CRAFTS: A Compass to Refine and Align Factory Performance towards Sustainability

Rebecca Stenger
Tom Thomaes
Marius Westphal

Blekinge Institute of Technology
Karlskrona, Sweden
2017
Abstract:
The manufacturing industry must align business values with sustainability to preserve a healthy socio-ecological environment, that ensures access for future generations to necessary resources. To better understand the interactions between business strategies and facility operations, this research aims to adopt a more holistic perspective of sustainable facility planning processes, applying the Framework for Strategic Sustainable Development. By using relevant environmental and social principles, methods, knowledge, and industrial practices, a strategic decision support was developed as a foundation for the manufacturing industry to improve their sustainable performance. This research (1) collected and analysed existing concepts and processes for sustainability in the industry; (2) developed a practical decision support tool; (3) reviewed the design by experts in the field; and (4) redesigned the tool by implementing expert recommendations. Based on the findings, it is crucial for decision makers to embed a strategic and holistic approach when considering facility design options. Therefore, the strategic decision support tool (CRAFTS) enables opportunities for a broader scope of possible improvements within the confines of the manufacturing facility by guiding experts in the field to decide between retrofitting and new construction. CRAFTS supports the industry to refine and align their business strategies and facility operations with sustainability.

Keywords:
Facility Planning, Retrofitting, Decision Making, Decision Support Tool, Strategic Sustainable Development, Sustainable Manufacturing
Statement of Contribution

This thesis has been a collaborative effort of the three group members, Marius Westphal, Rebecca Stenger, and Tom Thomaes. Together we tried to create useful support for practitioners in the field to assist strategic sustainable development in the manufacturing industry. Each team member contributed equally to the success of the thesis by participating in the design, data collection, and analysis as well as the process of writing and other results of the thesis. Eventually, with great work mentality, the team collectively developed a practical written guidance for the industry and a video introduction to the developed decision support tool. The commitment of each team member to the research and the organization within the team by own set responsibilities and tasks creditable maintained a strong work ethic. The quality of work and time invested of each individual was comparable. The supportive working culture and open communication we fostered invited help and support at any level. On top of that major decisions were always made in the team.

As the thesis required extensive teamwork in almost all stages, tasks that could be done together were realized in brainstorm sessions. If tasks were able to be executed separately, it was commonly decided who will take responsibility. The writing process for instance was split into subchapters which were assigned among the team members and revised and commented by each other. Throughout the whole thesis project, critical and strategic thinking was applied to ensure that the created content and results were understandable, easy, covering the scope and intention of the thesis, and able to be validated for accuracy. Discussions in the team helped to deepen the understanding and aligned individual viewpoints. Each opinion was heard, valued and if applicable tried to be implemented in our work. Overall the research process was iterative and nourished by the connection of our different skills. Although the personal qualities of the team members aligned to a great extent, each member was able to enrich the project with unique talents.

Rebecca with her talent for organization, logic, and overall structure maintained the high standard of the thesis. Through her planning and structured way of working, she helped the group to see the bigger picture, close gaps, and think outside the box. She also improved the work with her editing skills by critically reflecting and restructuring content. Her talent to bring out the best in everyone by providing a safe and comfortable environment was complemented by ensuring the overall well-being of the group and process. Rebecca also planned events for the group to strengthen team dynamics and relationships to maintain the high energy and working level that the group kept over the whole thesis project. With her great network, technical background, and experience in the field of manufacturing she enriched the project. Rebecca’s positivity and motivation was a great asset throughout the process which she complemented with her creativity and visualization skills.

Tom, as a proficient English writer and with his talent to critically assess other work, ensured a high quality of content. His literature research created the scientific base for this thesis. Tom has a talent to dive deep into a topic to find the important pieces of information necessary for our research. With his strategic thinking, Tom tested the robustness of the content by constantly questioning how we could be wrong. Being less familiar with the manufacturing industry, he showed great interest driven by a healthy dose of curiosity to analyse the topic with a different perspective. By making use of his broad scope of vocabulary, his creative contribution caused for a clear content flow and a source of inspiration. His self-confidence and straight-forward thinking contributed largely to the motivation of the team and the final thesis outcome.
Marius was our designer in the team. He has an outstanding talent for strategic visualization especially when using Microsoft Power Point. He can communicate complex contexts in an easy and understandable way by using pictures, simple language, and on-point presentation. His capacity to create complex tools for analysing data was of a high value for our team. Without it, our work would have been much less professional and efficient. Marius working experience in the manufacturing industry, his overall management knowledge, and his personal network gave the team invaluable insights. His excitement for the topic has always been our fuel for productivity and motivation. He was choosing the topic primarily and with his new and creative ideas throughout the entire working process, we were able to create a meaningful contribution. Marius’s critical thinking and questioning was always valuable for discussions and improvements of the thesis outcome. He provided honest feedback and made the whole team feel comfortable and strong.

We are more than grateful for this unique opportunity this project provided. We learned from each other and grew personally by creating something useful together. The dynamics of the team always allowed for a focused, constructive and dedicated working culture which enabled us to achieve the best possible results within the given time without sacrificing fun and joy.

Karlskrona Sweden,

24 May, 2017

Rebecca Stenger
Tom Thomaes
Marius Westphal
Acknowledgements

This thesis would not be the same without the help and support from wonderful people involved in the process.

Firstly, we would like to express our deep gratitude to our first thesis advisor Tony Thompson. He has elevated the quality of our work and our learning, by challenging us with insightful critique and the right questions to push us out of our comfort zone. Despite the distance between Sweden and the United States, Tony was the ideal thesis advisor. He gave us confidence and the freedom we needed to feel comfortable and provided the space for us to make mistakes. However, he encouraged us to find solution on our own by letting us consider everything in detail and over and over again. We also like to thank him for the time he invested in us and the clarifying and humorous conversations. It was a pleasure and we are really grateful for the chance to work with him. Thank you, Tony!

We would also like to thank our secondary advisor, Rachael Gould, for her time and constructive feedback. Rachael helped us to think outside the box and motivated us to go the way we think is right. She was always there when we were struggling and tried to push us into the right direction. Thank you, Rachael!

Secondly, special thanks go to all the experts in the field that were involved in the thesis process. Although it was voluntary, they took the time and were open and eager to support us with deep insights and feedback in several conversations. Their practical input not only strengthened our results but also empowered us to revise our work to make the best out of it, so that it can hopefully be useful in their day to day business. We are also grateful for the openness to share concerns and problems with which we were able to understand the industry better and develop a beneficial support.

Lastly, we would like to send a big hug to the staff from the MSLS program and our fellow students for the deep listening skills and guiding advice. Despite of the stress, they were always there to cheer us up with delicious dinners, adventurous trips and uplifting conversations. Thank you, guys!
Executive Summary

Introduction

The increasing pressure on the social and environmental system has left humanity with a daunting challenge to redirect the current unsustainable societal design. The scientific community is concerned that current trends will harm the environment in such way that mankind’s long-term survival and well-being is threatened (Oreskes 2004; IPCC 2007; Bolis, Morioka, and Sznelwar 2014). Therefore, humanity is urged to create an improved societal system that is able to sustain itself, whilst simultaneously fulfil the current need.

The manufacturing industry plays an important role by supplying the demand that is necessary in fulfilling current societal needs. However, the footprint of this sector is one of the major drivers that account for significant portions of the total environmental and social impact that humanity is responsible for (Egilmez et al. 2016). Due to increased governmental and public pressure, more sustainable manufacturing strategies are becoming mandatory rather than optional for the industry (Deif 2011; Joung et al. 2013). Besides these restraints, certain benefits arise if sustainability is embedded by manufacturing companies, highlighted in the Table below (Pujari, Wright, and Peattie 2003; Fraj-Andre’s et al. 2008; Jayal et al. 2010; Fantini, Taisch, and Palasciano 2013; Rajak and Vinodh 2015).

<table>
<thead>
<tr>
<th>Ecological</th>
<th>Social</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reduce (hazardous) Pollution &amp; Emissions</td>
<td>• Improve Employees’ Working Conditions, Moral &amp; Retention</td>
<td>• Drive Innovation</td>
</tr>
<tr>
<td>• Make use of Recycling Technologies</td>
<td>• Improve Local Community Relations</td>
<td>• Increase Efficiency</td>
</tr>
<tr>
<td>• Embed Renewable Energy</td>
<td>• Better Local Living Conditions</td>
<td>• Mitigate Future Risks</td>
</tr>
<tr>
<td>• Increase Resource &amp; Energy Efficiency</td>
<td>• Enhance Relations with Customers</td>
<td>• Increase Revenue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce Costs (Energy, Waste &amp; Material Expenses)</td>
</tr>
</tbody>
</table>

Benefits of Sustainable Manufacturing

Manufacturers need a practical approach to apply new ideas into their business strategies and operations with a facility that allows for sustainable solutions. A company can choose between two facility planning options that can help the company implement sustainability: retrofitting (by adding new features to optimize the manufacturing facility towards sustainability) and the construction of a new factory (by building a new goal oriented manufacturing facility that aligns best with sustainable practices). The decision process that relates to these options is crucial for the company's ecologic, social, and economic performance thus should be considerate, defensible, and accountable. However, the decision making context can change rapidly in a complex environment, making it fundamentally more challenging for companies to make decisions (León-Soriano, Muñoz-Torres, and Chalmeta-Rosaleñ 2010). Various modelling and analysis tools have been developed to support improvements, but fail in providing sufficient guidance to identify inefficiencies and opportunities for sustainable manufacturing. Therefore, support is required on how to achieve sustainable improvement in the industry (Deif 2011) and the decision between retrofitting and new construction by means of sustainable facility planning.
Applying the Framework for Strategic Sustainable Development (FSSD), as an overarching planning framework, we explored the practical implementation in the manufacturing industry to cope with the complex challenges around sustainability (Broman and Robèrt 2017). Therefore, the purpose of this research is to better understand the current situation of the manufacturing sector and find out how such an approach might contribute to better decisions, when weighing out the options of retrofitting and constructing a new facility. Consequently, our research question states: "How can a company assess sustainability trade-offs to decide between retrofitting and new construction of a manufacturing facility using an SSD approach?".

**Methods**

To answer the research question, we chose to use a qualitative research approach and divided the design into four phases, namely: (1) Data Collection & Analysis, (2) Design, (3) Evaluation, and (4) Redesign. This iterative research design combined several methods to collect data.

A literature review, online survey, and expert interviews were the chosen sources in the Data Collection & Analysis phase. The literature review gave us the opportunity to develop a basic understanding of the process planning methods and approaches that can be used to implement sustainability into manufacturing facilities. Due to the limited data in this research area, examining industry practices and specific experiences of respondents were a crucial method. The online survey was used to gather information about the current reality and practices the industry is applying. By sending out the survey to approximately 450 companies divided over six continents, we tried to explore how companies in the industry decide between retrofitting and new construction of their facilities to move towards sustainability. Additionally, 11 expert interviews revealed insights on how current decision processes are performed. To answer the research question, the conversations focused on the process behind the decision of retrofitting and new construction of a manufacturing facility. Knowledge from literature was compared with the expert interview and online survey data to consider if the results were supporting, complementing or contradicting each other.

Based on the findings and outcomes, a practical strategic decision support tool was created through brainstorming in the Design phase. The ABCD process, designed by Broman and Robèrt (2017), functions to guide companies through complex challenges and was an inspiration for the decision support to solve the complex decision to implement sustainability into facility planning. It is a step by step strategic planning approach that assist organisations to move towards sustainability by creating a strategic action plan. The steps include visioning, baseline assessment, creative solutions, and prioritizing.

In the Evaluation phase five interviewees provided feedback on the structure of the tool as well as recommendations in terms of how an ideal process should look like. It revealed what is most useful to them in their work within companies when considering facility design options.

This iterative creation of the tool allowed a development of the design, by implementing these insights in the Redesign phase. Potential recommendations were used to fill gaps and improve the initial design in terms of practicality. The current process design was verified with the results from the data of the literature review, expert interviews, and survey, to justify and validate the changes based on the feedback.
Results

Through the online survey, we were able to identify common process triggers and final factors that led to the conclusion to decide between retrofitting and the new construction. The results showed that 90% of all participants believe that it would be helpful to have some sort of support that would assist them with the issue at hand (Survey Question 14). The expert interviews revealed a general decision process structure, consisting of a factory assessment, definition of the factory’s future purpose and goals based on the initial analysis, and the design of the new ideal factory (Interview 1-11).

The interviewees recommended to enhance awareness of overarching connections between the different systems with which the factory interacts and to include a holistic view for the whole process (Interview 2,5,6,9,10). Based on these findings, CRAFTS was developed to support manufacturing companies to decide between retrofitting and new construction of their facility to move towards a more sustainable future. A brief video introduction was created to actively guide experts in the field through the process and to help them better understand the potential and benefits of using CRAFTS (youtu.be/M0Zlq7tO6G4). It was also used as a basis for feedback to improve the clarity, applicability, and functionality of the decision support tool.

CRAFTS consists of six interconnected steps allowing an iterative application in the manufacturing industry (see Figure above). Practitioners begin by co-creating an inspiring common vision to set a desired image of the company's future of success. By representing the core ideology and communicating it throughout all levels, the whole company is inspired to carry out the message of what the company stands for and what the common goals are. Assessing the current reality implies that practitioners will capture an image of the manufacturing facility and the company's activities. This analysis reveals to what extent the factory aligns with or violates against the definition of sustainability, specified by the eight Sustainability Principles (SPs) (Robèrt, Broman, and Basile 2013; Missimer 2015). To bridge the gap between the current and future state, a set of brainstorming workshops enables the company to create ideas and solutions that can be implemented in the ideal manufacturing facility design. Subsequently, practitioners are set to prioritize what facility solutions are most valuable and strategic for the company. By asking prioritization questions and assessing ideas against grading rubrics and factors, superior solutions can be extracted and combined to create realistic scenarios of the future facility. Conclusively, the two best rated scenarios for retrofitting and new construction are assessed in detail to select the ideal option.
Discussion

Although in recent trends sustainable manufacturing is becoming more prevalent among companies, it is argued that there is still much confusion on what sustainable manufacturing constitutes as well as sustainability in general (Dangelico and Pujari 2010; Siemieniuch, Sinclair, and Henshaw 2015; Survey Question 6,7,8; Interview 4,5,6). Equally in the survey results, it was apparent that the majority of the responding companies did not have a sustainable strategy applied yet (Survey Question 6). This led us to draw the conclusion, that most companies in the field are unaware of the importance of sustainability and the connected benefits pointed out in the literature (Pujari, Wright, and Peattie 2003; Fraj-Andre’s et al. 2008; York 2009; Jayal et al. 2010).

The literature also discusses that sustainable manufacturing requires the combined analysis of buildings and facilities supporting the manufacturing operations (Despeisse, Oates, and Ball 2013) and proposes two options to aim for an improved sustainability performance, namely: retrofitting and the construction of a new factory. The results in this research displayed that companies need guidance to identify the impact of the industrial improvements with respect to sustainable facility planning (Interview 1-11). In order to make this decision, the literature pointed out that a step by step process clarifies and adds value to the process which was confirmed by the interviews (Waage 2007; Interview 1-11). Furthermore, this research revealed that a strategic support tool with a holistic approach is favourable and needed for the industry when considering facility design options (Interview 1-8,10; Feedback 2-5). Despite the strategic approach of the backcasting technique, it permeated through that most decision makers in the field made use of a more traditional forecasting approach to execute these decisions strategically (Interview 1-11). This means that current decision making in the manufacturing industry is mainly based on analysing the current trends, setting the goals given these trends and think of actions to reach these goals. The FSSD enables a strategic planning approach that can close potential gaps as an attempt for the current manufacturing industry to become more sustainable. The most important challenge in this research is to combine a set of methods, approaches and tools to put them into the context of a broader framework for companies to weigh off sustainability trade-offs and decide between retrofit and new construction. By doing so, the strategic decision support CRAFTS was designed. CRAFTS includes the definition of sustainability based on the eight SPs and the triple bottom line. It thereby emphasizes on social sustainability which companies are aware of but not in the entirety as presented in the FSSD (Survey Question 10,12; Feedback 3). The full system perspective assures that directly affected communities as well as employees are taken into consideration instead of just valuing cost and efficiency in order to be successful.

The main objective of CRAFTS is to help companies decide between retrofitting and new construction of their manufacturing facilities. However, it also supports to find an appropriate solution for either only retrofitting or new construction. Even by going through the CRAFTS steps individually, one can have additional benefit, although the steps are interconnected. When using CRAFTS as a decision support, the way how it is being used is substantial for the success of the project. As CRAFTS is designed to be applicable for multiple sectors in the manufacturing industry, there might be certain areas missing for very specific industries. Companies which have never dealt with a decision like this, could be of disadvantage as measurement tools for the factory analysis are not provided. CRAFTS also lacks computer-based software (e.g. Excel, templates) to simplify the data collection and analysis and to make the tool more practical in general. Another drawback that comes with CRAFTS is the limited scope. Amongst others, the product produced in the facility, the supply chain or transport are
not included and will not affect the analyses. The scope and time restriction for this research also did not allow to pilot test the tool in the field. Further research is needed to measure the practical implementation and limitations of the tool.

**Conclusion**

The aim of the research was to discover how companies in the manufacturing industry can assess sustainability trade-offs to decide between retrofitting and new construction of a facility. The industry is compelled to supply the demand for products and services in the current societal system, while simultaneously aligning their business strategies and facility operations with sustainability. Especially in the manufacturing industry there are several factors that must be considered when assessing sustainability. By researching how decision makers in the industry currently cope with this complex decision, we found that companies do not address this challenge in a holistic way but rather focus on specific solutions in isolation when considering facility design options. Although the results showed that decisions about facilities are future-oriented because of the high financial investment and value of production to the company, money driven short-term decisions are still common in the manufacturing industry. This short-term thinking can be caused by project time restrictions or other board specifications. Furthermore, the complexity of such a decision, pressure of competition, and market trends can hinder decision makers from creating strategically sound solutions.

This highlights the need for a tool to bridge this gap of knowledge and unawareness of sustainability benefits combined with long-term decision making. Although the literature suggests several tools that allow for sustainable improvements, there is no overarching framework that includes a full systems perspective to assists the manufacturing industry in deciding between retrofitting and new construction of their facilities. Based on the findings, it is crucial for decision makers to embed a strategic and holistic approach when considering facility design options. If the manufacturing industry aims towards sustainability, this could help other sectors to move in the right direction. Therefore, the strategic decision support tool CRAFTS, developed in this research, enables opportunities for a broader scope of possible improvements by guiding experts in the field to decide between retrofitting and new construction. The tool is designed as a step by step process applying a backcasting approach to refine and align their business strategies and facility operations with sustainability. By using the FSSD as a holistic foundation, we can ensure that all components that account for sustainability were taken into consideration. As the scope of CRAFTS is specifically focused on the facility, additional sustainable strategies need to be implemented, which include for instance the supply chain, transportation or product portfolio.
Glossary

**ABCD Process:** A step by step strategic planning approach used in complex systems to support organisations to move towards sustainability by creating a strategic action plan. The steps include visioning, baseline assessment, creative solutions, and prioritizing.

**Backcasting:** A method to support planning and decision making by envisioning the desired future and asking what needs to be done today to strategically reach that vision.

**Backward Linkage:** An effect in which increased production by a downstream manufacturer provides positive financial externalities to an upstream manufacturer, in the case of a product manufactured in stages by different manufacturers.

**Baseline Assessment:** An assessment performed to provide information about the currently existing situation or state of an organisation or building.

**Climate Change:** Change in the state of the global climate that can be identified by changes in the mean temperature and/or the variability of its properties, due to human activities.

**Complex System:** A system that is constituted of a relatively large number of parts that interact in complex ways to produce behaviour that is sometimes counterintuitive and unpredictable.

**Core Ideology:** In an organisational vision, the timeless identity of the organisation – a stable core on which all activities are based. The core ideology consists of two components, the core purpose and the core values.

**Core Purpose:** In an organisational vision, an organisation’s reason for being. It answers what service the organisation if providing to society.

**Core Values:** In an organisational vision, the “how” of an organisation. Both what it represents today and what its members would like it to represent in the future.

**Cradle-to-Grave:** Refers to the process from creation to disposal, throughout the life cycle of a product.

**CRAFTS:** An acronym for Compass to Refine & Align Factory-performances Towards Sustainability: a strategic decision support tool with six steps that helps companies to decide between retrofitting and new construction of a manufacturing facility to move towards sustainability. The acronym also stands for:

- C-Step: Co-create vision
- R-Step: Represent core ideology
- A-Step: Assess current reality
- F-Step: Focus on ideas
- T-Step: Target ideal solutions
- S-Step: Select best option

**Design:** For the purpose of this thesis, the term design and redesign is used to describe the creation of the prototype of the strategic decision support tool CRAFTS.
**Envisioned Future:** Within an organisational vision, a description of the organisation’s positive aspirations.

**Framework for Strategic Sustainable Development (FSSD):** A model of five levels to clarify differences and inter-relationships between entities of different character in the sustainability context. The five levels are system, success, strategic, actions and tools.

**Masters in Strategic Leadership towards Sustainability (MSLS):** A international 10-month transformational master’s programme in Karlskrona, Sweden that focuses on advancing students’ knowledge, skills, and global networks, in order to build their capacity to be a strategic leader in the co-creation of thriving, sustainable societies.

**PESTLE:** An external factor analysis "Political, Economic, Social, Technological, Legal, and Environment Analysis" and describes a framework of macro-environmental factors used in the environmental scanning.

**Positive Feedback:** Natural effect in a process that causes a system to alter from its natural state in a faster rate, due to disturbance in the current natural equilibrium.

**Practitioners:** For the purpose of this thesis, we use the term practitioners to refer to professionals with diverse backgrounds and expertise representing different stakeholder roles within the manufacturing industry.

**Principle:** A basic condition that must be met for a system to continue in a certain state.

**Prioritisation (as it relates to the FSSD):** Step in the ABCD strategic planning tool where ideas are organised and filtered based on basic guidelines and other customizable factors. The basic guidelines imply right direction, flexible platform and sufficient return on investment of the action.

**Regression Analysis:** A statistical process for estimating the relationships among different variables.

**Retrofitting:** Process of adding new features to optimize the manufacturing facility with new or modified parts or equipment.

**Scenarios:** Simplified images of the future which are created (often with the aid of designers, storytellers or computer modelers), and then used to guide planning efforts.

**Socio-ecological System:** The combined system that is made up of the biosphere, human society, and their complex interactions.

**Stakeholder:** Person, group or organisation that has an interest or concern in an organisation.

**Strategic Plan:** The specific actions that an organisation chooses to move towards a goal, which are often recorded in a written document.

**Strategic Sustainable Development (SSD):** Planning and decision making to actively transition the current, globally unsustainable society towards a sustainable society based on
first-order Sustainability Principles. Once the transition to a sustainable society is complete, sustainable development also refers to further social development within that society.

**Stretch Goals:** One or more bold, daring, and possibly unachievable goals which make up part of an organisation’s envisioned future. These may be goals which the organisation is not totally convinced it can reach.

**Structural Obstacles:** Social constructions – political, economic, and cultural – which are firmly established in society, upheld by those with power and, due to variety of dependencies, difficult or impossible to overcome or avoid by the people exposed to them.

**Sustainability Challenge:** Combination of the systematic errors of societal design that are driving humans’ unsustainable effects on the socio-ecological system, the serious obstacles to fixing those errors, and the opportunities for society if those obstacles are overcome.

**Sustainability Principles:** The eight basic principles for a sustainable society in the biosphere, underpinned by scientific laws and knowledge. These principles state that in a sustainable society, nature is not subject to systematically increasing:

- **SP1:** … concentration of substances extracted from the earth’s crust.
- **SP2:** … concentration of substances produced by society.
- **SP3:** …. degradation by physical means.

And, in that society, that people are not subject to structural obstacles regarding:

- **SP4:** … health.
- **SP5:** … influence.
- **SP6:** … competence.
- **SP7:** … impartiality.
- **SP8:** … meaning-making.

**Sustainability:** Defined by the eight Sustainability Principles.

**Sustainable Manufacturing:** Creation of manufactured products that use processes that minimise negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound.

**SWOT:** An analysis that assembles an overview of the company’s external influences and internal characteristics. SWOT stands for: Strengths, Weaknesses, Opportunities and Threats.

**System:** A set of interconnected parts whose behaviour depends on the interactions between those parts.

**Systems Thinking:** The organised study of systems, their feedbacks, and their behaviour as a whole. Further, it identifies the underlying structures responsible for the patterns of behaviour.

**Tool:** A method or process used in management to support and accomplish a task or purpose.

**Triple Bottom Line:** Consists of three Ps: profit, people and planet. It aims to measure the financial, social and environmental performance of the corporation over a period of time.
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTH</td>
<td>Blekinge Tekniska Högskola (Blekinge Institute of Technology)</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CRAFTS</td>
<td>Compass to Refine and Align Factory-performance Towards Sustainability</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma-Separated Values</td>
</tr>
<tr>
<td>e.g.</td>
<td>Exempli gratia, meaning ‘for example’</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FSSD</td>
<td>Framework for Strategic Sustainable Development</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GVA</td>
<td>Gross Value Added</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>LCA</td>
<td>Life Cycle Assessment</td>
</tr>
<tr>
<td>MEW</td>
<td>Material, Energy, Waste</td>
</tr>
<tr>
<td>MFA</td>
<td>Material Flow Analysis</td>
</tr>
<tr>
<td>MSLS</td>
<td>Master in Strategic Leadership towards Sustainability</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PESTLE</td>
<td>Political, Economic, Social, Technological, Legal, and Environment</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium-sized Enterprises</td>
</tr>
<tr>
<td>SP</td>
<td>Sustainability Principle</td>
</tr>
<tr>
<td>SSD</td>
<td>Strategic Sustainable Development</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, Weaknesses, Opportunities, and Threats</td>
</tr>
<tr>
<td>THERM</td>
<td>Through-life Energy and Resource Modelling</td>
</tr>
</tbody>
</table>
# Table of Contents

Statement of Contribution ....................................................................................................... ii  
Acknowledgements .................................................................................................................. iv  
Executive Summary ................................................................................................................. v  
Glossary ..................................................................................................................................... x  
List of Abbreviations ............................................................................................................. xiii  
Table of Contents .................................................................................................................. xiv  
List of Figures and Tables .................................................................................................... xvi  

1 Introduction .......................................................................................................................... 1  
1.1 The Sustainability Challenge ..................................................................................... 1  
1.1.1 Global Sustainable Society ........................................................................... 1  
1.1.2 Moving Companies towards Sustainability .................................................. 1  
1.2 The Role of the Manufacturing Industry ................................................................... 2  
1.2.1 Conventional Manufacturing ........................................................................ 2  
1.2.2 Sustainable Manufacturing ........................................................................... 3  
1.3 Sustainable Manufacturing Facilities ........................................................................ 4  
1.3.1 Sustainable Factory Design ........................................................................... 4  
1.3.2 Retrofit of a Facility towards Sustainability .................................................. 5  
1.3.3 Construction of a New Sustainable Facility .................................................. 5  
1.4 Decision Making Process .......................................................................................... 6  
1.4.1 Strategic Decisions ........................................................................................ 7  
1.4.2 Need for Strategic Sustainable Support ....................................................... 8  
1.4.3 Types of Support ........................................................................................... 8  
1.5 Framework for Strategic Sustainable Development ................................................ 10  
1.6 Research Design ...................................................................................................... 12  
1.6.1 Purpose ........................................................................................................ 12  
1.6.2 Research Question ...................................................................................... 13  
1.6.3 Scope and Limitations ................................................................................... 13  

2 Methods ............................................................................................................................... 14  
2.1 Data Collection and Analysis .................................................................................. 14  
2.1.1 Literature ..................................................................................................... 14  
2.1.2 Online Survey ............................................................................................. 15  
2.1.3 Expert Interviews ........................................................................................ 16  
2.1.4 Data Analysis and Sense Making ............................................................... 17  
2.2 Design ...................................................................................................................... 18  
2.3 Evaluation ............................................................................................................... 18  
2.4 Redesign .................................................................................................................. 19
3 Results .............................................................................................................................. 20
  3.1 Online Survey ........................................................................................................ 20
  3.2 Expert Interviews .................................................................................................. 22

4 The Strategic Decision Support Tool CRAFTS ............................................................ 24
  4.1 Design Influence of the FSSD .............................................................................. 25
  4.2 CRAFTS ................................................................................................................. 25
    4.2.1 C-Step: Co-Create a Vision ........................................................................ 25
    4.2.2 R-Step: Represent the Core Ideology ......................................................... 28
    4.2.3 A-Step: Assess the Current Reality .......................................................... 30
    4.2.4 F-Step: Focus on Ideas ............................................................................ 34
    4.2.5 T-Step: Target Ideal Solutions ............................................................... 35
    4.2.6 S-Step: Select Best Option ..................................................................... 38

5 Discussion ......................................................................................................................... 39
  5.1 Relation of Results to Literature .............................................................................. 39
    5.1.1 Manufacturing and the Sustainability Challenge ........................................ 39
    5.1.2 Sustainability in the Manufacturing Industry ............................................. 39
    5.1.3 Need for Strategic Decision Support .......................................................... 40
    5.1.4 Strategic Planning using the FSSD ............................................................. 40
    5.1.5 Sustainable Facility Planning ...................................................................... 40
  5.2 Contribution of Results to the Field ........................................................................... 41
    5.2.1 Conventional Decision Making .................................................................. 41
    5.2.2 Conventional Facility Planning ................................................................... 41
    5.2.3 CRAFTS and Sustainable Manufacturing .................................................. 42
    5.2.4 Strengths of CRAFTS ................................................................................. 43
    5.2.5 Weaknesses of CRAFTS ............................................................................ 44
  5.3 Validity .................................................................................................................... 45
  5.4 Limitation of the Research ....................................................................................... 47
  5.5 Next Steps and Recommendations .......................................................................... 48

6 Conclusion ........................................................................................................................ 49

References ............................................................................................................................... 50
  Literature ......................................................................................................................... 50
  Expert Interviews ........................................................................................................... 60
  Expert Feedback .............................................................................................................. 60

Appendices .............................................................................................................................. 61
  Appendix A: Online Survey............................................................................................ 61
  Appendix B: Expert Interviews ....................................................................................... 66
  Appendix C: Expert Feedback ......................................................................................... 67
  Appendix D: CRAFTS ...................................................................................................... 68
List of Figures and Tables

Figures

Figure 1.1. The Five-Level Model ........................................................................................................... 10
Figure 2.1. Research Design .................................................................................................................. 14
Figure 2.2. Data Collection and Sense Making. ..................................................................................... 17
Figure 3.1. Distribution of Companies’ Production Location within Continents relative to Size (left) and Industry Sector (right) ..................................................................................... 20
Figure 3.2. Facility Areas assessed in the Current-State-Analysis .......................................................... 21
Figure 3.3. Triggers and Decision Factors for Facility Planning ............................................................ 21
Figure 3.4. Generic Decision Process ................................................................................................... 22
Figure 4.1. Process Overview of CRAFTS ............................................................................................ 24
Figure 4.2. Vision Segments .................................................................................................................. 26
Figure 4.3. Target Ideal Solutions ......................................................................................................... 35
Figure 5.1. Scope of Application for CRAFTS relative to the bigger System ........................................ 48

Tables

Table 4.1. Factory Model Categories ..................................................................................................... 31
Table 4.2. Factory Model Analysing Questions ....................................................................................... 32
Table 4.3. PESTLE Analysis................................................................................................................... 33
Table 4.4. SWOT Matrix ......................................................................................................................... 33
Table 4.5. Creativity Techniques ............................................................................................................ 34
Table 4.6. Weighing and Grading Rubrics and Factors .......................................................................... 36
Table 4.7. Grading Scheme ..................................................................................................................... 37
1 Introduction

1.1 The Sustainability Challenge

1.1.1 Global Sustainable Society

Humanity is confronted with a challenge that will require full societal attention on a global scale. With increasing pressure on environmental and social systems, the need for systematic stability and recovery becomes more and more crucial. Positive feedback effects will cause exponential pace of irreversible change, which can tip the earth into a new and unstable state (IPCC 1990; Walter et al. 2006). Scientists are concerned that current trends will bring negative societal impacts that will threaten mankind’s long-term survival and well-being (Oreskes 2004; IPCC 2007; Bolis, Morioka, and Snelwar 2014). These alarming academic outlines are urging humanity to create an improved societal design with a system that is able to sustain itself. On the one hand, the global population is exponentially growing, which causes a systematic increase in the production and consumption of services and goods. On the other hand, finite planetary resources are being systematically degraded in the current global economic system, therefore diminishing the ability for natural resources to regenerate themselves. These circumstances implicitly show that current societal activities jeopardize the ability for future generations to fulfill their needs, hence creating an undesirable future for the society as a whole.

1.1.2 Moving Companies towards Sustainability

With the prospects from the previous section in mind, it seems unavoidable that companies, as an important part of society, need to align their business values with sustainability in order to preserve a healthy natural and social environment. Dangelico and Pujari (2010) discuss that because of new environmental and social expectations from multiple stakeholders, the business climate is undergoing a rapid change. This in turn causes companies to address more sustainability issues to attract, satisfy, and retain their customers and increase shareholder’s value (Husted and de Jesus Salazar 2006; Miller, Pawloski, and Standridge 2010). However, the ongoing changes in business models are gradual (Sharma et al. 2008; Bhupendra and Sangle 2016). Instead of marginal improvements over pollution prevention or control measure, companies need to change their performance disruptively and significantly from existing processes. In addition, companies should focus on developing knowledge and innovation to benefit from sustainability (Vergragt and van Grootveld 1995; Holton et al. 2010; Bhupendra and Sangle 2016). The improvement of the business performance should not be merely focused on economic viability but also on environmental and social justification (Boons and Lüdeke-Freund 2013; Benn, Dunphy and Griffins 2014; Bhupendra and Sangle 2016). If a company does not focus on sustainability issues, Lash and Wellington (2007) suggest that companies will be at competitive disadvantage. Therefore, it seems evident that companies need to improve their sustainability performances toward a more sustainable society. However, in the corporate community, there has been substantial confusion about what sustainability entails (Aras and Crowther 2009; Willard 2012; Bansal and Song 2016). Ottman et al. (2006) defines a sustainable company as a company that strives to protect or enhance the natural environment by conserving energy and/or resources and reducing or eliminating use of toxic agents, pollution, and waste.
An exceptional source of opportunities arises when a company pursues sustainability. Implementing sustainability has become strategically important to the long-term profitability, growth, and competitiveness of a company (Hart 1995; Teh and Corbitt 2015). Furthermore, minimizing risk, preserving or improving reputation, and creating new business opportunities have also been recognized as benefits for companies who embed sustainable practices (Dangelico and Pujari 2010). However, if they do not have a sustainable practice yet, this would imply a radical change in their business strategy with risk prone investments and long-term commitments (Hart and Milstein 2003; Montalvo 2008; Bhupendra and Sangle 2016). The complexity of this shift can be challenging as companies are occupied with maintaining their market positions and increasing profits that enable them to continue operating (Willard 2012).

### 1.2 The Role of the Manufacturing Industry

#### 1.2.1 Conventional Manufacturing

The manufacturing industry functions as an important sector that supplies the demand for products and services in our current societal system. The socio-economic and environmental footprint of this sector is one of the major drivers that account for significant portions of the total environmental impact that humanity is responsible for (Egilmez et al. 2016). Furthermore, social issues around human health, safety, and education in the global manufacturing industry exacerbate the contributions to unsustainable conditions for employees and affected communities (Fantini, Taisch, and Palasciano 2013; Rajak and Vinodh 2015). At the same time, the manufacturing sector will unavoidably be subject to the negative impacts of climate change as well as resource scarcity (Kishita, Mizuno, and Umeda 2016). Therefore, the industry is confronted with the sustainability challenge on a system level and is compelled to take sustainability into consideration. In addition, more and more green manufacturing strategies are becoming mandatory rather than optional, due to increasing governmental and public pressure on a global scale (Deif 2011; Joung et al. 2013).

By looking at the manufacturing industry on a systems level, the industry is subject to several critical constraints, including at least: global population growth, economic growth, climate change, and resource depletion (Rahimifard et al. 2013). Moreover, manufacturing is not merely subject to these constraints but is also adding to the severity and complexity of the sustainability challenge at hand due to the current unsustainable activities in the industry. Manufacturing is regarded as a key sector in sustainability due to its high volume of resource consumption and the increasing annual introduction of new products that require a relatively high amount and generation of materials, energy, and wastes (Jayaraman, Singh, and Anandnarayan 2012; Siemieniuch, Sinclair, and Henshaw 2015). Furthermore, various environmental impacts such as atmospheric pollution, hazardous waste disposal, and toxic releases have affected the health of employees and immediate communities (Joung et al. 2013; Egilmez et al. 2016). Moreover, the manufacturing industry consumes one-third of the world energy and simultaneously generates carbons emissions, with projections in 2050 showing energy demand that doubles current figures (Nezhad 2009; Mani et al. 2012; Židonienė 2016). It is important to note that neither all products have a significant environmental footprint on each stage of physical product life cycle nor does the footprint stem from all aspects (material, energy, and waste) but almost all manufactured products have significant environmental impact in at least one of the stages (Dangelico and Pujari 2010).

Therefore, it is vital that the manufacturing industry acts to develop towards an environmentally and socially sustainable state, while simultaneously fulfilling the current societal needs. That is
why it is one of the key challenges in the 21st century (Gunasekaran and Spalanzani 2012). A mapping of relationships in the economy reveals that manufacturing has the highest backward linkage among the major sectors (The Manufacturing Institute 2017). It also remains a significant contributor to Gross Value Added (GVA) and Gross Domestic Product (GDP). As well as employment across economies, caused by a growing demand for manufacturing, which in turn spurs the creation of jobs, investments, and innovations elsewhere (The Manufacturing Institute 2017; Manyika et al. 2017).

1.2.2 Sustainable Manufacturing

Sustainable manufacturing can be considered as one of the most important issues to address for pursuing the big picture of sustainable development (Garetti and Taisch 2012). Both in delivering products that meet sustainability criteria (e.g. durability, reliability, minimised material requirement, low energy consumption) and in developing processes to deliver products for sustainability (e.g. minimum waste, minimum emissions, low energy consumption) (Siemieniuch, Sinclair, and Henshaw 2015). Global demand for more sustainable products is putting increasing regulatory and market pressure on manufacturing companies. For example, in Europe, EU policies and directives have increased the legal, financial, and market-related pressures on manufacturing industries to develop more sustainable products (Jorgensen 2008). Even though recent trends show that sustainable manufacturing innovation is becoming mainstream among the companies, there is still much confusion on what sustainable manufacturing constitutes (Dangelico and Pujari 2010; Siemieniuch, Sinclair, and Henshaw 2015). The U.S. Department of Commerce defines sustainable manufacturing as the creation of manufactured products that use processes that minimise negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, consumers, and are economically sound (International Trade Administration 2013).

As a common driver for society, sustainable manufacturing depicts an alternative option that increases the robustness of the triple bottom line, which consists of the ecological stewardship, social well-being, and economic prosperity (Herrmann et al. 2014). Furthermore, Dangelico and Pujari (2010) discuss that the literature highlights several tangible benefits that can arise from integrating sustainability issues in business operations: increased efficiency in the use of resources, reduced cost, reduced power consumption and wastes, increased sales, development of new markets, improved corporate image, product differentiation, improved employee health, and enhanced competitive advantage (Pujari, Wright, and Peattie 2003; Fraj-Andre’s et al. 2008; York 2009; Jayal et al. 2010). Apart from these economic benefits, there are various intangible socio-ecological benefits that arise, including: reduced pollution and emission better working conditions, moral and retention of health, and better local living conditions (Willard 2012; Fantini, Taisch, and Palasciano 2013). Consequently, it seems favourable that the manufacturing industry would implement sustainability to take advantage of these benefits to guide the industry in a new direction by rethinking and improving their business model viewpoints and mindsets (Porter and Van der Linde 1995; McPhee 2014).

Various sectors incline to set new goals to move towards sustainability. If the manufacturing industry aims towards those same goals, this could help other sectors to move in the right direction as well with a sustainable alternative (Nee et al. 2013; Siemieniuch, Sinclair, and Henshaw 2015). Currently, there are multiple external forces, which can and do inflict policies on organizations that encourage them to behave in a more sustainable manner, both in terms of ecological and social considerations. For instance, the International Organization for Standardization (ISO) to develop a standard for environmental management systems ISO 14000
and guidelines for social responsibility ISO 26000 (ISO 2017). Besides policies, companies interact with several social entities, such as employees, customers, supply chain partners, communities, and society as a whole (Benoit and Mazijn 2009). That is why manufacturing is essential to the health of the economy.

Despite the economic contributions of the industry, it still needs to improve its activities to move the global society towards sustainability. Hence, efforts to make manufacturing more sustainable must consider issues at all relevant levels – product, process, and system - and not just one or more of these in isolation (Jayal et al. 2010). However, if the manufacturing industry truly strives for a sustainable future it will require more than an enhanced level of corporate environmental responsibility but also well developed concepts for industrial sustainability. These trends have caused an increase in the concerns about where the manufacturing sector needs to move towards and how such decision based change could be realized.

1.3 Sustainable Manufacturing Facilities

Manufacturers need a practical approach to apply developed ideas into their production system and improve the environmental performance in a systematic way at factory level. This ecosystem view of a factory can be used to build cross-disciplinary models linking the manufacturing operations, the supporting facilities, and the surrounding buildings. (Hesselbach et al. 2008; Despeisse et al. 2012) In the further course of this thesis, the terms facility and factory will be used interchangeably.

1.3.1 Sustainable Factory Design

Many researchers have been involved in finding optimum facility design (Dwijayanti et al. 2010). As facility decisions are typically long-term based, the design may be focused on characterizations such as: physical conditions, facility operations, facility policies and procedures, regulatory requirements, and legal issues (Garcia 2007). In any industry, decisions on the focus of facilities usually depend on the economics of production and distribution. A factory with a clear competitive objective that focuses on a narrow product mix for a well-defined market will outperform a conventional plant with an inconsistent set of manufacturing policies that attempts to do too many conflicting tasks. (Fine and Hax 1985)

Therefore, Alves, Xavier, and Alves (2015) argue that the goal of effective facility planning is to provide companies with the tools to survive in a global market that demands higher quality, faster delivery, and lower prices. The main objectives are to:

- Drastically reduce waste in the supply chain;
- Reduce inventory and space occupied on the production floor;
- Create stronger production systems;
- Create appropriate systems for the delivery of materials; and
- Improve the organisation’s production areas to increase flexibility.

Sustainable manufacturing requires the combined analysis of buildings and facilities supporting the manufacturing operations, but these disciplines are typically managed separately resulting in missed opportunities to improve these areas in an integrated way (Despeisse, Oates, and Ball 2013). Critical elements for sustainable manufacturing are the production system as well as the buildings and facilities, which are servicing operations and provide heating, ventilation, air-conditioning, lighting, power, water, and waste removal (Despeisse, Oates, and Ball 2013).
Therefore, it is essential to be aware of the various parts of the manufacturing facility to identify potentials improvements (Backer 2009; Bohne 2014). For companies to implement sustainability in their facilities there are basically two options to improve sustainable performance, namely: retrofitting (by adding new features to optimize the manufacturing facility towards sustainability) and the construction of a new factory (by building a new goal oriented manufacturing facility that aligns best with sustainable practices). Both concepts will be explained in the following paragraphs.

1.3.2 Retrofit of a Facility towards Sustainability

Retrofitting enables an easy and cost-efficient way of upgrading existing manufacturing facilities for instance by extending the period of use or facilitating improved processes. As it is a capital good with a long use phase of up to 20 years or more, this can essentially contribute to an enhanced performance of sustainability on either one or all fields of the triple bottom line. Retrofitting is particularly suitable for Small and Medium-sized Enterprises (SME), being a low-cost alternative to new procurement of manufacturing facilities. (Stock and Seliger 2016)

It can thus be used as an approach for a positive change in a factory and add to the overall success of a company. In principle, the retrofit design should be innovative, within the interest of the industry involved, making use of existing components, and be able to store and use surplus energy when required (Ling-Chin and Roskilly 2016). Overall, retrofitting should improve operational performance and energy management by a wide variety of technical actions (Tanaka 2011). These include:

- Maintaining, refurbishing and re-tuning equipment to counter natural efficiency degradation and to reflect shifts in process parameters;
- Retrofitting, replacing retiring equipment and process lines to state of art technologies;
- Using heat management to decrease heat loss and waste energy (e.g. proper use of insulation, utilization of exhausted heat and materials from one to other processes).
- Improving process control, for energy and materials efficiency and general process productivity; and
- Reusing and recycling products and materials.

1.3.3 Construction of a New Sustainable Facility

The other option manufacturing companies have, moving towards a more sustainable future, is to consider the construction of a new goal oriented manufacturing facility. The facility is one of the most important elements of a business enterprise as it provides the physical capability to add value to the company’s business strategy. Facilities are expensive and the period of use can persist for decades. Therefore, Dwijayanti et al. (2010) argues that facility planning is concerned with the overall design, people, and allocation of machines within the given physical environment. Planning is also important in a manufacturing process due to the effect in achieving an efficient product flow. Estimates show that between 20%-50% of the total costs in manufacturing is related to material handling, which can be reduced by 10%-30% through an effective strategic planning. (Dwijayanti et al. 2010) Furthermore, Huang (2003) states that facility layout design determines how to arrange, locate, and distribute the equipment and support services in a manufacturing facility. This achieves minimization of overall production time, maximization of operational and arrangement flexibility, maximization of turnover of work-in process, and maximization of factory output in conformance with production schedules.
A new build factory needs to adapt to changing external requirements while aiming for a higher degree of sustainability. Today more than ever, a flexible future production has to address the triple bottom line, respond to the increasing variety and complexity of future products while producing with low costs. From the ecological perspective, the impacts of production should be reduced heading for zero emissions or even a positive influence of the factory on its local surroundings, improving the quality of air and water, exploiting local waste flows, and providing renewable energies. From the social perspective, the factory should serve as a place for people focusing on collaborative learning and development of human capacities. (Herrmann et al. 2014) Closing the loop of energy and material flows is one of the central challenges of factories of the future. This strategy can reduce the ecological impacts and create new economic business opportunities (Cerdas et al. 2015).

1.4 Decision Making Process

The decision process to choose between retrofitting and new construction of a facility can be crucial for the economic viability of a manufacturing company. Moreover, by making the right facility plan, a company can start paving the way for a more sustainable corporate future. To better understand how considerate, defensible, and accountable decisions are made it is important to look at the process of decision making in general terms.

According to Gregory et al. (2012), there are multiple methods for making decisions. The specific approach for the decision process between these two facility planning options is categorized as a prescriptive approach, which suggests ways to make better decisions. It is based on decision theory but adapted for the practical needs and constraints facing real operating decisions. It is evident that having a structured overview of all considerable features will help in making a rational decision. Gregory et al. (2012) proposes the following questions that should at least be addressed to gain a better overview:

- What is the context for (scope and bounds of) the decision?
- What performance measures will be used to identify and evaluate the alternatives?
- What are the alternative actions or strategies under consideration?
- What are the expected consequences of these actions or strategies?
- What are the important uncertainties and how do they affect management choices?
- What are the key trade-offs among consequences?
- How can the decision be implemented in a way that promotes learning over time and provides opportunities to revise management actions based on what is learned?

If decision makers are able to find sufficient answers to these given questions, clarity will increase around the specific characterizations of the decision that needs to be made. However, Mintzberg (1978) discusses that the environment is insufficiently stable and that decision makers are often insufficiently informed. Though data collection and monitoring are rapidly expanding in today’s market, emerging technology and changing markets can disrupt the stability of processes for companies (Bhupendra and Sangle 2016). Especially in a complex social and environmental system, where various social groups have different perspectives, the causality of earth systems makes it hard to predict future outcomes of human activities and environmental intervention. This in turn causes an increase of the complexity that can impede a decision making process, which makes it vital to use a systematic approach that internalizes both social and environmental factors into sustainable planning processes.
1.4.1 Strategic Decisions

The decision making context can change rapidly in a complex environment, making it fundamentally more challenging for companies to make decisions (León-Soriano, Muñoz-Torres, and Chalmeta-Rosaleñ 2010). Therefore, strategic planning processes can contribute to provide more clarity and ensure the direction a company is embarking on (Teh and Corbitt 2015). Without a vision and the use of appropriate strategies and tools, businesses may pursue measures that provide short-term benefits without the possibility of achieving long-term success. Additionally, a backcasting approach builds further on a goal oriented planning process (Holmberg and Robèrt 2000). Backcasting is a planning methodology based on envisioning a simplified future outcome in a complex system (Robinson 1990) and often encourages people to merge forces around shared visions (Ny et al. 2013). If a company has a vision in a rapidly changing market, it shows strategic robustness to their direct environment, giving them a competitive advantage (Collins and Porras 1996; Collins and Porras 2008). Holmberg and Robèrt (2000) argue that backcasting from specific scenarios can be helpful by asking decision makers to envision a future image of success for the company. If that image is clear, one can go back to the current reality to subsequently find the best strategic way to take steps moving towards the shared vision. Therefore, using scenarios can make companies more flexible and innovative by preparing them for possible eventualities. This planning technique is frequently used by managers to articulate their mental models about the future in order to make better decisions. Through this foresight technique, long-term planning value can be added by transferring complexity and contingency of future scenarios into commonly understood and tangible decision points, challenges, and potentials (Hirsch, Burggraf, and Daheim 2013). The literature proposes several scenario validation criteria to ensure that they form an adequate basis for making important decisions (Amer, Daim, and Jetter 2013):

- **Plausibility**: the selected scenarios have to be capable of happening;
- **Consistency**: the combination of logics in a scenario has to ensure that there is no built-in internal inconsistency and contradiction;
- **Utility/relevance**: each scenario should contribute specific insights into the future that help to make the decision and must be relevant to the company’s concern;
- **Challenge/novelty**: they should challenge the organization’s conventional wisdom about the future and must produce a new and original perspective on the issues; and
- **Differentiation**: they should be structurally different and not simple variations on the same theme.

The scenario building process as such is in line with various scenarios analysis techniques for instance, morphological analysis, minimal approach, wilson matrix, cross impact analysis, and consistency analysis (Amer, Daim, and Jetter 2013; Hirsch, Burggraf, and Daheim 2013). One of the most used scenario planning analysis techniques is the morphological analysis proposed by Fritz Zwicky (1962) to explore possible solutions to a multi-dimensional and non-quantifiable problem. By using this process, incompatible combinations can be eliminated to improve and refine plausible future scenarios. The literature highlights that at least two scenarios are needed to reflect uncertainty. Subsequently, creating an insufficient number of scenarios is considered inappropriate because it cannot demonstrate enough possible alternatives. However, it has been discussed that development of large numbers is also not desirable. Amer, Daim, and Jetter (2013) therefore propose, that a creation of 3–5 future scenarios are appropriate for a decision project.
1.4.2 Need for Strategic Sustainable Support

The literature revealed that companies lack a standardized set of tools for sustainability related decision processes. Hallstedt (2008) argues that a systematic approach to sustainability integration in decision processes therefore requires at least the capacity to:

- Understand the sustainability problem;
- Generate possible solutions/innovations;
- Evaluate and prioritize among alternative solutions;
- Implement prioritized solutions and follow up on their effects; and
- Communicate between company levels through a common “language/terminology”.

In the current literature, that deals with improved industrial concepts, there are numerous ideas that can contribute to sustainable manufacturing but there is a gap of knowledge on how to achieve the desired goals at operational level (Despeisse, Oates, and Ball 2013). Traditional thinking and acting in manufacturing companies suggests that the minimum amount of work should be done to meet environmental regulatory compliance, as going beyond this will increase costs (Sharma 2010). It is apparent from the literature that most approaches for progressing towards sustainable development are generic and high level. There is a lack of guidance and tools for manufacturers to identify improvement opportunities within their own factories. (Smith and Ball 2012) The literature also highlights that manufacturing industries lack the measurement science and the needed information base to measure and effectively compare environmental performances of manufacturing processes across resources and associated services with respect to sustainability (Mani et al. 2014). To assess the current level of the sustainability and offer a structured transformation and a clear roadmap for manufacturing enterprises to become more sustainable is missing (Deif 2011). However, in current sustainable manufacturing research, significant efforts are put on the development of metrics and tools for environmental performance analysis of manufacturing processes (Yuan, Zhai, and Dornfeld 2012). Various modelling and analysis tools have been developed to support improvements, but fail to provide sufficient guidance for identifying inefficiencies and opportunities for sustainable manufacturing. Therefore, guidance is required on how to achieve sustainable improvement in the industry (Deif 2011) and the decision between retrofitting and new construction by means of sustainable facility planning.

1.4.3 Types of Support

Companies tend to get lost in the diverse terminology regarding sustainable development and often lack the knowledge needed to make strategically sound decisions. Therefore, it is evident that companies rely on support to help them assess and resolve business questions, especially sustainability related decisions. This support can be computer-, human-based or a combination of both. Boundless (2017) proposes that the top benefits of decision support systems include:

- Speeding up the process of decision making;
- Increasing organizational control;
- Speeding up problem solving in an organization;
- Helping automate managerial processes;
- Improving personal efficiency; and
- Eliminating value chain activities.
Different concepts to various business product and service developments are geared towards environmental protection and/or social equality. Bhupendra and Sangle (2016) discuss that eco-innovation (Young 2006), design for sustainability (Spangenberg 2013), cleaner technology (Montalvo 2008), and cleaner production (Glavič and Lukman 2007) are linked with technological improvements to a sustainable performance of a company. While industrial ecology (Desrochers 2004; Ehrenfeld 2004) and product service systems (Mont 2002; Morelli 2006) are based on new business models for companies. On the social field Klettner, Clarke, and Boersma (2014) argue that corporate social responsibility, corporate social transparency, and triple bottom line are terms to minimise harm and maximise benefit in the relationships with stakeholders of a company.

Types of support available to help companies make decisions concerning facility planning span from computer programs, models, standards over external consultancies to tools and guidebooks. Due to the high variety of sectors in the manufacturing industry, each specific field is confronted with their own unique challenges. The support that can potentially solve these challenges bounded with a specific manufacturing sector is immense. However, there is insufficient or no support presented in the literature concerning sustainable facility planning and the decision between retrofitting and new construction. The examples of different kinds of support presented in the next paragraph are useful to resolve specific issues regarding sustainability in the manufacturing industry and facility planning.

All different kinds of support can contribute to sustainable manufacturing and overall sustainability. For instance, the system model for green manufacturing by Deif (2011) is a strategic model that guides as a roadmap for manufacturing enterprises. Companies can assess the current level of their greenness and create a structured transformation plan towards becoming greener and keep it green. Another support that is used for mathematical analysis and simulation is the THERM software by Despeisse, Oates, and Ball (2013). The Through-life Energy and Resource Modelling (THERM) integrates sustainable building design and process material, energy, and waste flow analysis (MEW). In other words, the tool will support sustainable manufacturing plant design and improvement. Apart from that, the OECD Sustainable Manufacturing Toolkit aims to provide a practical starting point for businesses around the world to improve the efficiency of their production processes and products, enabling them to contribute to sustainable development and green growth. A set of internationally applicable, common, and comparable indicators to measure the environmental performance of manufacturing facilities in any business size, sector or country is provided (OECD 2017). Companies could also make use of external services and consultancies, standards (e.g. ISO14001), workshops or internal documents as well as books and articles to help them with business decisions around sustainability.

By analysing the purpose and functionality of the support, the scope of application can be defined. All examples mentioned are trying to tackle a specific problem with a rather small scope. However, there is no overarching framework that includes a full systems perspective to assists the manufacturing industry to decide between retrofitting and new construction of their facilities. To do this, a set of tools need to be combined and set into context in a broader framework to give sufficient support and at the same time address the sustainable management of ecosystems and the global society.
1.5 Framework for Strategic Sustainable Development

The literature reveals that the manufacturing industry needs a systems approach to realise sustainability across the enterprise, bridge the information gap, and deliver business growth (Hallstedt 2008; McKinsey 2010; Mani et al. 2014). The concept of sustainability has been known for decades in the manufacturing industry however, a holistic approach is lacking, meaning that a robust sustainability strategy has not been incorporated into the structure of sustainable manufacturing (Gunasekaran and Spalanzani 2012).

This research is exploring a practical application of the Framework for Strategic Sustainable Development (FSSD) for sustainable manufacturing. The FSSD is an overarching planning framework which assists as a decision making and planning tool, but also helps to implement other tools in a synergistic manner, for mapping out the current situation in the socio-ecological system and the sustainability challenge. It comprises a model of the five levels, namely System, Success, Strategic guidelines, Actions, and Tools level presented in Figure 1.1 (Broman and Robèrt 2017).

Using an Strategic Sustainable Development (SSD) approach is therefore planning towards a desired vision of the sustainable future of a system or organisation with a strategic guideline using a systems perspective (Robèrt 2002). By applying the FSSD within companies across the world, sustainability practitioners in the manufacturing industry can develop a strategy to cope with the complexity of sustainability challenges.

The contribution of the FSSD is not limited to any sector but is rather dealing with the society on a systems level. The global society is fully dependent on the earth’s resources in order to sustain life. Consequently, society in the biosphere is the system that needs to be sustained (Broman and Robèrt 2017).

Since the Brundtland report (1987), public awareness concerning the concept of sustainable development has increased. The report stated that:

"Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland 1987)
This is the most common definition of both sustainability and sustainable development. Nonetheless, the definition is too general to be useful. In a complex society, it can be challenging to get a comprehensive understanding of which actions are sustainable and which are not. Therefore, the definition of sustainability, developed by the authors of the FSSD, sets the basic conditions that are necessary to fulfil for the ecological and social systems to not degrade systematically. The phrasing of the Sustainability Principles (SPs) of the FSSD is as follows (Robèrt, Broman, and Basile 2013; Missimer 2015):

In a sustainable society, nature is not subject to systematically increasing …
  SP1. … concentrations of substances extracted from the earth's crust.
  SP2. … concentrations of substances produced by society.
  SP3. … degradation by physical means.
and people are not subject to structural obstacles to …
  SP4. … health.
  SP5. … influence.
  SP6. … competence.
  SP7. … impartiality.
  SP8. … meaning-making.

To move towards sustainability, current violations of these principles can be analysed and strategically eliminated by an organisation in a stepwise process (Broman and Robèrt 2017). This strategic planning process, referred to as ABCD, is designed to implement the FSSD in an organisational context. The process is using backcasting to imagine future success, followed by looking back and assessing the scenario in the current reality through the lens of the success definition. Afterwards one can discover ways to fill the gaps between the current reality and the desired future (Robinson 1990; Dreborg 1996). Although described in a linear fashion, the ABCD process is more of an iterative procedure (Broman and Robèrt 2017).

Sustainability strategy development requires a clear vision with strategic direction, time, and a long-term focus (Estes 2009). The A-Step is incorporating information about the sustainability challenge in general, the socio-ecological system, and the FSSD. The aim of this step is to create a vision of success within in the boundaries of the Sustainability Principles. This vision includes the company’s core purpose, values, and overall stretch goals (Broman and Robèrt 2017). Without a sustainable vision and the use of appropriate strategies and tools, a company may pursue measures that provide short-term ecological, social or economic benefits without the possibility of achieving the long-term sustainability of systems (Waage 2007). In a market environment that rapidly changes, it is important for a company to understand the difference between what should never change and what should be open for change (Collins and Porras 1996). Communicating the vision throughout all levels of the company is vital to create a common goal and engage all employees (Mitchell 2002; Everse 2011; Decker and Decker 2015).

In the B-Step, the company’s current reality is analysed in the relation to the vision. Current challenges and assets are being listed to assess if a company violates or complies with the SPs. Such assessment entails an external and internal analysis. An operational assessment should be carried out to analyse in- and outflows across the whole organisation (Backer 2009; Bohne 2014). This includes also various impacts throughout the value chain (Broman and Robèrt 2017). A PESTLE analysis is needed to measure factors that can influence the company from outside (Zalengera et al. 2014).
This analysis is divided into six relevant fields, namely: Political, Economical, Sociological, Technological, Legal, and Environmental (Srdjevic, Bajcetic, and Srdjevic 2012). Furthermore, Benchmarking can be an effective approach to assess one's performance compared to other companies (Ulusoy and Kiz 2001; Ang, Zhou, and Tay 2011). Subsequently, a SWOT analysis assembles an overview of the company’s external influences (threads and opportunities) and its own internal qualities and characteristics (strengths and weaknesses) (Srdjevic, Bajcetic, and Srdjevic 2012; Yuan 2013; Mirzakhani, Parsaamal, and Golzar 2014).

As the gap between current reality and desired future is now visible, creative methods can be applied to identify possible solutions to fill those gaps in the C-Step. Brainstorming (Byron 2012), Semantic Intuition (Beebe and Undercoffer 2015), Reverse Method (Sawaguchi 2015), Rolestorming (McFadzean 2000) or Fishbone-Analysis (Kamila and Sutikno 2016) are often used techniques for this purpose. During this step, new goals might be discovered or adapting existing stretch goals is necessary (Broman and Robèrt 2017). In the D-Step, strategic guidelines are applied to prioritize among the possible solutions, established in the C-Step, into a strategic plan. The most basic guidelines include that an idea at least should be (1) a flexible platform to forthcoming steps, (2) is contributing towards the vision, and (3) provides sufficient return on investment. However, these guidelines can be complemented by customized factors specific for the company’s concern. (Broman and Robèrt 2017)

1.6 Research Design

1.6.1 Purpose

Due to the increasing challenges around sustainability as described in the previous sections, the topic of sustainable manufacturing has become an important topic over the last years. Currently, there is no consensus on how to implement sustainability in the manufacturing industry. This highlights the need to address sustainable development. Even though the FSSD provides a holistic and comprehensive approach, the fact that it is not applicable for the specific case to decide between retrofitting and new construction of a manufacturing facility means that there is little research on the practical implementation yet.

Therefore, the purpose of this thesis is to better understand the current situation of the manufacturing industry and find out how an SSD approach might contribute to better decisions, when weighing out the options of retrofitting and constructing a new facility. The goal is to use these insights and make it accessible to practitioners through a practical implementation of a strategic support. Companies of any location, sector, and size in the manufacturing industry, that have expressed a desire to work towards sustainability in the future, are able to use the decision support provided by this thesis. It addresses how to optimally utilise a company's full potential to contribute to a strategic transition towards a sustainable future by assessing trade-offs of the triple bottom line. The research thereby also aims to add to the development of affordable, sustainable design solutions to address unsustainable manufacturing facilities on a global scale. A decision support tool integrating the principles of sustainability and strategic planning is a significant step in influencing the sustainability awareness and behaviour of the manufacturing industry, which ultimately leads to a positive transformation in a company.

This research is aiming to contribute to the literature in the fields of sustainable manufacturing, operational production, facility planning as well as strategic sustainable development in a more general approach.
1.6.2 Research Question

To begin exploring the values of sustainable manufacturing, this research is designed to guide companies through the process of sustainable decision making. All factors connected to facility planning are considered to foster strategic sustainable development in the manufacturing industry. With the above stated purpose in mind we believe this question provides the best opportunity to find significant results:

“How can a company assess sustainability trade-offs to decide between retrofitting and new construction of a manufacturing facility using an SSD approach?”

1.6.3 Scope and Limitations

The decision support tool is geared to the broader manufacturing industry attempting to cover the general understanding of sustainability and sustainable manufacturing. This work should be used as a guidance to weigh out which options regarding the facility modelling from an SSD perspective are more beneficial. The target audience will mainly stem from a manufacturing background, academic researchers, practitioners within the organisational context as well as FSSD practitioners who aim to implement sustainable facility planning. The analysis only focuses on what happens within the ecosystem of a factory. We recognise the need for a more holistic perspective on industrial systems and on the whole society if sustainability is to be achieved. However, the boundaries have been drawn around the elements on which the organisation has full control. Due to the general nature of the decision support, a detailed way of executing each step, for instance by proposing industry specific tools or methods for the factory analysis, cannot be provided. We are aware that the use of the decision support does not, in itself, promise successful outcomes. Individual investigations and decisions are a necessary complement to the study as it only provides a general perspective. Due to time restrictions, the decision support tool was never fully tested, just backed with expert feedback.
2 Methods

A qualitative research approach with the following methods was chosen to answer the research question: “How can a company assess sustainability trade-offs to decide between retrofitting and new construction of a manufacturing facility using an SSD approach?”

The purpose of this thesis is to engage in problem solving through a cyclical process of thinking, acting, data gathering, and reflecting. This is intended to change and improve practice and understanding through the combination of systematic reflection and strategic innovation. (Savin-Baden and Major 2013)

Therefore, an iterative research process, containing four phases was designed (see Figure 2.1). The first phase involved the data collection and analysis. Information about process design and facility planning have been researched in the literature and complemented by expert and survey opinions. Prototyping the design of the decision support tool was carried out in the second phase, which included the implementation of gained knowledge by brainstorming. The current design of the process was then evaluated in phase three through expert feedback. Phase four included the implementation of the feedback in the tool design. The rationale for each of these steps, the methods, data analysis techniques, and validation will be explained in the following section.

2.1 Data Collection and Analysis

2.1.1 Literature

Relevant literature to the scope of our study was reviewed regarding the manufacturing industry and the connection with sustainable development. This literature review gave us the opportunity to develop a basic understanding of state of the art process planning methods and approaches that can be used to implement sustainability into manufacturing facilities. Furthermore, we have been able to research current facility planning practices and different factors to assess and improve sustainable performances.

Before conducting the research, a draft table of content and a concept table with main keywords were created. Keywords used to find previous and current research in the field were amongst others “facility planning”, “sustainable development”, “sustainable manufacturing”, “decision support”, “process design”, and “brainstorming” or combinations thereof. Databases that have been used to find suitable literature were BTH summon, Business Source, Scopus, and WebofScience. Additionally, a desktop research with the search engines Google and Ecosia was conducted, which revealed process design inputs for the manufacturing industry.

The types of data gathered were peer reviewed and consisted of journal articles, books, online articles, and web pages. Before the literature was added to the Zotero database, the abstract and
conclusion of the papers were skimmed through to filter and validate the importance for the research. It was also decided to only include articles published from 2007 onwards, unless papers from an earlier timeframe were able to provide sufficient data necessary for the analysis. In the filtering process, the research was validated using the standards of Savin-Baden and Major (2013). This was done by checking the relevance to the topic, originality of the work, quality of the analytical argument, quality of the conclusion, release date, and clear writing style. Preferably the literature originated from a credible source, as it is important that the data collected is trustworthy and validated, to prevent biases or false information. We defined a credible source as a scientific article with a high impact factor that was published in a recognized scientific journal with multiple citations.

Eventually, we collected 103 papers, 6 books and 12 online articles to find out more about existing knowledge and strategies to implement them in the process design. The collection of the articles was separated between the researchers and read with the keywords and the table of content in mind. Interesting and important paragraphs were highlighted in different colours (one colour was assigned to each topic, e.g. green for process design). That allowed us to read the article again and create a summary of important findings that could be implemented in the design of the support. The individual summaries were then shared and merged to a final summary, which served as a base for brainstorming sessions in the design process (second phase of the research process). The data collected through literature review and desktop research was also cross-analysed by the researchers to minimize personal biases.

### 2.1.2 Online Survey

An online survey was conducted to explore how companies in the global manufacturing industry decide between retrofitting and new construction of their facilities to move towards sustainability. A survey was chosen for this purpose as it is useful to reveal information about the current reality and practices the industry is using, it could be easily sent to a worldwide audience, and could implement multiple choice questions for a more focussed analysis. It was also used to map out business perspectives, management approaches, and methods. A research on appropriate survey techniques was conducted using Lietz (2010). Cognitive analysis on desired outcomes, timeframe, and useful types of data were considered by phrasing the questions accordingly. Before the survey was sent out, the questions were pilot tested by our thesis advisors to improve the quality of the questions and to receive valuable data. Eventually, the survey created with Google Forms consisted of 15 questions, including five follow-up questions. The aim was to create a concise survey with relevant content to retain audiences’ attention. Based on past experiences of the approached companies, the survey was set up to allow for respondents to include varying depths of feedback. The majority of questions were closed, whereof six multiple choice questions contained an “other” option, allowing respondents to add additional information. Furthermore, two open questions were included and designed to be answered voluntarily (Appendix A).

The survey covered five main sections, namely introduction, general questions, tools and concepts used in the company, the decision process, and finally the necessity of support. To frame the purpose of the research and the survey, an introduction paragraph was pre-pended. On top of that, a non-disclosure agreement was attached which declared how the data was used. The survey was set up anonymously and confidentially to encourage the respondents to be more forthright, especially when being probed on sensitive or controversial issues (Asher 2007).
We collected contact information of manufacturing companies around the globe to ensure a variety of sectors and sizes by making use of online search engines such as Google or Ecosia. Consequently, the survey was sent out via email. To get more responses, multiple contacts have been phoned directly or asked to forward the survey in their network. To increase the response rate, participants were able to communicate their contact information at the end of the survey or contact us afterwards, if they were interested in the outcome of the research. Approximately 450 surveys were distributed worldwide in the timeframe from 6 March till 24 March 2017.

The type of data gathered with the survey was ordinal survey and text data. Utilising Google Forms, the data was digitised and evaluated. A comma-separated values file (CSV) was created to gather all answers in Microsoft Excel to condition the tabular data. After sorting answers into several data sheets, they were either immediately transformed into a graph or first analysed by means of pivot tables to show correlations. By clustering data into categories, the complexity could be reduced. We are aware of potential human errors, language problems, and misunderstandings when answering an online survey. On top of that, it was not clear if the survey was filled out by an expert with knowledge about facility planning processes. Therefore, we checked answers for obvious deviations caused by user errors to ensure a lower fault tolerance of answers that were contributing to the result.

2.1.3 **Expert Interviews**

Primary data collection for the design phase (second phase of the research process) of the strategic support consisted of interviews with experts from various countries and sectors of the manufacturing industry. By using the literature and survey data as a foundation and complementing it with insights of the experts, we developed an initial understanding of how the similarities between answers could inform the design of the support.

It was planned to conduct at least ten interviews to clearly reveal gaps and challenges. Therefore, networks from the Masters of Strategic Leadership towards Sustainability (MSLS) community and personal contacts were used to identify suitable interviewees. To answer the research question, interviewees were specifically chosen according to expertise, knowledge about internal decision processes, and manufacturing sector to ensure diverse and credible insights. We tried to include and adapt the number of female interviewees to at least 10% to mimic the gender imbalance of the industry (U.S. Bureau of Labor Statistics 2014).

The potential interviewees were first emailed or called to determine a convenient time for an appointment. Thirty-eight companies were contacted, whereof eight interviews were arranged. Through recommendations of the experts, three additional interviews could be planned. The interviews were qualitative and semi-structured with a developed set of 11 questions (Appendix B) and a length of approximately 30 minutes, conducted in a period spanning about one month (mid February - mid March 2017). Semi-structured interviews were chosen as they allow greater breadth than the more focused and structured interviews, generate richness of the data, and provide opportunities for the researcher and interviewee to discuss the research in a more detailed manner (Teh and Corbitt 2015). A full list of the interviews is shown in Appendix B.

Each respondent was contacted beforehand to understand the background of the research and to prepare answers for the interview. As most of them were situated in different parts of the world, Skype was the method to connect with six of the experts. Three interviews were executed in person, and two by phone calls. In summary, interview partners were from five countries: Germany, Brazil, Sweden, Taiwan, and United Kingdom as well as various industries:
chemical, machinery, electronics, solar, and consulting. Gathered data was used to shape the design and focus of the support. As data concerning this research area is limited, examining industry practices and specific experiences of respondents was a crucial method in our research. To answer the research question, the interview focused on the process behind the decision of retrofitting and new construction of a manufacturing facility. In addition, follow-up questions were asked, when appropriate, to strengthen the quality of the interview.

The data was collected through note-taking. In more than half of the interviews at least two researchers were present, whereof one was the main interviewer. A post-interview discussion by the authors made sure that all key themes were identified and outcomes interpreted the same way. All data was gathered in a Word document and grouped into pre-coding categories which emerged during the conversations. Based on the nature of semi-structured interviews, questions and answers differed in each interview. Therefore, the pre-categorisation was not applicable to all of the interviews. After a combination, main categories were derived to facilitate the actual coding process. Answers from interviewees included insights into decision processes and existing tools and concepts as well as recommendations and feedback in terms of how an ideal process should look like. The interview data used in the research was sent to the respondents to get a confirmation about the content.

### 2.1.4 Data Analysis and Sense Making

After having obtained the required data, it was useful to go in depth of the research and try to assess the data in connection. The importance and relevance of the obtained data was analysed and how this in turn could lead towards a design of a strategic decision support. The literature laid the foundation for the research and indicated that a strategic method for manufacturing companies to implement sustainability, by considering retrofitting or a new construction of their facility, is missing. With the online survey, we tried to prove this assumption and check if it is an industrywide problem in the current reality. By comparing the data collected of these two methods, it was clear that a strategic support could be useful for the manufacturing industry to move towards a more sustainable future. Expert interviews were able to give more insights on decision making processes in the field when dealing with manufacturing facilities. Through literature, the basic construction of decision processes was researched. The gathered information was then compared with the expert interview and online survey data to demonstrate if the results were supporting, complementing or contradicting each other. Figure 2.2 shows the connection of the collected data through the three methods. The overlap in the middle indicates the data that was useful for the design of the decision support tool.

![Figure 2.2. Data Collection and Sense Making](image-url)
2.2 Design

The data collection and analysis (first phase of the research process) revealed that the manufacturing industry needs strategic support for sustainability decisions. Furthermore, the literature collected was used to gain insights and structures to design such a decision support. It also showed potential approaches, required analyses, and factors necessary for the decision. To answer the research question “How can a company assess sustainability trade-offs to decide between retrofitting and new construction of a manufacturing facility using an SSD approach?” we used this knowledge to merge it into a comprehensive decision support. When developing guidance for how companies can decide between retrofitting and new construction, combined with planning for strategic sustainable development, we paid attention to practicality and user friendliness. The FSSD comes with an application procedure for organizations to co-create strategic transitions, planning, and redesign for sustainability (Broman and Robèrt 2017). The ABCD process was an inspiration for the sustainable facility planning process created in this research, which led to our first design of a tool.

To create a practical strategic tool, brainstorming was used, complemented by the findings and outcomes of the literature review, desktop research, survey, and expert interviews. We used different brainstorm techniques to create and refine a variety of ideas for the first design. Rapid, prolific ideas were useful at this stage. The gathered ideas were then discussed, categorized, combined, and prioritized in a later stage of the brainstorming process and afterwards integrated in the design. Furthermore, to ensure that the design is useful for practitioners, we continually verified and refined the current process design on a theoretical basis, discussing the feasibility and inputs from expert interviews and literature. From the first design, we brainstormed new ideas, followed by the development, improvement, and evaluation of the process. This was repeated until a final shaped design of the decision support process was created in the given timeframe. Through this process several versions emerged, which developed from a four-step linear to a six-step iterative structure. Based on the data collection, we critically reflected on our design and checked if the support is general and easy enough to use and comprehensive for the manufacturing industry. On top of that, we tried to eliminate bias by requesting feedback and cross-checking the design with the BTH thesis advisors.

2.3 Evaluation

The iterative creation of the decision support tool allowed feedback on the design of the tool, by insights from experts and personal thoughts. We contacted five experts, of which three stemmed from the expert interviews conducted to create the design in the first place. Overall, contacts from two countries were involved: Germany and United Kingdom (Appendix C).

A summary of the design in form of a video was specifically created to gather feedback from experts in the field (youtu.be/M0Zlq7tO6G4) The content of the presentation was concise, clear, and coherent to ensure that the experts could give structural feedback on our research so far. The video was sent via email a week before, so that the respondents were able to look at, read through the summary, and think about valuable feedback, which was then discussed in a phone call in the timeframe of 26 April - 13 May. Reviewers were asked to specifically comment on the clarity of the tool design, logic, gaps or parts that required additional emphasis.

The expert feedback interviews were conducted through skype with a length of approximately 30 minutes. It was used to refine the design’s functionality and practicality in the context of
sustainability and selection of content in the individual steps. As this was the only way to gather feedback and learn from experiences of respondents, the interviews were crucial to refine the decision support tool. The questions focused on the content and detailed questions about steps in the process. These practitioners were largely part of the target audience and already participated in prior interviews. The feedback therefore provided insights on what is most useful to them in their work within companies. The data from the expert feedback interviews was collected through note-taking of at least two researchers present in the call. To make sure that all details from the call were identified and interpreted the same way, post-interview discussion were used. All data was gathered in a Word document and sorted according to the occurrence of the recommendation in the process.

2.4 Redesign

The expert feedback helped the overall project to become more proficient in general terms, which provided a broad area of application of the research results in the manufacturing industry. We reflected on the advice and determined if it was applicable for the whole manufacturing industry and not solely in isolation. On top of that, the feedback was cross-checked with relevant literature. Ideas that qualified were discussed on how to implement it in the tool. Overall, the collected data proved that the designed strategic decision support based on the FSSD can assist companies to decide between retrofitting and new construction of a manufacturing facility.

Finally, the design needed to be refined based on this evaluation and data analysis. Feedback from the experts as well as new insights gained in brainstorming sessions were implemented to include potential recommendations or to fill gaps within the first design. Problems were eliminated to make the decision support more functional and practical in regards to sustainability. To justify and validate the changes based on the feedback, the current process design was verified with the results from the data of the literature review, expert interviews, and survey. However, the tool needs more validation by multiple companies in different sectors with different conditions in the field.
3 Results

The following section presents all findings in response to the research question “How can a company assess sustainability trade-offs to decide between retrofitting and new construction of a manufacturing facility using an SSD approach?” The insights identified based on the online survey and the interviews with experts from the field are being presented and used as references throughout the following chapters.

3.1 Online Survey

A total of 51 replies were evaluated (Appendix A), representing an approximate response rate of 11% for this survey. This is due the fact, that we asked respondents to forward the survey to other manufacturing companies.

With the online survey, we tried to collect answers from the manufacturing industry at large to prove that the issue of deciding between retrofitting and the design of a new construction is industrywide.

The results demonstrate (see Figure 3.1) that we were able to collect insights from a variety of companies with different sizes, location of production, and industry sectors. Because of the significant amount of various answers, we decided to cluster them according to the country of production into five main continents.

Figure 3.1 (left) shows that the majority of companies produce their products mainly in Europe (60.7%), followed by Asia with 17.6%, and America with 11.8%. Furthermore, the survey sample revealed, that 55% have 250 or more employees, 31.3% consider themselves as a medium sized company (50-249 employees), and another 13.7% have 1-49 employees in their whole company. When asked about their main industry sector (see Figure 3.1 (right)), the top three answers were “Electronics & Communication” (15.7%), “Machinery & Robotics” (15.7%), and “Construction” (11.8%). On top of that, the samples modal value showed that most companies (19.6%) have one production location, the median suggest 13 locations while the average value is 19.9.
Based on the question, if the participant ever was in the situation of deciding between retrofitting and constructing a new manufacturing facility, follow-up questions were asked. This sample includes 28 responses (54% of the main sample) and is the base for the following results. As the main responsible for the given decision process, over one third of the responses (35.7%) named the “Production Management”. “Plant Management” and the “Executive Board” are both ranked on the second spot with 14.3% each.

For the following questions, the 28 participants could select multiple answers. Therefore, the upcoming percentages will be replaced by total counts, to see how many individual answers were selected for the most voted choices.

![Figure 3.2. Facility Areas assessed in the Current-State-Analysis](image)

Figure 3.2 displays which areas of the current facility were assessed. The most selected answers to evaluate the current state of a facility were “Production” (24 answers), the “Facility” (22 answers), and “Waste treatment” (18 answers).

![Figure 3.3. Triggers and Decision Factors for Facility Planning](image)

Through the survey, we were able to identify common process triggers and factors that ultimately led to the final conclusion to decide between retrofitting and the new construction (see Figure 3.3). The main trigger for considering a change of the manufacturing facility was with 14 votes “Factory efficiency and performance”. Followed by “Outdated factory” (12 answers), “Flexibility” (11 answers), and “New products” (10 answers). When asked about the factors important for the final decision, “Factory efficiency and performance” was again the most voted (19 answer), followed by “Cost factor” (14 answers) and “Sustainability” (13 answers). Therefore, “Factory efficiency and performance” is a substantial factor throughout the whole decision process.
Ultimately, the results showed that 90.2% of all participants think that it would be helpful to have some sort of support that would assist them in the decision process of retrofitting and new construction. This also includes the 45% of the companies that were never in this situation before.

### 3.2 Expert Interviews

Interview results from sustainability practitioners were captured into four generic categories. Interviewees were asked to share their experiences and insights about the decision process between retrofitting and new construction. Results are reported in a summary per category below. Interviewees are listed in Appendix B.

#### Process Trigger

When asked about the initial reason, why the company thought about retrofitting or building a new construction facility, several triggers were discussed. The main reasons were to improve the overall production process (Interview 1,3,4,10) as well as to reduce inefficiency of old buildings (Interview 4,5,9). Moreover, spatial reorganising within or around the factory was mentioned (Interview 1,3,4,7,8). Hereby insourcing, outsourcing, and offshoring were often stated as a potential solution, even before a decision process was started. Future expansions, new planned products or the overall increase of profit are further relevant triggers for several companies (Interview 1,3,6,9,10).

#### Decision Process

The process for the decision, that was described by various interviewees, overlapped and resembled each other to a high degree. The given answers, which differentiated in the level of detail, were grouped into three overarching successive steps, visible in Figure 3.4. All the interviewed companies began with a factory analysis, followed by defining the factory’s future purpose and goals based on the factory assessment, and closed the process with the design of the new ideal factory. The specific actions taken in those steps are described below:

The current state of the given facility was analysed, after the trigger was identified. This step often consists of factory walks, location scouting, and creation of an overview of current fixed costs of the facility (e.g. energy, water, waste, maintenance costs). Furthermore, the purpose and performance of the factory, the residual value, and social factors were assessed. (Interview 1,2,3,5,9,11)

The next step focuses on the definition of tangible goals of the project (Interview 1,2,4-11). Efficient spatial capacities, employees’ health, improved machinery, and the project expenses were often predetermined aims (Interview 5,6,7). To find other relevant factors, goals or ideas besides the trigger, best practice examples from similar manufacturers or from direct competitors were investigated (Interview 4,10). On top of that, internal employee surveys were conducted to get even more potential ideas for improvement (Interview 8,11). The final project goal was also occasionally tailored to fulfil the requirements of a credit institution to get better
conditions for sustainability projects (Interview 4,11). Step three is the design of an ideal factory (Interview 1-5,8-10). To find a potential conclusion for the given problem, various brainstorming techniques were used to gather numerous ideas (Interview 4,5,10). Different departments or external experts were invited to participate in several workshops to increase the quality and the quantity of ideas (Interview 4,5,10). Based on the outcome, multiple models or scenarios were created and continuously improved (Interview 3,4,5,10). Afterwards, the benefits and the drawbacks of the scenarios were discussed, summarised, and checked for viability (Interview 2,3,4,8,10). Consequently, the final options were presented to the responsible decision maker (Interview 1-10).

Final Factors for the Decision
The final decision for the process is often considered as long-term due to the high financial investment (Interview 3-6,10). Especially family-owned enterprises are aware of their legacy, try to plan far ahead, and use a high degree of synergy effects within projects (Interview 3-6). On the contrary, decision makers are not always interested in long-term goals. Due to in-house-incentives and bonus-systems, managers or CEOs are tempted to work towards short-term goals (Interview 1,2,6). This way of thinking also forces the project planners to come up with quick and sometimes inconsiderate solutions in a short amount of time (Interview 1). When talking about sustainability projects, regulations and permissions were of high priority and a crucial factor for the final decision (Interview 6,9,11). On top of that, sustainability projects are often bound to fail because the payback period is too long (Interview 4). In the end, decisions are always made by humans, and humans bring their own opinions and agendas into projects (Interview 6).

Recommendations for Tool Design
The interviewees suggested some general advice for the design of the decision support tool. These tips were, amongst others, to include a holistic view for the whole process, to be aware of overarching connections between the different systems in which the company and the factory interact, and to think long-term (Interview 2,5,6,10). To get the best outcome of the different brainstorming sessions and the workshop, it was advised to involve different stakeholders and experts (Interview 5,10). It was also strongly recommended, before starting the decision process, to look back at the initial trigger that highlighted the need for change. Here companies should ask “What did change?” or “Why do we think we need to change?” (Interview 2,6,8,11). Another recommendation from experts that already faced similar projects, was to not only evaluate the current manufacturing facility but also look at best practice examples from the whole industry (e.g. the automotive industry) (Interview 4,5,6,10). The interviewees also pointed out the problem between a simple and complete analysis. On the one hand, the decision should be based on a high degree of detail, on the other hand, the analysis should not be too complex and time consuming. (Interview 3,7) When calculating costs or other resources, it was recommended to overvalue rather than underestimate (Interview 4,5). Additionally, it was advised to find a solution in which decision makers can compare hard facts (e.g. costs) with soft facts (e.g. employees’ health) (Interview 4,5,9). Finally, it was suggested to summarise the outcome of the research in a more compelling guidance that companies can use to support them throughout the process. In this guide, savings and risk reductions should be highlighted to make it easier to communicate the message to decision makers (Interview 2,5,7-10).
4 The Strategic Decision Support Tool CRAFTS

This section introduces the design of a strategic decision support tool to answer the research question of this thesis: “How can a company assess sustainability trade-offs to decide between retrofitting and new construction of a manufacturing facility using an SSD approach?” The step by step process, based on the FSSD, is described in relation to the research question in the following paragraphs.

The Compass to Refine & Align Factory Performance Towards Sustainability (CRAFTS), is an iterative step by step process specifically created for the manufacturing industry. It is a guidance for practitioners in the field to decide between retrofitting and new construction of a manufacturing facility. Although the steps, presented in Figure 4.1, are building up on each other’s specific focus, a company can also benefit from conducting them individually (Feedback 3,4,5).

![Figure 4.1. Process Overview of CRAFTS](image)

Practitioners begin by co-creating an inspiring common vision to set a desired image of the company's future of success. It is vital that sustainability is considered in this vision, in order for the company to become successful. By representing the core ideology and communicating it throughout all levels, practitioners are enforced to carry out the message of what the company stands for and what the common goals are. In doing so, the core of the company should be retrievable on the workplace and in the mindset of the employees. Assessing the current reality implies that practitioners will capture an image of the manufacturing facility and the company’s activities. This analysis reveals to what extent the factory aligns with or violates against the definition of sustainability, specified by the eight SPs (Robërt, Broman, and Basile 2013; Missimer 2015). To bridge the gap between the current and future state, a set of brainstorming workshops enables the company to create ideas and solutions that can be implemented in the ideal manufacturing facility design. Subsequently, practitioners are set to prioritize what facility solutions are most valuable and strategic for the company. By asking prioritization questions and assessing ideas against grading rubrics and factors, superior solutions can be extracted and combined to create realistic scenarios of the future facility. Conclusively, the two best rated scenarios for retrofitting and new construction are analysed in detail to select the ideal option. It is assessed which planning strategy has the most potential to provide a strategically sound decision for improving the facility in a sustainable way.
4.1 Design Influence of the FSSD

The SSD approach is part of the ground layers in the strategic decision support tool design. Especially with a decision making and planning approach, the concept functions as a foundational step in order to assure sustainability for companies. With the help of the FSSD we were able to keep the systems view within CRAFTS. However, the FSSD does not solely focus on one sector specifically but rather on society as a system. Therefore, the decision support tool is trying to cope with the complexity by relating it back to the unsustainable manufacturing contributions on a systems level, where society fails to persevere sustainable development in the current reality (Rahimifard et al. 2013; Egilmez et al. 2016). As the FSSD is created for the society at large and different organizations, we tried to make the decision support more specific for the manufacturing sector by using the strategic planning tool that comes with the FSSD. The design of CRAFTS therefore mainly stems from the ABCD process to strategically move companies towards a sustainable future. This implies also other concepts for instance the use of systems thinking, strategic thinking, iteration or backcasting.

In the ABCD, the A-Step informs practitioners about what sustainability is and what the problems are that society is facing. A sustainability business case is complementing this introduction. By using the SSD approach in our research, we indulge companies to first look at the desirable future, using not only forecasting, but also backcasting techniques. This has the advantage that manufacturing companies are endeavoured to picture their vision of future success of sustainability, by laying out strategic guidelines that can help the company to practically work towards the desired future. The B-Step of the ABCD inspired the tool, as a thorough analysis of the present state is necessary to decide if a company should retrofit or build new. Components of the B-Step were used and complemented to adjust it for the manufacturing industry. In the ABCD, the ideas for the change are brainstormed in the C-Step and prioritized in the D-Step, where the most strategic and useful ideas are summarized in an action plan. For CRAFTS, we used this approach to create scenarios of ideal retrofit and new construction facilities which can be seen as the base for the decision. Learning from the prioritization process, we created a list of factors that guide manufacturing companies through that process. An additional step is introduced to weigh the two optima against each other to finally choose how the company wants to move towards a more sustainable future.

4.2 CRAFTS

4.2.1 C-Step: Co-Create a Vision

The C-Step is the first step in the process of CRAFTS and focusses on creating an inspiring and motivating common vision around sustainability that persists throughout the process. Thereby the company is enabled to design a desirable future, where it can strategically move towards using a backcasting approach (Broman and Robèrt 2017). This will explicitly help decision makers in the process to create an image of success. The C-Step provides a fundamental base to create a shared idea of what sustainability entails and coordinates what direction the company intends to take regardless of external conditions (Teh and Corbitt 2015). This means that if a manufacturing company decides to embed sustainability into their vision, all decisions should bring them one step closer to sustainability. A clear vision with strategic direction and a long-term focus is required for any strategic sustainable development process (Estes 2009). Especially for a decision around a manufacturing facility, the long-term approach is favourable as facility interventions are considered as high financial investment (Interview 2-6,11).
For the execution of a complete C-Step, a project team needs to be assigned to initiate the process. Ideally it consists of employees from different departments in the company to have a broad base of knowledge and expertise with different perspectives (Interview 5,10; Feedback 3,4). The project team needs to be familiar with the definitions of sustainability as described in this research, in order to make a decision that is aligned with the Sustainability Principles. Employees working together with different perspectives often leads to a synergetic result in which the cooperation gets amplified. Additionally, an external consultant, that is familiar with the specific market that the company resides in, should be suggested to ensure that the narrow view of internal experts is broadened (Interview 4,7,9,10; Feedback 3,4).

After the project team is assembled and familiarized with the SPs described in this research, it is time to structure and organize a workshop to lay the foundation for the discovery of the company’s vision. Providing creative space and asking the right questions to engage the participants is the main responsibility of the facilitators to create a vision that is appropriate and applicable. It was pointed out in Interview (5) that this step should be iterative as the business models can change rapidly.

After a successful workshop, a common vision should emerge with which the company can relate to and feels comfortable with carrying out to the world. It provides guidance about what should be preserved in the core of the company and what should be open for change (Collins and Porras 1996). This created vision should be within the constraints of the eight SPs and consist of the segments core ideology and envisioned future (Robèrt, Broman, and Basile 2013; Missimer 2015) as shown in Figure 4.2.

![Figure 4.2. Vision Segments](image)

**The Shared Understanding of Sustainability**

This segment is key to provide a knowledge base and clarity what sustainability entails, which is necessary throughout the process. Using the eight SPs, the ground terms of sustainability should be understood and explicable for practitioners. By doing so, a company can assess the current violations against the SPs in the A-Step. It also ensures that solutions are aligned with the eight SPs in the prioritization phase of the T-Step. *The Shared Understanding of Sustainability* runs as a red thread through the process to consistently confirm that the solution is based on sustainability.
Core Values

Core Values are guiding timeless principles that represent what the company stands for and functions as the company's identity. Throughout the process, the Core Values are needed to assess if solutions in the T-Step are aligned with the company’s identity. If the Core Values are retrieved in the C-Step it makes the assessment of solutions in the T-Step easier and more thorough. The Core Values should be intrinsic and based on the personal characteristics of the board (Collins and Porras 1996). Within the company all employees should be able to feel that the core values of the company are carried out. The Core Values represent the “how” of the company, both what it represents today, and what its employees would like it to represent in the future. The following sample questions should be answered to help retrieve the core values:

- How does the company interact with its employees, suppliers, and other stakeholders?
- What are the key ways in which it operates that are special and unchanging?
- What are the company’s management, leadership, and communication styles?
- Why does the company care about moving towards sustainability?
- What drives our economic engine?

Core Purpose

The Core Purpose is the company’s reason for being and should capture the soul of the company by discovering why it exists (Collins and Porras 1996). If the Core Purpose is clear, practitioners are able to think about solutions in the F-Step that are less focussed on how the company is operating today. If the company understands what it provides to society, it can try to come up with new ideas to provide the same product or service. However, the purpose is not the equal to the company's goals. As goals should be achievable, the purpose of the company can never be fully reached. Actions that could lead the company closer to their purpose can be taken and should function as a constant stimulation. To retrieve the core purpose, it can be helpful to ask the following questions:

- Who would miss the organization if it suddenly disappeared?
- What products and services does it provide to society?
- What does the company aim to do?
- What are we deeply passionate about?
- 5-Whys (Uthiyakumar Murugaiah et al. 2010).

This enables a company to think about what a company is adding to society apart from making a profit and providing jobs internally.

Stretch Goals

After the core has been identified, it is time to lay out general goals that the company wants to achieve in the next 10-30 years. It is important that the company is able to envision the future and what it can potentially look like if sustainability is implemented in their daily manufacturing operations. By setting challenging goals for the future, the company can motivate itself to strive for the best results, in order to realize the desired outcome of the company. These Stretch Goals should be hard to reach and will only have success if the team acts accordingly in pursuing to be successful (Collins and Porras 1996). The Stretch Goals should be formulated in such way that they are attainable and precise enough for a company to get a genuine idea how to reach them. Later in the process the specific solutions created in the F-Step, will be assessed against the Stretch Goals to see if the ideas are favourable in the T-Step.
**Vivid Description & Vision Statement**

Now that the goals have been set, the company should create a *Vivid Description*, of how it will look like if the company will reach its goals, and a *Vision Statement* to capture the most important parts of all segments mentioned above. The *Vivid Description* should be relatable for employees and it should explain what the company does (Collins and Porras 1996). The *Vision Statement* consists of a compelling sentence to summarize what the company tries to carry out and what it stands for. Creating these segments in the process to envision the future will help picturing an image of what success could look like. These sample questions will support to create a *Vivid Description and Vision Statement*:

- Imagine yourself in 20 years. What would you love to see, what should the company look like, what should it feel like to customers what should it have achieved?
- Imagine you are reading an article about your organization in 2040, what does it say?
- What year will it be when your children are your age, and if you could create a sustainable world for them, what would it look like then?
- Assuming society becomes sustainable, what do you feel your role is in that society could be?
- What can we be best at in the world?

### 4.2.2 R-Step: Represent the Core Ideology

With the completion of the C-Step, comes the subsequent R-Step: Represent the Core Ideology. Most companies have a deeper meaning as to why they exist. This tends to influence strategy, decision making, and behaviours at executive levels, but often is not thoroughly articulated to employees. Therefore, the key insight in this specific step is to communicate it throughout the whole company. This means that the core of the company needs to be retrievable on the workplace and in the mindset of all employees (Interview 2,5,6).

The R-Step is important so that all levels of the company know what the common goals are and how one can contribute to getting one step closer to the created vision on a personal and corporate level. It will also add to the engagement of workers and will create a common purpose. Getting the employees to see how their work matters on an organizational level will keep them motivated and productive, especially during times of change (Everse 2011). If the core ideology is communicated successfully, space is created for synergy to emerge and the company will work closer together in trying to get one step closer to the vision (Feedback 3). The employees will work as a team, in which everybody is needed to create a successful future (Everse 2011). Therefore, exchanging information and creating a common understanding of the same goal facilitates effective teamwork and community building.

By communicating the vision throughout the company, employees can help refine this vision to make sure that everything is considered, including for example the well-being of employees. Decisions are also more likely to be implemented if companies invite the staff to take part in defining the desired outcome (Mitchell 2002; Decker and Decker 2015).

The senior managers have a key role in this step and the responsibility to get everyone in the company on board. Subsequently, the thinking process of how the company can better carry out the vision together to move into the same direction needs to be started. There are different ways to communicate the vision throughout all levels of a company, for instance making use of IT (e.g. intranet, newsletters) to show what the company is doing and how the company is thinking about the vision (Everse 2011). Creating internal events and starting the conversation about...
what the company stands for and what it values most will lead to a better understanding of the vision throughout the company (Mitchell 2002; Everse 2011).

This step of the process takes time and should be ongoing and executed on a regular basis (Broman and Robèrt 2017; Interview 5). It functions as feedback to the C-Step in order to make the created vision more robust on all levels. This means, that if there are forgotten segments that are not represented in the co-created vision, it should be open for reconsideration and improvement.

As discussed by Decker and Decker (2015) the vision should be communicated using at least the marks (1) Understanding the Employees, (2) Target the Message to their Needs, and (3) Engage their Emotions to get to the desired result of a shared vision throughout all levels of the company.

**Understanding the Employees**

A common denominator among the world's leading companies is that employees have the same idea of the core purpose and values of the company. It is essential that the managing board is aware of where the employees are at: what they are occupied with, what they see as important, and what they see as improvement points within the company. On a managerial level this means that the employee's values and responsibilities should be recognized. Understanding the employees is important for the process because it will help to understand the company itself. This is needed for a considerate decision around all important company processes, including a facility planning decision.

**Target the Message to their Needs**

Once it is clear for the management board what the broader vision consists of, it is essential to develop the specific point of view for the employees. To get everyone on the same page it is crucial that the managing board explains the “why” behind the message. Openness and honesty are required to reveal what the company strives for and how all employees are needed to work towards the vision of success. It is vital to keep the message simple, yet deep in meaning. This allows the employees to sharpen their perspective of what it is they contribute to and how they personally can affect a successful result for the company as a whole. Consequently, it will affect the overall process positively, as more perspectives are considered and the needs are clear.

**Engage their Emotions**

The vision is part of the DNA of the company and should be recognisable for all workers. Therefore, the message that managers bring across must provide a fulfilling and complete representation of what all workers stand for. This means that the company has to drive down the benefits to the individual levels as much as possible (Decker and Decker 2015). That way everybody can feel emotionally engaged to work for a better future of the company. Yet at the same time employees should feel that they work in a team and that they need each other to be successful at their job. Companies should be aware and try to use a high degree of synergy effects within projects (Interview 3-6,9,10). The project team in the CRAFTS process can build further upon synergy effects, created in the first two steps, to benefit from a better cooperation between the practitioners and participants of the process.
A-Step: Assess the Current Reality

The A-Step is the main foundation for the upcoming steps, since it focuses on the assessment of the current reality of the manufacturing facility. The project team has to build the base to identify gaps and potential improvements in order to plan for the retrofit or the new construction. Due to the complexity of the given decision, this step helps to provide a thorough overview of all the current internal and external indicators of the factory (Interview 2,5,6,7,11). This evaluation includes among others, the machines and equipment, facility layout, waste management, political and environmental regulations, and employee safety (Survey Question 7,10,12,13; Interview 2-11; Feedback 1,5).

The full assessment in the A-Step consists of four major parts. To make sure that the company makes the right, strategic decision, it is important to first review the trigger that started the whole process. With the trigger in mind, a thorough analysis of the present state of the facility has to be conducted. Based on fundamental functions of a facility, a “Factory Model” was designed and included into CRAFTS. The model is separated in four categories with seven subcategories each. For each of these subcategories follow-up question about the impact and the necessity are provided. After the internal, an external assessment has to be carried out. This includes a PESTLE analysis and Benchmarking. The outcome of the three individual parts will be summarized in a SWOT.

Trigger

The first task in the A-Step is to assess the initial Trigger that led to the current need for change or improvement (Waage 2007; Survey Question 10; Interview 2,6; Feedback 1). Mitigating the risk of making wrong incentives by asking what prompted the need of deciding between retrofitting and new construction can help to shape the future journey. Practitioners should be aware of the reason why they are working on this particular project. The following questions can help to define the Trigger (Waage 2007; Hallstedt 2008; Interview 2,6):

- What is the reason of asking the question at this point in time?
- Which circumstance changed that prompted the need for this decision?
- Who started the thinking process?
- Who is the decision maker?

Internal Analysis - Factory Model

The Factory Model was designed to help companies to conduct a thorough analysis of the current manufacturing facility and to identify environmental, social, and economic Key Performance Indicators (KPIs). This is necessary to:

- ensure a sufficient analysis;
- reveal improvement potential and gaps;
- find SP violations; and
- make better decisions in a complex system.

Table 4.1 shows the four main categories and the 28 subcategories that are necessary for a facility to function. The model is based on the initial areas and functions, as described by Backer (2009) and Bohne (2014), and merged into four overarching categories. Furthermore, the research results helped to clarify and optimize the model for the decision process (Survey Question 12; Feedback 1,3,5).
It is recommended to start the assessment with the factory surroundings (Interview 1,2,3). This includes the on-site infrastructure, vehicle fleet, parking situation, outside equipment, and recreation or leisure areas. On top of that, practitioners should analyse the impact the factory has on the surrounding community (e.g. noise protection, pollutant emission), the on-site location as well as the location in the country. The Outside assessment provides the boundaries that have been drawn around the elements on which the organisation has full control of.

The Building assessment consists of the skeletal structure of the facility, floors and foundations, walls (e.g. facing, insulation), roofs, windows, and doors. Potential equipment attached to the building like solar panels, drainage system or sun blinds should also be analysed in this step.

Within in the factory (Inside), practitioners should assess different production machines, necessary storage space, waste management, sanitation, and the overall production line. Equipment inside the facility can range from manufacturing tool, over elevators and cranes to the embedded factory IT-system.

The last step of the Factory Model should be the Flow assessment (Interview 1,2,3). Based on the three previous described areas, it is easier to analyse the flows of the factory. These flows include lighting, air, heating, cooling, packaging, water, and required resources like fuel.

By asking the following questions (see Table 4.2) for each of the 28 subcategories, a basic understanding of the facility, the components, the function, as well as in- and outflows can be gained. These process questions are based on the work of Backer (2009), Bohne (2014), and expert interviews, which provided further insight into manufacturing facilities. The ecological and social questions are connected back to eight SPs described by Broman and Robèrt (2017).

<table>
<thead>
<tr>
<th>Outside</th>
<th>Building</th>
<th>Inside</th>
<th>Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Site Infrastructure</td>
<td>Skeletal Structure</td>
<td>Machines</td>
<td>Lighting</td>
</tr>
<tr>
<td>On-Site Vehicle Fleet</td>
<td>Floor/Foundation</td>
<td>Equipment</td>
<td>Air</td>
</tr>
<tr>
<td>Parking Situation</td>
<td>Walls</td>
<td>Production Line</td>
<td>Heating</td>
</tr>
<tr>
<td>Equipment</td>
<td>Roof</td>
<td>Storage</td>
<td>Cooling</td>
</tr>
<tr>
<td>Recreation/Leisure</td>
<td>Windows</td>
<td>Waste Management</td>
<td>Packaging</td>
</tr>
<tr>
<td>Location</td>
<td>Doors</td>
<td>Sanitation</td>
<td>Water</td>
</tr>
<tr>
<td>Community</td>
<td>Equipment</td>
<td>Space-Usage</td>
<td>Resources</td>
</tr>
</tbody>
</table>

It is recommended to start the assessment with the factory surroundings (Interview 1,2,3). This includes the on-site infrastructure, vehicle fleet, parking situation, outside equipment, and recreation or leisure areas. On top of that, practitioners should analyse the impact the factory has on the surrounding community (e.g. noise protection, pollutant emission), the on-site location as well as the location in the country. The Outside assessment provides the boundaries that have been drawn around the elements on which the organisation has full control of.

The Building assessment consists of the skeletal structure of the facility, floors and foundations, walls (e.g. facing, insulation), roofs, windows, and doors. Potential equipment attached to the building like solar panels, drainage system or sun blinds should also be analysed in this step.

Within in the factory (Inside), practitioners should assess different production machines, necessary storage space, waste management, sanitation, and the overall production line. Equipment inside the facility can range from manufacturing tool, over elevators and cranes to the embedded factory IT-system.

The last step of the Factory Model should be the Flow assessment (Interview 1,2,3). Based on the three previous described areas, it is easier to analyse the flows of the factory. These flows include lighting, air, heating, cooling, packaging, water, and required resources like fuel.

By asking the following questions (see Table 4.2) for each of the 28 subcategories, a basic understanding of the facility, the components, the function, as well as in- and outflows can be gained. These process questions are based on the work of Backer (2009), Bohne (2014), and expert interviews, which provided further insight into manufacturing facilities. The ecological and social questions are connected back to eight SPs described by Broman and Robèrt (2017).
These questions have been designed to help the company measure all aspects of the triple bottom line relating to the production activities of a manufacturing facility. Furthermore, this assessment helps the project team to compare the overall performance of the factory with different facilities in their business and provides a foundation for the upcoming Benchmarking assessment (Interview 4,6,8,9; Feedback 1). Starting with Process questions, the project team needs to analyse economic relevant factors like costs and timeframe. Afterwards, Ecological influences will be assessed to identify positive and negative impacts regarding the first three SPs. The five remaining SPs assess the Social impacts that the factory can be accounted for.

In order to answer these provided questions, the company should measure different KPIs of the facility impacts. Numerous types of metrics and assessment tool are known industry wide. For example, the Material Flow Analysis (MFA), which provides a measurement of the flow of materials and energy through the production process (OECD 2017). A Life Cycle Assessment (LCA) measures the impact of a product throughout all stages, from materials extraction, to manufacturing, distribution, use, and disposal or recycling (Mani et al. 2014, Interview 9,11).

**External Analysis - Benchmarking & PESTLE**

Apart from the internal analysis, an external analysis needs to be conducted (Survey Question 7,10,13; Interview 4,5,6,9,10,11; Feedback 1). For this, practitioners should find best practice examples from the industry (Benchmarking) and carry out a PESTLE analysis.

*Benchmarking* allows an objective assessment of one's performance compared to other companies. However, best practice examples do not only compare KPIs and quantifies performance gaps, they also reveal overarching managing approaches. (Ang, Zhou, and Tay 2011) Therefore, outstanding practices can be discovered and later be implemented into the company or manufacturing facility to achieve sustainable improvements and competitive advantages. In the *Benchmarking* process, practitioners are consciously looking for companies outside their own branch of industry that are well-versed in certain processes or functions. This is due to the fact, that similar processes in different sectors are differently efficient, since competitive factors vary to a high degree (Ulusoy and Kiz 2001). The process of Benchmarking can therefore to be understood as complex and it is advised to include external expertise for the best results (Interview 4,5,6,8,10; Feedback 4).

A *PESTLE* is a management method that allows an analysis of the six external factors that can have a significant influence on the company's performance. These are political, economic, social, technological, legal, and environmental factors. (Zalengera et al. 2014) Typical contents of a *PESTLE* are summarized in Table 4.3 (Srdjevic, Bajcetic, and Srdjevic 2012). However, these examples are by no means complete, and should be adapted according to the specific situation and sector of the company.
The *Benchmarking* as well as the *PESTLE* analysis are of a high value for the decision process, since they reveal potential, upcoming legal changes or current technology improvements. With the external view, practitioners should be able to discover and reduce future risks.

**Summary - SWOT**

The last part of the A-Step is to summarize all the major insights from the internal and external analysis into a *SWOT*. The Strengths-Weaknesses-Opportunity-Threats-analysis is a positioning analysis of the company’s own activities. The results of the external enterprise-environment-analysis are compiled into opportunity-threats while the strength-weakness are gathered from the internal analysis. (Srdjevic, Bajcetic, and Srdjevic 2012; Yuan 2013)

Afterwards, the overlaps are filtered and combined in a *SWOT* matrix. The *SWOT* matrix shown in Table 4.4 demonstrates the opportunities that can be further developed, highlights the threats that the company should secure to use its strengths, as well as those weaknesses that should be taken up for the same purpose. Finally, it also covers those risks that must be avoided twice, since it is precisely there, that the internal weaknesses of the company with the external threats of the environment collide. (Mirzakhani, Parsaamal, and Golzar 2014)

The *SWOT* is an important resource for the upcoming F-Step to quickly recap the gathered results. The identified gaps within and surrounding the factory are the fundamental base to create new ideas. Furthermore, the current *SWOT* will be presented and compared in the final S-Step to help the decision maker see the overall improvement potential of the solutions.
4.2.4 F-Step: Focus on Ideas

Based on the outcome of the internal and external assessment of the previous A-Step, the practitioners brainstorm to fill the gaps between the current state of the factory and the designed vision in the C-Step. Therefore, two different workshops need to be executed, whereof one is focusing on a retrofitting solution and the other on new construction. In the retrofitting workshop, it can help to gather ideas by keeping the four main categories of the A-Step in mind. The new construction workshop should in addition be as open as possible and inspired by best practices and the PESTLE analysis of the A-Step. By the end of this step, it is recommended that at least 150 ideas from each workshop should be gathered. It is advised to compile the ideas into two different Excel documents for the prioritization in the upcoming T-Step.

For an ideation workshop to create an ideal manufacturing facility, several brainstorm techniques can be used. It is important to note, that the design of the workshop heavily influences the outcomes. Therefore, it would be helpful to either have an experienced employee to guide the team through the workshop or to include an external expert for this task (Interview 4,5,10; Feedback 4). Making conscious decisions about the structure and content can make a workshop even more successful. Within the brainstorming sessions, following examples of guiding questions can be used:

- How would this need or desire be fulfilled in a sustainable world?
- How can we build an ideal facility based on current situation?
- What materials would it be made of in a sustainable world? Why?
- What processes would be used? Why?

Creativity techniques as shown in Table 4.5 are an essential support for the creation of an ideation workshop and provide guidance, variety, and fun throughout the creative process (Byron 2012). Some examples can be found in the following table:

<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic Intuition</td>
<td>An intuitive creativity technique that generates new ideas through a random combination of two words into one artificial word. (Beebe and Undercoffer 2015)</td>
</tr>
<tr>
<td>Brainstorming</td>
<td>Participants express their thoughts on a problem spontaneously. Criticism is forbidden, so that the idea finding is not inhibited. The evaluation of the incidents takes place in a later phase. (Byron 2012)</td>
</tr>
<tr>
<td>Reverse Method</td>
<td>The problem is turned upside down. Participants need to think about what they have to do or not to do to achieve exactly the opposite. (Sawaguchi 2015)</td>
</tr>
<tr>
<td>Rolestorming</td>
<td>This technique helps to see the problem from different persons view. Practitioners should ask the question: “What would X (e.g. Confucius, Einstein, Superman, Jesus, Customer, your Dad) in this situation do?” (McFadzean 2000)</td>
</tr>
<tr>
<td>Fishbone-Analysis</td>
<td>This is a diagram illustrating causality relationships. The Fishbone is a tool for the systematic determination of problem causes. (Kamila and Sutikno 2016)</td>
</tr>
</tbody>
</table>
4.2.5 **T-Step: Target Ideal Solutions**

The T-Step requires the lists of ideas that were gathered in the previous F-Step of the process for both retrofitting and new construction. Deciding upon a course of action based on a large set of data can be a difficult task to simplify matters. Such multidimensional data is often reduced to a few, or even a single number via data reduction methods. (Jiang, Zhang, and Sutherland 2012) The T-Step therefore is a high-level, criteria-based assessment of potential design solutions. It combines a prioritization procedure followed by scenario building and a decision between the ideal retrofit and new construction solution. It guides the practitioner through the process of how to thoroughly evaluate different ideas and to eventually find the best solution for the company (Interview 3).

![Diagram of the T-Step process](image)

The T-Step described in Figure 4.3, filters a lot of ideas, combines them to scenarios, and results in one ideal solution for retrofitting and one for new construction of a manufacturing facility. It consists of four main steps that build upon each other. In the **Screening** phase, ideas that are not aligned with the vision or SPs are eliminated. Followed by the **Sorting & Combining** phase where ideas are sorted in the four main and 28 subcategories of the A-Step. Finally, all ideas are **Weighed and Graded** to filter the best rated for the **Scenario Building** process. Here, realistic scenarios for a retrofitted and new manufacturing facility are puzzled together to create a desired future state. The highest graded scenario will then be adopted for the following S-Step.

**Screening**

Before practitioners can start this step, a list of sufficient ideas for both, retrofitting and redesign should exist from the previous F-Step. Preferably gathered in two separate Excel sheets, to provide a better overview and to simplify and speed up the process. All ideas are first analysed against the following four closed questions:

1. Does this action violate against any of the eight Sustainability Principles?
2. Does this action violate against the company’s vision created in the C-Step?
3. Does this action violate against the stretch goals created in the C-Step?
4. Is this action technically feasible and legal?
If one of the questions can be answered with no, the idea will be sorted out. However, it is also worth considering that some of the “noes” could be “maybes” and whilst the priority should be on the “yeses” as it is not always a clear cut (Feedback 2). With this Screening process, it is made sure that all the ideas that make it into the next prioritisation step are strategic and aligned with the company’s vision and the SPs.

**Sorting and Combining**
The remaining ideas, that lead the company into the right direction, need to be sorted in the four main and 28 subcategories of the A-Step. Each category should be filled with at least one idea to ensure the functionality of the process. If that is not the case, another brainstorm session can be planned to complete the list. The documentation can be eased by using an Excel sheet for the retrofit and new construction option, hence helping to have a better overview. By Combining similar ideas and Sorting them in the different categories it is clear how many ideas each category is covering. A combination of several ideas consequently counts as one.

**Weighing and Grading**
In this substep, the sorted ideas are graded against the three grading rubrics in Table 4.6. These include 21 grading factors to support the practitioner with the decision process. Using these rubrics as a basis for the decision allows the company to compare hard facts against soft facts of the generated ideas (Interview 6,9).

Before Grading the ideas, the grading rubrics must be weighed. The indicated percentages in Table 4.6 are recommendations and do not have to be adopted. The same applies to the list of factors from the Growth and Feasibility rubric. It is the decision of the company to customize factors, to balance which factors are missing, and what it specifically means to them (Survey Question 10,12; Feedback 3). The rubrics were chosen to ensure that the vision and sustainability, communicated in the FSSD, were covered. However, it was also apparent from expert interviews that the economic factors play a big role in decision making (Interview 1,2,4,5,6,9,11).

<table>
<thead>
<tr>
<th>Right Direction</th>
<th>(Financial) Growth</th>
<th>Feasibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stretch goals</td>
<td>• Increase capacity</td>
<td>• Requirement of Human Resources</td>
</tr>
<tr>
<td>• Vision</td>
<td>• Cost</td>
<td>• Timing (start, duration, ending)</td>
</tr>
<tr>
<td>• Environmental SP1</td>
<td>• Certainty of investment</td>
<td>• Technical feasibility</td>
</tr>
<tr>
<td>• Environmental SP2</td>
<td>• Payback Time</td>
<td>• Flexibility</td>
</tr>
<tr>
<td>• Environmental SP3</td>
<td>• Profits</td>
<td>• Factory efficiency &amp; performance</td>
</tr>
<tr>
<td>• Social SPs</td>
<td>• Savings</td>
<td>• Improvements necessary (outdated)</td>
</tr>
<tr>
<td>• Risk reduction</td>
<td>• Reputation (PR)</td>
<td>• Stakeholder views, requirements, relations</td>
</tr>
</tbody>
</table>

The factors listed in the Right Direction rubric should not be radically changed as they are dealing with the SPs and the desired future state of the company. This includes the vision and the long-term goals, created in the C-Step, to highlight and focus resources on investments that provide stepping stones for the future. The Growth rubric was determined through the analysis of the expert interviews. The factors most mentioned and considered for facility decisions were combined to form this selection (Interview 1-11). Based on the FSSD, the Feasibility rubric
was set up and complemented by survey results. Industry specific factors such as “Factory efficiency & performance” or “Improvements necessary (outdated)” were subtracted from the survey (Survey Question 10,12). An Excel sheet can be created to grade the given factors for each idea (Appendix D). The grading scheme is as follows:

Table 4.7. Grading Scheme

<table>
<thead>
<tr>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>very negative</td>
<td>negative</td>
<td>neutral</td>
<td>positive</td>
<td>very positive</td>
</tr>
</tbody>
</table>

The scheme presented in Table 4.7 was chosen to rank each idea according to the given grading factors. The negative numbers are highlighting the contradictory impact the action might have. This allows all ideas to be assessed and compared in the same way. The boundaries of the grading scheme have to be adapted to the company's individual needs. For instance, when analysing the grading factor “Profits” from the Growth rubric, the very positive value of “2” must be adapted to an amount of money appropriate to the company. However, for the decision details at this stage are not important and assumptions should reflect on the idea without neglecting the quality (Interview 2,7). It must be ensured that the ideas are all graded with the same assumption in mind to guarantee that potential errors are consequent as the actions need to be comparable. For example, the basis on what a “1” is assigned, and what gives the action that value needs to be consistent throughout the grading process of retrofitting and new construction and across the team.

After Weighing and Grading, the grades of each idea must be added up and divided by the number of grading factors per rubric. The resulting number needs to be multiplied with the assigned Weighing of the associated rubric afterwards. Then the total of the three grading rubrics is added and divided by three (Appendix D). Eventually, the five best ideas with the highest score of the 28 subcategories are used for the next step in the prioritization process.

**Scenario Building**

The Scenario Building is the last step in the prioritization process. A morphological analysis was chosen to work out realistic solutions for the future manufacturing facility. It is a useful tool and helps to visually analyse combinations of various conceivable development variations for all scenarios without contradiction (Amer, Daim, and Jetter 2013; Hirsch, Burggraf, and Daheim 2013). This must be carried out for the retrofitting and new construction option. The 28 subcategories are listed vertically and up to five ideas of each category horizontally in a table (Appendix D). In a round of experts it has to be decided how the ideas can be best combined to form a functional realistic future scenario of a manufacturing facility. Therefore, it is up to the company to decide what is most important and feasible for their future. A combination of several ideas to one strategy is also possible if the scenario allows for it. However, the practitioners have to be aware of connections that might have a negative effect on each other (Interview 2). The success of this process can heavily depend on the quality of the facilitation. A moderator is needed to keep the systems perspective and in cooperates abstract thinking (Feedback 4). Therefore, either an experienced employee or an external expert could be considered to guide the team through the workshop (Interview 4,5,9; Feedback 4).

There is no limitation of the number of scenarios that could be created, nevertheless there is a minimum of two scenarios required in the process to make a comparison (Appendix D). The more scenarios are being created, the more thorough the evaluation will be, which will
ultimately result in the best choice (Interview 3,10). However, the literature recommends to create between two and five scenarios for a decision like this (Amer, Daim, and Jetter 2013).

In *Scenario Building*, the main characteristics are underpinned with numbers to form a concrete future space and support communication (Hirsch, Burggraf, and Daheim 2013). An average value of each scenario can be determined by using the previous grading of the *Weighing* and *Grading* step. It is calculated by adding the gradings of each idea in the scenario and dividing it by the amount of ideas. The scenario with the best evaluation is adopted for the last step of CRAFTS, the S-Step.

**4.2.6 S-Step: Select Best Option**

The S-Step consists of a final comparison of the ideal scenario for retrofit and new construction. It provides clarity to decide between these two scenarios by analysing the assumptions made in the T-Step in more detail. Companies can use this comparison as a summary for decision makers to pave the way for a sustainable future.

The same factors of the previous step will be assessed again to make the analysis more comparable and specific. The boundaries of the grading scheme for each factor, set in the previous T-Step, remain the same but the calculations and research will be carried out in more detail. Again, an Excel sheet can be used to support the analysis of each factor in the three grading rubrics. The assumptions made in the T-Step have to be revised and proven by calculations and justifications. Accordingly, the grade that was given needs to be adjusted in order to make it comparable to the *Right Direction* rubric, as humans put more emphasis and trust in numbers rather than words when deciding. The choice of scale can also influence a decision by under- or overweighing one factor. Therefore, the scale should reflect what is a reasonable and familiar context for the company. (Gregory et al. 2012)

The S-Step is a summary of the detailed factor analysis, presenting the results in a compact manner, underpinned by grades for a better comparison of tangible and intangible factors. To make it easier to communicate the message to decision makers, savings and risk reduction can be highlighted in this analysis (Interview 2,5,7,8,10). Nevertheless, the sustainable factors of the *Right Direction* rubric should get the same priority, as it is one of the main purposes of CRAFTS. First by giving those factors appropriate grades, decision makers see the value and do not under weigh their importance in contrast to financial indicators. As in the previous step, factors can be added to include for instance concrete calculations about rent, heating, or material savings, as well as a research on minimizing storage, communication or IT equipment (Interview 7,8). However, it is important to note that these calculations will be afflicted with errors and can never be sufficient (Interview 2,7). Therefore, the practitioner needs to decide when the intended level of detail is achieved. By justifying, calculating, and adjusting the assumptions made in the previous T-step, factual based scenarios are created. They include amongst others problems, suggestions, estimated costs, source of money, and a time schedule to compare the retrofit option with a new facility (Interview 1,2).

Additionally, another SWOT analysis can be set up to summarize the key findings about each future scenario. This in turn can then be compared to the SWOT analysis of the current facility established in the A-Step. With that, the overall improvement potential for the manufacturing facility compared to current practices can be highlighted for the decision maker. By completing the S-Step, the company should be able to weigh out which option is better for the sustainable future of their business.
5 Discussion

5.1 Relation of Results to Literature

5.1.1 Manufacturing and the Sustainability Challenge

The literature discusses that, due to the socio-economic and environmental footprint, the manufacturing industry is accountable for significant portions of the global environmental and social impact (Egilmez et al. 2016). The industry is subject to several critical constraints, such as: global population growth, economic growth, climate change, and resource depletion (Rahimifard et al. 2013). However, it is also adding to the severity of these constraints, which in turn is adding to the complexity of the sustainability challenge as a whole. This is why Garetti and Taisch (2012) argue that sustainable manufacturing is considered as one of the most important issues to address for pursuing the big picture of sustainable development. Moreover, because the sector is nested in a bigger system it can help related sectors that have set new sustainable goals to move towards sustainability (Nee et al. 2013; Siemieniuch, Sinclair, and Henshaw 2015). External forces inflict policies that are incentivizing companies to embed environmental and social sustainability into their daily practice (Jayal et al. 2010). This was in line with the survey results, which pointed out that a substantial 41% of the respondents use a PESTLE analysis to gain insights for external factors that may affect the company (Srdjevic, Bajcetic, and Srdjevic 2012; Survey Question 7). Furthermore, from the interview results it became clear that laws, regulations, and community concerns must be actively complied with in any decision making process (Interview 2,4,5,6,8,9; Feedback 1).

5.1.2 Sustainability in the Manufacturing Industry

Although in recent trends sustainable manufacturing is becoming more prevalent among companies, it is argued that there is still much confusion on what sustainable manufacturing constitutes as well as sustainability in general (Dangelico and Pujari 2010; Siemieniuch, Sinclair, and Henshaw 2015). The interviews and survey, conducted in this research, revealed that multiple experts in the field are unaware of the extent of the definition of sustainability (Survey Question 6,7,8; Interview 4,5,6; Feedback 1,5). For example, in Feedback (1) it was mentioned that social factors were underestimated in their process design as the company did not make the connection between the social factors and the definition of sustainability. Furthermore, in our conducted literature review there seemed to be limited available resources in the social sustainability research field connected to the manufacturing industry, which was confirmed by Fantini, Taisch, and Palasciano (2013). Equally in the survey results, it was apparent that the majority of the responding companies did not have a sustainable strategy applied yet (Survey Question 6). This led us to draw the conclusion, that most companies in the field are unaware of the importance of sustainability and the connected benefits pointed out in the literature (Pujari, Wright, and Peattie 2003; Fraj-Andre’ et al. 2008; York 2009; Jayal et al. 2010). It was confirmed by the expert interviews, that the integration of sustainability in the mindsets of the management levels was missing (Interview 1-4,9,10), which can restrain further improvement of the sustainable performance of a company (Porter and Van der Linde 1995; McPhee 2014).
5.1.3 Need for Strategic Decision Support

The literature discusses that sustainable manufacturing requires the combined analysis of buildings and facilities supporting the manufacturing operations (Despeisse, Oates, and Ball 2013) and proposes two options to aim for an improved sustainability performance, namely: retrofitting and the construction of a new factory. Both options have their own strengths and weaknesses, depending on the company’s identity and the specific facility characterizations (physical conditions, facility operations, facility policies and procedures, regulatory requirements, and legal issues) (Garcia 2007). Various industrial improvements can contribute to sustainable manufacturing but there is a gap of knowledge on how to achieve the desired outcome of sustainability in the manufacturing industry as a whole (Deif 2011; Despeisse, Oates, and Ball 2013; Mani et al. 2014). Additionally, there is a lack of guidance and tools to identify the impact of the industrial improvement with respect to sustainability (Smith and Ball 2012). The research pointed out that a step by step process clarifies and adds value to the process (Waage 2007; Interview 1-11). However, there is no abundance of contributing literature that addresses the challenge of sustainable facility planning explicitly. Despite Yuan, Zhai, and Dornfeld (2012) arguing that significant research is put on developing new manufacturing tools, it became clear that a comprehensive tool is needed for achieving sustainable facility planning.

5.1.4 Strategic Planning using the FSSD

Holmberg and Robèrt (2000) and Hallstedt (2008) argue there is need for a systematic approach for sustainability related decision processes that uses a backcasting approach to realize a desirable instead of a likely future. Furthermore, this research pointed out that a strategic support tool with a holistic approach is favourable and needed for the industry when considering facility design options (Interview 1-11; Feedback 2-5). Despite of the strategic approach of the backcasting technique, it permeated through that most decision makers in the field made use of a more traditional forecasting approach to execute these decisions strategically (Interview 1-8,10). This means that current decision making in the manufacturing industry is mainly based on analysing the current trends, setting the goals given these trends, and think of actions to reach these goals (see Figure 3.4 in Section 3.2). The FSSD enables a strategic planning approach that can close potential gaps as an attempt for the current manufacturing industry to become more sustainable. The systems perspective and sustainability definition provided by the FSSD is embedded in the ABCD process, which was designed to support companies with complex challenges. As the decision of implementing sustainability in facility planning is considered complex (Feedback 3,4), a comprehensive decision support tool that contributes to the tools and strategic level of the FSSD could help the industry move towards sustainability.

5.1.5 Sustainable Facility Planning

The literature supports the research results to a great extent and confirms the need for a strategic tool in the manufacturing industry. Ninety percent of the responding companies and 100% of the interviewees indicated that support is necessary in connection with facility planning decisions (Survey Question 15, Interview 1-11). As apparent in the literature and survey there is a large number of existing tools that are being used to support sustainable manufacturing in multiple specific fields (Salwa, Evans, and Longhurst 2008; Despeisse, Oates, and Ball 2013; OECD 2017; Survey Question 7,8). The most important challenge in this research was to combine a set of methods, approaches, and tools to put them into the context of a broader framework for companies to weigh off sustainability trade-offs and decide between retrofit and new construction. A systems view throughout the process is crucial to take all the connections
between systems like production and community into consideration. Next to the systems perspective, discovering the initial trigger that caused the process of deciding has been mentioned by respondents (Interview 2,6). Ultimately, a lot of emphasis and effort can be put into the decision between retrofitting and new construction, however humans make the decision, which implies that individual opinions can influence the outcome in a negative way (Interview 6).

5.2 Contribution of Results to the Field

5.2.1 Conventional Decision Making

Although decisions about facilities are future-oriented, because of the high financial investment and value of production to the company, answers were contradicting our expectations. Financially driven, short-term decisions are still very common in the manufacturing industry, especially if the board is not involved or committed to the sustainability agenda (Interview 2,5,6,7). This short-term thinking can be caused by project time restrictions or other board specifications. Furthermore, the complexity of such a decision, pressure of competition, and market trends can hinder decision makers from creating strategically sound solutions. This also influences sustainability related projects as the investments often contain long payback periods, hence do not provide a high rate of return (Interview 1,2,4,9). However, some companies do have long-term considerations and value factors like responsibility and flexibility (Interview 5-8,11). Overall, most of the interviewees had a basic understanding of sustainability but unfortunately very little about the inherent benefits. Though, the impression we gained in the interviews was that all respondents were open to learn more about these terms. The challenges mentioned in the interviews were amongst others, the completeness of the evaluation to make the best choice between possible solutions (Interview 3). It was also evident that the challenges each company faced are unique as the purpose and trigger behind the decision varied. Most companies were forced to decide between retrofitting and new construction because of a market crises (Interview 1,2,4-7). Due to production decline, many facilities were vacant and unused. That prompted the need to think about the centralisation of buildings or other possibilities to reuse the given facilities. To deal with these kinds of challenges, the interviews revealed a basic structure of the decision process that is based on their experience.

5.2.2 Conventional Facility Planning

The conventional process, extracted from the interviews, starts with finding out the main trigger. Companies stated that improving the factory efficiency and performance to renew outdated factories are crucial. Subsequently, a current state analysis of the facility needs to be conducted. To ensure an appropriate scope of the analysis, time restrictions need to be set. Otherwise, there is a risk of losing overview by focusing too much on details that are not primarily important for the decision (Interview 7). In the survey, companies answered that the production and facility were the most essential factors influencing the decision. This implies that the main pillars of a facility are the building itself and the production line, as the core of the factory system. This result also emphasizes the importance of these two components for a facility to function and the priority of investment. Surprisingly, sustainability was considered as the third most important factor that led the company to decide between retrofitting and constructing a new facility, after costs and factory efficiency. From literature and these results it can be concluded, that the value of sustainability is starting to gain more importance in the manufacturing industry (Dangelico and Pujari 2010; Siemieniuch, Sinclair, and Henshaw
2015), as also social responsibility such as communities around manufacturing sites, workers or working environment are considered (Interview 5,6,8). Nevertheless, the cost factor is still considered as the most essential indicator in the current decision between retrofitting and new construction of a manufacturing facility (Interview 1-11). The interviews revealed, that in strategic planning, risk management is an important part to assess the occurrence probability and involved cost of an action. By implementing risk management in the decision process, ideas that could harm the overall vision or goals of the company can be eliminated beforehand (Interview 2,7,9,10).

After the factory analysis, a rough layout of ideal manufacturing facilities through modelling or scenario building can be created (Interview 2-7,9,11). To develop a variety of innovative ideas, best practices in the sector were considered to benchmark the company against the market. Especially big manufacturing sectors such as the automotive industry served as a role model (Interview 4,5,6). In general, the interviews indicated that the benchmarking process was to specifically focused on similar companies, instead of applying a broader view on sectors less connected to their industry. Additionally, created scenarios were scoped too early in the process, which did not ensure sufficient structural difference between the scenarios. Furthermore, the company's conventional mindset was not challenged enough to tackle long-term future goals. It was also evident that a factory assessment was incomplete, which resulted in a lack of ideas for the ideal facility. Apart from external practices, surveys were conducted to unleash the internal potential. Companies also tried to motivate their employees by publicising sustainability projects, such as photovoltaic or LED systems (Interview 4,8). Nevertheless, taking the opinions of the employees into consideration, was usually missing in facility-related decisions.

Conclusively, the interviews revealed that the current decision making design is based on a forecasting technique, meaning that companies assess current trends and consequently plan to act accordingly to imperatives in the likely future.

5.2.3 CRAFTS and Sustainable Manufacturing

The strategic decision support CRAFTS is in contrast to forecasting using the backcasting approach. This implies the definition of sustainability, the creation of a future vision and communication of the desired state throughout all levels of the company to unleash synergy effects. Additionally, CRAFTS reveals unsustainable behaviour of the current state by providing a full factory assessment and encourages practitioners to identify numerous potential improvements. Amongst others, minimum waste and emissions, as well as low energy consumption should be fundamental aspects of the retrofitted and new construction scenario that is brainstormed in the process. The corporate image of the company can also be improved by being prepared for upcoming environmental regulations and laws. Through innovation, flexibility, and self-sufficiency companies can profit from sustainable benefits and improve their competitive advantage. The iterative design of this process enables continuous improvement processes to be implemented in the company’s business strategies. The guidance also allows for customisability, which is essential in the different industry sectors (Feedback 5,6). CRAFTS should be used in the manufacturing industry to benefit from sustainable development and inspire other companies to follow their lead. The general nature of the strategic decision support tool also allows to tailor it as a standard for other company related projects.
5.2.4 **Strengths of CRAFTS**

CRAFTS is a tool created to be used worldwide in the manufacturing industry, independent from size and sector of the company. It combines a top-down with bottom-up approach and proposes a modern interactive way of working together, to strengthen the connection between management and employees. Compared to current industry practices, employees have to actively play part in the strategic decision process.

The acronym CRAFTS describes the function of the tool “Compass to Refine and Align Factory-performance Towards Sustainability” and also represents the six-step process: “Co-create a Vision”, “Represent the Core Ideology”, “Assess the Current Reality”, “Focus on Ideas”, “Target Ideal Solutions”, and “Select the Best Option”. This allows the user to better remember the purpose that is also supported by the power of the compass, used as a logo (Appendix D).

CRAFTS is timely and relevant to practitioners in the manufacturing industry. It responds to the lack of guidance retrieved from the literature and confirmed by the survey and expert interviews. CRAFTS includes the definition of sustainability based on the eight SPs, which cover all segments of the triple bottom line. It thereby emphasizes not only on the environmental but also on the social segments of sustainability, which companies are aware of but not in the entirety as presented in the FSSD (Survey Question 10,12; Feedback 3). The full systems perspective assures that immediate communities as well as employees are also taken into consideration instead of merely valuing costs and efficiency in order to be successful. The process that practitioners are guided through is a learning-by-doing approach and will be aligned by personal insights and modifications during that experience. Even if practitioners have little previous knowledge about sustainability, it should not hinder them from applying CRAFTS successfully in their company. Additionally, recommendations given by the tool are customizable and adaptable to individual needs of the companies.

The tool assists with the complex problem of deciding between retrofitting and new construction of a manufacturing facility by proposing an adequately multifaceted process (Feedback 3,4,5). However, it also supports to find an appropriate solution for either only retrofitting or new construction. As both options run through the same process simultaneously assessing the same aspects, an equal comparison can be conducted. Even by going through the CRAFTS steps individually, one can have additional benefit, although the steps are interconnected. That means that by completing the C-Step for instance, a company can create a compelling vision for their sustainable future without the need to continue the process (Feedback 3,4,5). However, if CRAFTS is applied in its entirety, companies will apply a backcasting approach that urges to create a desired future state before making decisions with wrong incentives. Prior to starting the full factory assessment, the initial trigger that led to the need for improvement should be reflected. By doing so, the practitioners involved in the process can agree on a common denominator to work with the same mindset on the project. CRAFTS also provides fundamental factors that assist companies during the facility analysis, to ensure a thorough baseline of the current state. In contrast to conventional practices, this approach implies potential improvements on all facility levels.

The strategic decision support in cooperates workshop design and techniques to foster creative thinking and to generate multiple solutions for the design of future facilities. This process is participatory by involving employees, stakeholders, and managers from varying fields of expertise, leading to a better motivation and acceleration of the process (Interview 4-7,10).
Benchmarking analyses throughout different industry sectors can provide new insights and function as a source of inspiration for sustainable solutions. CRAFTS draws to a close through a comparison of realistic scenarios. Weighing off hard and soft facts allows for a fair choice of the best option and ultimately make all factors more comparable.

Due to the general nature of CRAFTS it can also be used as a standard or template for other projects not related to the initial purpose (Feedback 3,4). All of these characteristics make CRAFTS a powerful tool for the manufacturing industry to implement strategic sustainable development into their business strategy. This impression is reinforced by almost all interviewees, saying that this process is what a company needs and how it should be done in the industry (Interview 1-11; Feedback 2-5).

### 5.2.5 Weaknesses of CRAFTS

CRAFTS is a tool specifically designed for the manufacturing industry and that is where practitioners can unleash its full potential. If used for other purposes, the tool might not be as powerful to lead to the desired results. As the decision between retrofitting and new construction of a manufacturing facility is complex and long-term, the tool to support that decision also needs to be complex (Feedback 3,4). However, the process can be too complex especially for smaller enterprises. If companies do not have the resources or means to invest in such a process, the use of the tool might not be appropriate. As CRAFTS is designed to be applicable for multiple sectors in the manufacturing industry, there might be certain areas missing for highly specific industries. Nevertheless, Feedback (3) indicated that it is appropriate to allow companies to adjust it to their individual needs.

When using CRAFTS as a decision support, the way how it is being used is substantial for the success of the project. A vision set in the beginning, that is not aligned with the SPs, can influence the whole process. The tool can also be misused by either reducing it excessively or use it for a purpose it is not built for. In both cases, the outcome and the decision can be weakened if the process is not executed completely. As there is no control over how companies will use the tool, the outcome may not always be as intended because of incorrect interpretation by practitioners. The modern interactive way of working together, implemented in the decision support tool, could also lead to problems within companies that do not have the open mindset and connection throughout the company yet (Feedback 3). Additionally, it was highlighted that the success of the tool heavily depends on the moderator and the team working on the project, which is not specified by CRAFTS. Feedback for the composition of the team was to include a “challenger”. This person could be an external consultant who knows the market but also has knowledge about the company. By making use of this external view, the qualitative outcome of a well-structured workshop can be boosted up to 30-40%. (Feedback 4) This feedback was appreciated and implemented in CRAFTS.

Feedback (3) stated that companies of the 21st century should be able to do an economic efficiency calculation. Nevertheless, as CRAFTS is not providing any measurement tools for the factory analysis, companies that have never dealt with this decision, could be in a disadvantageous position. Additionally, how the analysis is conducted has possible implications on the result. Ratings of people could be inconsistent, allowing an action to be preferred over another. CRAFTS also lacks computer-based software (e.g. Excel, templates) to simplify the data collection and analysis and to make the tool more practical in general. Appended templates would support the workshops and ease up the process of harvesting results.
In the end of the CRAFTS process, the company will have one best retrofit and new construction option to decide between. However, the tool is not able to provide clear answers for what the best option is because ultimately companies are responsible for the decision and their individual problems that need to be solved. Another drawback that comes with CRAFTS is the limited scope. Amongst others, the product produced in the facility, the supply chain or transport are not included and will not affect the analyses. The scope and time restriction for this research also did not include a pilot test of the tool in the field. Although the Feedback (2-5) gathered from experts was positive and promising, it does not prove the practicality of usage. A test phase could refine the tool and allow to tailor it more explicitly for the industry.

### 5.3 Validity

In this research literature, an online survey, and expert interviews were the sources of data collection. These methods were chosen due to the design-orientated research and to consciously strengthen the validity of the results. To create a practical tool for the manufacturing practitioners, the industry and their challenges needed to be understood first. However, research has to complement these insights with academic literature. Eventually, validated interviews with experts from different fields were used to prove the findings. The design of CRAFTS was validated by the feedback of experts including their ideas for improvement.

**Survey**

The survey was mainly set up to elaborate more on where the challenges in the manufacturing industry are, how decisions are made, and to prove that strategic support is needed to move companies towards sustainability. Out of approximately 450 surveys, a response rate of 11% was achieved. This is due to the fact that the survey was sent out to public email addresses of companies all over the world. We were aware that the respondents therefore may not be experts, if not forwarded to the specific department. Taken this into consideration, the data gathered had to be treated with caution. From a research standpoint, the relatively low quantity of answers led to a low level of confidence and did not eliminate amplified outliers. The degree of credibility due to this low quantity was also not very high. Additionally, these results were critically assessed due to possible misunderstanding, wilful neglecting or excessive pride of respondents cannot be ruled out.

We decided to use a closed survey to achieve better results due to user friendliness. The general survey questions in the beginning of the survey covered the company’s size, industry, and location of headquarters and production to demonstrate a variety of industry wide opinions and the universal existence of the problem. The companies who did answer were spread globally therefore representing the manufacturing industry on a global scale to a certain extent. An insight of current approaches and tools used by companies to tackle sustainability related problems was gained followed by questions on how companies dealt with the decision to get a better understanding of current practices. To ensure qualitative answers, only companies which were ever in that specific situation have been asked to elaborate on their experience. As slightly more than half of the companies already made these decisions, the follow-up questions gave us more insights about potential challenges.

Choosing an online survey as a method to gather worldwide data for this specific research was appropriate. Although we made sure that the survey was equally sent out to all the continents, the answers were mostly from Europe. This in turn had a negative influence on the response rate and reduced the quantity of answers as well as the statistical degree of certainty. If more contacts were known globally and industrywide, personal expert interviews would have been
favoured over the survey. Due to the survey structure, several answers had to be predetermined, which could have led to biased results. However, the respondents were able to add optional answers which was only used twice. The survey formed a base for the assumptions made in the research for a certain extent and proved the need for a strategic tool to support sustainable decision making in the manufacturing industry. It also revealed the relevance of expert interviews to get more in depth results.

When analysing the survey data, we checked for obvious deviations caused by user errors. Such an error occurred in an answer when selecting the location of headquarters and production. The headquarter was stated to be in Argentina, and the location of production in Antarctica. This answer was discussed to not be realistic and we assumed that it was wrongly chosen, as both answers are closely together in the default drop-down menu. Subsequently, the answer was corrected. In the analysis, it was also tried to categorize information to highlight connections and analyse it in isolation. The result however, did not allow a thorough conclusion when combining answers. This is due to the fact that a regression analysis for estimating the relationships among data was not possible, as the amount of data was limited.

**Expert Interviews**

Interviews were used in the research to get insights on decision processes around facility planning. In total, 11 experts in the field were interviewed, thereof seven from Germany in middle sized to big companies. We are aware that this is not particularly a thorough representation of the worldwide industry. However, we made sure that the sectors of the companies and the positions of the interviewees differed, to guarantee a variety of answers, opinions, and insights.

The expert interviews were a great source to gain knowledge about current practices in the manufacturing industry and how a strategic tool like CRAFTS could support sustainable development. The time, interviewees were able to share, was limited to 30 minutes. Therefore, additional time would have been valuable to extract more details by asking follow-up questions. Although a wide range of interviewees from all over the world would have been desirable, the contacts mainly stemmed from Europe, with a focus in Germany. Additionally, a greater number of interviews and a longer timeframe could have led to more insights and opinions from different angles which could have had directly benefitted the research.

When analysing, an interview that was seen as more passionate and pleasant could have received more emphasis than the raw data of the survey or other interviews. As the experts were influencing the outcome of the research to a great extent, this may have had critical consequences. However, we were aware of this fact and attempted to be as objective as possible by treating the information equally and cross-checking it with literature.

**Expert Feedback**

The expert feedback was based on the introduction video of CRAFTS (youtu.be/M0Zlq7tO6G4), forwarded to get insights about the practicality of the content. The overall reaction of experts was positive. Feedback (2-5) said that the use of symbols and graphics in the presentation made it easy for a broad audience to understand the concept of the tool. The feedback on the structure of the tool highlighted a thought through and practically oriented content (Feedback 2-5). Additionally, the implementation of a modern interactive working environment was highly recommended as it could lead to better employee motivation and competitive advantage. This also allows a systematic integration of all levels in a company.
However, we were warned that this approach is not yet popular or known in a lot of companies (Feedback 3).

The drawback of the conducted expert feedback interviews was limited to the European continent. As the interviewees also appreciated the content as well as the way it was presented, constructive feedback was limited. Nevertheless, the video helped to communicate CRAFTS in an easy and understandable manner.

When analysing the feedback data, it was first checked if the recommendation was already implemented in CRAFTS. If so, we made sure that the communication is clear enough to reduce misunderstanding or potential oversight. However, when the feedback was not part of the tool, we reviewed the literature to find similarities and built the idea into CRAFTS. Recommendations that were too specific or did not align with the purpose of the tool were rejected. Feedback that was not used to improve CRAFTS, was for instance to suggest tools for the factory analysis. During the Feedback (3), we could find consensus with the interviewee that it was clearly out of scope for this research, as CRAFTS should be used industrywide and globally. The experts also requested Excel sheets or other support to better document the process, which was not manageable in the given timeframe (Feedback 4,5). Another comment mentioned the importance of the product that is produced in the facility (Feedback 2). Due to the scope of the research this could not be implemented.

5.4 Limitation of the Research

Given the time available, we designed the research to achieve a valid outcome. However, we acknowledge that more in-depth research would further elevate the quality of this thesis.

When developing CRAFTS, we put a lot of emphasis in the practicality for the industry. Due to the time constraint, it did not allow us to have a facility tour to get more insights or test the tool in the industry with an appropriate case study. With this knowledge, more clarity and understanding through visualizing an actual facility could have influenced the decision support. As the literature to this specific decision was also limited, gaining knowledge from companies that dealt with this challenge before, were beneficial. In our research, we conducted 11 expert interviews and an online survey. If we would have had more time, a greater number of appropriate contacts for the survey could have been gathered. This would have had a direct influence on the amount of survey answers, hence the outcome. The intended scope of the research was designed to represent the global manufacturing industry. However, most of the received survey answers and expert interviews came from Europe. Additionally, with more time, a greater number of experts from countries all over the world could have been interviewed. Further, a case study comparison of a factory before and after the decision between retrofitting and new construction could have been used to implement insights into the decision support tool.

Based on industry recommendations, we acknowledge that for the achievement of sustainability on a system level our scope needs to be broadened to a cradle-to-grave perspective. Thereby, the manufacturing industry can inflict reduced resource consumption and increased product durability to improve circular activities.
5.5 Next Steps and Recommendations

The next step needed are to test and refine CRAFTS, based on case study evidence. Further research needs to be done on the implementation of the decision support tool in a long-term process to make it more valuable for the manufacturing industry. An application in companies of any size and any sector should be used to gather more feedback on how the guidance impacts the industry worldwide. It also needs to be proved, that the method is effective and produces lasting change.

Further research should also include the development of a computer based software incorporating video tutorials of all the steps and additional Excel sheets for the analysis. CRAFTS should also be tested in regards of its applicability and practicality. Measures could also be determined, that the methods used in the tool reduce the gap between employees and management in the current situation. Sharing CRAFTS and the insights learned through applying it, could also be used in the industry for other projects. As the tool is focusing on the sustainable decision between retrofitting and new construction, it should be researched how the tool can be designed even more general to make is customizable for any kind of decision for sustainable development within the manufacturing industry.

Figure 5.1 displays the scope in which the manufacturing system resides. For the achievement of sustainability on a systems level, an extension of the scope should at least include the supply chain, product, and resources. The full scope analysis should be researched in more detail, as well as the implementation of best practices. On top of that, further analysis should be conducted to gather information about current strategic planning approaches. This will ultimately give more input to improve the decision support tool.

![Figure 5.1. Scope of Application for CRAFTS relative to the bigger System](image-url)
6 Conclusion

The aim of the research was to discover how companies in the manufacturing industry can assess sustainability trade-offs to decide between retrofitting and new construction of a facility. This question was asked, as the state of the art manufacturing industry is confronted with a challenging situation, to preserve a healthy ecological and social environment. The industry is compelled to supply the demand for products and services in the current societal system, while simultaneously aligning their business values with sustainability. Especially in the manufacturing industry there is a list of factors that must be considered when assessing sustainability. The process of sustainable development with all its interconnections and influences can therefore be perceived as complex.

By researching how decision makers in the industry currently cope with this complex decision, we found that companies do not address this challenge in a holistic way but rather focus on specific solutions in isolation when considering facility design options. Although the results showed that decisions about facilities are future-oriented, because of the high financial investment and value of production to the company, money driven short-term decisions are still common in the manufacturing industry. This short-term thinking can be caused by project time restrictions or other board specifications. Furthermore, the complexity of such a decision, pressure of competition, and market trends can hinder decision makers from creating strategically sound solutions. The initial assumption made in the research that a strategic tool in the manufacturing industry is missing to move towards a sustainable future, was confirmed by the literature and industry insights. It was also found that a common definition of sustainability in the manufacturing industry is lacking as well as a strategic approach. By interviewing experts from the field, it was apparent that it is more valuable to provide an overarching guidance on how sustainability can be strategically implemented in facility planning rather than the suggestion of individual methods and tools for this complex decision. This highlights the need for a tool to bridge the knowledge gap and unawareness of sustainability benefits combined with long-term decision making.

Although the literature suggests several tools that allow for sustainable improvements, there is no overarching framework that includes a full systems perspective to assists the manufacturing industry in deciding between retrofitting and new construction of their facilities. Based on the findings, it is crucial for decision makers to embed a strategic and holistic approach when considering facility design options. If the manufacturing industry aims towards sustainability, this could help other sectors to move in the right direction. Therefore, the strategic decision support tool CRAFTS, developed in this research, enables opportunities for a broader scope of possible improvements by guiding experts in the field to decide between retrofitting and new construction. During the research, we identified clear synergy effects between the ABCD process, designed for dealing with complex decisions, and the general process design filtered from expert interviews. Therefore, CRAFTS is designed as a step by step process applying a backcasting approach to refine and align their business strategies and facility operations with sustainability. By using the FSSD as a holistic foundation, we can ensure that all components that account for sustainability were taken into consideration. Due to time restrictions, we recognise the need for more verification by further testing the tool with cooperating manufacturing companies. As the scope of CRAFTS is specifically focused on the facility, additional sustainable strategies need to be implemented, which include for instance the supply chain, resources, transportation or product portfolio.
References

Literature


**Expert Interviews**

Interview 1  Schilling, Clemens. 2017. Interview by authors. Aschaffenburg, Germany. February 27.

Interview 2  Timm, Karl-Peter. 2017. Interview by authors. Aschaffenburg, Germany. February 27.


**Expert Feedback**


Appendices

Appendix A: Online Survey

Question 1: How big is your company?

- 55% Big (250 & more employees)
- 31% Medium (50-249 employees)
- 14% Small (1-49 employees)

Question 2: In which industry sector does your company operate?

- Electronics & Communication: 8
- Machinery & Robotics (automation): 8
- Construction: 6
- Metal: 5
- Chemistry & Pharmacy: 4
- Textile & Clothing: 3
- Paper & Pulp (printing, publishing): 3
- Furniture & Fixture: 3
- Energy, Oil & Gas: 3
- Transport: 3
- Agriculture, Food & Beverage: 3
- Other: 1
- Plastic & Rubber: 1

Question 3: In which country is your headquarter based?

(note: categorised into continents)

- EU: 31
- Asia: 9
- America: 6
- Oceania: 3
- Africa: 2
Question 4: In which country are the majority of your production and assembly plants? (note: categorised into continents)

- EU: 28
- Asia: 12
- America: 7
- Oceania: 2
- Africa: 2

Question 5: How many facility locations do you have? (note: clustered into groups)

- 1-5: 30
- 6-10: 6
- 11-15: 4
- 16-20: 4
- 21-30: 2
- 31-40: 1
- More than 40: 4

Question 6: How important is sustainability on your company agenda?

- Pre-Compliant: 1
- Compliant: 7
- Beyond Compliant - Early-stage: 26
- Beyond Compliant - Late-stage: 8
- Integrated Strategy: 9
### Question 7: Which tools are you using to assess the current state of your manufacturing facility?

<table>
<thead>
<tr>
<th>Tool</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO/DIN/SA standards</td>
<td>47</td>
</tr>
<tr>
<td>Key Performance Indicators (KPI)</td>
<td>47</td>
</tr>
<tr>
<td>Stakeholder analysis</td>
<td>30</td>
</tr>
<tr>
<td>3R / 6R concept</td>
<td>30</td>
</tr>
<tr>
<td>Eco-labelling, Eco design</td>
<td>27</td>
</tr>
<tr>
<td>Life Cycle Assessment (LCA)</td>
<td>24</td>
</tr>
<tr>
<td>PESTLE analysis</td>
<td>21</td>
</tr>
<tr>
<td>Ecological Footprint</td>
<td>19</td>
</tr>
<tr>
<td>Factor 4, 10, X</td>
<td>5</td>
</tr>
<tr>
<td>IDEF0</td>
<td>3</td>
</tr>
<tr>
<td>OECD Toolkit</td>
<td>1</td>
</tr>
<tr>
<td>Shadow Carbon Price</td>
<td>1</td>
</tr>
<tr>
<td>GRI v4</td>
<td>1</td>
</tr>
<tr>
<td>FDA Compliance</td>
<td>1</td>
</tr>
</tbody>
</table>

### Question 8: Which methods and concepts are you using in your manufacturing facility?

<table>
<thead>
<tr>
<th>Method/Concept</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean Management</td>
<td>37</td>
</tr>
<tr>
<td>Six-sigma</td>
<td>36</td>
</tr>
<tr>
<td>SS</td>
<td>35</td>
</tr>
<tr>
<td>EMS</td>
<td>32</td>
</tr>
<tr>
<td>CSR</td>
<td>19</td>
</tr>
<tr>
<td>Kaizen</td>
<td>18</td>
</tr>
<tr>
<td>Kanban</td>
<td>17</td>
</tr>
<tr>
<td>Virtual Enterprise/Factory</td>
<td>16</td>
</tr>
<tr>
<td>Industry 4.0</td>
<td>13</td>
</tr>
<tr>
<td>SPD</td>
<td>11</td>
</tr>
<tr>
<td>MEW flows</td>
<td>8</td>
</tr>
<tr>
<td>DFE</td>
<td>7</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Natural Capitalism</td>
<td>1</td>
</tr>
</tbody>
</table>
Question 9: Was your company ever in the situation of deciding between retrofitting (improving) or constructing a new manufacturing facility?

- Yes: 45%
- No: 55%

Question 10: What triggered the need to consider changing your manufacturing facility in the first place?

- Factory efficiency and performance: 14
- Outdated factory: 12
- Flexibility: 11
- New products: 10
- Sustainability: 8
- Cost factor: 7
- Location: 6
- Sales: 5
- Regulations/Standards: 4
- Working conditions: 4

Question 11: Who was the main responsible for the decision process?

- Production Management: 10
- Executive Board: 4
- Plant Management: 4
- Operational Management: 3
- Facility Management: 2
- Board of Directors: 1
- Sustainable Management: 1
- Technical Management: 1
- Technical Manager: 1
- Process Management: 1
Question 12: Which areas were analysed in order to check the current-state of your facility?

- Production: 24
- Facility: 22
- Waste treatment: 18
- Material use: 16
- Supply Chain: 14
- Energy use: 12
- Emissions: 12
- Working condition: 8
- Water use: 2

Question 13: What factors ultimately led the company to decide between retrofitting and constructing a new facility?

- Factory efficiency and performance: 19
- Cost factor: 14
- Sustainability: 13
- Outdated factory: 12
- Location: 6
- Flexibility: 6
- New products: 4
- Sales: 3
- Working conditions: 3
- Regulations/Standards: 3

Question 14: Would it have been helpful (could it be helpful) if you had support for the decision between retrofitting and constructing a new manufacturing facility?

- Yes: 90%
- No: 10%
## Appendix B: Expert Interviews

<table>
<thead>
<tr>
<th>#</th>
<th>Country</th>
<th>Sector</th>
<th>Size</th>
<th>Location of main production</th>
<th>Interviewee Position</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germany</td>
<td>Machinery, vehicle manufacturing</td>
<td>big</td>
<td>Germany</td>
<td>Head of Engineering</td>
<td>male</td>
</tr>
<tr>
<td>2</td>
<td>Germany</td>
<td>Machinery, vehicle manufacturing</td>
<td>big</td>
<td>Germany</td>
<td>Head of Facility Management</td>
<td>male</td>
</tr>
<tr>
<td>3</td>
<td>Sweden</td>
<td>Machinery, lifting solutions</td>
<td>medium</td>
<td>Sweden</td>
<td>Operational Management</td>
<td>female</td>
</tr>
<tr>
<td>4</td>
<td>Germany</td>
<td>Machinery, printing</td>
<td>big</td>
<td>Germany</td>
<td>Real Estate Management</td>
<td>male</td>
</tr>
<tr>
<td>5</td>
<td>Germany</td>
<td>Chemical</td>
<td>big</td>
<td>Germany</td>
<td>Group Excellence Officer</td>
<td>male</td>
</tr>
<tr>
<td>6</td>
<td>Germany</td>
<td>Chemical</td>
<td>big</td>
<td>Germany</td>
<td>Marketing &amp; Sales</td>
<td>male</td>
</tr>
<tr>
<td>7</td>
<td>Germany</td>
<td>Construction machinery</td>
<td>big</td>
<td>Germany</td>
<td>Manager Capacity &amp; Order Management</td>
<td>male</td>
</tr>
<tr>
<td>8</td>
<td>Brazil</td>
<td>Electronics</td>
<td>big</td>
<td>Brazil</td>
<td>Real Estate Portfolio Coordinator</td>
<td>female</td>
</tr>
<tr>
<td>9</td>
<td>Taiwan</td>
<td>Photovoltaic manufacturing</td>
<td>big</td>
<td>Taiwan</td>
<td>Technical Manager</td>
<td>male</td>
</tr>
<tr>
<td>10</td>
<td>England</td>
<td>Consultancy</td>
<td>small</td>
<td>-</td>
<td>Senior Consultant</td>
<td>male</td>
</tr>
<tr>
<td>11</td>
<td>Germany</td>
<td>Photovoltaic manufacturing</td>
<td>big</td>
<td>Germany</td>
<td>Head of Production</td>
<td>male</td>
</tr>
</tbody>
</table>

### Interview Questions:

- How many facilities do you have?
- Was your company ever in the situation of deciding between retrofitting (improving) or new construction of a manufacturing facility?
- What was the reason behind (the why) the question?
- How did process look like?
- Who was the main responsible for the decision process? Who was in the project team?
- How important was sustainability in the process and company (Bob Willard)? Was the decision connected to the vision, and long-term goals of the company?
- What did you analyse?
- How did you analyse? What tools did you use?
- Which factors did you feel were most important for the final decision?
- Where do you think you need the most support with / struggled with? What did you profit the most from?
- Would it have been helpful if you had a decision support tool to assist you with this question?
## Appendix C: Expert Feedback

<table>
<thead>
<tr>
<th>#</th>
<th>Country</th>
<th>Sector</th>
<th>Size</th>
<th>Location of main production</th>
<th>Interviewee Position</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>England</td>
<td>Paint Industry</td>
<td>big</td>
<td>England</td>
<td>Technical Director - Global Operations + Project Director</td>
<td>male</td>
</tr>
<tr>
<td>2</td>
<td>England</td>
<td>PVC</td>
<td>big</td>
<td>England</td>
<td>Sustainability &amp; Corporate Social Responsibility Manager</td>
<td>male</td>
</tr>
<tr>
<td>3</td>
<td>Germany</td>
<td>Chemical</td>
<td>big</td>
<td>Germany</td>
<td>Marketing &amp; Sales</td>
<td>male</td>
</tr>
<tr>
<td>4</td>
<td>Germany</td>
<td>Chemical</td>
<td>big</td>
<td>Germany</td>
<td>Group excellence officer</td>
<td>male</td>
</tr>
<tr>
<td>5</td>
<td>Germany</td>
<td>Photovoltaic</td>
<td>big</td>
<td>Germany</td>
<td>Head of Production</td>
<td>male</td>
</tr>
</tbody>
</table>
Appendix D: CRAFTS

CRAFTS Logo

<table>
<thead>
<tr>
<th>IDEAS</th>
<th>CATEGORIES</th>
<th>RIGHT DIRECTION</th>
<th>(FINANCIAL) GROWTH</th>
<th>FEASIBILITY</th>
<th>FINAL IDEA SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>Location</td>
<td>45%</td>
<td>-25%</td>
<td>-35%</td>
<td>1</td>
</tr>
<tr>
<td>Goals</td>
<td>Equipment</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Roof</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Windows</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Machines</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Storage</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>Flows</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

**GRADING SCHEME:**
- Very Negative
- Negative
- Neutral
- Positive
- Very Positive

**T-Step: Target Ideal Solutions**

<table>
<thead>
<tr>
<th>Idea 1</th>
<th>Idea 2</th>
<th>Idea 3</th>
<th>Idea 4</th>
<th>Idea 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FINAL SCENARIO SCORE:** The Scores of the picked Ideas are divided by the quantity of picked Ideas

**T-Step: Scenario building**