CHALMERS
UNIVERSITY OF TECHNOLOGY

Methods for technology assessment for sustainable manufacturing

A gap analysis between state-of-the-art literature and industry needs

Bachelor of Science Thesis

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Abstract

Extensive research in the area of sustainability has been made during recent years to develop methods that assess sustainability performance of products and processes in the manufacturing industry, but to what extent these methods are used by this industry for sustainable development is not obvious. This report includes the result of an analysis of the use of sustainability assessment methods within the industry. The result of the analysis aims to conclude if methods in general are used by the industry or if they only exist in the literature, i.e. if there is a gap between the state-of-the-art literature and industry needs regarding sustainability assessments. The result is limited to only include the economic and environmental aspects of sustainability. The analysis is based on a literature review of 49 articles and six interviews with experienced respondents from the Swedish manufacturing industry, all working with sustainability issues. A comparative analysis was then done between the literature and the interviews to determine the presence of a gap and possible causes to it. Based on the comparative analysis, a conclusion was drawn that there is a gap between the industry and literature regarding the usage of sustainability assessments. The causes was concluded to be at least one of the following nine: *The industry does not understand methods content, the industry does not understand methods' benefits, the industry applies a short-term thinking, methods are too comprehensive, the industry and academia do not collaborate when developing methods, practitioners lack required competence, difficulties collecting data, inappropriate interference from stakeholders in decisions, methods provide insufficient guidance regarding trade-offs in decision making.* In order to foster sustainable production, industry and academia need to cooperate to close the gap between them, both regarding the development of methods and the implementation of methods. This thesis constitutes a complement for future research regarding adaption of sustainability assessment methods suitable for the manufacturing industry.

Keywords: Gap analysis, sustainable production, literature study, sustainable manufacturing, indicators, triple bottom line, industrial sustainability, decision making, sustainable thinking, integrated assessment.

Sammanfattning

Omfattande forskning gällande hållbarhetsbedömningar för att bedöma påverkansfaktorer i tillverkande företags produktion har genomförts länge. Om industrin använder de bedömningsmetoder som forskningen tagit fram är däremot osäkert. Denna rapport syftar till att analysera användandet av hållbarhetsbedömningar inom industrin. Analysen har genomförts dels genom en litteraturstudie inom ämnet hållbarhetsbedömningar samt en jämförelse av informationen med intervjuer av anställda inom hållbarhetsfrågor på tre svenska tillverkande företag, en forskare inom ämnet vid ett svenskt universitet samt en konsult inom hållbar verksamhetsutveckling. Resultatet syftar till att slå fast om det finns ett gap mellan vad den samtida vetenskapen inom hållbarhetsbedömningar tillhandahåller och vad industrin efterfrågar och peka ut eventuella orsaker till denna situation. Resultatet är begränsat till att endast innefatta de ekonomiska och miljömässiga aspekterna av hållbar utveckling. Arbetet utfördes vid institutionen Industri- och materialvetenskap på Chalmers tekniska högskola 2018.

För att kunna fastställa om ett gap existerar eller inte besvarar rapporten frågeställningarna: *Vilka parametrar avgör om metoder används inom industrin eller inte?* samt *Hur mottagliga är industriföretag att bedöma ekonomiska och miljömässiga hållbarhetsfrågor i produktionen genom att använda hållbarhetsbedömningar?*

Utifrån analysen av intervjuerna samt litteraturstudien kan slutsatsen dras att det finns ett gap mellan industrin och litteraturen gällande hållbarhetsbedömningar. Vad detta gap grundar sig i varierar mellan situationer men sammantaget utmynnade analysen i följande nio faktorer: *Industrin förstår inte metodernas innehåll, industrin förstår inte metodernas fördelar, industrin tänker i många situationer kortsiktigt resultatmässigt, metoder är för omfattande, industrin och forskare samarbetar inte vid utveckling av metoder, krävande datainsamling, otillräcklig kompetens hos användare, inkonsekvent påverkan av beslut, metoder tillhandahåller inte tillräcklig handledning vid beslutsfattande.*

För att vidare överbrygga klyftan mellan industrin och akademin måste de samarbeta i större utsträckning. Både vad gäller utvecklingen av metoder, liksom genomförandet av nämnda metoder. Detta för att när hållbarhetsbedömningar utvecklas och förbättras blir metoderna en stabil grund för beslutsfattande. Om industrin och akademin kan få ökad förståelse baserat på ökat samarbete kan en utveckling som uppfyller dagens behov utan att äventyra förmågan hos kommande generationer att möta sina egna behov bli verklighet. Detta arbete ligger till grund för vidare studier inom ämnet för anpassning av hållbarhetsbedömningsmetoder till vad industrin efterfrågar och därmed öka användandet av dem.

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First and foremost we would like to specially thank the project supervisor, PhD Ilaria Barletta for her expertise and enormous support throughout. It is greatly valued by us and this project could have never been conducted without her. We would also like to direct a thank you to the project examiner professor Björn Johansson for his involvement.

To the department of Industrial and Materials Science at Chalmers University of Technology under which this project has been carried out, we are grateful for the opportunity to work in this field of study as a contrast to the rest of our education so as to give nuance to it.

Regarding the data collection to answer our research questions we would like to thank the interviewees at Volvo Group Trucks Operations, SKF, SAAB Surveillance Gothenburg, Effort Consulting and the Institute of Technology at Linköping University.

As all the group members were fairly new within this way of working, specifically regarding literature studies, we want to direct a thank you to the division of Language and Communication and to Chalmers' Library for their guidance on how to go about through the project.

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Gothenburg, May 2018

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Acronyms

ALCA Attributional Life Cycle Analysis. 24, *Glossary:* ALCA

CBA Cost Benefit Analysis. 20, *Glossary:* CBA
CLCA Consequential Life Cycle Analysis. 24, *Glossary:* CLCA
CSA Corporate Sustainability Assessment. 22, *Glossary:* CSA

EE Eco-Efficiency. 20, *Glossary:* EE
EIA Environmental Impact Assessment. 20, *Glossary:* EIA
ELCA Environmental Life Cycle Assessment. 21, *Glossary:* ELCA

GRI Global Reporting Initiative. I, VIII, XI, *Glossary:* GRI

LCA Life Cycle Assessment. 18–21, 24, 26, 27, *Glossary:* LCA
LCC Life Cycle Cost. 21, *Glossary:* LCC
LCI Life Cycle Inventory. 24, *Glossary:* LCI
LCSA Life Cycle Sustainability Assessment. 21, 26, 35, *Glossary:* LCSA
LCT Life Cycle Thinking. XI, 21, *Glossary:* LCT

PSS Product-Service Systems. 17, *Glossary:* PSS

RQ Research Questions. 1, 5, 6, *Glossary:* RQ

SA Sustainability Assessment. 1, 2, 11, 13–26, 29, 31, 32, 34–36, 38–40, *Glossary:* SA
SLCA Social Life Cycle Assessment. 21, *Glossary:* SLCA
SLCC Swedish Life Cycle Center. XII, 18, 31, *Glossary:* SLCC
SPA Sustainable Performance Assessment. 20, *Glossary:* SPA

TBL Triple Bottom Line. 2, 17, 20, 21, 24, 26, 32, 35, 36, 38, *Glossary:* TBL

UMP Unit Manufacturing Process. 24, *Glossary:* UMP

Glossary

ALCA Attributional Life Cycle Assessment purpose is to determine the inconveniences associated with the use of a product and production at a certain time. 24

CBA Cost Benefit Analysis aims to estimate strengths and weaknesses of various alternatives, e.g. transactions and project investments. Cost Benefit Analysis is used to determine options that provide the best possible approach to gaining benefits and preserving savings. Focus on the economic dimension. 20

CLCA Consequential Life Cycle Analysis captures the environmental impact of the production system and contains more than the physical relationships reported in Life Cycle Assessment. 24

CSA Corporate Sustainability Assessment is a business focus that includes and manages risks arising from economic, social and environmental development. Corporate Sustainability Assessment creates long-term shareholder value. 22

EE Eco-Efficiency purpose is to use less natural resources and energy but create more goods and service. 20

EIA Environmental Impact Assessment is an assessment of both the positive and negative consequences of e.g. programs or of a plan before deciding on the proposed measures. 20

ELCA Environmental Life Cycle Assessment is an important guide for identifying environmental problems and reducing impact on businesses. 21

GRI Global Reporting Initiative is a sustainability reporting where they collectively compile all data. I

LCA Life Cycle Assessment solely assesses the environmental impact associated with all stages of a product's life cycle. 18, 21

LCI Life Cycle Inventory means that an inventory of flows from and to nature is created for a production system. A flow model for the technical system is constructed with data on inputs and outputs to develop the inventory. 24

LCSA Life Cycle Sustainability Assessment evaluates social, environmental and economic aspects in decision-making processes to create more sustainable products throughout their life cycle. 21

LCT Life Cycle Thinking goals are to reduce resources of the product and improve its social performance through its life cycle. 21

PSS Product-Service Systems enable a coherent delivery of services and products with the goal of achieving environmental performance. 17

RQ Research Question describes the question of a paper, which problems to be answered through the work. 1

SA Sustainability Assessment is a comprehensive method that includes environmental, social and economic aspects that are useful for supporting decision-making in a wider perspective. 1

SLCA Social Life Cycle Assessment is a method useful for assessing the social aspects of a product along the life cycle. 21

SLCC Swedish Life Cycle Center aim is to apply life cycle thinking globally and is a forum for e.g. industry and institutes & government agencies. 18

SPA Sustainable Performance Assessment is a combination of its social, environmental and economic performance. 20

Stakeholder Stakeholder is a group or organisation that has an interest in the organisation that may affect or be affected by the organisation. 4

TBL Triple Bottom Line is a framework that includes social, economic and environmental aspects. 2

UMP Unit Manufacturing Processes are an integration of few processes, where the unit process corresponds the conversion of the input material and the output, product and effect on the environment. 24

1
Introduction

This chapter presents the background to the subject of sustainability and why there is a need for this type of analysis that the report presents. It also presents what the aim of the report is, broken down in Research Questions (RQ)s which are to be answered. A short presentation of limitations needed to clarify the scope of the analysis is also included. The chapter ends in a short introduction about which methodologies have been used, which stakeholders that have been accounted for and a short discussion on ethics regarding the subject of sustainability at large.

1.1 Background

Extensive research on the topic of Sustainability Assessment (SA) have been carried out for a long time, but it is uncertain if the manufacturing industry to which it concerns is adapting to the research made. To which extent the research is implemented in the industry is difficult to establish and this might result in a gap. This gap presumably divides the information that methods for sustainability assessments provide and the actual use of them in the industry. This is to be investigated.

Since the academic research and the manufacturing industry are separated by default, an irregular flow of communication is created. This leads to that the correlation between the different assessments performed by both parties varies greatly. This may result in lack of knowledge regarding how the sustainability assessment methodologies are to be applied in the industry.

Sustainability at large is a hot subject, especially environmental sustainability as the effects of previous unsustainable industrial evolution has become more recognised. Today, companies and individuals have to make active choices to improve this situation. In later years, social and economic sustainability have grown in their applications as well, also as a result of previous methods not providing a better outcome. One of the most recognised definitions of sustainability the one expressed by Gro Harlem Brundtland in 1987.

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987).

This description will further be used to define sustainability in this report.

1.2 Aim

The project aims to determine the existence of a gap between the need for assessing sustainability performance in the manufacturing industry and the SA methods in the scientific literature.

1.3 Problem

The result of this investigation will determine the existence of a gap between what the manufacturing companies need and the state-of-the-art literature on sustainability assessments. This is to be the main question at hand. The investigation will eventually lead to questions affiliated with the two actors involved in the problem, the academia and the manufacturing industry. To be able to conclude what causes a gap, both involved actors need to be analysed. From the research perspective, it is of great importance to identify what factors are essential in achieving a certain result. Identifying these factors would make it possible to estimate the quality and usability of research to the industry environment. The report intends to answer the research questions presented below, the first regarding the literature perspective and the second regarding the industry's perspective.

RQ.1 What factors decide if the methods are used in the industry or not?

The companies from the manufacturing industry on the other side of the gap are the target of the literature. The difficulties in transferring and converting information between the research studies and the industry might lead to a gap. The main question when studying the industry's part of the situation is if the companies are practising sustainability assessments on their processes and/or products as according to the state-of-the-art literature or not.

RQ.2 How amenable are manufacturing companies in assessing economic and environmental sustainability performances in production using SA methods?

1.4 Limitations

Limitations to the project aims at clarifying the limits to resources that will be used to achieve the certain results of the project. These limitations are:

- The time frame of the project stretches from January 15th to May 14th 2018.
- A complete SA includes all three aspects: economic, environmental and social sustainability. This report will only include the economic and environmental aspects, but when discussing the so called Triple Bottom Line (TBL) the social aspect will be included as this area within sustainability is as important as it is. It will also be included when discussing ethical views on sustainability work.
- As for the interviews that will be carried out to gather information about the industry, a number of six interviews is set to be the goal. This, because it will

allow a broader spectrum of people in different positions and in different type of companies working with different questions, using different methods. This is also estimated to be reasonable, resource wise, within the time frame of the project.

- The Scopus database will be used in the search of literature. To only use Scopus was motivated by it being vast enough to reach enough relevant literature for the review. It is the largest database of peer-reviewed literature with excellent reputation.

- The EU's new data protection regulation, the General Data Protection Regulation (GDPR) which enters into effect on the 25th of May 2018, implies, among other things, stricter requirements for personal data processing. With this in mind, the interviewees will be anonymous but their title and the company will not, with their approval.

1.5 Methodology

The report contains a gap analysis, including an evaluation of the gaps existence in manufacturing companies with two parts of research studies, one literature review and one containing practice in the industry. The availability of relevant companies and individuals to interview will determine if the data will be primary or secondary. The interviews will be carried out differently depending on the companies and the background information available beforehand, meaning that either the interviews will be unstructured or semi-structured depending on which technique is more appropriate in each situation. The goal is to do six interviews as this will give various input data and a reasonable amount with respect to the time frame of the project. The interviews will be kept with high quality output rather than prioritising quantity.

The literature review will cover what SA methods and methodologies are implemented within manufacturing companies, or rather what academia believes should be implemented. The interviews, on the other hand, will be conducted so that they will provide information on what is actually implemented or not and why. This is to enable a discussion on the existence of a gap. Note that throughout the report, manufacturing companies or manufacturing industry will be referred to as the industry.

1.6 Stakeholders

This project contains two archetypes of Stakeholders. The first one is:

- Researchers in the area of sustainable manufacturing and production, since the result of this project will contribute to their field of knowledge.

The second is:

- CEO's, production engineers, environmental, sustainability consultants and engineers in manufacturing companies since this project is addressing their needs for sustainability assessment.

Apart from the two archetypes of stakeholders the examiner and supervisor mentioned below are also relevant stakeholders as the project is performed under their supervision and department.

- Examiner: Björn Johansson, Professor in Sustainable Production at the department of Industrial and Materials Science, Chalmers University of Technology.

- Supervisor: Ilaria Giovanna Barletta, PhD student in Sustainable Production Systems at the department of Industrial and Materials Science, Chalmers University of Technology.

1.7 Ethics

When information is gathered from the economic and environmental sustainability viewpoints, the result will lead to a discussion whether or not this will impact the ethics of decision making. There might be differences in what decision is more ethically correct and which is most sustainable from the other two perspectives. Generally, trade-offs occur between the three pillars, economics, environmental and social. This might stir a discussion regarding ethical decision-making.

Furthermore, environmental aspects are an ethical discussion since its effects have become prominent in later years. The decision on whether or not to make environmental improvements in a company can always be affiliated to ethics since it requires a trade-off on what decision and area is more important than the other.

2
Methods

The methodology presented in this chapter is a step-by-step run-trough of how the analysis was carried out. It begins with describing the process of the literature review in detail and then thoroughly presents the process of conducting the interviews. Lastly it presents how the information from these two sources was used as material for the rest of the report with the aim of answering the RQs presented in the previous chapter.

2.1 Data collection

A systematic approach of the reviewing process suggested by Creswell (2014) were practised to capture, evaluate and summarise the material from the literature. Two options of databases, Web of Science and Google Scholar was deemed inappropriate. This because Google Scholar contains articles with little to none approval of quality, and Web of Science with too high requirements for articles to be included. Scopus database provided an appropriate trade-off since all articles have to go through adequate publication requirements, but not too strict to leave out crucial articles. Below follows a detailed description of all methodological steps involved in the process of the literature review presented in the order that they were executed.

2.1.1 Selection of keywords

To get a sense of what keywords are relevant for the project, a number of articles relevant to sustainability provided by the project supervisor were studied (Barletta, 2016; Sala, Ciuffo, and Nijkamp, 2015; Ness, Urbel-Piirsalu, Anderberg, and Olsson, 2007; Pagoropoulos, Pigosso, and McAloone, 2017; Herrmann, Bergmann, and Thiede, 2009; Peruzzini and Germani, 2014; Margherita Peruzzini and Pellicciari, 2016; de Olde, Bokkers, and de Boer, 2017; Heijungs, Huppes, and Guinée, 2010; Arvidsson et al., 2017; Anastasiia Moldavska and Welo, 2015; Stevens, 2014; Harder, Holmquist, Molander, Svanström, and Peters, 2015; Zhang and Haapala, 2015; Hur, Kim, and Yamamoto, 2004; Pope, Bond, Hugé, and Morrison-Saunders, 2017; Halog and Manik, 2011; Almannai, Greenough, and Kay, 2008; Trianni, Cagno, and Neri, 2017; Herrmann, Bergmann, Thiede, and Zein, 2007; Taisch, Sadr, May, and Stahl, 2013). The articles contained certain keywords and the ones relevant to sustainability and decision making were extracted. This was done by taking the already defined keywords in the article or by suggesting new ones. All in all, this resulted in 54 keywords. To narrow the scope to a more manageable amount of relevant articles, the number of keywords were reduced. The process of reducing the number of keywords was managed in a methodological manner developed by the

group. The method for reducing keywords was divided into three consecutive steps named: filtering, identifying terminology and combining independent keywords.

2.1.1.1 Filtering

In the first step, the filtering process, keywords were compared with the two research questions RQ.1 and RQ.2. An assessment where all keywords were individually discussed and examined. The keywords were examined with respect to the relevance between the specific keyword and the research questions. If the specific word was relevant to the research questions then it was saved for further evaluation. Words less relevant were excluded.

2.1.1.2 Consistency check

The succeeding process aimed at identifying differences in use of terminology. Keywords that were synonymous were grouped together and complemented with new synonyms to form a complete set of keywords. An example would be *methods*, referring to the methods used when conducting a sustainability assessment. *Method* could in that particular context be considered synonymous with *tool*, *measure* and *system*. To account for the usage of different terminology the Boolean operator *OR* were used when searching for articles in databases to include all relevant articles despite the use of different terminology. By grouping words together and using Boolean operators, the number of unique keywords was reduced.

2.1.1.3 Combining keywords

With less amount of keywords the next and final process included an analysis of each of the words that were not considered as independently related to the topic. These words were assessed regarding if they were suitable for a combination with other independent words to form a combination with a more relevant connection to the topic. Examples of words considered as independent was *Decision-maker* and *Industrial ecology*. Words that were not considered independent were, for example, *manufacturing* and *production*. This puts the so called independent words in context with the non-independent words. By using the Boolean operator *AND* between the independent words, the words are combined and exclusively returns articles that are include both words.

2.1.2 Searching the database

As stated previously, the database Scopus was chosen as the only database. The final selected keywords were used as search words in Scopus to find relevant literature within our domain discipline. The Boolean operators *AND* and *OR* were used between the keywords. Keywords synonymous with each other were combined with the *AND*-operator and when not, the *OR*-operator was used. For clarification, see table 2.2 below. The search result was then combined with the *exclude* function provided in Scopus to narrow the result of the search to only include documents that were not connected to the excluded subject areas. Because of how the thesis was presented to be relevant within manufacturing, some subject areas in Scopus were excluded. Table 2.1 presents the excluded and included subject areas.

Table 2.1: *Included and excluded subject areas when searching the Scopus database.*

Included	*Excluded*
Engineering	Psychology
Environmental Sciences	Health Professions
Decision Sciences	Arts and Humanities
Business Management and Accounting	Mathematics
Econometrics and Fiances	Immunology and microbiology
Multidiciplinary	Medicine
	Biochemistry, Genetics and Molecular Biology
	Earth and Planetary Sciences
	Physics and Astronomy
	Agricultural and Biological Sciences
	Health Professions
	Veterinary
	Pharmacology, Toxicology and Pharmaceutics

In table 2.2 below, a presentation of the searches that were carried out are presented. This includes the chosen parameters, e.g. Boolean operators and exclude functions. A total of nine different queries were performed, see table 2.2. The result was first sorted by *Date (newest)* then restored and sorted by *Cited by (highest)*. The result of the search was limited to only show documents in English.

Table 2.2: *Keywords and search strings.*

String	*Keywords and Boolean operators*
1	TITLE-ABS-KEY ((“Sustainability assessment methods” OR “Sustainability assessment tools” OR “Sustainability assessment measures” OR “Sustainability assessment system”) AND (“Manufacturing” OR “industry” OR “production” OR “operations”)) AND (EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “PHYS”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “MEDI”) OR EXCLUDE (SUBJAREA , “BIOC”) OR EXCLUDE (SUBJAREA , “EART”))
2	TITLE-ABS-KEY ((“Decision-making” OR “decisions”) AND “Sustainability assessment” AND (“Manufacturing” OR “industries” OR “production” OR “operations”)) AND (EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “PHYS”) OR EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “BIOC”) OR EXCLUDE (SUBJAREA , “MEDI”) OR EXCLUDE (SUBJAREA , “IMMU”) OR EXCLUDE (SUBJAREA , “ARTS”) OR EXCLUDE (SUBJAREA , “HEAL”) OR EXCLUDE (SUBJAREA , “PSYC”)) AND (LIMIT-TO (LANGUAGE , “English”))
3	TITLE-ABS-KEY (´´Sustainability assessment” AND (“reasons” OR “activities” OR “drivers”)) AND (EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “MEDI”) OR EXCLUDE (SUBJAREA , “ARTS”) OR EXCLUDE (SUBJAREA , “BIOC”) OR EXCLUDE (SUBJAREA , “PHYS”) OR EXCLUDE (SUBJAREA , “PSYC”) OR EXCLUDE (SUBJAREA , “VETE”))
4	TITLE-ABS-KEY (“Sustainability development” AND (“system-based methods” OR “assessments”)) AND (EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “MEDI”))
5	TITLE-ABS-KEY (“Sustainability analysis” AND (“tools” OR “measures” OR “systems” OR “methods”)) AND (EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “MEDI”) OR EXCLUDE (SUBJAREA , “BIOC”) OR EXCLUDE (SUBJAREA , “PHYS”) OR EXCLUDE (SUBJAREA , “IMMU”) OR EXCLUDE (SUBJAREA , “ARTS”) OR EXCLUDE (SUBJAREA , “PHAR”) OR EXCLUDE (SUBJAREA , “PSYC”) OR EXCLUDE (SUBJAREA , “VETE”))
6	TITLE-ABS-KEY ((“Decision-making” OR “decisions”) AND “Sustainability assessment”) AND (EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “PHYS”) OR EXCLUDE (SUBJAREA , “MEDI”) OR EXCLUDE (SUBJAREA , “BIOC”) OR EXCLUDE (SUBJAREA , “ARTS”) OR EXCLUDE (SUBJAREA , “IMMU”) OR EXCLUDE (SUBJAREA , “PSYC”) OR EXCLUDE (SUBJAREA , “HEAL”))
7	TITLE-ABS-KEY (“Industrial ecology” AND (“Decision-making” OR “Decisions”)) AND (EXCLUDE (SUBJAREA , “AGRI”) OR EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “BIOC”) OR EXCLUDE (SUBJAREA , “MEDI”) OR EXCLUDE (SUBJAREA , “PSYC”) OR EXCLUDE (SUBJAREA , “ARTS”))
8	TITLE-ABS-KEY (“Integrated sustainability assessment” AND “Barriers”)
9	TITLE-ABS-KEY (“Industrial sustainability” AND “Circular economy”)

2.1.3 Retrieval of reviewing material

To get the best coverage when selecting material from the searches, the material was selected with respect to the criterion *influence* according to Gentles, Charles, Nicholas, Ploeg, and McKibbon (2016) under the chapter *Purposefully selecting literature on conceptual grounds*. *Influence* meant choosing articles that were referenced many times. This was achieved by selecting the 20 most cited articles from every separate search. To get the latest information about the subject, the 20 most recently published documents were also collected from the database. A total of 40 documents were elected per search where this method was applied. This was motivated by the presumption that the most cited documents covered early, groundbreaking subjects in the area but that the newest documents included the latest view points and updated information. If the search generated less than 40 documents then all documents were collected.

All documents collected from Scopus were evenly divided between the members of the project group. The documents were then evaluated on their ability to contribute to the project. The evaluation process was done by reading the document's abstract and conclusion, it was then decided whether or not the documents could contribute to the thesis. The documents that were relevant for the thesis were noted down. If the reader was not able to determine the level of relevance then the particular document was brought to a discussion within the project group were a consistent decision could be made. Even though a document could treat a different area then manufacturing within the subject of sustainability assessment, e.g. biofuel production the document could still be considered as relevant to the project because it could contribute with information that might be considered as general and thereby present in both areas.

2.2 Interviews

The other source of information for the project was collected from interviews with seven representatives, five people at different positions from three Swedish manufacturing companies based in the Gothenburg area, one researcher with extensive experience from the industry working at a Swedish technical university and one from a consultancy firm within sustainable production. All interviews are presented in Appendix A.

For confidentiality reasons, names of interviewees will not be revealed but their titles and the company or department of the university they are employed at, will. Below follows which number refers to each interview.

(1) Volvo Group Trucks Operations
Manufacturing technology manager

(2) The Institute of Technology at Linköping University.
Associate professor in Sustainable Production

(3) SKF
Project leader in Product Environmental Compliance and Performance

(4) SAAB Surveillance Gothenburg
Quality manager - Surveillance Business Area

(5) Volvo Group Trucks Operations
Director of Research & Technology Development

(6) Effort Consulting
Management consultant

(7) SAAB Surveillance Gothenburg
Environmental Manager - Gothenburg site

In the interviews, Appendix A, Q is denoted for questions and A is denoted for answers from the interviewees.

2.2.1 Structure of interviews

A qualitative interview was chosen for this project because it gives the respondents the ability to share their experiences. The interviews began with open questions and ended with specific questions, using the Funnelling Technique. The purpose of openly formulated questions was to avoid the interviewee to be affected in their answer. Negations, conductive and long questions were avoided. New ideas were allowed to be brought up during the interview as a result of the interviewees earlier comments. The interviews had low grade of structuring and gave the respondent the opportunity for a broader response. The questions were well prepared and compiled in a formula with high grade of standardisation to ensure they could be replied to (Patel and Davidsson, 2011). The question formulae was sent to the interviewee a few days prior to the interview to enable them to prepare some answers.

2.2.2 Selection of interview questions

Problem oriented sub-questions were generated through brainstorming and discussion within the group. Here, problem oriented means that the questions were angled towards as if there were issues in the different areas such as implementation and prioritising in the company regarding resources. The sub-questions emanated from RQ.2 were each sub-question intended to partly contribute to answering the question of origin. The first draft included many different questions, all related as sub-questions to the two more comprehensive research questions. The sub-questions were later reduced by rewriting them in a more open form to include only the most relevant questions that would suit all interviewees. The re-written questions were compiled into a smaller and standardised question formulae, divided into the sections: *Company approach*, *method-related*, *information*, *limitations*. The different sections provided the interview with an easily followed structure. The interviewees were presented with the same questions in order to give a standardised format of the answers.

2.2.3 Selection of interviewees

The interviewees were carefully selected by expertise from the project supervisor and PhD student Ilaria Barletta with knowledge in the subject of sustainability assessments. Some of the approached interviewees where employees from four different companies within manufacturing were three were actors in the automotive industry and one from the aerospace and civil security industry. Furthermore a consultant within sustainable development and a professor with extensive experience from the industry working with sustainability at a technical university in Sweden, were interviewed. A total of six standardised interviews were conducted with the seven different company representatives mentioned above where the interview with SAAB was done with two representatives on the same occasion to complement each others information. The qualifying criteria for the selected interviewees were decent working experience within sustainability in the industry. This experience was important to be able to ensure and attain good results from the interview to be able to answer the questions about the situation of sustainability assessments in the industry.

2.2.4 Conducting interviews

The participants were interviewed for about 40 minutes each by the project members. Each interview was recorded and then transcribed. All interviewees were informed about the recording and was able to decline being recorded if they did not so wished. By recording the interviews, the project members could focus on the discussion with the interviewee rather than trying to take notes which also could disturb the interviewee. Three of the interviews where made face to face, two of them using video call and one by phone.

2.3 Analysis of literature data

With inspiration from Creswell (2014) under the section *A Literature Map of the Research*, categories were constructed which the research on the topic could be divided into. The purpose of the creation of categories was to organise and to visually present the material that would come out of the literature review. The categories were created through a free discussion within the group, where each member would suggest certain categories that they found relevant to the research questions. Each member got the opportunity to express their point of view which was then noted on a whiteboard. Similar suggestions were grouped together and the process continued with specifying what kind of material would be appropriate under each category. The process of grouping categories was iterated resulting in fewer categories. The categories were then sorted in the order that they appear in the full process of doing a sustainability assessment, resulting in three categories that would later form the sections in the results chapter. The categories were sorted in a certain order where the first category is the beginning of the whole SA-project and the second last category is the last step of the SA-project, i.e chronological order.

The literature documents were read and relevant information with respect to the three categories was extracted and sorted in an MS-Excel matrix under each category. The data in each category were then processed and compiled as a section in

the report document.

2.4 Analysis of interview data

The relevant information from the recorded and transcribed interviews regarding the three categories, was extracted, sorted, processed and compiled to be presented in the results chapter of the report together with information from the literature review. The full version of the interviews is to be found in Appendix A.

After the material from the literature review was categorised it was necessary to compile all the information in the relevant subsections to be able to analyse the data and find causes for a possible gap. The information gathered from the two sources of information, the literature and the industry, were compared and analysed. This analysis is the basis for the well founded conclusions that are drawn regarding whether or not there is an existing gap.

3
Results

The following chapter presents possible causes to a gap. A situation where there is a gap between state-of-the-art literature and industry needs is defined as when one or multiple factors mutually or individually contributes to an unsuccessful result of a sustainability assessment. The whole concept of SA could be illustrated along a time line with different phases. These phases are prerequisites before implementation, implementation and lastly decision-making, these and their sub-areas are illustrated as a logical structure in figure 3.1 below. The possible causes to a gap where investigated in these phases. Dividing the result into these categories makes the analysis of information efficient and structured, it also makes it possible to identify what phase of the SA that contributes the most to a gap.

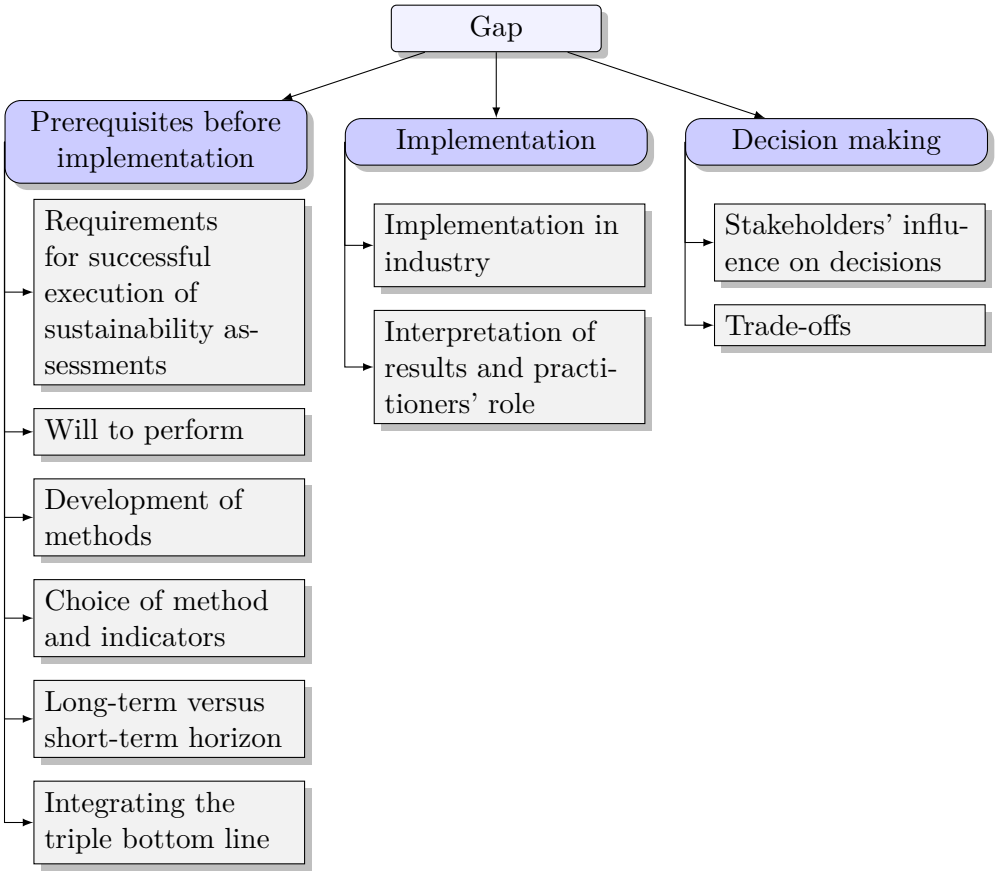

Figure 3.1: Visual representation of the organisation of the result areas in which possible causes to a gap between state-of-the-art literature and industry needs could occur.

3.1 Prerequisites before implementation

Before an SA-method can be implemented in a company's production, the preparation and planning processes needs to be done before deciding which SA-method to use. This part of the process is characterised by preparatory work like setting a scope, requirements for managing an SA and how the function of an SA-method is dependent on how it is developed. In this chapter, causes to a gap that are coherent with the attributes of SA-methods in general and requirements for a successful SA are presented.

> Despite the growing interest in application of sustainability assessment in the manufacturing and a great number of developed assessment tools, only few of them have been used by manufacturing companies. One of the reasons is that sustainability assessment tools may appear too theoretical and abstract, or too technical and complicated for manufacturing companies. Researchers attempt to create the ideal assessment tool, whereas manufacturers do not know from where to start their journey toward sustainability, causing a gap between the two communities (A. Moldavska and Abreu-Peralta, 2016).

3.1.1 Requirements for successful execution of sustainability assessments

If the manufacturing industry is going to be able to successfully manage SAs there is a need for certain requirements from methods in general to be met. These requirements would facilitate the following process of doing an SA and are presented in detail in this section.

As there is an increasing popularity for SAs, which Plevin, Delucchi, and Creutzig (2014) states, then there is a need for clear guidance for the SAs to become successful. For companies to become more profitable and survive in the long run the business strategy has to take into account the concept of sustainable development and be adapted in order to satisfy the increasing environmental and social demands, according to Cubas-Díaz and Martínez Sedano (2018) . Regarding A. Moldavska (2017) , the top five factors for an SA to become successful, ranked by 104 sustainability professionals are: *leadership commitment*, *sustainability strategy*, *data collection capabilities*, *understanding of purpose and benefits of SA* and *focus on continuous improvements*. For SAs to be successfully developed and implemented as well as supporting well founded decision-making four requirements must be met, which Halog and Manik (2011) states: It must be supported by scientific and technological means, frameworks to support policy-making needs to be well-formulated, participation from public stakeholders need to be actively involved from the beginning and support the process throughout. These requirements are backed by multiple sources (Halog and Manik, 2011; Bond, Morrison-Saunders, and Pope, 2012; Aliabadi and Huang, 2016). Ramos, Ferreira, Kumar, Garza-Reyes, and Cherrafi (2018) for example argues that incentives and management support was specifically considered fundamental for the successful implementation of improvements. Moreover, according to Efroymson et al. (2013) , to be able to effectively incorporate the measurements with the expected outcome of an SA, clarification of definitions, aim and priorities

regarding sustainability is essential. Gibson (2006) also highlights the importance of the preparation process ahead of an SA and specifies the need of SAs that clearly states the decision requirements and rules for compromising a decision in certain situations with participation from stakeholders.

At the design stage within a product or process development, it is important to introduce sustainability considerations. Decisions at this level determine more than 70 percent of the cost of product development and manufacturing (Waage, 2007). SAs are rarely made in the design phase of a system. The assessments are traditionally made when the system is completed and fully implemented. The problem with assessing a system in the design phase is the consideration of effects of processes upstream and downstream in the system, especially the economic and social aspects. If problems with the system are identified during the design stage, then issues could be solved with reduced cost of changes and less time consuming with more long term perspective compared to if the system is already implemented (Saavalainen et al., 2017; Margherita Peruzzini and Pellicciari, 2016).

On the other hand, the downsides of application of SAs in the design phase are not absent. There are several methodologies that have one or more disadvantages in terms of utilisation, such as comprehensiveness, requiring detailed process data, qualitative, time consuming and dependent of the quality of data collected. For application early on in a design phase these factors mentioned are disadvantageous (Ordouei, Elsholkami, Elkamel, and Croiset, 2016). There is especially a lack of frameworks in manufacturing for introducing sustainability assessments already in the design phase. More specifically, what is missing is guidelines for merging of environmental assessment with cost and human-related issues management. There is also poor availability of a practice method for anticipating the assessment of impacts in the design stages (Margherita Peruzzini and Pellicciari, 2016).

3.1.2 Will to perform

The level of the industry's motivation to use SA-methods could lead to an unsatisfying analysis of the SA due to low level of ambition and engagement to receive a complete analysis as possible. This section treats the incentives of what makes industry apt to perform regarding sustainability.

The ever increasing popularity within the automotive industry to perform SA is driven by many different causes. One of which is based on the fact that the automotive industry is one of the most resource-intensive industrial systems in the world (Jasiński, Meredith, and Kirwan, 2016; Paper, 2018). This increases the demand for SAs, both from the automotive industry and from the society itself. This becomes problematic when the same industry is unlikely to over-perform when it comes to sustainability, but rather barely stay above the regulations set up by authorities (Jasiński et al., 2016).

On the contrary, a director of Research & Technology Development at Volvo Group Trucks Operations (5) argues that they are often not just passing the environmental legislation. Instead, they strive to be a more environmentally conscious company

which aims to pass the limit with a good margin. Instead of adapting later, they try to foresee the evolution of these legislation so that they can work proactively. When the legislation later comes into effect, they have already implemented or switched to the technology that the law permits. (5) also pointed out the strategic benefits of this approach if a recession hits, they stay ahead of regulations so that the large investment of resources that SAs are, can be done when the economy is thriving. Continuing, (5) also argues that the reason Volvo Group Trucks Operations is working with sustainability is cost rationalisation, environmental goals and environmental legislation. If the company wants to expand operations to a certain country, they have to comply with current environmental legislation there. Since customers are sensitive about the environmental impact, (5) continues, it is not enough to barely stay above regulations, especially if the brand is a premium one. As the bar for needed sustainability work is passed, there is rarely any driving force left for companies to perform further.

A management consultant at Effort Consulting (6) who is continuously contacted by manufacturing companies says that many times it is certifications they are after. This to be able to show different stakeholders, as well as potential and current customers, that they are up to par when it comes to different areas, often through certifications such as ISO9000, ISO14000, ISO45000 and Svanen. Another key aspect, (6) argues, is the strongest actor at the end of the chain, such as leading manufacturing automotive companies, who sets demands on their suppliers to prove that they work seriously with quality and can deliver high quality products, for instance through previously named certifications. A project leader in product environmental compliance and performance at SKF, (3), also states that some certificates are requirements from investors or banks as well. This is because if the company can show fewer risks, and more desirable risk management, the company can secure better loans.

An associate professor in sustainable production at the Institute of Technology at Linköping University (2), argues that companies often perform SAs when they want to find out something specific about their production. For example, what impact a certain product they manufacture has on the environment. (2) also states that the main purpose of assessments from a company perspective is to get a better idea of what a company's footprints or environmental impacts are.

3.1.3 Development of methods

In this section, factors related to how development of SA-methods affect the actual design and function of the method are presented. The design and function further decide if the method would be suited in the industry or not.

SA-methods are often developed with multiple stakeholders considered compared to the implementation in practice in manufacturing companies, where the assessments are rarely made with respect to more than one stakeholder, according to Nee, Song, Ong, Conference, and Engineering (2013) . Sala, Farioli, and Zamagni (2013) and A. Moldavska (2017) claims that stakeholders' involvement in the decision-making and implementation of the SA should be further developed to create a more nuanced

tool that incorporates all the different stakeholders.

The future development of SA-methods is impaired due to a deadlock condition within the scientific community. Phillis and Andriantiatsaholiniaina (2001) describes the situation as a consequence of researchers waiting for crucial political issues to be considered by policy makers, while at the same time policy makers are waiting for crucial ecological measurement and ecological issues of sustainability to be highlighted and raised by researchers. The developing process of certain SAs are based on a technical mindset rather than on the wishes and aspirations of the practitioners of the methods. Arvidsson et al. (2017) explains that SAs are often developed with the current technology and the current effect on the TBL in mind, but not implemented in the industry until long after the tools tend to become outdated. This delay in implementation in combination with outdated technology and viewpoints creates inaccurate tools. A management consultant at Effort Consulting (6) claims that there is a situation where many similar methods are created and labelled as a method of their own, causing confusion in the industry when it really is almost the same content. The more specific the method is, the harder it is to see the entire picture, (6) claims.

Since "soft" values are hard to quantify, developers use enormous resources developing extensive frameworks to make them quantifiable. On one hand these frameworks make it possible to quantify indices, on the other hand it creates complex tools for the users who needs them the most, argues Bell and Morse (2001) . An associate professor in sustainable production at the Institute of Technology at Linköping University (2) says there is a problem when researchers do all the work themselves when developing methods for implementation on a company's production. An example is given in an article written by Peruzzini and Germani (2014) , who state that there are numerous tools for assessing the sustainability of Product-Service Systems (PSS) and extended networks but even though the vast offer of methods, they tend to be too theoretically orientated and hard to implement on real processes.

Furthermore, the professor in sustainable production, (2), continues on by stating that researchers who develop the methods needs to put more time in collaboration and incorporate the company and those who will use these tools in the development process. In cases where involvement from the industry is limited an American research team bridged this by developing a method with a generalised perspective, making it easy for companies to understand and implement the thought, principles and guidelines of design and manufacturing at the companies. (2) also claims that for companies to be able to master the function of co-developed methods they need an explicit person or function internally who takes over the development, keeping it up-to-date.

3.1.4 Choice of method and indicators

For industry to achieve a satisfying qualitative result from an analysis, the proper method needs to be selected. There is however different circumstances that could lead to a less suitable choice of method or measures, these are presented under this section.

The wide spread of applications, processes and practices in combination with the general, broad view of sustainability leads to additional challenges for researchers and practitioners. There is a risk that inappropriate assumptions and conclusions are being drawn about certain SAs where they might be considered appropriate for use in areas where they are not applicable. To lower this risk there is a need to understand diversity of practice and suitability of an assessment process for a specific case according to Pope et al. (2017) . A project leader in Product Environmental Compliance and Performance at SKF (3) discusses when there is a valid argument for making an assumption such as a simplification, i.e. not measuring certain parameters in production called a cut-off. (3) insists that if the question is about deciding "yes" or "no" regarding a process in the factory and the process does not affect the intended area of measurement or if the simplification is insignificant for some machines or processes this is valid to exclude. The project leader further claims the knowledge of making a simplification or not to be about routine and work experience of the employee in charge to know which factors who do not matter in the analysis.

Efroymson et al. (2013) claims that the choice of indicators could vary significantly depending on, for instance, where the company's production is based. In a certain location, one indicator might be considered more relevant than another. It is up to the stakeholders to decide what indicators are going to be selected and the importance of stakeholders influence on the selection are often underestimated. Another situation where there is a high demand regarding the choice of indicators is in manufacturing companies that produce a significant amount of bi-products valuable for the after-market due to more complex demands on the measurement of the indicators (Efroymson et al., 2013).

According to a project leader in Product Environmental Compliance and Performance at SKF (3), it is important to understand what is to be answered by the analysis to be able to make a proper choice of what to measure. This happens through discussion on what the team finds relevant. In Life Cycle Assessment (LCA), questions such as "What is the function?", "What is the goal and scope?" could arise. SKF tries to implement these in ISO-standards. However, there is no process to follow and it cannot be read from a paper or a flowchart. It is more about discussing what would be an appropriate measurement method. An associate professor in sustainable production at the Institute of Technology at Linköping University (2) finds inspiration from other companies and inspect how other companies implement methods and their results. This way they can try to find methods that are only some part of an existing method or processes that they use. Companies do not want to use any stand-alone tools that are time consuming for them, but instead try to get environmental aspects into methods and product development processes or simulation gear. Companies encounter a great deal of difficulties on how to find all these methods developed by researchers. Most methods developed by researchers are hence not applied. Similarly to what (2) mentioned about making use of others' experiences, a project leader in Product Environmental Compliance and Performance at SKF, (3) mentioned that in terms of methods, at SKF, they use a lot of advising from Swedish Life Cycle Center (SLCC) where Swedish companies

help each other out a lot with what is new and what their concerns are. Networking and consulting is of utmost importance.

For a company such as SAAB Surveillance with few products in the production, the company is experiencing problems with finding SA-methods to be used on their production. A quality manager at SAAB Surveillance (4) claims that the company's small production volume, which to a large extent is a "dry" production, is not suited for SAs, in comparison to more lean-based productions with higher production volume. A director of Research & Technology Development at Volvo Group Trucks Operation (5) explains how they previously had a department working specifically with LCA but has now decided to outsource. This, due to low utilisation and it was also difficult for one central department to cover the whole organisation globally with respect to competence. Volvo Group Trucks Operation expect the suppliers of these services to meet requirements and keep the competence up to date. They still have one person with required competence regarding these assessments, who could discuss more specific details with the SA suppliers.

Peruzzini and Germani (2014) argues that some SA-methods have a very narrow scope, making them limited to the specific area of focus. However, in Gibson (2006) it is highlighted that one of the strongest aspects regarding SA-methods is how many of the methods can be applied to a variety of cases and different scenarios due to the flexibility that comes with a majority of the methods. Even though these methods could be applied to a lot of cases, other problems could obstruct a successful implementation of the method. An associate professor in sustainable production at the Institute of Technology at Linköping University (2) means that simpler and more implementable methods have been developed to offer companies less resource-intensive methods. However, the associate professor claims that the credibility of the result of these methods is low and therefore there will be a trade-off regarding the accuracy regarding which method companies choose to implement. The management consultant at Effort Consulting (6) says that a lot of work with SAs consists of adjusting the method for the assignment that is given which can be very different from case to case. It is rather impossible to send an organisation through an SA-method, meaning that it would be too roughly performed and further claims that it is more about working with human change instead, which (6) claims is always hard.

3.1.5 Long-term versus short-term horizon

In this section, certain method's limitations regarding the time frame they are valid is presented. Likewise, the attitude of industry to focus on improvement from a certain perspective, the consequences of it and how it affects the ability to use SAs and to make decisions towards sustainable improvements in industry is presented.

Many SAs have the disadvantage of not being able to predict mid-term to long-term changes regarding considered impacts. In today's constantly changing world, methods such as LCA becomes incomplete due to its inability to include dynamic elements required when the scope is widened beyond a short-term perspective, according to Arodudu, Helming, Wiggering, and Voinov (2017) . Another method ex-

periencing difficulties dealing with the long-term perspective is Eco-Efficiency (EE), according to Huppes and Ishikawa (2005) . It indicates a relation between empirical and economic activities, such as a cost or a value and an environmental impact. When applying these given costs and values in the assessment, Huppes and Ishikawa (2005) believe believe various empirical issues with a long-term aspect must be resolved, as changing market values have a direct impact on the EE score.

Gibson (2006) argues that even though some tools are unable to predict changes in the longer perspective, there is a situation in the manufacturing industry where the benefits of long-term improvements are often overlooked. A management consultant at Effort Consulting (6) describes a situation where they are contacted by a company that wants to improve its production regarding sustainability. When trying to help the company towards sustainable production, they sometimes need to include more areas in the analysis which the company has previously overlooked. To convince the company's management team of the importance to include those areas in the analysis is, according to the consultant, considered to be challenging. Companies are often aware of not focusing enough on some areas and has therefore already chosen to exclude this. The main problem to overcome is the short-term thinking and that the suggested improvement might not be profitable in the most recently upcoming annual reports but rather in those in, say, five to generate a positive economic result in the short term. This becomes a problem when trying to integrate the environmental part in the improvements since a longer perspective is required for environmental improvements to prove beneficial. Companies tend to be discouraged to fund and use an SA-method without guarantees that it will pay off since investments in these methods tend to be costly years. In those later years it will be important to already have implemented the changes because the society is increasingly realising that the industrialisation has not been sustainable. Here, the consultants have to persuade management into changing their minds in establish trust. Hacking and Guthrie (2008) suggested from a literature review that if the criteria of the SAs are clearly stated then it is easier to follow through and implement the long-term improvements and lower the risk of focusing on the short-term goals that are more economic and politically oriented leading to the neglecting of the environmental aspects. The benefit of focusing on the long-term perspective is that it makes an easier integration of areas regarding the TBL.

3.1.6 Integrating the triple bottom line

The ability to incorporate different areas into one coherent, optimal result is argued by many researchers to provide sustainable solutions. Difficulties when trying to do this integration using SA-methods is analysed in this section.

Buytaert et al. (2011) discusses how different SA tools cover different areas. In general, most of the tools are environmentally focused, for example; LCA, Environmental Impact Assessment (EIA) and Sustainable Performance Assessment (SPA) while other methods such as Cost Benefit Analysis (CBA) focus on the economic dimension. Because many SAs are based on environmental grounds only, there is a fundamental flaw since sustainability can only be achieved through sustainability in regard to all dimensions, also known as the TBL: the aspects of economic, environ-

mental and social. A quality manager in the Surveillance Business Area at SAAB Surveillance agrees with this, since (4) explains that sustainability is more than just environmental impact, as it also consists of social and economic aspects (4). This results in the need to integrate different SAs by taking into account broader externalities, interrelations and stakeholders, these with often conflicting requirements and needs (Jeswani, Azapagic, Schepelmann, and Ritthoff, 2010; Halog and Manik, 2011). Add to this the complex interrelated and complementary aspects of the three dimensions of well-being; economic, ecological and social, and it becomes obvious that it is a very complex task to achieve sustainability among environmental, economic and social goals of the community, allowing for well-being of the present without compromising for future generations (Ciegis, Ramanauskiene, & Martinkus, 2009).

There have been many attempts to integrate the different pillars of sustainability with the help of performance indices, different surveys and tools to create economic indicators of the environmental and social performance of companies to mention some, but all fail to present any formula for simple calculation (Cubas-Díaz and Martínez Sedano, 2018; Sala et al., 2015). For example LCA has been modified many times to cover more aspects and interrelations; Life Cycle Thinking (LCT), Life Cycle Sustainability Assessment (LCSA), Environmental Life Cycle Assessment (ELCA), Life Cycle Assessment (LCA) and Social Life Cycle Assessment (SLCA) to mention some (Jeswani et al., 2010; De Luca et al., 2017). According to the sustainability consultant at Effort Consulting (6) the problem lies within the complexity of sustainability. Value chains may stretch as far away as Asia, and social values are both different and hard to keep track off. It is harder the more you involve and it is therefor easy to skip this aspect, which he argues is something that often occurs. This creates the importance of understanding the entire spectra but still keeping focus on the important issues.

To implement and integrate all three sustainability dimension, a lot of criteria are used which often leads to intermediate results which may be important for the expert but may be difficult to interpret in decision-making (Hannouf and Assefa, 2017; Kolotzek, Helbig, Thorenz, Reller, and Tuma, 2018). Kolotzek et al. (2018) argues that this leads to issues with the interpretation which in turn leads to ethical problems of weighting different areas of the TBL against each other. Moreover, the inability to incorporate the three pillars leads to a less reliable result and is due to both scarcity of data and unsolved methodological problems, according to Phillis and Andriantiatsaholiniaina (2001) .

3.2 Implementation

The second step of an SA is the implementation of the method in the industry. Issues occurring during implementation of previously developed methods, which leads to interpretation issues of inadequate results are presented in this section.

3.2.1 Implementation in industry

To successfully implement an SA-method, its demands needs to be fulfilled by obtaining sufficient information. Possible pitfalls regarding obtaining relevant information will be presented in this section.

SAs carried out in the manufacturing business often incorporate products and processes with tens of thousands of components and parts. It becomes obvious that structured and well defined data is crucial in the first steps of an SA (Stindt et al., 2017; Perrin et al., 2017; Phillis and Andriantiatsaholiniaina, 2001; Hertwich, Pease, and Koshland, 1997; Hannouf and Assefa, 2017; Saavalainen et al., 2017; Ordouei et al., 2016). For many tools within SAs, the tolerance of imperfect data is low and the data requirement is extensive, in which the implementation, e.g. analyse complex manufacturing systems, of the method would be too complicated (Hertwich et al., 1997; Anastasiia Moldavska and Welo, 2015). It is also unclear how to use proximate information when dealing with data gaps, which makes the assessment even harder. At Volvo Group Trucks Operation, a director of Research & Technology Development (5) says that they are looking at which processes that have a greater impact and are easier to get relevant data from when evaluating which changes can provide the most beneficial results. Processes with a manual workforce are according to (5) more difficult to to analyse and visualise what a change in the process may do to the outcome.

When seeking out what people from the manufacturing industry considers to be important when implementing SAs, A. Moldavska (2017) came up with the conclusion that lack of time, focus on the economic issues, weak cooperation between the departments and a lack of systematic work with measurements are preventing an implementation of Corporate Sustainability Assessment (CSA) effectively. The situation where tools and methods are not used are caused by different complexities. According to a manufacturing technology manager at Volvo Group Trucks Operation (1) it is mainly because the methods are either time-consuming, resource-intensive, data-demanding or a combination of the three. A project leader in Product Environmental Compliance and Performance at SKF (3) stated that academia has a completely different long-term perspective and has more time to work with the methods compared to the industry. In the industry there is often a lack of time which can make the methods too complicated for the industry to use.

Hacking and Guthrie (2008) claim that when using and implementing SAs in developing countries the unavailability of data is a big issue and can further increase the uncertainties in such estimates. An associate professor in sustainable production at the Institute of Technology at Linköping University (2) and a project leader in Product Environmental Compliance and Performance at SKF (3) mentioned that

the ability to access data is challenging. In some cases, (3) explained, there are sub-contractors who manufactured a product for the company, that are not willing to give up information if there is no legal requirement for them to do so. It is then difficult to collect all the data required for an assessment. At SKF, (3) also mentioned that to gather all the relevant data takes a lot of time. He gave the example of trying to measure energy levels when a factory is in standby mode can take several months. Even the credibility of the data is of importance, who is the information from and what the educational level of those at the companies are weighted in.

Generally, for all methods the data requirements and methodological agreements are the biggest challenges, according to Buytaert et al. (2011) . Hertwich et al. (1997) and Hannouf and Assefa (2017) discusses further that this is mainly because SAs often require large and specific amounts of data which makes the collection difficult. For example, Graymore, Sipe, and Rickson (2010) evaluated the effectiveness of five commonly used SA frameworks at a regional scale: Ecological Footprint, Ecosystem Health Assessment, Well-being Assessment, Quality of Life and Natural Resource Availability. Evaluating the five frameworks at that level turned out to be difficult due to two factors; the extensive amount of data and the availability of it at that particular level. Phillis and Andriantiatsaholiniaina (2001) states that an SA becomes more difficult when the scope is widened to include regional, national or international level due to a less firm connection between cause and effect.

A management consultant at Effort Consulting (6) describes that the first stage in a sustainability project at a company is to look at if there is sufficient quantitative data delivered by the company. Commonly there is not, and they need to collect further data. They also perform interviews to collect more qualitative data. Based on this, the consultants can make certain conclusions about what kind of company it is and what their strengths and weaknesses are. Saavalainen et al. (2017) discussed how qualitative and quantitative data respectively compliment each other. Despite the challenges of collecting quantitative data it is argued that implementing only improvements based in qualitative data are inadequate. If the manufacturing industry is to become sustainable, the assessments need to be based on quantitative data as well. To more easily collect quantitative data from the processes in the industry it is important to make the environmental impact of the new product design and manufacturing processes quantifiable. This needs to be done by the manufacturing company parallel to its economic and social responsibility goals, argued by Raoufi et al. (2017) . A manufacturing technology manager at Volvo Group Trucks Operations (1) explained how the academic approach considers a lot of specific indicators and parameters which are not adapted to the industry and could be hard to implement. Kolotzek et al. (2018) states that it is not always possible to quantify required parameters, both due to the nature of the parameters, but also the lack of required data. This leads to the final weighting of indicators being ignored and as a consequence the SA might be incomplete in a corporate context. Since indicator weighing is used for developing corporate strategies towards sustainability goals, important input regarding improvement is put at risk of not being forwarded to executive decision-makers (Kolotzek et al., 2018).

3.2.2 Interpretation of results and practitioners' role

Practitioners role in a company is to implement and analyse SA-methods. When the analysing part of an SA-method is completed and a result is acquired, the result needs to be interpreted by industry's decision-makers in order to make a decision towards sustainable improvements. In this section possible pitfalls regarding practitioners' ability to do analysis and pitfalls during the interpretation phase are brought up.

Traverso, Asdrubali, Francia, and Finkbeiner (2012) argue that it is not only the large data requirements that make some SAs hard to use and implement. It is also the challenge of how to take such complex and potentially confusing data and present it in a straightforward manner to decision-makers who might not be experts in the field of sustainability.

Despeisse, Ball, and Evans (2013) provide information about the importance of combining a thinking framework with an action framework to establish more clarity for practitioners in conducting practice improvements. Combining these two frameworks would enhance the connection between industrial ecology, cradle-to-cradle and improvement strategies. According to Raoufi et al. (2017) practitioners lack proper tools and training regarding sustainable development of systems and tend to use an ad hoc approach. This highlights the importance of a well-educated workforce with the right competence within the sustainability environment to be able to provide the manufacturing area with superior sustainable solutions from the TBL. Methods for assessing the sustainability of a design of a manufacturing process, such as the combination of Unit Manufacturing Process (UMP) and Life Cycle Inventory (LCI) are examples of methods needing expertise, making them hard to use for engineering educational purposes (Raoufi et al., 2017). According to an associate professor in sustainable production at the Institute of Technology at Linköping University (2), there is a challenge to understand how the methods work and how it can be difficult for people with lack of educational experience and knowledge of the methods, to understand what is defined as relevant data. (2) also pointed out that companies do not always provide enough time for practitioners to implement an SA. If the company however do have enough time to do the methods properly and ensure that the information is correct, the associate professor suggest to perform the methods several times or letting consultants or students do them as (2) claims they have more time and resources than the companies have.

LCA tools strengths in assessing machining processes are, according to Goindi and Sarkar (2017) , their ability to assess the sustainability and environmental impact. Its weakness, however, is how easily the results can vary depending on the choice of UMP. To give a correct analysis, consideration of choice of UMP is therefore of high importance. This was stated when presenting a comprehensive review of dry machining. The results of the methods, Attributional Life Cycle Analysis (ALCA) and Consequential Life Cycle Analysis (CLCA), are subjects to variation and depend on the preferred choice of methodological steps, such as the procedure of how effects are modulated, made by the person in charge of the model (Plevin et al., 2014). At SKF a project leader in Product Environmental Compliance and Performance (3), discusses how they often make so called cut-offs to exclude data that does not

have a high impact on the result. Regarding the methods that are being used, these cut-offs are based on previous experiences and how well-educated the practitioners are. The problem with a cut-off can be, according to (3), that the cut-off exclude too much data, which leads to a misleading result.

The final result handed to decision-makers could also be affected by how some calculations in production are difficult to give precise results because of uncertainties in variables. Therefore, estimated values are often employed instead. The director of Research & Technology Development at Volvo Group Trucks Operations (5) explained that their previous department often used overall work experience when trying to estimate values and the importance of doing the same estimates every time through consistent thinking. To take notes of the process, it will become a new method usable in situations where time is insufficient or simplification of a method is needed. According to (5), the most important thing is that the methodology of the simplified method is executed the same way. Efroymson et al. (2013) further highlights the lack of adequate data available to be analysed as decisive for the outcome of the analysis. When working with models that calculate indicator values, the lack of adequate data will lead to difficulties when selecting and interpreting indicators which may result in untrustworthy projections.

3.3 Decision making

The last step of an SA is the decision making. Activities that relate to the decisions has to be made after the implementation process when the results of the SAs are received and included. Difficulties in making the correct decision could lead to wrong decisions being made and the purpose of the SA is lost.

> By shifting the decision-making process from a debate about values, in which everyone feels qualified to participate, to a scientific calculus, which only certain highly trained experts can authoritatively critique, cost–benefit analysis takes control away from the citizenry and places it in the hands of an elite corps of expert economists (and those who can afford to hire them) (Jasiński et al., 2016).

3.3.1 Stakeholders' influence on decisions

To make improvements regarding results of SA-methods, decision makers have to make correct interpretations of the received information from practitioners. Following section will present possible issues when involving stakeholders interest in the decision-making phase.

Decisions towards sustainability should be a function which depends on economic, environmental and social aspects and goals. When the industry is making decisions towards improvements after an SA, all three aspects should be considered together and intertwined (Gibson, 2006). Decision-making has two sustainability goals according to Andriantiatsaholiniaina, Kouikoglou, and Phillis (2004) . Firstly, *achievement of human development to secure high standards of living* and secondly *protection and improvement of the environment now and for the generations to come.*

Gibson (2006) states that environmental aspects have long been treated in second hand by decision-makers in the industry where other more prioritised areas in the organisation have been favoured for decisions towards improvements.

Decisions that are most likely to be affected by contextual factors, i.e. emotions and expectations from stakeholders are decisions within areas of context-specific character. These contextual factors will decide if a change in the organisation is viable or met with scepticism (Gibson, 2006). To support decision-making processes involving different types of stakeholders with different skills, LCSA can be considered as a valuable tool (Traverso et al., 2012). LCSA enables working towards sustainability by providing decision-makers with guidelines regarding priorities inside the company concerning resources and investments to make decisions towards use of sustainable technology and products (Valdivia et al., 2013). The purpose of an integrated solution-oriented approach such as the one provided by LCSA, is to demonstrate how LCSA can be used by decision-makers and to select the alternatives most sustainable (Hannouf & Assefa, 2017). If the SA is somehow unsuccessful, an undesired outcome occurs which is defined as when the SA recommends a more harmful product or progress, according to (Hertwich et al., 1997).

3.3.2 Trade-offs

Trade-offs are an important aspect when making decisions by interpretation of result and stakeholders interest. In this section, issues related to trade-offs will be presented.

Trade-offs in decision-making are essentially unavoidable and they are value charged (Gibson, 2006). Hacking and Guthrie (2008) claims that trade-offs are undesirable in theory, but are usually inevitable in reality and thus, compromises must be made. Bond et al. (2012) claims that these trade-offs are crucial for making sure the decision making based on the result of an SA are not disadvantageous for the industry that they are applied within, nor regarding their effect on the TBL. To be able to manage trade-offs, decision-makers need to ensure that SAs account for any sustainability trade-offs. This could be done by following guidelines on how to handle a certain trade-off situation, Bond et al. (2012) claims.

In Hacking and Guthrie (2008) , they discuss the need for politicians to get involved in the trade-offs within companies. A project leader in Product Environmental Compliance and Performance at SKF (3) also agrees to this statement, saying that there is a gap between academia and politicians. The demands of society must come from the European Union or other government, as all companies and individuals do not possess incentives for better environmental performance. Phillis and Andriantiatsaholiniaina (2001) states the need of a tool to bridge politicians influence on decision-making regarding sustainability assessments.

A decision based solely on a specific scenario can produce undesired results in another. It is important that decision-makers perform a complete system view using tools like LCA (Bond et al., 2012). Although some uncertainties exist, an SA-method

such as LCA can produce useful information to support decision-making (Plevin et al., 2014). According to a director of Research & Technology Development at Volvo Group Trucks Operations (5) it is possible to enter LCA as a parameter in the product development process and make trade-offs where it is visible that improvements can be done, related to the environmental aspect, without it costing a lot of money. Plevin et al. (2014) states that to interpret the results of an LCA it is important understanding the method, used data in the analysis and significance of made assumptions. Decision-makers who use the results of LCA may otherwise be mislead, leading to the wrong decision being made (Plevin et al., 2014).

4
Discussion

The results from the analysis are discussed in this chapter. First and foremost all the major findings of causes to a gap from the analysis are presented in a figure, then each category's findings are further discussed. At the end of the chapter, limitations to the analysis and future research are reflected upon.

4.1 Major findings

The most significant findings to possible causes to a gap between state-of-the-art literature and industry needs are discussed in detail in this section. The causes are sorted and discussed under the same corresponding section they appeared under during the result chapter for a clear structure of the analysis. Below follows a visual presentation of these core causes in figure 4.1, where the causes are illustrated as the bubbles outermost from the origin. These main factors are considered as the most common according to our analysis and could individually or mutually contribute to the gap between state-of-the-art literature and industry needs.

Figure 4.1: Illustration of major findings from our comparative analysis. The figure illustrates possibles causes of a gap between state-of-the-art literature and industry needs.

4.1.1 Prerequisites before implementation

The core causes related to methods presented from researchers and the preparatory work that comes with them are discussed. What the discussed causes have in common is that they are all part of the first process of an SA before the actual implementation of the methods in the industry.

4.1.1.1 Requirements for successfully executing sustainability assessments

According to the literature review and the information from interviews with industry representatives, it has become clear from both parts that for companies to successfully execute SAs it is crucial that stakeholders support it, are involved in the process and understand the results of it. For this to be possible, both parts claimed that there is a need for tools and frameworks as support to the stakeholders. What the stakeholders have to provide in their involvement is a clear aim, strategy and priorities for the SA to be conducted so to receive a high quality output. For the result to be successful, high quality data is essential which includes that the company has to ensure data availability, which is a subject that will be returned to in upcoming sections of this report.

Several sources in the scientific literature pointed out the importance of implementing SAs in the design phase of a production system or product as 70 percent of costs is represented by development and manufacturing in this phase. In doing this, costs could be reduced if changes were to be made here as a result of the assessment. On the other hand, researchers also pointed out that it is problematic to implement SAs during this phase. If implementing the SA too early, the result will be based on assumptions because of inadequate data availability and lack of comprehensiveness.

4.1.1.2 Will to perform

The study showed in many ways, both presented by researchers and the industry representatives, that the incentives for performing SAs are influenced by profitability and that it applies to both long-term and short-term perspectives. It can be concluded from the results of the study that the companies need to be motivated externally as there is a lack of incentives to work with SAs in people in general and, mainly, stakeholders. The fact that there is a need of SAs was motivated by that the manufacturing industry is resource intensive and therefore need to work with sustainability. There were different sources pointing towards companies not wanting to over-perform because of this lack of incentives. This was contradicted by an interviewee from Volvo Group Trucks Operation who claimed that they always over-performed, past regulations, as a strategic move. This was, to be noted, done as an economic incentive as they could then choose to allocate resources in times of high growth and not in case of a recession.

If the incentives are not profitability or external regulations, then it was common in the industry, according to an interviewee, that the incentives were to get different certifications. This would then enable companies to become suppliers to companies who demanded the certifications of their suppliers but also so that the company could brand itself as an environmentally friendly company. The certifications would also provide a sort of risk management proof that could be used for shareholders when needing investments. Although, both of these examples can be re-formulated as economic incentives.

4.1.1.3 Development of methods

The attribute and analysis function of a method are dependent on the developing strategy and what researchers, i.e the developers, consider to be important during the development process, according to several sources from literature and several interviewees. The researchers' approach to develop methods to be as scientifically correct as possible leads to comprehensive methods with the drawback that they tend to be too resource intensive to implement in industry, which is a topic lifted frequently in the report. A project leader in product environmental compliance and performance argues that since the academia has a lot more time when developing tools and methods, they become more complicated than the industry can use. If the methods demands too much adaption from the industry then the users may be discouraged of using the methods since they are not suitable for their particular situation. An associate professor in sustainable production at the Institute of Technology at Linköping University, (2), argues that developers of methods needs to observe the obstacles that practitioners experience in industry and modify the methods to the areas where they will be applied. Because of this it is argued, both from academia and the industry, the importance of developing methods together with the industry, including stakeholders in the development process.

Since all values from processes in the industry are not quantifiable, methods need to be further developed or complemented with a framework with firm guidance on how to convert qualitative values to quantitative with consistency, presented numerous times in the results. If methods lack this guidance then there is room for inconsistent conversion of parameters that would lead to an inadequate assessment.

4.1.1.4 Choice of method and indicators

There is a need for stakeholders to be aware of their abilities to affect the outcome of an SA. If they are not, it might lead to the result of an SA being misleading as stakeholders influence on indicators is often underestimated. This will further be discussed in this section.

In the report it was presented that commonly, methods developed by researchers needed to be simplified and so called cut-offs when applied in industry. The need for them to be modified are, as mentioned several times, that the methods are difficult to adjust to the individual company, production or product and also too resource intensive regarding time and money. Examples were given by interviewees and literature that, in industry, assumptions of unavailable data at the time of the assessment are often needed to be done. Here, it was argued, there was a need for understanding that not every assumption and simplification of method can be applied in the next case, on a new product or part of production. This, it was argued, required that the practitioners needed competence to understand in what situation certain indicators are an appropriate choice and when not so to not provide inappropriate and incorrect results. What was lifted by several sources was that the cut-offs and simplifications needed to be made through experienced practitioners. This was underpinned by interviewees who mentioned a forum, SLCC for exchanging information and experiences on life cycle work between Swedish manufacturing companies. This way they could make use of others' experiences as well.

4.1.1.5 Long-term versus short-term horizon

Judging from the results, there seem to be a situation where the industry practice a lot of quick sub-optimisation and assessments focusing on parts of the production or from one perspective at a time. This might work in the short-term perspective but to achieve a sustainable solutions that will last longer, a more comprehensive evaluation using SAs needs to be made, according to the results. Unfortunately, as the management consultant said, to convince stakeholders to also focus on another area they did not focus on initially is challenging because companies often have an expected outcome of an SA. Again, the stakeholders' involvement and influence is underestimated.

Most of the management is mainly interested in presenting a solid economic growth for the shareholders. With this economic priority, improvements within production are often expected to generate a positive economic result in the short term. This becomes problematic when trying to integrate the environmental aspect in the improvements. A longer perspective requires environmental improvements to prove beneficial, presented in the report. Companies tend to be discouraged to fund and use an SA-method with a long-term perspective without guarantees that it will pay off since investments in these methods tend to be costly as they are extensive.

4.1.1.6 Integrating the triple bottom line

In the results, it was argued that sustainability was defined only when all pillars were included, the TBL. In order to become sustainable, one has to incorporate the entire triple bottom line in the evaluation. Unfortunately many sources point towards that the sustainability that is sought is limited by the mindset of large parts of the industry. This because the word sustainability is often interchangeable with environmental sustainability, thus creating an deceptive view of sustainability omitting the TBL. The scientific literature has started to increase the incorporation of all three dimensions in the methods developed. A reason for this, was argued in the results, could be the difficulties in quantifying soft values. Trying to include tools to interpret these soft values in the methods, they became too extensive and resource intensive for industry and the methods are hence not applicable. Soft values are, according to several sources, hard to interpret which aggravates the situation when decision-makers need to both evaluate and later, base decisions on the results. This causes the development of SA-methods, which take into account all three dimensions of sustainability, to become very complex, which per definition make said method resource intensive and difficult to implement in the industry. Since companies today often are multinational, it becomes difficult to incorporate all the different regulatory frameworks throughout the entire value chain, which increases the complexity even more.

4.1.2 Implementation

Difficulties in implementation of previously developed methods and expertise required by these methods will be discussed in the section below.

4.1.2.1 Implementation in industry

Since many tools within SAs have a high data demand and are resource-intensive, in connection with the industry lacking systematic application and keep focus mainly on the economic aspects, the tools are often hard to implement in the industry, according to the study. Companies must provide resources to collect enough data and fully understand the methods so that the correct indicators can be chosen. If resources are not provided and the interest of executing the methods correctly is low and companies tend to focus on profit rather than social or environmental aspects.

Data availability was presented in the study to be a large issue. The ability to collect data is connected to the companies production technique, geographic location of suppliers and the scope the analysis, mentioned by different sources. Companies with suppliers in developing countries tend to more frequently experience problems of collecting data due to the use of older machines and a higher degree of manual workforce. In situations where data is available there can still be situations where companies are opposing the collection of data, arguing it would create disturbances in production. Some companies expressed that when needing data from suppliers, they experience resistance from the suppliers as this exposes them, putting them in a vulnerable position. One source stated that an analysis of a company's production with a wide scope, including the whole supply chain on a regional or global level might provide a complete view of a company's impact but the obscure relationship between cause and effect at these levels decreases the availability of accurate data for the analysis.

In cases where data is not available, companies have to either approximate or exclude data to perform an assessment which may give a misleading result. Since these approximations are difficult, there is a great demand of proper educational level within the work force to be able to make correct approximations for the result to be credible. This in turn makes the companies economically sensitive to either make poor approximations or no approximations at all, both limiting the use of SA methods.

Lastly, it was also shown through the study that quantifying qualitative parameters and indicators is a challenge since it is not always obvious how to put a figure on a qualitative measure, even when using the methods provided. Some sources pointed to the need for researchers needing to make the indicators of the methods more adaptable to the industry to be able to account for both qualitative and quantitative data.

4.1.2.2 Interpretation of results and practitioners' role

To provide manufacturing companies with sustainable decisions and solutions, it was be presented in the study that practitioners need access to the proper tools, sys-

temic guidance and competence to know what relevant data is and how to evaluate it. The lack of these creates sub-optimal results and inaccurate decisions. Regarding education, the study points out that system boundaries of unit processes might be set too large, creating an overly resource intensive data-collection. It could also be too narrow, resulting in a lop-sided view of the process. It was presented to be just as important for management to be educated as well as they need to understand the results to be able to make decisions based on it. If decision-makers do not have the required expertise then there is a need for tools to convert the results so to be easily interpreted. If there is not enough expertise or resources at the company then it is common to outsource to consultants or students, which was presented by an interviewee. It still takes resources from the company to pay for the service and to collect the required data, as stated previously, but the work and competence is outsourced.

It is important that previous experiences of methods are shared and learned from, creating an organisational learning, lifted by several sources. The study presents that estimated values are often used because of resources being scarce and data short at hand. Thereby it is of great importance that the methods are performed in a repetitive way with consistent thinking so that possible uncertainties are highlighted in order for said assessment to not become misleading. When making simplifications of methods and assumptions of data, always repeating it the same way, then it often develops into a new method, according to the study.

To make methods more user-friendly, many sources pointed out that developing methods together with representatives from the industry could be a way to make them more user-friendly and thereby increase their applications. This, in combination with allocating more resources for the implementation of methods will allow practitioners to succeed to a greater extent and in turn result in more successful methods.

4.1.3 Decision making

During the following section, decision making is discussed and reflected upon. Difficulties lie in making the correct decision that lead to wrong decisions made and the purpose of the SA goes lost.

4.1.3.1 Stakeholders' influence on decisions

Sustainability is more than environmental aspects, as it consists of social and economic aspects as well. When performing SAs, decisions should be made on the entire system, in order to be comprehensive, presented in the study. The outcome of an SA does not always affect decision-makers as the decision is commonly predetermined. It is common that stakeholders influence decisions to benefit profit. Sources indicated that stakeholders need to be provided with guidelines so that they do not bias the decisions.

There are different ways to implement an SA and the results vary depending on which method is chosen. Decisions and interpretations should be made on the basis

of TBL as an integrated whole and not only on each component. In this scenario the example that the management consultant lifted, on the development of factories in developing countries is relevant as ethical and social aspects are trumped by profitability.

4.1.3.2 Trade-offs

The study presents that trade-offs occur when basing decisions on all aspects of the TBL and they are undesirable but inevitable. Sources argued that to make correct decisions when incorporating all aspects of sustainability, decision makers need access to guidelines. Companies are not always able to make use of the SAs that cover all aspects presented by researchers because they are, again, too resource intensive and comprehensive.

Sources from the study argue that when needing to make trade-offs in decision-making processes, error sources can occur. The methods implemented are meant to prevent these but do not always succeed in doing this because of different reasons, even though the methodology of the method has been correctly executed. Interests within larger companies might be biased towards profit, rather than the environmental or social aspects, according to multiple sources. Decision making is performed on the incentives from stakeholders and/or management and as previously discussed, they have a large impact. For these incentives not to be biased, sources from both industry and academia stated that there needs to be political involvement in the decision making on a regional level, a national level or even the EU level.

As some parts of the industry believe that resources are too short at hand to perform the vast methods that research provide, some perform simplified methodologies, as stated several times in the report. These simplifications, including the exclusion of indicators, could lead to error sources in the decision making. When making these simplifications, some sources stated that the practitioners need to understand that a simplification of a method can work in a specific case and yet be inadequate in another. This means that simplified methods need to be evaluated for each scenario and case to not cause the wrong decision, making disadvantageous trade-offs. One way for companies to prioritise their decisions based on what is most sustainable is by using an LCSA. Thus, companies can see a comparison between different options as well as see what distinguishes between them.

4.2 Limitations of study

The results of this study should be carefully reviewed. Scientific articles have regularly pointed out the coherence of the three perspectives in the TBL: economic, social and environmental, for a complete sustainable improvement whereas this study was limited to only focus on the economic and environmental aspects.

The proportion of sources of information are also significant in the report. A majority of the information presented were found in scientific articles from the Scopus database while information regarding the industry is mainly gathered from interviews with seven Swedish industry representatives. Even though the information from the scientific articles discusses the industries' perspective, it is mainly the interviewees' input that has formed the basis for that perspective. The large difference in proportion between interviewees and literature could lead to the result being skewed more to the information presented in the scientific articles or that the few interviewees point of view represent the entire manufacturing industry of all sorts. While the literature illustrates a global scope, the picture provided by the industry is limited to Sweden. To enable a conclusion within the time frame, the results of the interviews will need to be assumed to represent the entire industry and hence might lead to an incorrect or over-exaggerated conclusion. It could be noted that what industry has presented, has often been validated by the industry perspective in literature.

What is also interesting is to analyse how different types of interview strategies could give different results. Since the interviews where done using different tools, e.g video call or face to face, this might have affected the quality of one interview compared to another. It is also difficult to assess how much two interviewees affect each others answers if they are both interviewed during the same occasion.

The reviewing material was limited to the Scopus database. Even though Scopus is considered to be a qualitative source to information, combining Scopus with other databases would give an even greater result of scientific articles. The search result of relevant articles in Scopus was extensive, leading to a decision to limit the scientific literature to this source.

While a majority of scientific literature within the area focus on specific methods and their pros and cons for use in the industry, this report adds a general perspective of causes common to many SA-methods leading to a gap between state-of-the-art literature and industry needs regarding SAs.

4.3 Further research

There are a few areas for future research or suggestions to complementary work which has been found during the study. Areas where complementary studies could be done is to involve the social part of the three pillars in TBL. This analysis does not include this aspect, which result in a less complete view. Another future area of research is to investigate how the companies could be more included in

the development of sustainability assessment methods. If research in that area is carried out, reasons why researchers exclude companies when new methods are developed could be found. Moreover it could be of great interest for future research to investigate how a collaboration between the two parties could be designed to increase use of methods and maximise benefits.

5
Conclusion

This study aimed at answering the following two research questions:

RQ.1 What factors decide if the methods are used in the industry or not?

RQ.2 How amenable are manufacturing companies in assessing economic and environmental sustainability performances in production using sustainability assessment methods?

5.1 Regarding research question 1

SAs are tools assessing the sustainability of an organisation, for example a unit-process, a product, etc. SAs are used for a variety of reasons; to uphold regulatory frameworks, for purchaser requirements and end-user requirements to mention some. They have been shown to be resource-intensive, particularly data demanding, time consuming and require a high level of expertise. It is important to point out that SAs themselves do not increase sustainability, but instead provides a well founded basis for decision making in the sense of sustainability. Said basis have been shown to be problematic, since the methods provided by the scientific literature often leave the decisions up to the decision maker after said methods are conducted. This puts the responsibility on decision makers, who are often in management positions, to themselves incorporate all three dimensions of sustainability into their decision, which becomes problematic.

Another major contributing factor is that the SAs often are complicated to implement, which are caused by a variety of reasons. One of which is the aspiration from developers to incorporate the entire TBL in a method which in many cases causes the already resource-intensive methods to become even more complex. Combine this with the lack of incentives to incorporate TBL from the industry's perspective. This because the difficulties in quantifying soft values, which makes regulations hard to establish for authorities. In addition to this regulations are the main driver of the implementation of SAs, which in turn creates a gap between the academia's SAs and the industry to which they are applied.

For SA methods to be used by the industry, there is a need for:

- ... an underlying demand in the company for assessing the level of sustainability of a process or similar.
- ... an appropriate level of complexity of the method.
- ... expertise in the company to manage the the SA.
- ... methods to be adapted to the intended area of use at the company.

This study concludes that when these factors are present, SA methods could be used by the industry.

5.2 Regarding research question 2

From different sources, both in academia and the industry, there are multiple causes to why the industry does not use some of the SAs developed by the academia, hence creating a gap. Below the different causes of said gap will be presented.

Multiple sources in the study pointed out that the industries' main incentives, for executing SAs are commonly of economic character. Partly because environmental regulations set by authorities have to be followed to avoid financial repercussions. Partly because of increased sustainability awareness from end users which causes the need for branding and lastly, some customers require certain certifications from suppliers. Although it is argued, both from the academia and the industry, that the driving forces within the industry for using SAs could be increased by an increased understanding that in order for the companies to become successful in the long run, they have to take into account the concept of sustainable development.

Moreover the study has shown that from both academia and the industry, the methods often include error sources in the implementation. Error sources are common to be approximations of data, or incomplete data. Too large errors result in disadvantages for the decision maker and the accuracy the SA result affects the level of sustainability in its outcome. As well as error sources, trade-offs are also a large part of SAs, especially in the decision-making process. Trade-offs are necessary as companies need to achieve economic sustainability but the decision makers, are the ones who often have to trade environmental and social aspects for economic ones.

Another reason why SAs are complicated to implement is the lack of useful data which often leads to approximations, which could lead to incomplete results and a misleading basis for decision making. Add to this the need for practitioners to obtain the required competence and systemic tools to perform the methods correctly and it becomes obvious that competence is key. Practitioners also need to convey their knowledge to others in their organisation, including decision makers. The need from the industry might not align with the methods from academia, since it is argued that some methods are developed with the purpose of having a narrow scope, for example on a single unit-process, while other methods focus more on wide-scope application that could incorporate an entire corporation, which in turn differs from the industry's need.

5.3 Overall conclusion

This review is limited by incorporating only economic and environmental aspects as well as limitations in regards to the scientific literature reviewed and interviews conducted. Even so, this review provides a proficient perspective in regards to the two research questions answered with well founded conclusions.

The answers to the research questions above is underlined by the lack of cooperation between the two communities. It can be concluded that SA methods are complicated to implement as well as a lack of competence among the practitioners. A problematic aspect is that developers often decide what is relevant in regards to indicators and outputs when developing methods without involving the industry. If academia develop SAs in cooperation with the industry to which they are to be applied, the user-friendly experience from developers as well as the competence in the industry can interlink with each other, thus reducing many of the major factors contributing to the existence of a gap.

The review concludes, as stated above, that in order to bridge the gap between the two communities, the industry and academia have to collaborate to a greater extent. Both in regards to the development of methods as well as in the implementation of said methods. It is crucial that the industry fully understands the importance of taking into account the concept of sustainable development in order to become more profitable and survive in the long run. It is of equal importance for the academia to fully understand that the industry have limitations of resources, as well the need to make trade-offs. This so that when developing and improving sustainability assessments the methods become solid foundations for decision making. If the industry and academia can incorporate said understandings based in increased collaboration, a development that meets the needs of the present without compromising the ability of future generations to meet their own can become reality.

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A

Interviews

A.1 Manufacturing technology manager

Q: *What is your role as a Manufacturing Technology Manager in sustainability?*

A: I have not worked with sustainability specifically, but sustainability is applicable everywhere. When choosing future technologies in production, these must be the most sustainable. I work as a manufacturing technology manager for many different areas of measurement technology, surface technology and process fluids. I look at our future needs in production and what within future technologies that may be of interest to us. I am responsible for the manufacturing technology road-map.

Q: *You say that you are using the continuous sustainability work in processes. Is there any particular method you use in this work?*

A: I would not argue that there is currently a methodology that we use. If there are any useful methods, then these are time consuming and are a combination of several different methods. We would not be able to work with one method because then everyone would not focus on their primary tasks. I do not think it is just because the methods are time-consuming, but also because it is not possible to answer the questions either. It is a holistic perspective, we evaluate without considering sustainability from the economic perspective, the environmental perspective from a security perspective. These assessments exist, but they are not dressed in a sustainability assessment tool.

Q: *Would you say that Volvo allocates sufficient resources to achieve the sustainability goals set up?*

A: Yes, there are overall goals and we have a team working with Global Reporting Initiative (GRI) which is sustainability reporting where they collectively compile all data.

Q: *We investigate in whether there is a gap or lack of research in this area, or which causes intruders to choose not to use the tools / forks that exist?*

A: There are different complexities that are the reasons why many tools are not used or used but not spread. It can be time-consuming, resource-intensive, data-demanding or many other aspects. What is most important is not to slow down the trend. Development on time if you say so. If you really want to put it down in detail, in all the tools, and describe as many people write about, would take a lot of resources that we could not invest in all that we are investing in today.

Q:*All the time trade-offs about what you want to invest in development and what you want to invest in sustainability?*

A: I do not think it is a trade-off, since sustainability is already a big area covered. Good corporate development is very sustainable for a stakeholder. On the other hand, the academic approach considers a lot of specific indicators and parameters which are not adapted to the industry.

A.2 Associate Professor in sustainable production

Q: *What is your role when working with sustainability companies?*

A: Sustainable, and generally sustainability assessments, are not as common as I see it but more so that you want some approach to how to work with and manage environmental issues in the company. It may be that you have an environmental management system such as ISO14001 or a management system. Simply put, you have a plan for how to work with different assessments, called life cycle analysis. I visit companies and meet environmental managers and look at how they work with the environment of companies. Depending on what focus you have and who you speak with as eco-designers or product developers, you have a bit different focus depending on who you work with and what the company does.

Q: *Do you consider the use of sustainability assessments as common in manufacturing companies?*

A: Well, that depends on what you mean by SA. The very concept is not common, but what happens is that you can make life cycle analyses or social life cycle analyses. But you do that when you want to find out something special, you have a certain need or when you lack knowledge about what impact our product we manufacture has on the environment. Sometimes it may be that you base your work on previous life cycle assessments. So when you have done it once then you think you do not need to do one every time. It may take quite some time to do a full life cycle assessment.

Q: *What is the purpose and goal of the assessment? Are sustainability assessments a priority in the company?*

A: The purpose is to get a better idea of what a company's footprints or environmental impacts are. "What part of business affects the environment and where is the most improvement potential?", and also: "What can be done by yourself?". If you have an environmental management system then you set goals. In ISO14001 (environment and quality) you try to find out what your significant environmental aspects are and set goals that make it possible to improve and follow up.

Q: *Would you say this is a priority in companies?*

A: Not always, it depends on the industry. If there is any financial gain in it, you do it, but it is usually not a priority because it is time consuming.

Q: *How come you work with companies to begin with?*

A: Because we have such applied research that requires companies to participate, 50 % economic support. I am also interested in environment, manufacturing and product development.

Q: *Why does a company contact you, what do they most often need help with? What is the company's motivation?*

A: They may be new within the field and they may want to know more about the methods available or need research. I focus on re-manufacturing so they may contact me to know more about re-manufacturing, e.g. if we were to start with re-manufacturing because our customers demand it, how should we proceed and get there?

Q: *Just to get a little context there, what do you mean by re-manufacturing?*

A: It is available in all industries, but one example is a copier. Copiers are re-manufactured to a large extent. You withdraw products from leases, picking them apart and removing parts that need replacing. There are several examples such as computers, cell phones or mass car parts that are re-manufactured. If you turn a car in for service, the staff might ask if you want a new spare part or a recycled part. It is quite common to choose a recycled part as it is half of the price compared to buying a new one.

Q: *When doing these ISO14001, as in your case, or an LCA, what would you say is the biggest challenge when starting out such work?*

A: The challenge is to understand how the methods work, get into it - that is the starting point. It is challenging if you did not take university (or similar) courses to know how to get the right and relevant data. Another challenge is also that it takes time. It may be that companies do not provide the time that will be needed to carry out a sustainability assessment.

Q: *You mentioned before that the aim was that companies should get a better picture of their environmental impact. How do companies decide which method to use? How do you determine which method is best considered when making a sustainability assessment?*

A: I do not know, it is probably different from case to case, which method they choose. I guess they look at how other companies do in industry and how it works out for them. This way they can try to find methods that are only some part of an existing method or processes that they use. Companies do not want to take any stand-alone tools that are time consuming for them, but try to get environmental aspects into methods and product development processes or simulation gear.

Q: *You have mentioned LCA and ISO14001, do you know any other methods used by companies to make different such assessments?*

A: If you look at the product development page, there may be modules in CAD tools, where you can get some environmental assessment. You enter what you have for different materials and manufacturing methods, so you can get out of the environmental index there. There may be CAD tools, material rolling tools and even if you are planning their production, there may be environmental aspects there. This can be reflected differently depending on the layout chosen.

Q: *Would you consider different assessments based on resource intensive and time-consuming to implement?*

A: It is probably different, depending on whether you use a brand new or stand-alone tool that only has one focus. Then it may require a lot of resources and time if you want to complete a full life cycle analysis. If, on the other hand, it is included as a small feature, upgraded version of its product development tool or production planning tool, then I do not think it takes as much time and you actually get the answer automatically in some way.

Q: *When implementing different assessments, ISO or LCA, how do you ensure that the methodology is followed up as standardised?*

A: It is probably a bit different depending on what tools are used. Some things can be internal, that you follow up on the quality, you have checklists and double checkers and help. But if you are thinking of ISO14001, there are external auditors who go in and ask questions if you have done or met the ISO14001 requirements according to standard. There are also standards for life cycle analyses and then there are certain requirements to be met there. Some can be verified in an external company or accreditation body, or you can do it internally.

Q: *Once you have used a tool or a method you will receive a decision basis or information afterwards. Would you say that the information or decision sheet is sufficient, or what are your views on the information available afterwards?*

A: It is a bit difficult. It depends on how good the method is and how high the quality of the data is that you have put in. If you do not know your stuff or the data input is not good enough - if you put shit in, shit will come out. But as I said it is all from case-by-case. Those who use life cycle analysis well get a better idea of what their products environmental impacts are, and they can spread their knowledge to their surroundings and specifically to customers. That is how we work to reduce our environmental impact.

Q: *How do you ensure that the information is correct?*

A: You can try to get it verified by comparing with others, for example, if there are any competitors who have received something else or similar information. Another way is to do it several times, let a consultant or students come in and do the analysis. But I do not think sustainability assessments are really serious, but it is like companies wanting to keep a close eye on what we are having the biggest problems with and how we can work with it. It does not have to be super exact numbers.

Q: *The methods that companies use to assess different sustainability aspects, how do you ensure that you have the best method from research? How do you ensure that the methodology used is good or if it is too old?*

A: It is a bit difficult. You have to think about it when choosing a method, how to go about when searching, and then you might look to the industry about which methods are used and whether they have worked well or not. Companies encounter a great deal of difficulties on how to find all these methods developed by researchers. Most methods developed by researchers are, like I said, not applied.

Q: *Why do you think that is?*

A: Within, for example, eco-design, there are over 100 different methods scientists have developed, "this is cool, do like I do". However, one has not thought so much about how these methods should be implemented within companies, and then it becomes problematic.

Q: *But are companies not actively looking for new methods and, as stated, only use what the industry is using?*

A: Yes, I do not think you have time to look for this, but I know, for example, a company in Stockholm where a woman is responsible for environmental issues, she has studied at KTH and learned a bit about different methods, then she has used take note of the knowledge she received there in order to create her own method that she uses in the company she is working on. It works well. Then you can also go to the different standards available, such as ISO14001 to get support there. The best way to get methods used in industry, it is important that industry is involved in the development itself and feel that they can take over that method later. There is some research on it.

Q: *It is always a trade-off with companies, how much resources you are willing to put on different methods. Would you say that these methods are still reasonably resource-intensive? Or is there a feeling in the industry that too much resources needs to be put into them?*

A: Sometimes companies may feel that they are not environmental experts, and they feel they need too much resources to make a full life cycle analysis. That is why it has also been developed simpler life cycle analyses because they are more implementable. But then there will be a trade-off there, if you make a very simplified LCA and do not get really credible results, but some companies can buy themselves free of this by hiring a consulting firm that does the job. Then it costs money instead of time.

Q: *Is it common to hire external knowledge in that way or are there many who work within the area?*

A: I think it is quite common. For example, with the company Ångpanneföreningen, that goes in and perform a life cycle analysis for a company, they are experts in the method and then they only need data input from the company itself. It also depends on how big the company is; how much and what skills they have. There are big companies that have good environmental skills and they can perform these methods themselves and run their own race. But those who do not have this knowledge or resources then use the company by external consultants.

Q: *You mention time and money as different trade-offs, are there other trade-offs or compromises you encounter when making decisions?*

A: Sometimes it is impossible to get the data. Say you have a sub-contractor who has manufactured a product for a large company that supplies world wide. Then they may not be willing to disclose information if there is no legal requirement for them to do so. If information is not available, it is difficult to conduct a sensible environmental assessment.

Q: *You mentioned before that it is important that industry is involved in the development of new methods, does that lead them to becoming applicable only to that company or industry? Would you be able to develop a little bit about that?*

A: Yes, for example, if you have a research project or a master thesis where you should implement a method on a company then it is crucial that the student or the researchers do not do all the work themselves, but instead working with the companies and those who will use these tools, so they feel that they are involved in the development and feel this is something they can use themselves and also make the methods as useful as possible from the start. Moreover, you should have a clear person or function at the company that takes over the development and maintain this method and updates it as needed.The methods themselves must be very manageable and that companies benefit from its use. Researchers can sometimes have the tendency to develop things that they think are really great, from a scientific perspective, but difficult to understand.

Q: *These methods that are developed with the help of companies, can the result be too company-specific to the industry?*

A: It may be so in some cases. So you have to look at it like maybe a part of a method is generalised and then explain how to customise it for just that specific company. Such methods that, for example, have got a good response, these are designs for sampling methods, designs for assembly. Some Americans have developed a method of that sort with a generalised perspective and it is quite easy to understand, making it easy for companies to understand and implement the thought, principles and guidelines of design and manufacturing at the companies. A successful method that many people know and use.

Q: *Background to this, do you think there is a gap between different kind of tools the theory / academy develop and what the industry actually use and need?*

A: Yes you could say that. In order to get more useful methods, the academy who develops the methods must put more time on collaborating with companies.

A.3 Project leader in product environmental compliance and performance

Q: *What is your role within sustainability?*

A: I work at a department at SKF Group, supporting the entire SKF Group in all countries with advice and assessment of sustainability issues. It is often about compliance, like: do not have hazardous substances in products. But also product performance so that we have products that perform while at customers - in their applications, do not consume too much energy and use less material. We help with that kind of assessment. And in that case we sometimes also make assessments of our own production - how did we purchase the components for these products? In some cases, we also do other assessment support, e.g. life cycle analysis work, but most of the support is knowledge-based support. My title is a project leader on product environmental compliance and performance.

Q: *Do you use so-called Sustainability Assessments to improve your production from a sustainability perspective?*

A: Yes, we do and, as a continuation of the next question: with the purpose of SKF's requirement of environmental / health / safety perspective we perform risk assessments which assesses of what is dangerous in its direct production.

Q: *Is that an internal requirement for SKF?*

A: If you follow ISO OHSAS 18001, Occupational Health and Safety Standard, you will have an external freight forwarder. It is a certificate for the entire group and sets the requirements on our suppliers. We also have other standards such as ISO 50000 which is energy efficiency and on large suppliers we also have ISO 14000 which is about environmental work. So it is a lot about maintaining these standards. Requirements also come from investors or banks to provide loans. This to minimise risks in the company. E.g. to get better loans if we can show fewer risks. This is something that almost all companies have.

In terms of methods we also make environmental and social assessments of material flow analyses just like a LCA but, in fact, we only perform these as far as inventory goes. We have the grandeur but do not always translate into environmental data impacts. We have tried some social impact assessments. E.g. if we change a supplier in India or in China - what difference does that make? The focus is not so much on the social, but significantly more within LCA and material flow analysis. Historically, we have done 50 plus life cycle analyses and material flow analyses, but the activity decreases a bit. It is driven by whether we think we have good data and when it 's time we will do some more studies.

Q: *How do you work with sustainability assessments in manufacturing?*

A: Great reporting. We have about 120 factories (sites) within SKF in almost every continent. We have a system that reports into what is called GRI - that is the base and can be read in our annual report. We also set environmental targets on the group. Some new ones are about water use or about waste, to climb the waste

pyramid and transcend from depositing and combustion to recycling and avoiding it is use. We must follow those goals and we use that kind of data primarily when we are performing material flow analysis. A lot comes from the site and their reporting where it might be visible that they e.g. use a lot of energy, etc. From this we look at what is big and what is small. We think a lot about the product, but also on the actual sites, for example, when choosing a machine, per say a new grinding machine. Studies have to be made to see what is important and not when buying a new grinder. So, there are some more zoomed studies as well.

Q: *Which tools are used in this case?*

A: On the case of a machine like before, a LCA but simplified would be used - this data is inserted into excel sheets so that people at the purchasing department or project managers in production can use it because it is easier to interpret. This generates different factors that they can use. Sometimes it is a scale from "low", "middle" to "high" and sometimes it is decimals like "0.1". It is a bit different.

Generally: We collect data that they [the sites] report as well as collecting complementary data ourselves if needed, make a model, get results, generate a worst/best case scenario and a scale between them then hand out to decision makers. This includes what numbers we are talking and where it differs most.

Q: *So your role in this chain will be?*

A: Talking to someone who needs support, like "What exactly is the question? How should we solve it?". Checking if we already have the information - "Can we do it ourselves or should we outsource to a consultant?". My role is the first contact: to understand what needs to be done.

Q: *How do you customise the sustainability assessment methods for each scenario?*

A: Usually someone has contacted me for an interview. Find out what their question is. Sometimes you do not understand the question yourself. We discuss what is relevant. If we're talking LCA:" What is the function? What is the goal and scope?" You try to "lean" it towards ISO standards. Often it's not LCA that is to be used but you check the reported data which is much easier. Then I discuss with colleagues whether it should be a water footprint, blue, green, red water, or other standards - "What is needed?" However, there is no process to follow or something that can be read from a paper or a flowchart. It is more about discussion. We also determine plausibility. Sometimes it is very time consuming to be able to answer the questions and often we have to say no.

This is the biggest factor: it takes too much time. That, or the question itself is to hard to interpret. Maybe sometimes they can not directly affect something in the question. E.g. a product developer needs a component, but it is not them who control which product is to be purchased but rather a buyer controls it. But, above all, it takes a lot of time to gather information (data). If you do not already have the data but have to measure it, then you have to explain how it is to be measured, why, your source of communication might be in India, etc. This means several months in lead time, so it is very resource-intensive.

A lot is about routine and experience within it. Sometimes you know which factors who do not matter. E.g. to make ball-bearings (lathes and grinders), coolants are needed to prevent it from getting too hot (lubrication to keep it clean). A study was made where it was presented that it is affects were less than 5 percent in any case, so for the different sites we can know in advance whether it will be included or not in a model. In some cases, one only looks at what actually changes, e.g. in comparison to each other. So one simplifies: excludes it from the scope (in goal and scope).

Q: *So you rely on experience in this case?*

A: According to ISO (LCA), you have to make "cut-offs" as you say, so that you do not include data collection because there will be too little to collect.

Q: *What methods are often used to make SA's and why?*

A: Absolutely the one most frequently used is Failure Mode and Effect Analysis (FMEA); statistical risk minimisation. Also environmental assessments; material flow analysis: Draw up its system, talk about it, material (direct, indirect), waste and energy. These are the approximate steps. You find a hot-spot and then you are done. You do not usually commit to a full LCA. By methods it is probably the most common. In products, if it is to be conveyed to customers, LCA is probably the most common, but then there usually already are usable models preferred to a new model.

Q: *Do you think sustainability assessments are easy to implement on manufacturing or is it too comprehensive or complex? Why? How do you solve it?*

A: It is quite difficult. Often you must find a cut-off or we have to include suppliers too, to collect all the life-cycle data. They, in return, do not want to give up this data to their purchasers due to the risk of us saying, e.g. "You're this efficient here so you should cost less". For our own production there are no major difficulties but we do not hand out ISO standards to everyone and we would not be able to use it operationally in the factory, daily, but rather it is a project for answering specific questions made by a specialist.

Q: *What are the reason for simplifications?*

A: If the question is about deciding "yes" or "no" about something in the factory, if it does not affect or if it is insignificant for some machines or processes, for example.

Q: *How do you ensure that the methods are followed?*

A: Internal reviews on health, environmental, safety-work but in LCA we only have 4 eyes, examining at the other's job. Sometimes an external company (Axel Nobel or something nearby, who also does LCA's) might ask if it is reasonable. There is also SLCC (Swedish Life Cycle Center) in Gothenburg which is a collaboration between quite a few companies. Within SLCC there is good privacy and confidentiality, and you can ask more specific questions on e.g. recycling of plastics in Africa, scenarios, etc. So we often make use of industry experts.

Q: *Do you often use external expertise?*

A: Yes, it is quite common. Here, many people work with LCA and then become consultants because they have a LCT, which is a bit more holistic and difficult.

Q: *If difficulties arise during the implementation of SA's, what are they?*

A: Almost always gathering the data: measuring data, gaining access to factories. E.g. to measure energy levels when the factory is in standby mode - just waiting for it to happen can take two months. The timing is difficult. Also, in stand-by, the factories want to get started again and do not want to go and measure data. It is easier in modern factories where this can be logged automatically, but with older machines it is much more difficult.

Q: *How do you ensure that the information obtained from SA's is sufficient? What is sufficient information? (Credible information that can lead to sustainable development for the company)If not enough information: What will be the next step?*

A: In LCA, data quality rules are used a lot, e.g. age, sufficiently specific, etc. This is applicable all the time, especially age and if the production looks similar. If so then existing data can be used. If we do it ourselves, we will lean on it, or if sites report (GRI reporting) then there is more of a filter - if something exceeds more than 30 percent from the average and stands out then you will ask some questions. You sit manually, looking at the numbers and determine if it is reasonable. If it comes from suppliers it is often obvious - say they have an energy consumption that corresponds to all of Sweden's, it can be a hundreds of times wrong, it reveals pretty fast. But if it is about more qualitative information like if they're following legislation, then there are supplier quality auditors who decide what is most risky, so they visit them.

Q: *How is the quality of the information evaluated from the SA? What information is needed in advance to evaluate the quality?*

A: Auditors. It depends very much on who is the sender. For major chemical companies, it is more credible than if it is a small company in India. Who you receive the information from and also the level of education from those is weighed in.

Q: *What are the difficulties in interpreting the results from an SA to a valid decision basis?*

A: "How well does this answer to the question we had from the beginning? Have we made the question too wide or have we done a lot of other things that have diluted the question? Did we get the right information?" We look at the inventory and at the hot-spots. "What is the uncertainty in the report?" There is so much to take in to account in e.g. a LCA so the measurement uncertainty is high. There is always a plausibility assessment and a lot of expertise included. In the end you have to determine if you can stand for the results or if you have to collect more data. It has also happened that the cut-offs have been too tightly set.

Q: *How do you ensure that you are using the latest methods and research within SA to get as good assessments as possible?*

A: We had a team in research but not anymore. Now it is up to my team to keep us up to date within research but we ca not be updated within everything. There are online services as well as consulting companies that are updated in chemical and environmental legislation. But in terms of methods, we use a lot of SLCC, we Swedish companies help each other out a lot with what's new and what are we concerns are. It is a lot of networking and consulting.

Q: *Do you often choose new methods or old ones?*

A: We often test new ones but we mostly read and discuss a lot. But not so many new ones are being used. The latest are social impact assessments and such. There we contacted some companies within it and did some studies.

Q: *Does the company have enough resources (time, knowledge of responsibility, money, and motivation) to execute the methods? If not, what is the reason for this?*

A: It is a priority issue. Do we want more information to our controllers? or whatever it is. If we can show that there is a need for it, it will never be a problem as long as it does not require hours of hours from a factory, then maybe we need to take in external resources. But if we can solve it ourselves, it is no problem. We take the most important ones. Preferably, you want a customer who pays; customer requirements are much easier to work with. E.g. automotive customers wanting to lower CO2 (g/km) and want to know how much better our seals are in our bearings and how great the affect is trough simulations, lab tests, LCA, etc. Customer requirements are much easier than if a bureaucrat at SKF asks. But if we must, then we must.

Q: *Do you believe that there is a gap between theory and industry? Why?*

A: Yes, there is absolutely. The academy has a completely different long-term perspective and has more time to work with it. In industry there is often a lack of time where there may be evidence of major studies in some kind of general knowledge to use it for faster studies. This can make the academy's methods more complicated than the industry can use. A lot of methodology development is adapted to industrial requirements. Sometimes graduate students have done major studies at the factories because they needed it. LCA have a little bigger chance now, gets more information and can be a bit more complicated.

There is also a gap between the academy and our politicians. The demands on society (citizens and companies), especially if it gets more international, it must come from the EU or government since not everybody has their own, personal incentives for better environmental performance. Government authorities' methods may not be up-to-date.

Q: *If any - What trade-offs usually occurs in decision making?*

A: It is extremely difficult. We try to see if we can internalise externalities. We may have an impact on environmental impact. If we can compare apples with apples, then we try it, but it is often unclear what is "OK" for a factory to have an environmental permission. It is government requirements if we can monetise whether we can figure out what consequences we would have. Social aspects are difficult, it becomes very philosophical. It is part of the decision-making but concerns more localisation of factories, so it affects job opportunities, labour issues e.g. adding a super-automated factory to a non-developed country is not super lucrative. Often, minimum requirements apply.

A.4 Quality manager & Environmental manager

(4)-Quality Manager for SAAB's production business in Gothenburg.

(7)-Environmental Manager for Surveillance Business Area at SAAB and Environmental Coordinator for the site in Gothenburg.

Q: *What are your roles within sustainability?*

A(4): Quite little in terms of sustainability, ensuring that processes in sustainability and environmental impact are followed in the sense that I am a quality manager and to ensure that things work. (7) has greater responsibility in ensuring the platforms, etc.

A(7): Many people are not really aware of their role which concerns sustainability, however, following processes means working sustainable throughout. E.g. at SAAB, you examine chemicals before they are collected.

Q: *When reviewing these chemicals, do you use any specific sustainability methods? ex. LCA?*

A(7): No, what we look at when assessing chemicals coming in, it is only the risks of the chemicals regarding environmental and, above all, safety. Mainly if they are prohibited, but beyond that, there is no sustainability assessment performed on them. Our production is quite special as we manufacture incredibly few products for such a large business. In other words, the products are very expensive. This means that such a matter of transport as a matter of principle is a non-question for us because we manufacture such few products and there are few deliveries to and from production in comparison with other producing companies.

A(4): We manufacture radars. Also radar systems and microelectronics, both broadcast and reception. Delivering some tenth of product per year.

Q: *Even though you manufacture few products, do you perform any sustainability assessments on the few processes you have? Both economically and environmentally?*

A(4): From an economic perspective, we evaluate our production facility, "Do we have the right capability and ability to produce what we are producing in the amount to be produced?" Based on a production plant perspective, we make an investment basis and evaluate how much we will produce, what capabilities we have, if we have the right equipment, all personnel in place, etc.

Q: *Do you have any special tools for the purpose when you look at this production facility or when you evaluate?*

A(4): Well, they are about economic calculations, risk analyses, most commonly. Then we work out a sustainability perspective with energy consumption and the aspects. We also do this from a production perspective: "How do we use our labs and processes that we have in house?" This, (7) and our property manager, works with, with a consumption perspective.

A(7): You work with a lot of questions about sustainability, but you may not know that it is within sustainability.

Q: *But there is no structured tool for evaluating these energy issues?*

A(7): Yes, but it is fixed on SAAB level. We report sustainability on SAAB level. There are quite a few of our employees who have a look at it I would say. It will be a task for me as environmental manager to report it to the Central Environment Department as a sustainability report.

A(4): When looking at the electricity consumption that is more connected to the plant, some people are employed to work with technical questions regarding the property and then we have a number of planners where I, as a quality manager, am one of them. Looking at figures regarding electricity consumption and the use of labs here in Gothenburg. We push on those who use the lab.

Q: *Are these any numbers that you compare with previous data?*

A(4): Looking at what the numbers say, what are the numbers of and if it is relevant to have those levels. As (7) said, the questions come up in different forums. Here we have a local forum with a number of different people looking at energy issues, and when our environmental manager does the monthly reports, it goes out through the management team.

Environmental manager shares a picture of the various consumption in the company. Everything from electricity consumption to office paper from a compilation of environmental reports comparing data between 2017 and 2011.

A(7): The number of employees has risen, while all other environmental data have fallen. A proof that we worked a lot towards sustainability.

Q: *As an Environmental manager, do you work a lot within production to develop your processes from an environmental point of view? For example, to ensure that you do not contribute to any emissions, or use of metals that are not particularly environmentally motivated to use.*

A(7): I understand what you are looking for, my job is a lot about keeping an eye on the chemicals we buy, that we are looking at remediation equipment, for example, if we were to waste something that we checked it out. A lot of jobs with energy use, but we are not directing production. Looking at our production, it is a lot of assembly, much less than e.g. Volvo in size; small-scale and dry. No large chemical baths or paintings and very screw and small amounts of glue. Other industries may have a surface treatment bath or paintings that provide a little more direct environmental impact.

A(4):After all, sustainability is more than just environmental impact, but you also have social and economic aspects. We think about how we work with them and improve their business with many aspects. As (7) said, maybe we are working on many of these issues, but we do not put them under any sustainability ceiling so there is no sustainability assessments in that sense. We have different types of improvement activities, social involvement with Chalmers, etc. We try to get more women in technology and try to benefit from society at large. Then we will probably work

in a larger perspective. From a business perspective, if you look at the production activities in the work of people who come out here and such aspects.

Q: *Does your production look like a project workshop?*

A(4): Yes, to a large extent, bigger antennas are still in production. We build containers where systems are installed. There are approximately eight construction sites and a lab where system tests are performed. We also produce products in slightly larger volumes (one hundred) and there it is a bit more like a traditional flow. Major features of functional production where an operator is responsible for a product type in a certain part of the production. Other departments are responsible for testing with different subgroups.

Q: *Is there some internal unit within the company that work continuously with improvements in your production, not only ensuring quality more under an overall perspective. E.g. purchase of machine?*

A(4): We have a production technology organisation and it includes production technology, methods and machines. This also includes measurement and test development. They too set up the scope of production in the longer term. New products - new ways to build. There we have three specialists, two who work with sophistication and measurement concepts unveil new ways to measure. Two specialists who focus on building sets how to connect design and production. One that focuses on production technology and flows. Together they cover how production sites together with management team based on strategy for the business. E.g. organisation of surfaces: where equipment should be placed, rebuilds and so that capacity can be used optimally. These assessments are made of which products are produced now and further on, what kind of technology and production techniques are required, how it affect the premises and staff needs. These specialists work with improvement work in a broader perspective.

Q: *How do these specialists measure these improvements?*

A(4): Good question, I have no good answer. I do not think we do this in any coherent way. More estimates of the number of premises, how does it affect the economy, budget and how much staff we need.

Q: *Many SA's are standardised methods, where it can be an advantage to get a holistic assessment instead of working with sub-optimisation. These specialists that you talked about are actually focusing on each part and trying to do it as well as possible to provide decision-making to the management as I understand it?*

A(4): Both yes and no, they are divided into areas, but they are expecting them to cooperate as well.

Q: *What do you think is the reason why standard SA's have not reached your production?*

A(7): It is too small of a question for our production because it is so dry and so little impact that sustainability is not such a big issue for our production from an environmental perspective. There are not many questions that are very important

in it. For example, in the graph that I showed about electricity consumption, many factors included in that decrease.

Q: *If you look at the graph between 2012 and 2014, you see a big decrease in energy consumption, does this decrease derive from any specific change, e.g. in production?*

A(7): There were several things but focusing on it is the biggest reason.

A(4): No production change that led to the reduction of machine purchases, but more consistent understanding of how we work and maybe how we use the lab.

A(7): The biggest change is probably because we replaced some products that needed chilled and air-dried. Processes that went around the clock. Now the machines are not running around the clock, but it does not account for the whole change.

Q: *How is quality evaluated in the information?*

A(4): There we have a problem in knowing exactly where the consumption comes from. There it is more about the broader sense, thinking about what is causing district heating or electricity consumption. "Where can the biggest posts be?" and then resonate for it. Some things are obvious that they are drawing a lot of e.g. cooling. But what will be the next step after reducing these major processes and it is a bigger challenge.

Q: *In the case of the smaller, more difficult more heavily estimated items or parameters, would you be able to think about using SA's to locate them or do you not see it as a worthy investment?*

A(7): I would say that an energy-based consumption is better in this case than a sustainability assessment. In that way we only look at the energy issue.

Q: *Do you set requirements on your suppliers that they comply with certain guidelines?*

A(7): Because we produce very few and expensive items, we don't have that many suppliers so have had a bit of trouble with that.

A(4): We perform supplier audits. Each time a new supplier enters, they go through a qualification assessment and the questionnaire includes financial questions from their perspective and how solid they are as a company and supplier. How do they work with their own processes, occupational safety, different types of environmental issues. No absolute requirement with ISO14001. In any case, we want the companies that we work together with work properly and are healthy economically, work environmentally and environmentally, and also have ethical perspectives.

A.5 Director of Research & Technology Development

Q: *What are your role in sustainability?*

A: I work with technology development and pre-development related to production and logistics. Sustainability becomes part of the technology solutions / concepts that are developed. We do not measure or follow up in business / business goals how we work with those issues, such as energy efficiency associated with production processes. Instead it is more like; Here we have a potential about this much, and from that potential, we address a certain kind of technologies. From the technologies a solution is then built that suits the company and correlates with the environmental goals set.

In Technology road-maps, a part of it is environmental goals. Product update drives the company forward, from a production perspective, it is cost rationalisation, environmental goals, environmental legislation that comes in. In a large global company, environmental legislation comes in on different occasions and in different forms. If we want to act in the country, we must comply with current environmental legislation there.We are often not just on the limit regarding the environmental legislation, instead we would like to be a little more environmentally conscious company that would like to pass the limit with a good margin. Instead of doing something late, we try to keep track of where the laws go and find solutions that give us the time needed, so when the the legislation comes into effect, we have already implemented or switched to the technology that the law allows.

It is not always easy, sometimes it costs a lot of money to do the technical progress with this way of work, but it is interesting at least.

Q: *When you say that you that would like to pass the limit with a good margin in environmental legislation, do you use some sustainability assessments then?*

A:We have always reported to Nasdaq's sustainability assessment for example, but we ended that last year. Noticed that there was no fair competition when you could buy benefits by paying different companies to get a better rating. Took a lot of time to be precise, every year that environmental report. Have done this reporting for a 10-12 year. It was seen as positive when doing business, that we made this. Then when we discovered that some companies could buy benefits and thus make easier assessments, then one ca not really trust the sustainability assessments index. There are other equivalents, that I do not know the name of, which we work with. They are a more fair assessment that does not reflect the size of the wallet.

Nazdaq is well known and if you look at it, it contains many parameters with many well-written reports. Took 10 years for us to realise that others could buy an advantage. Looking from the outside, it is probably not easy to know. We have also said that to them and to others when we do these assessments, that what we are interested in is a real assessment of situations.

Q: *Other types of assessments, e.g LCA, is that a method you are using?*

A: Yes, we do, on and off. On the product we always do. Cradle-to-grave on all components. What we have begun looking at is process LCA, we have a doctoral student who looks at how we connect processes and make a sustainability assessment. Especially with regard to painting and similar things. Will be relevant in the case of electric vehicles where you get other types of material that have a different type of environmental impact. Where the process controls how you work with the material. We have come a bit but not that far, for now it is only in painting and finishing processes. for example there is no process-LCA on the final assembly. There we have used product-focused LCA where we use the GABI database for this.

Q: *Why are you focusing only on the painting-process and, for example, not at the final assembly regarding Process-LCA?*

A: We believe we have a greater process impact there, where it can provide the most and where you have the opportunity to measure and follow up the most and where it has a significant value to do this. Final assembly is very manual and harder to see how we influence and how we get one outcome or another. I am sure you can measure approximately where we should be, but what should we do about it; We have determine that is much harder, but if you had a white paper as I had, we considered it appropriate to start with the painting-process because it has a lot of ovens, heating, air flows that we can optimise and control in a different way.

Before you decide where you want to put your resources, you have to estimate their process, what do we have for parameters that we can optimise, is there something else we can optimise (there always is). What can you optimise, moving a person from one station to another may not affect the process-LCA result so much. To lower a oven with two degrees Celsius or to reduce the air volume or the flow of air, run a shorter time, maybe even turn off to optimise in another way and still get the same output. By electrostatic painting, the colour is sucked to the product so that you hardly get any waste at all. The painting section is like a separate climate zone inside those boxes where the painting takes place. Can you control it in a good way and optimise its sequence. We have 820 standard colours, but you can get any colour you want in addition to it. These 820 are not produced every day but you can add this sequence to minimise cleaning. Some require slightly higher temperatures, some should be painted several times, etc. It is a lot of process knowledge, and if you think of the LCA perspective, then it becomes a parameter to take into account and we think you can get an impact because of this. Initial measurements and assessments that we have made has shown that there is more to do if you put on an LCA perspective because you can get another optimised cycle or sequence compared to if you did not do it. Then you may lose something from another perspective, but then you have to make a balance where the two cases are set against each other and see what the results are and see what you lose in terms of winning the environmental part.

Q: *This assessment is, of course, for assessing the situation, what would you say is the purpose of it?*

A: When we are making investments in the future, LCA will have a bigger footprint in our investments. Of course, you must achieve the environmental goals, but you can complete the environmental goals with a great result. But what are the incentives for you to be great? You can simply pass the bar of sustainability goals but we prefer doing this with a good margin. There is always a problem with incentives regarding this as there is always more to do than is done. Then the driving force disappear and there are economic and logistical driving forces that push the solution to where the company stands. If you can enter LCA as a parameter in your sustainability assessments, you can do a trade-off where you can see that we can do a lot related to the environment without it costing a lot of money and lose very little in the logistics setup or that is at least manageable, and the outcome is that we get a solution that is amazing. This is something you ca not visualise today, so we think that such a tool can help us find the possibilities that this could give us because we do not know if they exist or not. It may be that we are as good as we can be and that we can not find anything but at least then we know it, then we have facts on the table.

Q: *What determines what method you use?*

A: Previously we had our own department here at Volvo who only worked with LCA but for one to two years back we outsourced that part and we have decided to outsource that competence instead, because we thought we had a large department with little utilisation and it was difficult to cover it like a global resource. Now you can buy more regionally or locally, assuming you have the same way to measure things. I do not know exactly what kind of methods they are, a colleague of mine is more up to date on this.

Q: *About outsourcing, was the reason an economic incentive that led to doing it or was it that there was a lack of knowledge?*

A: The knowledge existed. I was not part of the decision so I do not know exactly what caused the decision but they did not think it suited the company. They tried to act more towards core competence and LCA is great, but it is a support function for an assessment. Then maybe you should buy it, because if we have an internal department, there is a requirement that the people in that department should get the skills at the right rate to keep up with it. Otherwise we will be forced to buy in external services, nevertheless. They then made the decision that it was easier to remove that part from the organisation and instead outsource those services. Those people can then get the quality skills development because they can work on other companies because otherwise they were just stuck with working on our cases.

Q: *Is it consulting company you buy from then?*

A: In Sweden we buy from IBL, the environmental institute, they are the ones we have a contract with. In other countries, I do not really know, it depends a bit. Perhaps the environmental institute here in Sweden also supports other countries in Europe. There are lots of local companies and institutions that have knowledge of local legislation. It was a bit complicated in the situation we discussed earlier when

we had a central department here in Sweden that would keep track of legislation in about 20 countries. It takes up quite a lot of time.

Q: *We talked about LCA before, do you use any other method to do a sustainability assessment?*

A: LCA is the biggest, there are surely other methods somewhere, but what is communicated is LCA. That is what we do and in the product projects, we always conduct LCA's. There might be others, as well.

Then there is energy measurement, where we measure our energy consumption or optimisation of energy use. An example of this is when you start the smelters in the foundry so that they do not start at the same time as the rest of the Swedish population will start the coffee maker at home. Then maybe you should not push the system to the maximal limit. You may come up with the conclusion that you should go with a 2 degrees hotter warming in the night time, because you do not need to heat the same as it is a demanding process that costs a lot to heat up. Partly differentiate your own production relative to it but also optimise it, so that the entire cycle is taken into account, not only locally. In the same way as when turning off the lamp when you go out, many of the machines in production are in standby (are idle) during night time, so why not turn them off? It is quite a lot of energy.

We have started to look at our robots that are going from max to a direct halt which lead to a very rough move. It is expensive and damage the gear quite a lot. We are looking into that area with parabolic trajectories, with a softer acceleration and retardation, so you can have a softer motion. You may save 30 % with a softer motion pattern. Requires some other thoughts and methods of preparation and a lot of work with the robot's control system, since they are initially programmed to move from A to B linearly. There is a lot to do if you dig deeper into the technology and there are some things we have started and certainly a lot of things we have not discovered yet.

A lot is about visualising, like visualising its energy consumption. We have a factory in which we have printed out lists of consumption in the production hour by hour. If you have forgot to turn off your machine, then it is clear that there is a hot spot at that night time, when its consumption is high compared to all other consumption during the night. It makes a difference, especially if the machines are large and many as in our production. It is a matter of consciousness, a way to work and it do contributes to sustainability.

Q: *When you are doing your assessments, when analysing electricity consumption and LCA, how do you look at complexity and resource demands in those situations?*

A: In the past, we had a department that included this, about 40 people who performed LCA's. And it took a lot of time. Those who work with it think it goes fast and onward. It has to be analysed to be understood. I think it is complex and difficult from my perspective but there are tools that make it manageable. Because it is complex and difficult, and must be implemented, it is not a free of cost assessment.

Q: *When you say tools that make it manageable, is there anything in particular you think about?*

A: What I am thinking of are databases that you can buy, interface that has a lot of material data built-in. It is always complex if you have cables that contain many different materials, where it can be difficult to estimate the amount of material. The easiest thing is when it comes to pure metals and not alloys of different kinds, just because it can be difficult to estimate different amounts of material layers in an alloy.

Q: *How do you make sure it is as correct as it can be?*

A: You try to have a method, someone who performs it, someone who checks that you performed it correctly and then you build up a common knowledge base and sometimes you have to make a review. You may be calibrating something, you may send a piece of material on analysis with an independent entity that calculates it in relation to what we have done and compares the results. It is no super exact science, if you do not know everything in detail, it is your best estimate or guess that is used. As long as you do it the same way every time then you can evaluate yourself, but you have to have a method and structure and then you always want to be as close to the truth as possible. It is always like this when it comes down to the details. Sometimes, someone has to decide a certain outcome because when it comes down to extreme detail then you can not always separate the result A from B.

Q: *During data collection especially in regards to LCA, it may be difficult to know exactly when many parameters can be dynamic and alloys that we talked about, are there other things you think might be difficult during the implementation?*

A: Yes, but it is important that you as a company must have the resources and knowledge, and then you have a vision of why you perform it. It is nice to be able to report their figures, but in some way it will help you, so it is going to help your business so you can earn it in the end. Regarding products, the customer or market requires for it to be reported, otherwise you cannot sell your product if you cannot present an LCA or similar assessment. But in terms of process LCA, there are no other stakeholders than the company itself, it is something the company needs their own incentives.

Q: *When you make a process LCA, the information you get from that assessment, do you consider it sufficient to base decisions?*

A: That is the best we have, I do not know if it is enough, but it is the one we use. It is quite new, we have worked for three years with process-LCA and right now we are just focusing on a certain group of processes. We try to integrate it with decisions that come within the area but it is very difficult, I cannot really answer that question, but it is the best we have, but it is no measure of whether it is good or bad.

Q: *How do you make the compromise, we say you get a result from LCA, pointing out that some type of change should be carried out, but that the company believes it is too big of an investment to implement?*

A: Yes, but there is always a balance, the framework that I could say that we are following is in that case that we will make money on the change. It will be a business case in the end. If LCA point to a direction that means you will miss the business case, then yes, you will need to re-design or choose to buy it. It is not fun to have a product that does not meet the requirements, then it will not be able to get on the market. It might lead to a re-design, new material choice, choice of new suppliers that make the product arrive at an acceptable level. You wish to be as ideal as a company to maximise and have the best product on the market and to be desirable, but then when it comes to economics it destroys that dream sometimes, i.e. that it costs too much so that it is not possible to manufacture in the volume we want or the production is too complicated. Then you can take another solution that meets the interests of stakeholders who require this.

Q: *How do you ensure that you are using the latest methods?*

A: Now that we do not have it ourselves internally in the company, we expect that our suppliers of these services will meet those requirements and be kept up to date. It is part of the mission. We still have some competence left in the company who understand what they are talking about like my colleague I mentioned before, and others who can have a more profound discussion. That way, we check the work, if they use the right kind of tools and methods that we understand so that we can take advantage of the results. All problems can be solved, it is just about how well the solutions are that you choose and make sure that they live up to the requirements. On some things, LCA must be done. You are required to be able to re-collect the product and recycling is a requirement. If you are required to recycle the product then we need to know what material it is consisting of. I am poorly updated on what the legal requirements are and what is required from the market.

Q: *When it comes to motivation to make a sustainability assessment (legal requirements vs. ambitions)?*

A: We try to be a premium brand in the truck part. It is not enough to just pass the bar as the customers are sensitive to it. Customers want to see that we can handle more than the basic requirements, otherwise it indicates that one cannot afford it or simply do not care enough. It is a safety margin for the customer. We do not have to be the best in class, that is not what is demanded, it is about building up a trust regarding the product and the company. If there are new legislation's coming, as there is, you do not want the road to get there to be too long but you want a good starting position. It costs less in the long run. Since it is cyclical business, you do not know what position you are in when a new legislation enters into force. It may be the worst recession and maybe you do not have the money to make a big investment, but you may want to make a smaller investment at that time because you know that better times are ahead, but it may take a couple of years. At that time, you may lay closer to the requirements bar, we may not be able to afford now, but when things get better we will fix it. If you are going to do everything the last day, you are not in control of your own life anymore, because you have already tied up every minute left. But if you work on it a bit before you have more flexibility and life becomes easier and that is how it works.

Q: *The theory of sustainability assessments is basically based on an ideal situation where resources are endless in industry, is reality a completely different one?*

A: The results should be presented on a special occasion, we have our gate structure that we review when we have development projects. We have a standard scheduled plan and we just start when we need to as we know when the gates are closing. If it takes six months to perform an LCA then we can plan our work. If someone requires longer time than that then they need to adapt to us.

Q: *What do you do when you notice that it will not be possible to get everything together on time?*

A: It has to work, you have to make cuts or you can buy more resources. It is not just one person sitting and performing an LCA. If we are going to make LCA on 10000 parts and have four weeks for example, how many people do you need? Then you can make a schedule, how many can you make per day. Say we realise that we need 120 people full time then we can buy in so we meet the need for us to get the results. No problem is unavoidable, but money solve all problems. The more time you have, the cheaper it becomes, because you can distribute it over a larger period of time. We do not want to land in any panic situation. Of these 10000 products in the example, some products may be ready before others. LCA can be made on a regular basis for each product type that is being completed. There is nothing wrong with the methods, but it is all about planning. You can always end up in situations where things get too late if something went wrong along the way because of poor communication, someone has done something wrong or you need to re-think something. You cannot plan everything, you have to start when you know have a certain amount of time until deadline.

Q: *Complex processes where it can be difficult to implement a standardised method, there must become a kind of simplification along the way?*

A: Yes, definitely, you can take the overall experience and guess the best you can. Just guess the same thing every time through a consistent thinking. You may notice and it will become a new method that you can use in situations where time is insufficient and simplifications needs to be made. The most important thing is that the method is repeated in the same way, it is probably the skills within LCA of those who do these which is important here.

A.6 Management consultant

Q: *What is your role within sustainability?*

A: I work as a consultant so I do assignments for clients who want help with different things. My background is Industrial Economy at Chalmers and then Quality Operations Management as my master's, so I am mostly in operational processes and production processes and flows and understand how they merge and how to make them smarter. I look at sustainability as a whole, but then you must include questions about working environment, security, gender equality, diversity and anti-discrimination. You also have to bring the environmental thinking with chemicals, carbon dioxide emissions and so on. So you bring the overall picture into doing this kind of development work so that you do not sit and develop something that is really effective but also really poor from an environmental or security perspective.

Q: *Why do companies contact you?*

A: Either way they want to get better in the broader sense. Or, they want help showing that they are certified if we work with ISO standards such as ISO9000, ISO14000, ISO45000. Many companies fulfil all three because their similarities. When certified, it means that you have a system and work systematically with your business and develop it and keep track of some important issues such as the skills of the staff. Then, an accountant comes and check if you do as you should and as you say you have done. We also have environmental diplomas and "Svanen" as well, which is more of an environmental certification that we can help with.

Q: *Do the companies that contact you miss these internal departments or is it mainly to access your expertise?*

A: It is usually a bit smaller companies that we work with where we stand for the expertise. We can go into larger companies too, but then we will come in and complement with more cutting-edge knowledge within e.g. process mapping. But then you often have a more clear, limited part that you work with.

Q: *Do you think SA's are prioritised within companies?*

A: Yes, if we assume our, Effort's, viewpoint that sustainability is very broad, we always have the perspective with us on assignments. That is not always the case as ordinary people think that sustainability is about carbon dioxide emissions and the climate, and that is not the way we always work because it is not always relevant. Quite a lot of companies have a lot of offices and then you can work with other, more important issues such as vicarious traumatisation which is then a more important sustainability issue for them.

I would put it like this, sustainability assessments do not have the greatest demand, but companies often have more specific questions in some areas they need help with. This may then grow, where you then do an assignment where you look at the whole and lay a strategy for "What sustainability issues are important to you? Where is your biggest impact?". Then you can set up a plan for how to work with it. This is common practice within companies.

Q: *What is the purpose for companies to be certified?*

A: The customer is clearly the strongest stakeholder. In many industries, where the automotive industry is one, there is a major player at the end of the chain, such as Volvo Trucks, who then demand from their suppliers that they can prove that they work seriously with quality and can deliver good products and then you need to be ISO certified. And then it is clear that then there are a number of hundreds or thousands of suppliers around the world with the requirement to get certifies. And this may carry questions to us. Companies are also not dumb. They know that they are benefiting from this in business because it goes hand in hand.

Q: *Could you quickly explain what a project setup looks like?*

A: Usually, our consultancy firm enter and make a form of initial analysis in the company where you have different questions you want answers to and more knowledge about. You will begin with looking at if there is more quantitative data or do interviews and get more qualitative data. Based on this, you can make certain conclusions about what kind of company it is, what they are good and bad at. Then we finish that analysis part with an action plan where we propose various actions to correct. Then many of the companies usually want to carry out the activities themselves and others need help. Then thereafter the assignment continues.

Q: *What would you say is the biggest challenge in your work up until this action plan?*

A: Then I would say that if you encounter a sustainability issue that the company never focused on before, then it is convincing the management that it is also important. Previously, they may not have been concerned about e.g. environmental work. Here you see that the company do not know what they are doing and that they are in the need of some structure. From an environmental perspective, but also economically because it might reduce the use of, for example, chemicals and it might also up the efficiency. They are usually aware of this lack of focal point and has therefor already taken a stand. Here we have to persuade them into changing their minds. It is difficult when you get into that situation. It is important to create trust. Otherwise, I think there are not many obstacles.

Q: *Except from ISO-certifications and general SA's: are there any specific methods that you use which have a clear methodology?*

A: We do a lot of internal audits which is a set methodology as it is an ISO standard, ISO19011. It is a kind of methodology, to judge how good an organisation is and indirectly, how sustainable it is. We at Effort come from a quality movement and there are so many methods here and there. When I get to a customer, I do not always say it is a lean assignment, but you always have it. There is, for example, the $7 + 1$ different types of waste and you see that here you move and move materials in a variety of ways or have lots of different unnecessary elements so you act on this. I have colleagues who are environmental scientists, and another colleague, whom you had contact with, is more about leadership and working environment. Their methods can definitely be LCA, but they have different methods for different types of emissions, how to build an environmental monitoring team or how to work with chemicals. Then these methods may not have a name.

Q: *We have done a literature review within this area where we have encountered countless of methods. Could it be that there are too many methods for you to be specialised within all of them and also to simply know of them?*

A: Exactly. When doing a literature review you are in the world of research. There, everyone creates their own method with new names which is very confusing for the industry when it really is almost the same content, in my perspective.

The problem here is that the more specific your method is, the harder it is to see the entire picture. Maybe here you focus too much on carbon dioxide emissions and not at all on the social aspects with value chains stretching far away in Asia. No one knows enough about the suppliers way down this chain. There you loose all that work. This is a difficulty with sustainability, to understand enough but keep focus on the important issues.

Q: *How do you certify that, e.g. when you do internal audits, that you follow the methodology for that tool?*

A: In the case of auditing it takes education and then you know what is in store. You also bring your written certificate.

Q: *As you have made your action plan, how do you certify that it will result in sufficient results and reaches those goals you have set up in the beginning?*

A: It is not always clear. It is about logic reasoning and cause and effect due to experience, as you have done this before.

Q: *Trade-offs can always appear. How do you make this work?*

A: I would say that it is important that the questions regarding social and environmental aspects are treated as "staff functions" revolving the more value adding processes. This because the purchasing department can retrieve help from the environmental department, but also from production, design and development and retail. All of these should have access to environmental functions and therefor it is more of a staff. What happens is that they will be viewed as less important and what exceeds them are the value adding processes ability to create profitability and money in the bank for the shareholders. It takes to get that thought in with the stakeholders to value these sustainability issues, especially the environmental and social aspects. Maybe this would not be profitable for show in the most recently upcoming interim report but long term, approximately five to ten years, then it will have been important to already have implemented it because the society is realising more and more that the industrialisation we have made is not sustainable. We have to create more circular flows so that we do not kill our planet. At the same time we also do not want to create war and misery through using people close to slavery. If you want to stay alive as a company and to flourish in ten years, then you have to work proactively in adding these value adding activities.

Example: Let us say we need to increase production and open a new factory in e.g. India as there is a growing economy. Then, the mission is to get started with the factory. It will end up somewhere within the production department. What I mean is that if you really have understood sustainability then the first thing the

production manager does is to invite HR. They may then include how to work with the social aspects, inviting the environmental department, the legal department, all of which are important. So, they sit down and think: "How can we do this now without damaging and creating scandals in an environmental aspect or socially in utilising Indians with limited means, and instead be an example to others?". It is a good example of how you really understand how to work sustainable. To be a cross-functionally working company.

Q: *Do you believe that you work like this in industry or are there issues implementing this approach?*

A: I think that there are both good and bad examples. It is harder the more you involve and it is therefor easy to skip something, which I think some do. I visited a company who had been searching for a production facility in China. They had been there twice with a year apart and they expressed them selves as "When we went there the second time we did not recognise a single person in production and I believe it was because they were no longer alive because of the poor working conditions in the factory". Still, they felt it would be worthy putting their factory there to save their company.

Q: *So it is money which controls the outcome?*

A: Yes, exactly. And what I want to push here is that seeing it this way today, then you will fall short in a few years. It is crucial to start working today to eliminate it.

Q: *In the end out your action plan, when you have given your results, what difficulties occur when interpreting it? Stakeholders involved before the investigation could have expectations on specific results. How do you conclude a valid decision?*

A: We basically have our own model that we modify. It is about sustainability in organisations. In organisations, to talk about environmental, social and economic sustainability is difficult. When we come in we lift different questions where e.g. leadership and organisation is one. How do we lead and organise?

For example it could be that the purchasing department and environmental department sit closely together in the office or that they have coffee breaks together. This could lead to that the purchasing department will become more aware of environmental issues. To talk about organising comes more naturally than talking about economy and the environment, respectively. Instead, here we talk organisation in an integrate way. Further questions could be what kind of management model, the owners have since there is a big difference if it is a municipally owned corporation run by politicians or if it is a private company. Also, what kind of IT-system and infrastructure, what possibilities there are and how does it work? What kind of buildings do you have, what does the processes look like, which do you have? These are the ones I can think of at the top of my head but the model we use goes through these step by step while going through the analysis so that all the different perspectives are taken into account.

Q: *Do you take part in the final decision?*

A: No, we usually work quite closely in the process. Usually your assignments are given by some management or decision-makers and then you usually know their mandate and what they want done. Then, it is pointless to suggest anything else, it will only be weird. We keep in mind that we do have an employer. Finally, you have a meeting where we present our recommendations. Since we are a selling company, we want to present it in a way that it will be attractive to the customer to continue working with us in the implementation of the activities, too. Of course there is a conflict of interest. Me, e.g. am really good at making life cycle analysis and therefor I always suggest this to the company no matter the reason of employment and then you have to have some integrity so that you do not make a fool out of yourself. We are a generalisation company and not specialists. We are specialised in sustainability which, of course, is a broad concept. We always hand out a palette of recommendations that we can supply and there we have to be able to deliver independently.

Q: *So your focus belongs more within quality and economy then?*

A: What I find absolutely most fun with sustainability is finding different ways to think when trying to gather the whole. "How can we update our business model, offers, products and services so that none of it will become unsustainable by definition?". This is what I find most exciting so that is what I try to stick to. Then, of course, you sometimes have to read up life cycle analysis' as a basis. For one of my customers, they got recommended to choose more environmentally friendly products. This they did through looking at their own suppliers and what kind of products they bought the largest quantities of, which was concluded was a pump. They went to the three largest suppliers of this type of pump, in the same range of quality. Out of these they chose one that had gone through an LCA and that kept high quality. In a situation like this one, my job is to recommend them to look at environmental data and life cycle analysis. We do not perform the analysis ourselves and I do not have to know anything about life cycle analysis more than understanding that it is a valid way of comparing products to each other from an environmental perspective.

Q: *So at Effort you do not work as much with pure sustainability methods where you use a set methodology conducted from research?*

A: No, I do not know of anyone who could fit us where you can conduct an analysis on an organisation including it is products and services. It is more about adjusting the method for the assignment that you are given which can all be very different. It is very hard to send an organisation through a method and say "Your sustainability lies on a steady three on a scale from one to ten", it feels like it is too rough. It is about working with human change which is always hard. Sustainability is about all the decisions that need to be made in a company all the time. In a sustainable company, every decision has to take into account all the classical perspectives: economy, social and environmental.

Q: *You previously mentioned that there are so many methods that everyone just seems to want to put their own name on one. What do you think is the reason to any of these not being used in a larger scale in industry?*

A: I think it is about not being able to package it well enough. If you take lean production as an example, it is widely spread throughout the industry but you ca not call that a model for sustainability. It is more about quality and efficiency. That is one that you could take a look at and try to understand why that became so commonly used. The same goes for LCA, really. Although it has taken some time for them to succeed but it is still big and well established.

One thing I want to lift is Agenda 2030, the global sustainability goals that were established in 2015 and has begun to settle a bit. We did a huge drive trough of this when it arrived as an assignment for the University of Gothenburg but no-one showed interest of it until now - two to three years later. Now, lots of huge companies have Agenda 2030 in their sustainability reports. I even saw during the world championship in handball that one company promoted themselves with "We support these two goals out of the 17 global goals. Which do you support?". There, it began establishing. I do not know if you have heard of them but the 17 goals are within economy, social and environmental perspectives. They visualise where action needs to be taken, e.g. "Do we affect the marine life? No? OK, then we would not implement this goal and instead have to focus on some other". "Equal cities" is one that maybe applies to companies working with design of infrastructure and perform larger projects, then that is what their focus should be on. So on a strategic level it is a good framework for sorting your work within sustainability. If you have not already checked it out, you should. As LCA is on a more technical level and on product level, the global goals are more applicable on the top layers of companies and management - "What company do we want to be?".