the end of the modules' life. As for now, none of the projects are old enough, thus, none of modules have been dismantled yet. This dismantling process is possible without leaving any residuals as the modules are installed with point or screw foundations that do not damage the ground and minimize soil sealing (Containerwerk, 2021a; Figure 14).

While a conventional construction site exists 15 to 18 months until the entire building is finished, the prefabricated modules of Containerwerk are assembled on-site within three to four months which leads to lower construction emissions (Containerwerk, 2021a).

4.5.3. Social Objective

All interior modules in the container are prefabricated by external suppliers. One example is illustrated in Figure 7, picturing parts of living room, bathroom, kitchen and hallway of an apartment (from left to right). A partnership with the supplier *Integrationswerk Heinsberg* that is working with disabled employees is planned. The social organization is located close to Containerwerk's production facility and allows Containerwerk to support a local, social company (Integrationswerk, 2021).

Figure 7: Interior of a container

Source: *adapted from* Hohloch (2019c).

For the current project of a micro hotel with 20 apartments, two barrier-free rooms are required by the German government while Containerwerk offers five. For another project, the company provides containers at minimum costs to the University of Applied Sciences in Esslingen/Göttingen, Germany, to support research of care containers. These containers provide a nursing surrounding for old people through the installation of falling sensors on the floor and rails on the ceiling to assist when moving from bed to chair. Containerwerk supports the university to realize the concept which will be presented on a fair in 2022.

Another social project sponsored and implemented by the city of Hamburg, Germany, and an architectural office in Hamburg, consists of three apartment houses with 43 rooms in total for the resocialization of delinquent young orphans. All rooms are developed by Containerwerk and provided at minimum costs. Thus, the company did not generate profit with the social project. Additionally, the company supports the development of a life-movement resort in Kempten, Germany. The resort will enable to work, eat, do sports and grow food together in a community which will take place in different forms of housing, e.g., wood constructions, high quality tents or containers which will be provided by Containerwerk. Moreover, Containerwerk

also contributes to a sharing economy as the company generates an energy surplus with its solar panels which is provided to the local community. By supporting these projects, Containerwerk aims to have a social impact.

4.5.4. Economic Objective

The founders of Acondo and Containerwerk started the project with the goal to provide living at low cost, though, they realized that it was not suitable with the cost intense R&D needed. Today, expenses for R&D and costs for individual orders still exceed the revenue. As the demand is given and the company receives orders consistently, it will manage to sell 600 containers in 2021, resulting in 200 more compared to the previous year. This enables Containerwerk to break even by the end of 2021.

Furthermore, sustainable procurement and responsible corporate images become continuously more attractive to investors which is depicted by investors' valuation of sustainability around the world (Hawn et al., 2018). Flammer (2013) points out that sustainable responsible companies experience a significant stock price increase. Nevertheless, even though investors value companies associated with sustainability, it is questionable what significance and materiality SD has for investors (Hawn et al., 2018). In regards of Containerwerk, it can be observed that not every site manager or investor is willing to pay more for, e.g., the renewable foam which is more expensive than less sustainable options. In summary, it can be observed that the trend towards SD is evolving but has not reached all mindsets yet (Hawn et al., 2018).

Regarding its own financial sustainability, Containerwerk planned to start serial production in the last quarter of 2021. Thereby, the company enables to reduce costs per unit by, e.g., buying higher quantities of materials to realize lower purchase prices or developing fixed defined variations to facilitate predictability for prefabrication, resulting in lower costs for suppliers and prices for itself. Through serial production, Containerwerk will manage to become profitable. Nevertheless, being able to sell containers at low cost as initially planned is not feasible yet and will be a long-term goal. In the following, Containerwerk's competitive environment will be further analysed.

4.5.5. Competitive Environment

Companies in the construction industry in Germany reported the highest value of orders ever received in May 2021 worth around 7.7 billion € (WiWo, 2021). Nonetheless, the industry is facing challenges due to scarce and expensive primary resources, such as construction wood and steel (WiWo, 2021). This can be attributed to supply chain issues due to Covid-19[2], as the slow or even temporarily stop of raw material deliveries meet a growing demand of resources (Harapko, 2021; Hein & Junge, 2021). Containerwerk's supply of resources and containers is also affected, resulting in delays of deliveries. In addition, the imposed sanctions between China and the US further impede the situation because both parties increasingly obtain resources from Europe. These circumstances will hamper the industry at least until the end of 2021 and lead to a postponement of Containerwerk's planned serial production to January 2022 (Hein & Junge, 2021).

These events influence the entire construction industry. In the following, the competitive environment of Containerwerk and its competitiveness within the industry will be further assessed by a comparison to other types of constructions and competitors. First, used sea-freight containers will be compared to new ones. Afterwards, advantages and disadvantages of custom-made container modules and modules based on other materials such as wood will be elaborated. Lastly, Containerwerk's product will be compared to traditional non-modular constructions.

Sea-freight container modules

New sea-freight containers that are bought in Europe cost up to four times as much as used ones (8,500€ for a new container compared to 2,000€ to 3,000€ for a used one). It is notable that even a new one might not be flawless as it crossed the ocean once since all containers are produced in South Asia. Moreover, none of the containers are shipped empty as it would be too expensive.

The Dutch company *TempoHousing* develops container-based modules aligned with the mission that high quality is prioritized over cost leadership which depicts similarities to Containerwerk's mission (TempoHousing, 2019a). For insulation, *TempoHousing* uses conventional panels that are 60x120mm which reduce the interior space of a container

[2] Covid-19 is an infectious disease (World Health Organization, 2021).

compared to Containerwerk's method that maximizes the living and renting space for both, users and investors (TempoHousing, 2019b). Ivan Mallinowski outlines that the modules'

> "*walls have the same insulation value as conventional ones, yet they are half as thick. Thanks to our multi-patented monolithic methods there are no thermal bridges anywhere on the container*" (Containerwerk, 2019).

Neither co-founder of Containerwerk, Markus Goldmann, nor Michael Krátký, can identify serious competition in this tiny house segment which includes houses up to 37m^2 based on the definition of the American construction law (Tiny Houses, 2021). In this sector, Containerwerk has a unique selling position with its insulation technique and sustainable construction process. This enables the company to build a brand image based on good appearance and references of customers without explicitly following a specific brand strategy. In addition, the company can keep up with the competition in this segment in terms of prices. Whereas Michael Krátký sees the potential of Containerwerk mainly in this tiny-house segment, Markus Goldmann is convinced that they can achieve a long-term competitive advantage in the entire industry.

Custom-made container modules

Custom-made containers refer to specifically manufactured modules or modified sea-freight containers. Exemplary, the *CHS Container Group* located in Bremen, Germany, offers specialised containers for mobile workshops, high-security transports, air freight traffic or refrigerated containers (CHS, 2021). Depending on the operational requirements, new sea-freight containers are obtained from South Asia and modified in Germany, or the containers are manufactured from scratch. As a raw resource, new sea-freight containers are four times cheaper than custom-made container modules. However, due to technical requirements, e.g., for static load-bearing capacity, several modules are built from scratch as the conversions of sea-freight containers would be even more expensive. Although the customization could enable more flexibility in terms of size, width and length, CEO Carsten Leopold of *CHS Container Group* reported that 98% of their orders are aligned with the international standard dimensions due to the logistic benefits.

Modules out of wood or other materials

As containers mainly consist of steel, one of the main challenges is fire protection. Fire protection is the best for concrete constructions as it catches fire the latest, followed by wood and lastly steel. Containerwerk provides a fire protection of F60 which means that the module

holds 60 minutes before starting to deform after catching fire. If the company would like to stack and combine more than three containers on top of each other, F90 is needed which Containerwerk cannot fulfil yet. As an idea, a scaffold of recyclable concrete could be designed to embrace the containers and enable more floors than three. For staircases, recyclable concrete is used for fire protection requirements as well. Containerwerk tries to apply it as minimal as necessary in prefabricated elements and prepares these elements in a way that they can be dismantled and reused several times. Nevertheless, in case of staircases, Containerwerk has to switch to less sustainable resources because steel and wood do not meet the fire requirements. Even though the recyclable concrete is designed as long-lasting, mobile and easily reusable as possible, concrete which mainly consists of cement generates high carbon emissions.

In addition, the bureaucratic process is very slow compared to other materials as there are no standard regulations for containers. Exemplary, wood modules can follow established regulations for fire protection. For containers, many certificates for fire or noise protection have not been issued yet. However, it can be outlined that the portion of prefabrication is lower for wood modules, and they cannot be upcycled since wooden stands would be damaged by cutting them up. Therefore, the mobility and flexibility of wood constructions are not comparable to containers.

Traditional constructions

As elaborated in 4.2., modular constructions hold environmental (less waste, pollution, emission and energy), social (less accidents, safer, healthier) and economic (faster process, cost cutting, higher quality) benefits by shifting the majority of activities off-site. This is aligned with the findings of a McKinsey Report by Bertram et al. (2019) which states that modular construction represents the future of buildings as the advantages over conventional construction are significant: lower costs, accelerated schedules, greater predictability of both time and cost and improved building quality.

Nevertheless, conventional construction out of stone and concrete is becoming cheaper due to cheap labour. With a selling price of 1,700 €/m^2, Containerwerk cannot compete with all conventional constructions which start at 1,250 €/m^2 depending on construction type and quality of execution. To become competitive in terms of prices, Containerwerk aims to scale high quantities in serial production with the target of a price below 1,000 €/m^2. To achieve this goal, the company increased its potential manufacturing capacity to 3,000 containers a year

while up to 200 modules can be built simultaneously. This can be achieved due to the semiautomatic process which is highly depending on machines and only realisable as machines are cheaper compared to labour long-term.

Nonetheless, Containerwerk is facing limitations compared to traditional constructors as they can only produce one floor of barrier-free buildings, thus, multilevel assisted living which requires barrier-free apartments is not possible. As buildings become bigger and higher, the costs and the complexity of transport increase due to the high number of prefabricated modules that need to be moved. Moreover, the dimensions and set sizes limit the flexibility as well. Finally, regulations in terms of fire and noise protection slow down processes.

4.5.6. Expansion and Growth

Different uses of space and customizable solutions visualize the full potential of the modules. Containerwerk cooperates with Scandinavian companies that buy the containers explicitly due to the unique technique. The company realized projects with containers that were cut into half to fit smaller spaces of $12m^2$ or created an office space out of two containers by cutting off a wall of each, connecting them and stabilizing them through pillars. Another option is to stack two containers and combine them through outdoor stairs to enable a living space of $50m^2$ (Bellinger, 2019; Figure 5). In addition, Containerwerk designed and built a self-sufficient research station and guest house for *Rausch Schokoladen GmbH* in Costa Rica as illustrated in Figure 8 as well as Figure 17 and 18 in Appendix IV. Further potential partners and projects are evaluated nationally and internationally (Containerwerk, 2020a).

Figure 8: Research station in Costa Rica

Source: Anta & Santos (2019a).

Moreover, restructuring of cities, the temporary use of space and the establishment of mobile cities are opportunities for Containerwerk to grow with its flexible, mobile, scalable solution (Containerwerk, 2019). As analysed within an investigation of the *Fraunhofer Institute for systems and innovations research*, the future will be about mobile cities with the tendency towards small apartments in available areas, e.g., parking decks, which is aligned with the concept of tiny houses (Tiny Houses, 2021). For the future, Ivan Mallinowski outlines Containerwerk's vision:

> "*One vision that I have is that in a number of years' time we will no longer be giving our children a car for their 18th birthday, but a residential container. And when the children start to study or move away from home, they simply take the container with them and have it set up at a provided site*" (Containerwerk, 2019).

5. Teaching Notes

5.1. Synopsis

The case aims to provide a solution to the issue of waste within the construction industry by introducing the concept of a CE. The objectives to contribute to a CE are elaborated through the case of Acondo and Containerwerk. Moreover, the analysis of Containerwerk highlights how this contribution can lead to a competitive advantage. The main purpose of the case study is to connect theoretical frameworks with real-life examples to demonstrate how companies can be profitable while acting sustainable aligned with the concept of a CE.

Firstly, the case outlines challenges in the construction industry and introduces modular construction as a sustainable solution. Secondly, Acondo's and Containerwerk's commitment to sustainability are depicted and Containerwerk's objectives to contribute to a CE are elaborated. Lastly, Containerwerk's position in the competitive landscape of building constructors is analysed. The case study concludes with a growth outlook for Containerwerk.

5.2. Target Group

This case study is designed for the use as a teaching tool in management- and strategy-related Undergraduate or Master-level courses such as Strategic Management or Innovation Management. Due to the focus on sustainability, the case could also facilitate discussions in courses like Social Entrepreneurship, Environmental Management or Social Innovation.

5.3. Learning Objectives

By analysing the case, students should be able to connect strategic frameworks with real-life examples regarding the topic CE. More specifically, they should understand the economic, social and environmental reasons to contribute to a CE and how companies could benefit from this commitment. This case aims to show students the importance of SD exemplary illustrated in the German construction industry. By analysing two companies acting in this industry, students should be able to

- Identify organizational obstacles and possible solutions,
- Apply strategic management frameworks to solve real business challenges,
- Understand how sustainability and profitability are linked,
- Operationalize concepts as strategies for achieving outperformance.

Besides these subject-specific skills, students should be able to further develop interpersonal as well as analytical skills by in group and in class discussions.

5.4. Teaching Strategy

The following teaching strategy provides the organizational frame for the case study. It is conceptualized for a 90-minutes class while additional preparation is recommended to get the most out of the taught content. As a suggestion, the instructor should distribute the case study as well as the frameworks provided in chapter 2 as mandatory readings beforehand, demanding an additional reading workload of 15 minutes each. In addition, the instructor should have developed a profound knowledge of both as well.

As an introduction in class, the instructor should recap the frameworks as well as the case study to align the students' knowledge and answer their questions. According to the board plan provided in Table 3, the introduction should take up to 20 minutes. Afterwards, the class should be divided in groups of 6 to answer each of the teaching questions. For the first one, the TBL aligned with the CE concept should be analysed in the case of Containerwerk, for the second one, the question should be answered by adapting Porters Generic Strategies to the case. The group work is designed for 20 minutes each. For the next 25 minutes, the whole class should interactively discuss their findings together while the instructor should take care that the answers are following the solution provided in chapter 5.5. During the last minutes of the session, the instructor should outline the main takeaways and wrap-up the case study. Due to Covid-19, the teaching case can also take place in a video conference setting via online video tools.

Table 3: In-class Board Plan

Activity	Conducted by	Content	Time (in min)
Introduction	Instructor	Recap of frameworks	10
		Recap of case study	10
Teaching question 1	Groups of 6 students	TBL aligned with CE concept	20
Teaching question 2		Porter's Generic Strategies	20
In-class discussion	Class & Instructor	Discussion of the answers to Teaching question 1 & 2	25
Conclusion	Instructor	Main takeaways & wrap-up	5

Source: Own illustration.

5.5. Assignment Questions and Analysis

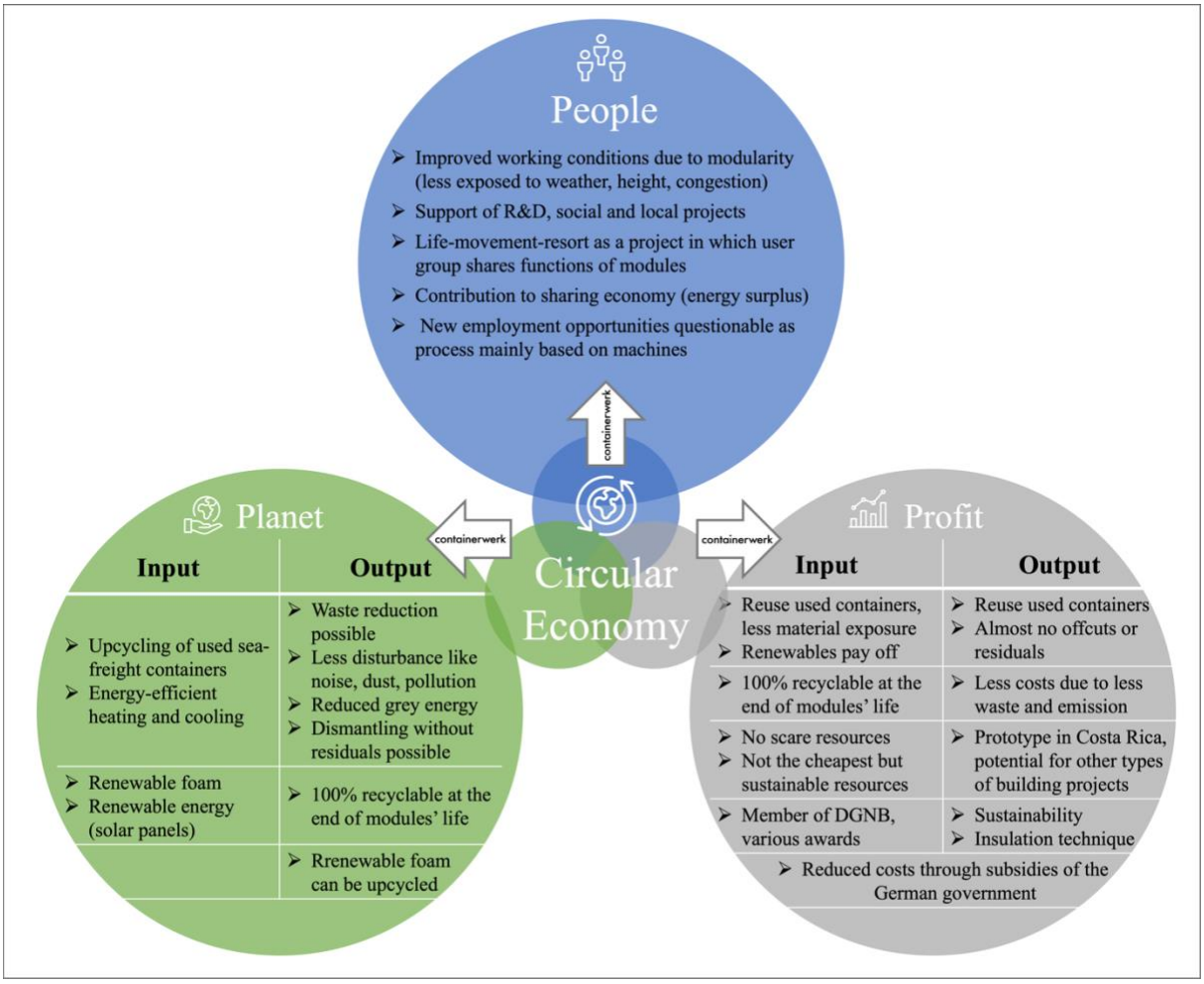
The following section provides in detail solutions to the teaching questions as a guideline for the instructor. They are designed to lead through the case and to provide a structure how to apply the theoretical management frameworks to the real-life examples. Whether the case is used in an Undergraduate or Master-level course, a different level of managerial knowledge as well as analytical skills can be expected to answer the following questions correctly.

5.5.1. TQ1: Incentivizing to contribute to a CE

TQ1: What are the objectives for Containerwerk to contribute to a CE?

To answer the question, the students should be able to utilise the TBL framework which is adapted to the elements of a CE and illustrated in Figure 2 (chapter 2.2., page 6) (Elkington, 1997; Korhonen et al. 2018). The theoretical framework should be applied to the example of Containerwerk by analysing its environmental, economic and social objectives as well as of the modular constructions in general. An overview can be found in Figure 9.

Figure 9: CE applied to the case of Containerwerk



Source: Own illustration *adapted from* Korhonen et al. (2018).

Environmental objective: Planet

Input

First, reduced virgin material and energy are mentioned on the input side. Based on the case, students should be able to identify that Containerwerk is upcycling used sea-freight containers that are not in use anymore and/or would have been scrapped otherwise. By converting them into housing modules, it can be argued that their functionality is increased, and their quality becomes higher which is embedded in the definition of upcycling. In addition, natural resources and energy for the shell of the apartments are saved because the containers are not specifically manufactured for this purpose.

Second, students should point out that virgin inputs are to the extent possible renewables from productive ecosystems, e.g., the renewable foam used for insulation consists of 99.9% vegetable oil. The whole insulation process is aligned with the requirements of the Energy Saving

Ordinance and enables energy-efficient heating and cooling. Moreover, solar panels have been installed to obtain the entire energy from renewable sources.

Output

Regarding outputs, the framework highlights that waste and emissions should be reduced. In general, it is outlined in the case that modularity can lead to waste reduction of 76% as an off-site factory facilitates waste management in terms of controlling, reusing, recycling and disposing waste. Further benefits of prefabrication are less construction site disturbance regarding noise, dust and congestion.

As Containerwerk converts containers without welding or melting elements, no grey energy is released. The only offcut that arises from the converting process is Corten steel which is cut off for windows, however, these parts will be recycled. Due to shorter construction time of modular constructions compared to conventional ones (three to four months vs. 15-18 months), fewer emissions and pollution are emitted. In addition, soil sealing is minimized and the dismantling of a container can be executed without leaving residues.

As another aspect, students should derive from the framework that resources in production-consumption systems should be used several times instead of once. Containerwerk tested and verified that the entire container can be dismantled into carriable parts which can be all reused. Also, the insulation foam consists of a renewable raw material whose waste are nutrients that can be used by nature. The foam can be upcycled and reused in production processes.

Economic objective: Profit

Input

Regarding the economic objectives on the input side, students should outline that Containerwerk faces reduced raw material and energy costs through buying reused containers that are cheaper than new ones. More cost savings can be realised by starting serial production as the company will be able to reduce costs per unit by, e.g., buying higher quantities and developing fixed defined variations. In general, modularity enables to reduce material costs since less materials have to be replaced due to vandalism, site theft or weather extremes. In terms of energy, modular constructions allow for a high level of energy efficiency and higher efficiency in installation. In the case of Containerwerk, the company has its own energy source which increases efficiency because of direct access to the source and less dependency on third

parties. The investment in renewable energy through solar panels pays off in 10 years, thus, energy costs will no longer occur in the long-term.

As the modules can be dismantled and are 100% recyclable at the end of their life, it can be outlined that the value of the resources can be used several times instead of once. However, due to the early development stage of the projects none of the used modules have been reused yet. Also, in terms of resources, more containers are imported than exported to Europe. Thus, Containerwerk's main resource cannot be defined as scarce. However, currently, resources in the industry are facing delays and are more expensive due to Covid-19 as well as imposed sanctions between China and USA. Regarding other resources, it can be mentioned that Containerwerk prioritizes qualitative and sustainable products which might not always be the cheapest option, e.g., the renewable foam. Therefore, students should analyse that the use of costly resources is intentionally not always minimized, whereas scarcity, delays in deliveries and cost increases are temporary issues due to recent incidents.

Containerwerk's image as well as its responsible and green market potential has been confirmed and certified by various organizations such as DGNB and honoured by awards like the *"Green Product Award 2018"*. SD is embedded in its mission and internally highlighted by founders, co-founders and CEOs which can be identified in the interviews.

Output

On the output side, students can outline that value leaks and losses are reduced due to the reuse of containers which might have lost value otherwise by not being used or scrapped. As there are no offcuts besides the windows, material losses are reduced as well. Moreover, the exact amount of foam is pushed into the module by the insulation machine without residuals. Overall, this results in a minimum amount of waste to manage. As elaborated in the output part of the environmental dimension, the construction procedure obtains less waste and emissions which leads to reduced costs to control for both.

Regarding new markets, students should point out that the flexibility of the container itself allows for various forms of living. Currently, the extension of the modules is planned for tiny houses or hotel rooms, but projects like the research station in Costa Rica demonstrate the potential for other types of projects in new markets. This is underlined by the variety of Containerwerks' projects, such as care containers and life-movement-resorts.

Through the certified sustainable sourcing and responsible business image, Containerwerk is attractive for investors as sustainable projects become increasingly lucrative for them. Moreover, the unique insulation technique allows for more rentable space compared to other methods which further attracts investors. The sustainable mission is aligned with recent promotions of the German government as they subsidize, e.g., energy efficient buildings (BEG). However, it can be mentioned that the trend towards sustainability is still evolving for investors, as Containerwerk deals with site managers that are not willing to pay more for renewables and for the German government, because the bureaucracy process is still slowing down progress.

Social objective: People

Regarding the social dimension, students can point out that modularity allows for better working conditions compared to traditional constructions as around 85–90% of the modules can be prefabricated in off-site facilities. Thus, employees work less under weather extremes, at height and congestion, resulting in improved safety and health. In terms of Containerwerk specifically, the company supports R&D of nursing containers and contributed to a resocialisation project for delinquent young orphans. Both projects were driven by social incentives and not economic ones as they sold the containers at minimum cost without generating profit. For the contribution at the planned life-movement-resort, it can be argued that the user groups at the resort share the function of the physical product, the container module, instead of owning it. However, this part of the social dimension of Korhonen et al. (2018)'s framework can only be applied to this project.

In terms of renewables, it can be mentioned that the energy surplus is given to the local community. As a sharing economy is defined as collaboratively fee-based sharing of materials, it can be elaborated that Containerwerk is thereby contributing to a sharing economy (Zervas et al., 2017). The company supports further local projects in their community as materials for the interior are purchased from local, social initiatives such as *Integrationswerk Heinsberg*.

In addition, students should derive from the literature that the social objective of a CE refers to employment opportunities due to, e.g., potential new use of resources (Korhonen et al., 2018). As Containerwerk increased its manufacturing capacity to 3,000 containers a year with expansion plans nationally and internationally, new employment opportunities occur. However, the opportunities are limited as the production process is semiautomatic and highly based on machines. Furthermore, the planned cost reduction due to serial production can only be realised

because the machines are cheaper in a long-term compared to labour. Therefore, it can be argued that this part of the social dimension is not fully met.

Wrap-up

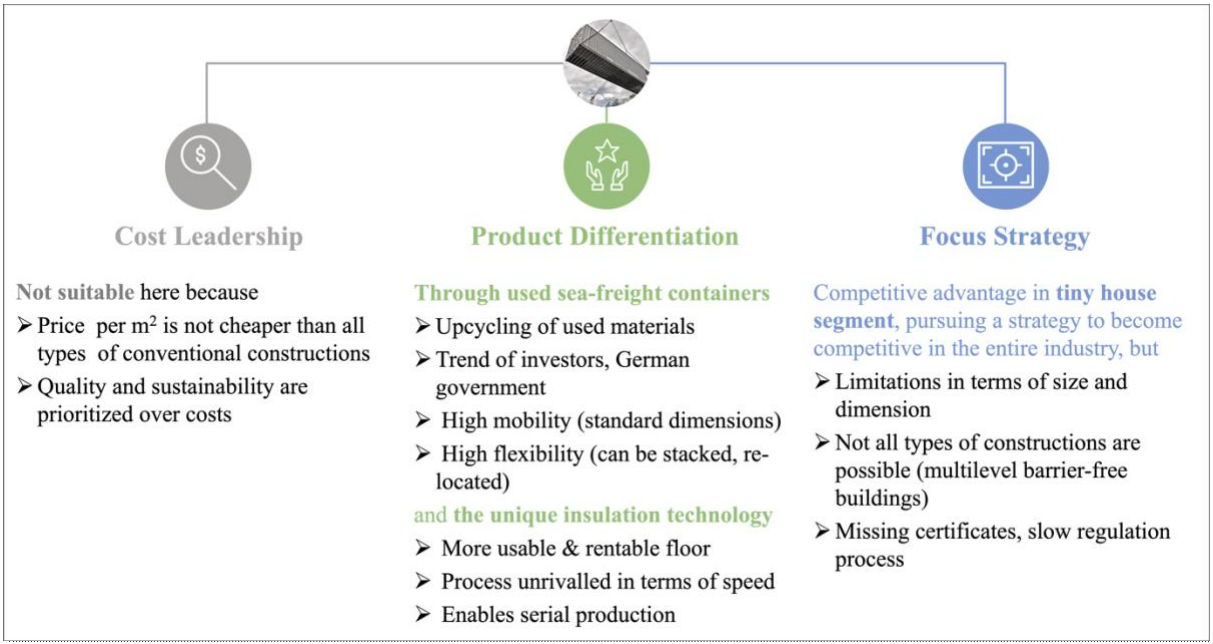
Based on the analysis of the case, incentives for all three dimensions could be outlined. Especially the environmental and the economic objectives of Containerwerk are aligned with the framework. Environmentally, upcycling, recycling, the use of renewables as well as less waste and less grey energy can be highlighted. In terms of profit, reduced costs due to the reuse of containers, less material exposure and minimal offcuts can be analysed as well as the attractiveness for investors and the German government. With the start of serial production, profitability can be reached. For the social dimension, it is questionable whether Containerwerk contributes to all elements of it. Even though local and social projects are supported, only limited employment opportunities are provided. In addition, it can only be argued for one of the projects that user groups share the functions of the modules instead of owning it. However, according to Murray et al. (2017), CE integrates economic and environmental performance while the social dimension can create tension with the other objectives and can be questioned as part of the contribution as the least expanded among researchers. Thus, the students should point out that there is no consent in literature on the social dimension to a CE. Nonetheless, students should highlight that Containerwerk is contributing to all three dimensions of a CE but not to the same extent.

5.5.2. TQ2: Achieving a competitive advantage through contributing to a CE

TQ2: How can Containerwerk achieve a competitive advantage through its contribution to a CE?

Students are asked to answer this teaching question by applying Porter's Generic Strategies illustrated in Figure 4 to evaluate the adaptability of each of the three strategies to the case of Containerwerk (chapter 2.4., page 9). As a result, students should elaborate that cost leadership is not pursued as main strategy. They should identify the differentiation strategy as suitable and further elaborate how Containerwerk is differentiating itself from competitors through product differentiation. Finally, they should analyse if the focus strategy is applicable by discussing whether Containerwerk is achieving a competitive advantage in a narrow segment or the entire construction building industry. An overview of the solution is provided in Figure 10.

Figure 10: Porter's Generic Strategies applied to the case of Containerwerk



. Source: Own illustration *adapted from* Hambrick (1983).

Cost Leadership

According to Porter (1997), one way to gain a competitive advantage is through providing value to customers at lowest cost. In chapter 4.5.5. it is mentioned that Containerwerk's price per m^2 is too high to compete with all types of conventional constructions (1,700 €/m^2 vs. 1,250 €/m^2). The target of starting serial production in the beginning of 2022 provides evidence that Containerwerk aims to offer more competitive prices. However, it is not stated that the company pursues to sell their apartments at the lowest price as it is embedded in its mission that quality and environmental sustainability are prioritized over costs (e.g., renewable foam is prioritized over cheaper options). Thus, students can conclude that Containerwerk is not following a cost leadership strategy.

Differentiation

As outlined in literature, a company needs to create significant value which can be obtained (Porter, 1997). Containerwerk is converting used sea-freight containers into living space. This product in combination with the patented insulation technology can be analysed as significant value that is perceived as unique by customers like Scandinavian companies and investors. Whilst the differentiation strategy is costs-sensitive, it is highlighted in literature that costs are not the main part of the strategy. This is aligned with Containerwerk's strategy as well.

Product differentiation through the attributes of used sea-freight containers

Compared to conventional buildings and custom-made containers, the used sea-freight containers are upcycled, can be 100% recycled and are therefore sustainable sourced. As outlined in chapter 4.5.4., the trend towards sustainability is evolving for both, investors and the German government which makes Containerwerk's apartments more attractive for investments and increases federal subsidies. Through their international standard dimensions, they can be stacked, combined and easily transported which allows for high mobility. In addition, the containers can be re-located which makes the apartments more flexible than conventional ones.

Nevertheless, they have fixed sizes and the possible height of buildings out of stacked containers is limited due to fire regulations. However, it can be argued that the fixed size is part of its unique value and Containerwerk is developing ways to overcome the limitations, e.g., by building a scaffold of sustainable concrete that fulfils fire regulations.

Product differentiation through technology

Containerwerk is the only company worldwide with the unique multi-patented technology for monolithic insulation. Thereby, the walls of the containers are half as thick as conventional ones which result in more usable floor and rentable space. In addition, their production process is unrivalled in terms of speed. Through this worldwide unique procedure, Containerwerk gained a unique selling proposition and will be able to start serial production.

Focus Strategy

The focus strategy is based on value creation in a narrow segment and can be combined with a differentiation strategy and/or a product at lowest cost (Porter, 1986). As elaborated above, Containerwerk is not pursing a cost leadership strategy. In the following, it will be discussed whether the company can achieve a competitive advantage with its differentiation strategy in a narrow segment or the entire industry.

On the one hand, it can be argued that Containerwerk pursues to meet the needs of the whole industry. The modules can be stacked, dismantled and reassembled and can be therefore combined and used as, e.g., hotels, student dorms or office spaces. As Containerwerk also executed projects like the research station in Costa Rica, it can be highlighted that other forms of living could be realised and operations should not be limited geographically. On the other hand, it can be mentioned that multilevel buildings that require barrier-free floors, e.g., assisted

living, will not be possible if Containerwerk keeps up with its mission to source sustainably and does not switch to less sustainable products like concrete. Even though the modules can be stacked, the size of the interior and the dimensions are set. Containerwerk realized projects with different dimensions, however, set sizes are required to enable serial production. Furthermore, it can be outlined that bigger buildings consist of more modules that need to be transported which increase costs and complexity. Although the German government fosters the development financially, it slows down the bureaucracy process as several certificates for essential requirements are missing which hampers the expansion. This is not an issue for buildings based on wood modules or traditional constructions.

Overall, it can be concluded that Containerwerk aims to achieve a long-term competitive advantage in the entire industry. For now, the company generates a competitive advantage in the narrow segment of tiny houses with a unique selling proposition that is honoured by awards, investors and partners like Acondo. Therefore, it can be argued that Containerwerk is following a focus strategy combined with a differentiation strategy.

Wrap up

After having analysed the competitiveness of Containerwerk, it can be summarized that a cost leadership strategy is not primarily pursued. Although its target of serial production can reduce costs, it cannot not be concluded that the company will be able to achieve a lowest cost position. As Containerwerk creates unique value to customers through its sustainable product and the insulation technique, students can outline that a differentiation strategy is followed. Finally, it can be concluded that the company generates a competitive advantage through differentiation in the tiny house segment. Containerwerk's extension of this advantage to the entire industry is depending on factors such as certificates and regulations and cannot be concluded within this thesis.

6. Discussion and Conclusion

The objective of this thesis was to provide a solution aligned with the concept of a CE to the issue of waste in the construction industry. Therefore, modularity as a type of construction has been presented and Acondo and its partner Containerwerk have been introduced for a practical perspective. To further elaborate the dimensions of a CE, Containerwerk's product, production process, objectives and competitiveness have been analysed. This analysis is based on literature about sustainability and the industry, interviews that have been conducted with representatives of both companies, a visit of Containerwerk's production facility and managerial frameworks which have been chosen according to the topic.

To answer the first teaching question, the TBL framework extended by the concept of a CE was applied to the case of Containerwerk to analyse its environmental, social and economic objectives to contribute to a CE. It became apparent that generating environmental impact through sustainable sourcing, upcycling and recycling is embedded in Containerwerk's mission. Furthermore, it is highly interesting that the semiautomatic process which enables serial production and thereby ensures its economic sustainability also restricts the company's social dimension as only limited employment opportunities are created. It became evident that the cost advantage through machines which enable profitability are in this regard prioritized over the social objective, while cost saving through less sustainable products are not an option in terms of environmental impact. According to the literature, the social dimension of a CE is the least expanded one among researchers and can lead to tension with one of the other objectives. This finding can be depicted in this case, nevertheless, it can be concluded that Containerwerk is contributing to all objectives but not to the same extent. Furthermore, it can be stated that becoming profitable is crucial for the longevity of the HO. Therefore, this thesis contributes to theory by suggesting that a contribution to a CE can be achieved without pursuing all three objectives to the same degree.

The analysis of the second teaching question has been based on Porter's Generic Strategies to discuss Containerwerk's competitiveness. It became evident that Containerwerk targets cost reductions through serial production, however, cost leadership cannot be identified as its main priority. With a strong differentiation of its product and its technique that are perceived as unique by customers, Containerwerk manages to stand out. Thus, a competitive advantage can be achieved in the narrow segment of tiny houses. Moreover, it becomes clear that

Containerwerk does not want to limit its operations to this segment. However, it is questionable whether the uniqueness of the product and the resulting challenges can enable the company to follow a differentiation strategy in the entire industry. Therefore, it cannot be concluded within the scope of this thesis. Overall, the analysis provides strong indication that this framework serves well as a tool to evaluate a company's competitive strategy.

This case outlines that it is possible to link profitability to the concept of a CE. Through its high investment in R&D to develop its unique production process, Containerwerk does not generate profit directly after its foundation but will become profitable in 2022. The case provides one solution to the increasing problem of waste by upcycling and reusing resources but also by limiting the creation of waste to a minimum. Regarding growth prospects, Containerwerk could extend its existing cooperation with universities to design an even more sustainable and self-sufficient product through, e.g., roof vegetation that has an air-conditioning effect. In general, the case with its practical perspective on the construction industry highlights that the industry is reorienting towards sustainable solutions, making Containerwerk one of the pioneers and role models with a case that could be inspiring for other industries.

As this thesis is highly based on primary data, the generalizability of the results is limited. For a more accurate analysis, additional interviews with various stakeholders of Acondo, Containerwerk and competitors could be conducted. Moreover, the missing historical data on CE due to the novelty of this concept seems to be a limitation regarding the adaptability of the social objective. However, the literature offered enough information to provide a conclusion of this dimension to the case. Nonetheless, future research should be devoted to the development of CE and sustainability for researchers, governments and businesses. Additionally, the short- and long-term impact of Covid-19 and the imposed sanctions as well as the development of tiny houses should be further investigated. These trends are crucial for the growth and competitiveness of Containerwerk, pursuing a vision of a future that is living in a cube.

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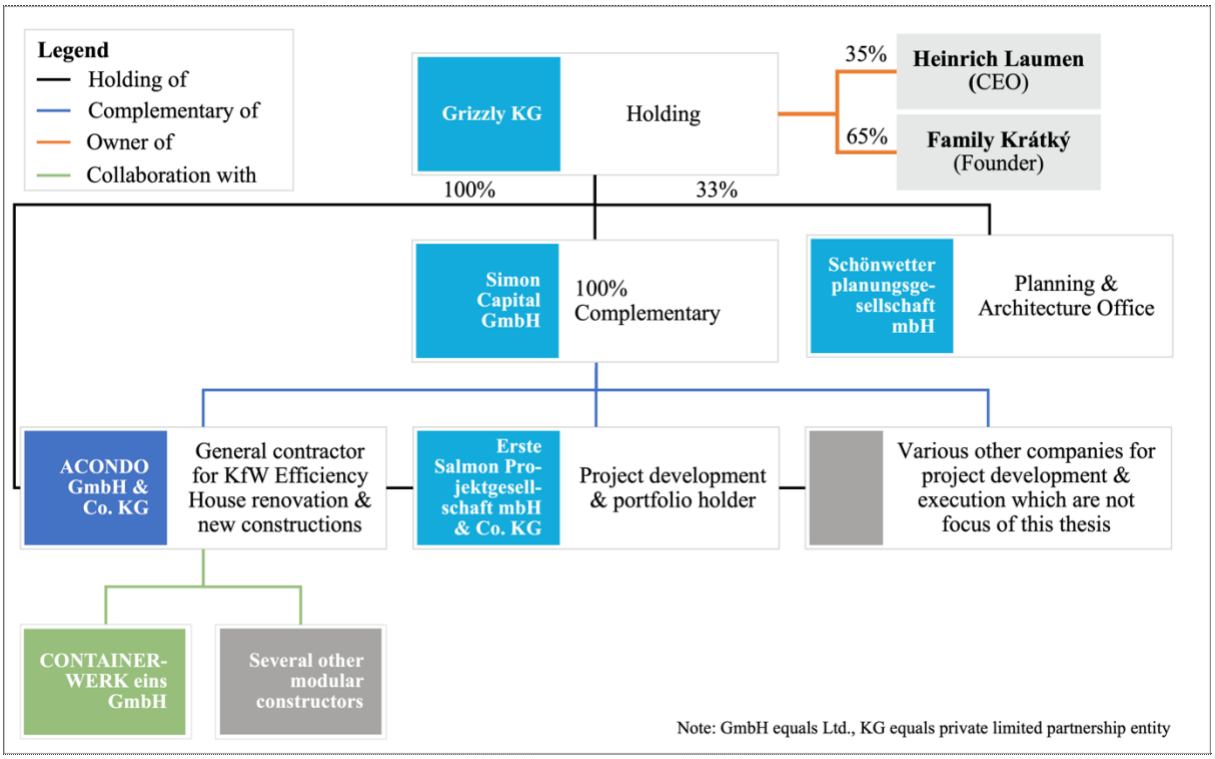
8. Appendix

Appendix I: Acondo's organisational structure

In the following, the organizational structure of Acondo is described and illustrated. Acondo is a general contractor company which is 100% owned by *Grizzly KG*. *Grizzly KG* is a private limited partnership entity whose shares are divided by Acondo's CEO Heinrich Laumen (35%) and the founder of Acondo Michael Krátký and his family (65%). As highlighted by the black lines in Figure 11, *Grizzly KG* holds among others 100% of the shares of *Salmon Capital GmbH* and 33% *of Schönwetter planning entity mbH*. *Salmon Capital GmbH* is 100% Complementary of several private limited partnership entities as illustrated by the blue lines in Figure 11 (Appendix II.II.).

Salmon Capital GmbH acts as a service provider company through which properties are bought and orders are acquired (Salmon Capital, 2020). These orders are planned in accordance with the planning and architecture office *Schönwetterplanungsgesellschaft mbH* which employs twelve people and is located in Weilburg, Hesse, Germany. A planned project is forwarded to the executing companies such as Acondo. Acondo is responsible for projects for KfW Efficiency House renovations and new constructions and establishes collaborations for the projects with modular constructors like Containerwerk. Various other companies are founded for the project development of other project types but as they do not constitute the focus of this thesis, they are not further mentioned. Another private limited partnership entity is *Erste Salmon Projektgesellschaft mbH & Co. KG*, a project development and portfolio holder company which holds all inventories such as properties, land and houses (Appendix II.II.).

Figure 11: Organisational chart of Acondo



Source: Own illustration *adapted from* Appendix II.II.

Appendix II: Interviews

Appendix II.I.: First interview with Acondo

The first interview has been conducted on the 22nd of February 2021 with Heinrich Laumen, CEO & owner of Acondo, and Michael Krátký, Acondo's founder & owner. The purpose was to get an understanding of the company's mission, strategy and main activities. Moreover, the partnership with Containerwerk and the main characteristics of its product have been elaborated. Both participants agreed to record the interview. The interview script below is based on the recording of the face-to-face conversation. It was hold in German and translated into English afterwards.

Could you introduce Acondo and its main activities?

Acondo is a general contractor for modular buildings and housing renovations. Our mission to acquire projects in the modular construction industry following the purpose of developing and designing sustainable, mobile and flexible solutions. In general, we are a service provider for various modular construction methods based on wood, concrete and containers, whether they are used sea-freight ones or custom made. Based on properties' characteristics, we choose the module that fits the best. For all our projects, it is important that the materials are sustainable

sourced. For example, one of our projects is in collaboration with a firm that collects and processes wood panels that naturally fell from the tree and therefore lay on the forest ground. They would rotten at some point. Thus, the sustainable part is that the trees are not felt and materials, the wood panels, that would not be used otherwise get a purpose for the economy. All projects regarding used sea-freight containers are developed with Containerwerk.

Why are you only pursuing modularity projects?

Modular constructions are more employee friendly. Instead of working outdoor on construction sites under all weather conditions, employees can work indoors in an off-site fabric most of the time due to the high degree of prefabrication of the modules. The prefabrication allows to shorten the time on the construction site for a whole building to three to four months compared to 15-18 months for a conventional one. This leads to fewer emissions, less dirt and less noise for neighbours. Thus, modularity is a sustainable alternative to traditional constructions.

Can this sustainable development be observed in the entire industry?

I (Michael Krátký) have been active in the real estate and construction industry for over 35 years. Back then, investments in construction projects were solely driven by return and the location of the building. About 15 years ago, the investors' mindsets started to change and sustainability as well as renewables became more important for them. Nowadays, these topics have sometimes an even higher weight for investors than the actual return. But not only investors, also the German government is fostering sustainable construction projects, e.g., energy efficiency through the KfW Efficiency House Standard. Based on different efficiency classes, companies could benefit from building sustainably as projects are subsidized. A KFW standard of 100 is the minimum energy efficiency that has to be reached by law. The lower the number, the higher the energy efficiency and the resulting subsidy. Our projects reach KFW standards between 40 and 55. Also, architects estimate that gravel pits are starting to groan which are essential for constructions out of concrete. Resource scarcity is another factor that sensitise us, the government and the entire industry for sustainable constructions.

How did the collaboration with Containerwerk start?

In 2009, Ivan Mallinowski and I (Michael Krátký) travelled through Canada to explore apartment modules based on sea freight containers. We got inspired by the compact solution for living space. Due to conurbations and the increasing demand for flexibility, we saw the market need for these solutions in Europe as well. We started our journey with the resource sea

freight container which is solely produced in South Asia and highly available in Europe. Some containers have made one trip from South Asia to Europe and stranded in one of the European harbours as they were just paid for one trip with no follow-up order. Therefore, we decided to use used sea-freight containers, a raw material that might otherwise been scrapped and upcycle it by transforming it to a living space. We got used to the special attributes of containers such as a high stability through the Corten steel which does not rust through and the flexibility to transport and move the containers due to their international standard dimensions. However, difficulties occurred due to their building physics as they are heavy and plumb. We realized that the transformation and R&D process was more complex than expected as well as expensive. Initially, we wanted to produce the containers for mass production to sell cheap living space, but we had to change plans and switched to a combination of qualitative, sustainable and mobile modules. Today, Containerwerk has a production facility with six halls in Wassenberg, Germany, close to the Dutch border. Together, we realized projects like a boarding house in Wertheim together with other companies. Several other projects are planned. In general, projects with other dimensions than 26m^2 are possible, but the economic efficiency is in my perception only given with the 26m^2 flat. Nevertheless, Containerwerk worked on containers with different dimensions with several other companies such as a Scandinavian student housing builder.

What is the unique selling proposition of Containerwerk?

Ivan Mallinowski developed an insulation system which is the company's unique selling proposition. In this segment, there is no such thing on the market. It includes sustainable materials like a renewable foam that is pressed from the inside on walls and ceilings via computer under a lot of pressure so that no empty space remains. Thus, no thermal bridges arise which allow for high energy efficiency and low heating costs. During that process, the container is fixed from the outside because the pressure is so high. The foam can be taken out and is degradable at any time. Overall, the container and its inserted materials are 100% recyclable. In accordance with its mobility and enabled flexibility through its dimensions, this sustainable living solutions is very attractive for investors as, e.g., a student dormitory can be placed in one city while the whole building or parts of it can be moved to another one after a few years.

Would it be an option for you to expand internationally?

Currently, we only realize projects in Germany. An expansion to Austria could be considered but otherwise, we do not have any ambition to expand internationally. Due to high transport

costs of the modules, it would not be lucrative. In addition, there are certain building regulations in each federal state even within Germany which could become even more challenging across borders.

Appendix II.II.: Second interview with Acondo

The second interview with Michael Krátký took place on the 3rd of August 2021. The purpose was to answer final questions regarding Acondo's collaborations and its perspective on Containerwerk's competitiveness. Furthermore, the legal structure has been explained which can be found in Appendix I. Michael Krátký agreed to record the interview. The interview script below is based on the recording of the face-to-face conversation. It was conducted in German and translated into English afterwards.

When was the year of foundation of Acondo and how many employees does the company have?

Acondo was founded in 2009, we have 11 employees with Heinrich Laumen as CEO.

How many collaborations do you have and what makes Containerwerk unique amongst them?

In total, we have eight partnerships with various modular constructors. For used sea-freight containers, Containerwerk is the only company worldwide which provides sustainable, high-quality container solutions based on used sea-freight containers. Their technology is their unique selling point which makes the product unbeatable, and I would not work with another provider in this segment.

What is your perception on Containerwerk's competitiveness?

Regarding an occasion hostel, hotel or tiny house close to rivers, a sea or the ocean, I do not see any competition for Containerwerk. However, the company is facing various limitations in terms of dimensions. The bigger buildings get, the more expensive it becomes to carry all prefabricated parts to the construction site. Also, only one floor of barrier-free buildings is possible that hampers the development of multilevel assisted living which requires barrier-free apartments. In addition, it takes time to get certificates for fire protection and sound insulation and the German government is making slow progress here. Therefore, I cannot identify an advantage against competitors in the entire construction industry. Currently, the situation in this industry is challenging as raw materials become more expensive and supply chain problems

like delivery delays occur due to Covid-19. The China embargo further complicates the situation as USA and China are buying resources in Europe at prices which European companies cannot compete with.

Appendix II.III.: First interview with Containerwerk

The first interview has been conducted on the 9th of April 2021 with Containerwerk's co-founder & partner Markus Goldmann. The purpose was to discover the company's product, production process, structure and goals. During the interview, the main advantages of Containerwerk's product as well as the challenges have been discussed. The interview script below is based on notes taken during the conversation via phone. The interview was hold in German and translated into English afterwards.

What are the special characteristics of containers?

A container has unbelievable statics (weighs 3.5t, can hold 26.5t), it cannot rust through because it consists of its Corten steel and it is a resource that is not exhausted. On the entire planet, there exist 38 million 40 cube (length 11.80m, height 2.50m) containers, while six million are produced every year. All sea-freight containers are produced in South Asia while more containers are imported to Europe than exported. The reason is that not every container has a follow-up order and it is too expensive to transport them empty back and forth (2,000€ to 3,000€ cost a used sea-freight container, to shop it from Hamburg to Lisbon costs at least three times as much). In general, containers have a low volume which is bad for energy saving (best space: sphere). Therefore, space needs to be maximized. Our insulation technique allows for a width of 2.20m, while 2.00m is the maximum which could be reached without the method, such as panel in front of the walls which results in a loss of space. Besides volume, more floor and rentable area can be achieved (26m^2 (=11.80 * 2.20) compared to a maximum of 23.6m^2 (=11.80 * 2.00)) which makes a noticeable difference in such tiny houses. Specific about sea-freight containers are their international standard dimensions which every haulage and railway company is familiar with. In addition, we can make sure that containers did not transport any toxic materials based on a CSC (Container Safety Convention) plate which documents the materials the container transported.

What makes your production process sustainable?

We have two locations, in Wassenberg and Stuttgart, Germany, while our production facility is in Wassenberg. During our entire production process, we aim to process as less waste,

emissions and pollution as possible which is certified by the DGNB. The SDGs, mainly goal 12 and goal 13, lead as a guiding principle. Through upcycling used sea-freight containers, no grey energy is released. Furthermore, we use a renewable foam for insulation that is 99.9% vegetable oil based. The materials in the interior are, e.g., real wooden panels while we are also planning on working with *Integrationswerk Heinsberg* as a local supplier which is working with disabled people. Because of our sustainable process with our unique insulation technique, we have customers from Scandinavia that buy our containers due to that. Moreover, we gained several awards for that and we are very proud of that.

What are the main differences to other construction methods?

Building in stone and concrete is becoming cheaper and cheaper due to cheap labour. Thus, the price is being pushed down (Containerwerk cannot compete with all conventional constructions which start at 1,250 €/m^2 depending on construction type and quality of execution.). Other modular construction such as wood modular construction are also a sustainable alternative to traditional methods and in terms of regulations such as fire protection, they have more established certificates. Nevertheless, their degree of prefabrication is lower. Moreover, containers can be dismantled while wood modules could not because they would have to be cut up for it which would damage the material.

What are challenges you are facing?

One of the biggest challenges for us is fire protection (it is the best for concrete, then wood, lastly steel). Currently, we fulfil fire protection properties of F60 (meaning that the steel lasts 60 minutes before it starts to melt) but buildings with more than three floor require F90 or above which we cannot provide. To achieve this requirement, a scaffold of recyclable concrete could be established to embrace the containers and enable more floors. In addition to fire protection, the bureaucracy hampers the progress for building standards because the German government does not know how to evaluate sea freight containers, thus, each individual case has to be examined. Again, for wood constructions, these standards already exist.

Is Containerwerk profitable?

Currently, Containerwerk is not profitable. Regarding financing, our 1st block of investment was financed through equity and the second round is covered by one of the federal states of Germany. We target to break even by the end of this year and start serial production but due to current incidents, we had to postpone it to the beginning of 2022. Our goal is to produce 3000

containers per year while up to 200 modules can be built simultaneously through a process with a high degree of automation. The semiautomatic process is highly depending on machines and would be way more expensive with manpower. In addition, such a high capacity could not be realised with labour. Through serial production, we will manage to become profitable. We would like to enable a price per m^2 of 1000€ compared to a selling price of 1,700 €/m^2 currently. Besides that, serial production can enable high quantities in series production and provides suppliers the opportunity to scale as well and plan for the long term, to reduce costs for them and therefore prices for us. Overall, it is important for us that sustainable sourcing stays always a priority embedded in our mission. We want to become profitable to be able to achieve even more without compromising on impact.

How would you elaborate the market need for your product?

Based on research by the *Fraunhofer Institute for systems and innovations research*, the future will be about mobile cities with a tendency towards small affordable flats, close small gaps, on car park deck etc. We offer such a mobile solution based on modules that can be easily stacked and combined as needed. The facade design has a low weight and allows for variability. Thus, the modules can be integrated into existing housing structures. We also successfully finalized projects with modules that were cut into half to fit even smaller spaces of 12m^2 or created an office space out of two containers. We cut off a wall of each and connected and stabilized them through pillars. We are willing to further innovate.

Appendix II.IV.: Second interview with Containerwerk

The second interview with Markus Goldmann has been conducted on the 1st of August 2021. The purpose was to further understand the objectives behind the production process, the social contribution of Containerwerk and its standing compared to competitors. The interview script below is based on notes taken during the conversation via phone. It was hold in German and translated into English afterwards.

When was the year of foundation of Containerwerk and how many employees do you have?

Containerwerk was officially founded in 2017 and we have around 50 employees.

You said that sustainable sourcing is important for Containerwerk. Could you further elaborate Containerwerk's environmental impact?

First, we have 13,000m^2 roof area completely equipped with solar panels that cover Containerwerk's total electricity supply with an investment that will pay off after 10 years. Therefore, we do not need to purchase electricity and can be self-sufficient. In addition, we upcycle containers while no parts of the container are separated or welded. Waste only occurs as holes need to be cut in the container for windows. However, because they consist of high quality Corten steel, the parts are recycled by recycling companies. No waste is generated through the foam as the machine stops as soon as the space is filled. For some projects, we use recyclable concrete as minimal as necessary and only to fulfil fire protection requirements for, e.g., staircases. Recyclable concrete is reusable and at the end of a container's life cycle, it can be dismantled and rebuilt somewhere else. Yes, it is unfortunately that we have to use concrete in general, but we use the recyclable one as minimal and long-lasting as possible. More sustainable options such as wood are not feasible yet.

You also mentioned that the containers are fully recyclable. Has this been tested?

We have broken down containers into individual components and tested and verified that the entire container can be dismantled into carriable, reusable parts. However, none of the containers of our projects are old enough to be at the end of their life cycle and therefore have not been dismantled yet.

How much more expensive are used ones compared to new and conventional containers?

A new container which still crossed the ocean once costs around 8,500€ containers. An entire new one that never crosses the ocean would be even more expensive, probably more expensive than newly made. We are ¼ cheaper than those who make containers conventionally.

Have Containerwerk already built a specific brand image?

We have a good presence at trade fairs and receive great references from customers. However, we do not pursue a specific brand strategy.

Do you support social projects?

For one of our projects, a micro hotel, we created 20 hotel rooms which required two barrier-free rooms by law while we designed five of them. Another project is the one with the University of Applied Sciences in Esslingen/Göttingen. We provide containers at minimum

cost for them to develop care containers. With a rail on top, people are assisted to move from bed to chair and sensors in the floor react if someone falls. The concept will be presented at a fair next year. We supported another project initiated by the city of Hamburg and an architectural office for the resocialisation of delinquent orphans. We provided 43 modules in three locations in Hamburg. Also, we got an enquiry for a Life-movement Resort in Kempten which combines living, healthy nutrition and sports. Participants will share a living area based on a mixture of different forms of living with wood, high-quality tents and containers. We are accompanying this development for two years. Last but not least, we provide the surplus of solar energy we generate with our solar panels to the local community.

How attractive is a sustainable corporate image for investors?

Sustainability is becoming more and more important for investors and site-managers. However, everyone wants sustainable solutions but does not want to pay for it, e.g., the renewable foam costs more than less sustainable options and not everyone is willing to pay for it.

What is Containerwerk's long-term goal?

Last year, we sold 400 containers, this year it will be 600. We will become cheaper if we build in higher quantities enabled through serial production. Moreover, as more material is needed, purchase prices per unit become cheaper. Our goal is to become competitive in the housing market in a long-term perspective through living that is affordable for everyone with a price below 1000€/m^2. Right now, I cannot depict serious competition in Europe and we can keep up with the competition in this segment in terms of prices. We started in a niche, but we will become better than the competition in the industry.

Appendix II.V.: Interview CHS Container Group

This semi-structured interview has been conducted on the 17th of August 2021 with the CEO of *CHS Container Group* Carsten Leopold. The main purpose was to further understand the incentives of a company producing custom-made container modules to establish comparability to Containerwerk. Carsten Leopold agreed to record the interview. It was conducted in German and translated into English afterwards.

What is your company offering?

The *CHS Container Group* with its headquarter and production facility in Bremen, Germany, develops, designs and produces innovative room modules and special containers for every

requirement on land and sea. Our room modules do not have static properties like containers and are more expensive due to, e.g., the rock-solid insulation. For the special containers, we use either 20-or 40-foot-high cube containers or produce and customize them by ourselves.

Where do you obtain your containers?

As all containers are built in South Asia, they are delivered from there. Afterwards, they are modified in Germany according to the requirements of the customer. For other orders, our containers are built from scratch, e.g., air freight containers. In this example, the sizes of the container deviate from the international standard dimensions with 4mx2.3mx1.5m. This is necessary because it has to resemble the fuselage of an aircraft, fulfil the proof of quality assurance required for aviation and the container is purely made of aluminium so that it is lighter but still has static strength. However, even if we establish the container from scratch, 98% fulfil the international standard dimensions because this offers huge logistic benefits.

How could you compare the custom-made container modules to new sea-freight ones pricewise?

Custom-made container modules are way more expensive, around four times more expensive than new sea-freight containers. But for some technical requirements, e.g., for static load-bearing capacity, it would be even more expensive to modify a sea-freight containers because the floor slab would have to be extensively rebuilt otherwise. Taking the example of air freight containers, it would be difficult and especially expensive to transform a sea-freight container into the required aluminium case with special dimensions.

Appendix III: Project *"My Home Wertheim"*

The temporary living company *Wohnen auf Zeit MAX Wertheim GmbH* developed a region's first, short-term residential quarter in Wertheim, Baden-Wuerttemberg, Germany (Figure 12). Within this project, Containerwerk and Acondo have been involved. The project has been realized in the beginning of 2020 and has been designed for short-term trips of business travelers and tourists. The boarding houses consist of 21 container modules provided by Containerwerk. All modules have been prefabricated at Containerwerk's production facility and haven been delivered fully finished (Figure 13), with strip foundations (Figure 14) and all necessary connections. Thus, only roofing elements and facade had to be installed which enabled to setup the modules in four to five days (Containerwerk, 2020b).

Figure 12: *"My Home Wertheim"* at night

Source: Containerwerk (2020b).

Figure 13: Fully equipped interior of a module of "My Home Wertheim"

Source: Containerwerk (2020b).

Figure 14: Strip foundations to avoid soil sealing

Source: Containerwerk (2020b).

Appendix IV: Additional Figures

Figure 15: Containerwerk's founders and CEOs Ivan Mallinowski (left) & Michael Haiser

Source: Containerwerk (2021e).

Figure 16: Award winners reception of the *"Germany - Land of Ideas"* award in 2018

Source: Containerwerk (2021f).

Figure 17: Project Costa Rica: Shipment of containers at the harbour

Source: Anta & Santos (2019b).

Figure 18: Project Costa Rica: Transport of modules with trucks

Source: Anta & Santos (2019c).