



FACULTY OF TECHNOLOGY

**DATA-BASED SUSTAINABILITY PERFORMANCE
ASSESSMENT IN PRODUCT DEVELOPMENT
WITH MATURITY MODEL**

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ABSTRACT

Data-based sustainability performance assessment in product development with maturity model

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Including sustainability into product development process is one of the key challenges what manufacturing companies are facing today. The objective of this research is to understand what sustainability means in product development and how companies could improve their performance in it. This is constructive research by its nature, it combines a quantitative online survey and data analysis with a qualitative analysis based on semi-structured interviews and themed written answers. This research obtained the following main conclusions: (1) companies can increase their sustainability performance in product development by i) setting sustainability policy and targets which are clear and measurable, ii) increasing stakeholder collaboration during product development process and iii) ensuring strict and uniform data policy. (2) The most significant pain points were i) a company-specific understanding what sustainability means in product development, ii) ability to define and measure component level sustainability effects, iii) and finding balance with customer expectations and viable business. (3) Finnish manufacturing companies sustainability performance in product development is succeeding in more conceptual level but clear deficiencies are observed in practical level. (4) Key characteristics of sustainable product development are: i) it is internally driven and proactive, ii) it considers whole product and process life cycle, and iii) its performance is evaluated as combination of economic, environmental and social sustainability dimensions.

Keywords: Sustainability, Product development, Maturity model

TIIVISTELMÄ

Dataan perustuva kestävä kehityksen suorituskyvyn arviointi tuotekehityksessä kypsyysmallilla

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Oulun yliopisto, Konetekniikan tutkinto-ohjelma

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Työn ohjaaja yliopistolla: Professori Emil Kurvinen

Vastuullisuuden sisällyttäminen tuotekehitysprosessiin on yksi keskeisistä haasteista, jonka valmistavan teollisuuden yritysten on kohdattava nykyään. Tämän tutkimuksen tavoitteena on ymmärtää, mitä vastuullisuus tarkoittaa tuotekehityksessä ja miten yritykset voivat parantaa siihen liittyvää suorituskykyään. Tämä on luonteeltaan rakentava tutkimus, joka yhdistää kvantitatiivisen verkkokyselyn ja data-analyysin, sekä kvalitatiiviseen analyysiin, joka perustuu puolistrukturoituihin haastatteluihin ja teemoitettuihin kirjallisiin vastauksiin. Tästä tutkimuksesta saadut keskeisimmät johtopäätökset olivat seuraavat: (1) yritykset voivat parantaa vastuullisuuden suorituskykyään tuotekehityksessä i) määrittelemällä vastuullisuuspolitiikan ja -tavoitteet, jotka ovat selkeitä ja mitattavia, ii) lisäämällä sidosryhmien välistä yhteistyötä tuotekehitysprosessin aikana ja iii) varmistamalla tiukan ja yhtenäisen datapolitiikan. (2) Merkittävimmit haasteet olivat i) yrityskohtainen ymmärrys siitä, mitä vastuullisuus tarkoittaa tuotekehityksessä, ii) kyky määritellä ja mitata komponenttitason vastuullisuusvaikutuksia, iii) sekä tasapainon löytäminen asiakkaiden odotusten ja kannattavan liiketoiminnan kanssa. (3) Suomalaisten valmistavan teollisuuden yritysten vastuullisuuden suorituskyky tuotekehityksessä onnistuu käsitteellisemmällä tasolla, mutta käytännön tasolla on havaittavissa selviä puutteita. (4) Vastuullisen tuotekehityksen keskeiset ominaisuudet ovat: i) se on sisäisesti ohjautuva ja ennakoiva, ii) se ottaa huomioon tuotteen ja prosessin koko elinkaaren ja iii) sen suorituskykyä arvioidaan taloudellisen, ympäristöllisen ja sosiaalisen vastuullisuusulottuvuuden yhdistelmänä.

Asiasanat: Kestävä kehitys, Tuotekehitys, Maturiteettimalli

FOREWORD

This thesis was done as an assignment to a case company. It provides the latest knowledge about sustainability performance in product development in Finnish manufacturing industry. Research process of this thesis started in May 2022 by defining the needs of the case company. Actual writing started in August 2022 after the subject of the thesis was formed.

First, I would like to express my sincere thanks to Head of Engineering Global Business Line in Finland Panu Rahikka, M.Sc., who provided this unique opportunity and warmly introduced case company and its operations. I would like to thank everyone else from the Engineering team who helped me with this journey and offered their advises. In addition, I would like to thank all participants in this research because without your contribution this would not be possible.

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Helsinki, 12.01.2023

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TIIVISTELMÄ

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LIST OF ABBREVIATIONS

BO	Baseline Operations
BoM	Bill of Materials
CE	Circular Economy
DfE	Design for Environment
DfX	Design for Excellence
DJSI	Dow Jones Sustainability Index
IoT	Internet of Things
ISO	International Standards Organization
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
NPD	New Product Development
PLM	Product Lifecycle Management
PSSM	Personnel Skills and Sustainability Management
R&D	Research and Development
SIS	Strategic Implementation of Sustainability
SPD	Sustainable Product Development
SPS	Sustainability Policy and Strategy
SPSS	Sustainable Product-Service System
SST	Sustainability Scope and Targets
TBL	Triple Bottom Line
TPIS	Tools and Practical Implementation of Sustainability

1 INTRODUCTION

1.1 Research background

According to Lehto et al. (2011) as high as 70% of total product related life cycle costs are defined during the early design phases. Baumgartner & Ebner (2010) highlights that many companies pursue towards more sustainable operations but their intentions remain unclear and it seems that clear strategy and knowledge are missing. In manufacturing industry New Product Development (NPD) plays a major role and companies can acquire substantial benefits when it is fulfilled correctly. Majava et al. (2014) points out that meeting customer needs is important for the new product success. This added to the matter that customers and government are demanding more actions towards sustainable products it is important that sustainability is not neglected. (Alblas et al., 2014).

Recent studies have shown that sustainability is complex entirety and there is not just one meaning and way to implement it into action (Alblas et al., 2014; Baumgartner, 2014; Hallstedt, 2017). There has been contradictory claims about customers willingness to pay more about more sustainable products. Usually more sustainable products means more expensive products and in highly competitive situation that can be though decision which to value more, price or sustainable alternatives. (Dangelico & Pujari, 2010; Held et al., 2018; Johansson et al., 2021). In addition, measuring success of traditional product development is typically measured by lead time and financial performance of the product where Sustainable Product Development (SPD) tries to evaluate product development performance from environmental, economic and social perspectives. (Gbededo et al., 2018; Krishnan & Ulrich, 2001).

There exists no standardized method to evaluate or benchmark sustainability and product development performance. Companies are mostly comparing their performance to their own previous performance and to industry forerunners. This increases the need for collective performance assessment method. Maturity models have been developed in previous academic research by Baumgartner & Ebner (2010), Eisner et al., 2022; Hynds et al. (2014), and Watz & Hallstedt (2022) but with low utilization into action.

1.2 Research problem, objective, questions and hypotheses

This thesis aims to clarify what sustainability means in product development and what are the biggest pain points and drivers in SPD. The uncertainty of product development process as well as challenges in measuring and implementing sustainability creates need for more precise research about this topic. As companies are required to take more comprehensive sustainability measures covering all three sustainability dimensions which are economic, environmental and social. Therefore, many new aspects needs to be considered in their operations. (Mani et al., 2010).

The objective of this research is to understand what sustainability means in product development process and how could companies improve their performance in it. Objective of this research is supported by three research questions and they are presented below:

RQ1: What are the requirements of sustainable product development and how it differs from normal product development?

RQ2: What is the current state of sustainable product development and how companies are performing in it?

RQ3: How could companies improve their sustainability performance in product development?

According to the figure 1 the first research question is answered after the literature review, second research question is answered after the empirical research part and third research question is answered after discussion part where findings from literature review and empirical research are combined. This thesis utilizes both qualitative and quantitative methods to answer presented research questions. Data gathered from the online survey is analyzed and semi-structured interviews are held to confirm findings and to capture detail which might have been missed in online survey. Maturity model to assess sustainability performance in product development is also created as part of this thesis.

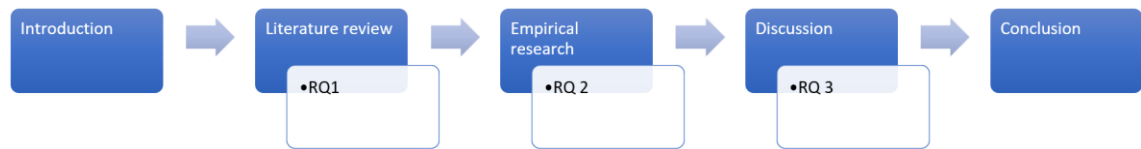


Figure 1. Research structure.

To support the research questions two hypotheses are formed which are tested based on the quantitative research results. Hypotheses are following:

H_1 : Companies have challenges in implementing sustainability.

H_2 : Large companies have better sustainability performance than smaller companies.

1.3 Research scope

This research is considering sustainability performance in product development process and in general activities which are supporting product development process. Other processes are given minor emphasis in this research. All companies taking part in this research are manufacturing physical products and have operations globally across the world. Geographically participants in this research are in Finland and this research is focusing companies performance mostly in Finland except considerations about supply chain and customer networks. Participating companies are not limited out by company size or by its product type since this research is considering overall sustainability performance in product development in Finnish manufacturing industry. Conclusions in this research are mostly limited to the developed maturity model where the results are based.

This research focuses into the overall performance of the industry and do not try to evaluate the differences between companies. However, participated companies received company-specific reports which they can use to benchmark their performance against the industry average. Those reports are not discussed in this thesis.

2 LITERATURE REVIEW

The purpose of this literature review is to answer the first research question: **What are the requirements of sustainable product development and how it differs from normal product development?** In addition, latest insights about SPD are reviewed to give comprehensive outlook of best practices and insights in manufacturing industry.

2.1 Product

The simplest way to define a product is that it can be anything that can be sold (Haines, 2014, p. 7). To define that more specifically, product can be tangible or intangible or both of those elements (Harkonen et al., 2015). That can be sometimes confusing because products are often understood as physical things that can be owned, traded, and distributed. Products can be more, for example they can be services, software, and algorithms. (Saaksvuori & Immonen, 2008, p. 153). The difference between tangible and intangible products is that tangible products are physical goods such as toilet paper, food ingredients or package of product which can be manufactured and sold. It can be also something more complex like cars and mobile phones. (Harkonen et al., 2015; Stark, 2016, p. 123; Uusi-Rauva et al., 2005, p. 60). Intangible products cannot be physically inspected, and they could be such as information, formula, service, or algorithm. (Koppius, 1999; Harkonen et al., 2015).

There are other ways to define product, but the basic conception is similar. In the extended model of customer value, product is divided into three layers which are product layer, service layer and intangible layer. The product layer consists of the physical product which provides the core function, service layer includes services which are bundled with the product and intangible layer consists of knowledge, emotions, and experiences of the product. (Steiner & Harmon, 2009). Importance of different product layers working together has been increasing last years. It can differentiate company from competitors, increase customer loyalty and create aftersales service businesses which are more profitable than core product itself. Therefore, it is crucial for companies to understand and identify different product definitions to cover all customer needs. This requires skillful product manager who has strong understanding about company overall business strategy. (Bacon et al., 1994; Majava et al., 2014; Makovec, 2014; Schönsleben, 2019; Steiner & Harmon, 2009).

Green products can also be defined with many ways but the basic purpose behind definition stays quite the same. Typically, green products are known to be ecological and environmentally friendly. (Chen & Chai, 2010). For example, minimizing use of non-renewable and toxic materials needs to be taken care of when designing green products, waste prevention when manufacturing the products and ability to properly disposal the product after use. This means that green products have minimized environmental footprint during their complete product lifecycle. (Albino et al., 2009; Miroshnychenko et al., 2017). There still exist many challenges regarding green products. High costs when investing and producing green products, variation in consumer preferences and suspicion about green advertising claim to name a few. (Chen & Chai, 2010).

2.2 Product development process

NPD is important for company success because it offers the possibility to take competitive advantage in the markets. In addition to mergers and acquisitions it is one of the major ways how companies can differentiate, adapt and even redesign their businesses in evolving and unstable markets. (Brown & Eisenhardt, 1995). Understanding how NPD process work is necessary for companies who aim for SPD. Many definitions exist for NPD in the literature. Ulrich & Eppinger (2016, p. 2) defined NPD as follows “*Product development is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product.*” Krishnan & Ulrich (2001) describes NPD “*as the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale.*” Hence it is important to recognize different market trends and perform NPD activities with a commitment.

NPD is seen as a sequential process which transforms a set of inputs into a set of outputs. A typical NPD process is presented in figure 2 where six sequential steps are performed to get the wanted output, which is the product. Simultaneously well-defined and structured NPD process enables quality assurance, coordination, planning, management, and improvement in every phase of NPD. The first phase is planning, it contains opportunity identification, project approval and launch of the project. Output of this phase is specified project mission statement, which contains goals, constraints, and assumptions of the project. In concept development the needs of the target market are recognized, and different alternatives are evaluated. Selected concepts are taken into further development and testing. Product architecture is defined, and product is decomposed into subsystems

and components in the system-level design phase. Initial decisions about product detail design and manufacturing are made. The layout model of the final product is usually made with specifications of key components and subsystems. In detail design phase materials, exact dimensions and tolerances are decided. Final decisions about manufacturing and purchasing are decided. Documentation is in key role because all drawings, Bill of Materials (BoM) and purchase specifications are generated in this phase. During testing and refinement phase different product prototypes are evaluated. Customer involvement is high in this phase and there is the possibility of finding some minor problems which might need some changes before the production ramp-up phase starts. The shift from production ramp-up to ongoing production is normally gradual. It requires training of the production workers and precise evaluation of the product and process to find there still lying issues. (Ulrich & Eppinger, 2016, p. 12-16).

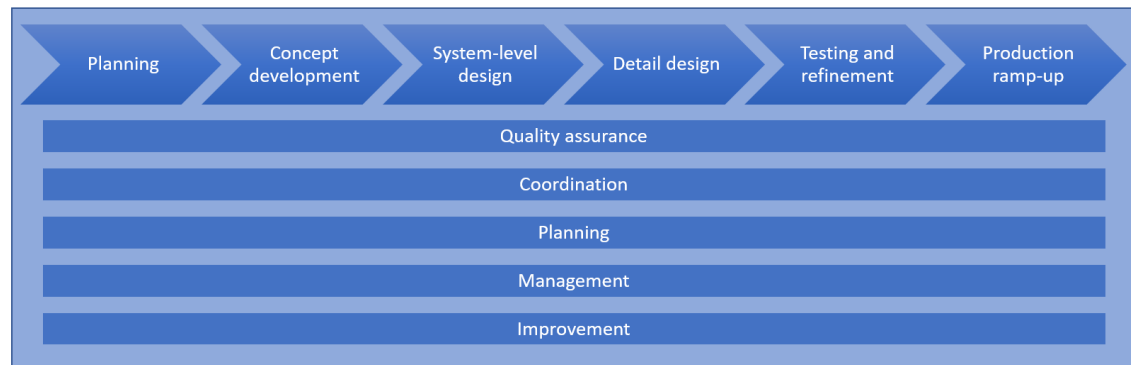


Figure 2. NPD process flow chart, adapted from (Ulrich & Eppinger, 2016, p. 14).

2.2.1 Success of product development

According to Bacon et al. (1994) early phases of NPD projects are critical and those can have significant effects on time needed to bring the product to the markets and in financial performance. Decisions made in the early stage have significantly lower costs and additional changes in product features incur lower cost penalties. To enable early-stage decision making in NPD and shorter development cycles, robust and well-understood product definitions are needed. Therefore, sustainability must be also considered in the early-stage and the product's whole life cycle must be evaluated. Integrating R-strategies in the early stage is a good example of this. (Bacon et al., 1994; Shetty, 2016). In addition, other things affect the NPD project success, which are presented on table 1 below. It is worth noticing that research of 12 NPD projects success or failure by Bacon et al. (1994) has similar results than newer research by Cooper (2019).

Table 1. Success factors of NPD projects.

Bacon et al., 1994	Cooper, 2019
Utilizing core competences, previous products, and mature technology	Product has unique benefits and features that are better than competitors
Understanding customer needs, competitors' products, and market behavior	Market-driven and customer-focused products
Clear definitions and requirements with customers and suppliers	Sharp, early product and fact-based product definitions
Strong management, cross-organizational support, and information sharing	Iterative development process to get things right
Prototyping and testing of complete product	Doing "homework" before developing new products
Risk management strategy and plan	Targeted to global markets
Same team defines and develops the product	Properly executed product launch
Aligned with overall business strategy	

Majava et al. (2014) states that meeting and understanding customer needs is required and vital for new product success. Brown & Eisenhardt (1995) found 41 different factors affecting NPD success. Understanding customer needs, reacting to markets, external communication, efficiency of development and senior management were related to success of NPD. However, the key factor affecting the success was product advantage. Chen & Chang (2013) states that matching customer needs is necessary for success of NPD and to respond that quality function deployment method enables to translate customer needs into specified technical requirements for every different NPD stage (Diaz et al., 2021).

According to Artto et al. (2008, p. 7) projects are unique and effective way to implement predetermined goal. Regardless of the business type project management principles, models and tasks are similar across different industries (Artto et al., 2008, p. 20). Then it is justified to say that there are no right and wrong ways to do it, just the way which works best for the company's needs. Also, if companies want to maintain competitive advantage, they need to act fast in fluctuating markets to react high competition where proactive NPD can be a valuable resource. Therefore, companies can look retrospectively at older projects, learn from mistakes, and find similarities to improve their operations. Network diagram in figure 3 from Brown & Eisenhardt (1995) portrays success factors in NPD

which are proven to be beneficial for companies trying to achieve the best financial performance. As seen from the figure 3, internal factors like senior management and project leader have major impact on NPD success and they affect factors after them before final performance. Suppliers and customers as external factors are also important to include to achieve great NPD success. Factors requiring efficient team performance are shown often, which points out the importance of seamless teamwork and sufficient control from above. In addition, market conditions and product fit to markets have prominent affect to product performance such as early entry to the markets and recognized customer need. (Brown & Eisenhardt, 1995).

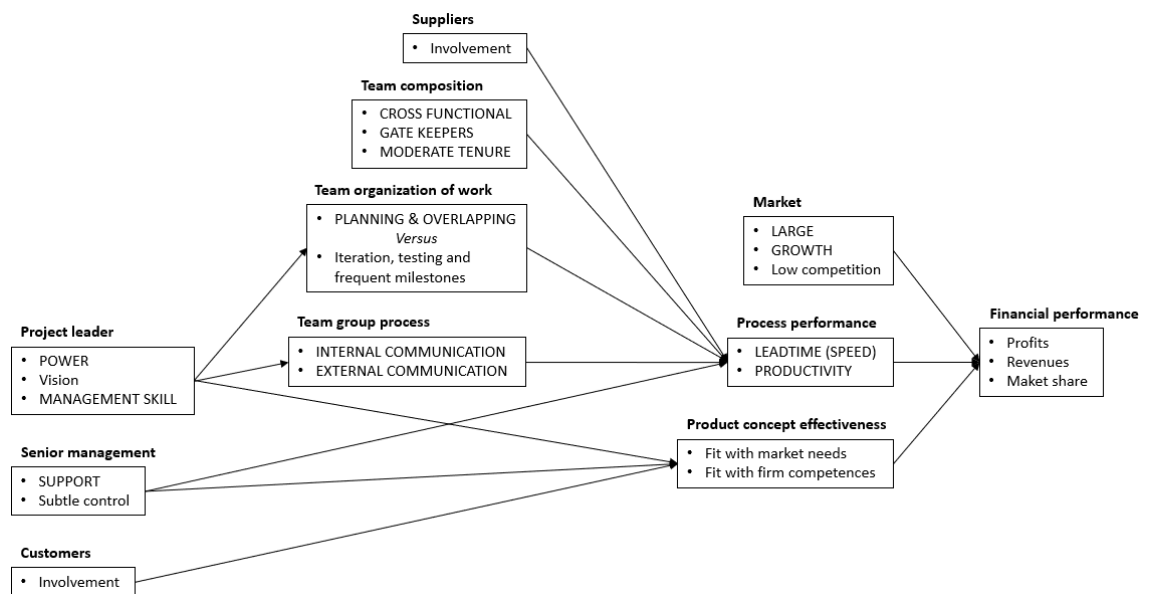


Figure 3. Factors affecting the success of NPD projects, adapted from (Brown & Eisenhardt, 1995).

2.2.2 Stage – Gate approach

The Stage-gate model is presented by Cooper (1990) which is a NPD technique. It provides robust, visible, and straightforward way to manage NPD process. Using stage-gate model will reduce ad hoc decisions and deficient actions because it forces to understand and do everything which is needed before advancing to the next stage. Senior management who has authority and are responsible for decision-making are called gatekeepers. Stage-gate model and its different stages are presented in figure 4. Stage-gate model starts evaluating different ideas and requirements continuing to define the scope and other technical features. Precise investigation of different technical features and market conditions are made before moving into physically developing prototypes.

Following that the whole product is tested before launching it. Lastly the entire process is reviewed to find out strengths and weaknesses to enable continuous learning. (Cooper, 1990; Watz & Hallstedt, 2020). To further develop this model Cooper (2017, p. 188-193) has included agile methods into stage-gate model. It enables close customer involvement by including customers into iterative design sprints. During the process, the overall design of the product improves, communication increases, and it eases managing uncertainties.

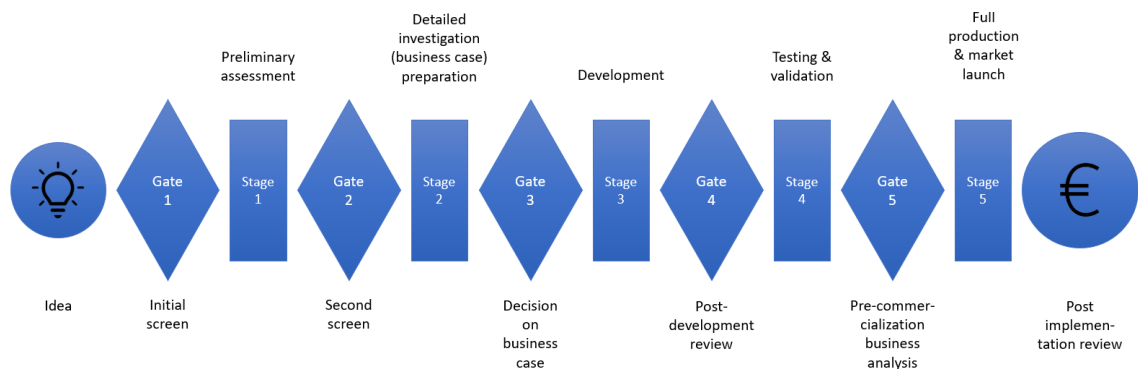


Figure 4. Stage-gate model, adapted from (Cooper, 1990).

To maximize its capability, sustainability should be considered during different gates. According to Watz & Hallstedt (2020) this corresponds to higher sustainability maturity than when comparing to companies where sustainability activities are limited to ad hoc customer requests and regulatory compliance. The best practice would be to consider sustainability during every gate. (Chapas et al., 2010).

2.3 Product lifecycle management

The process or business activity which manages a company's products from initial idea to its disposal is called Product Lifecycle Management (PLM). It manages company's all products from part level to portfolio level. The main objective of PLM is that it ensures fast and easy data gathering as it provides easy data access and distribution within the company and its stakeholders. (Barrios et al., 2022). Furthermore, literature shows that PLM can increase product revenues, analyze, and reduce product costs and thus it will maximize product value. (Saaksvuori & Immonen, 2008, p. 3; Stark, 2016, p. 1).

PLM is further development of engineering data management and product data management which emerged in 1980s when manufacturing companies realized that they need to have way to manage increasing amount of data, files, and computer aided design

models. Those systems enabled companies to combine document files, BoMs, and models together. This enabled to revise existing data or models which is revolutionary factor on reusing data. (Saaksvuori & Immonen, 2008, p. 1-2).

There are many ways to define and differentiate different product life cycle phases and there is no right or wrong way to do it. If the company wants to maximize its PLM and life cycle thinking possibilities it must find the most suitable way to do so. Terzi et al. (2010) have defined product life cycles into three different phases. First Beginning of Life (BOL), then Middle of Life (MOL) and lastly End of Life (EOL). Multilevel model of different product life cycles and what each phase consists of is presented in figure 5. BOL phase includes design and manufacturing of product and process. During BOL phase the product is mostly in the hands of the company. With different tools products are generated and eventually moved to manufacturing. In MOL phase, products are no longer in the manufacturer's hands and are distributed to the end user. MOL phase also includes the use by end users and support provided by external service providers. Here it is possible to collect valuable information about usage and service history. Unfortunately, as said by Alblas et al. (2014) companies usually suffer from absence or fuzziness of externally collected data and in some cases the data exists, but the company is not able to collect and filter it. Last phase is EOL where products are retired. If lifecycle data is properly gathered, then product disposal shouldn't be a problem. It is easy to recycle parts and return them back to production when you know what it consists of. (Terzi et al., 2010). However, Diaz et al. (2021) found out that most companies suffer from knowledge of what happens to their products at EOL phase and communication with EOL stakeholders was insufficient for most of the companies.

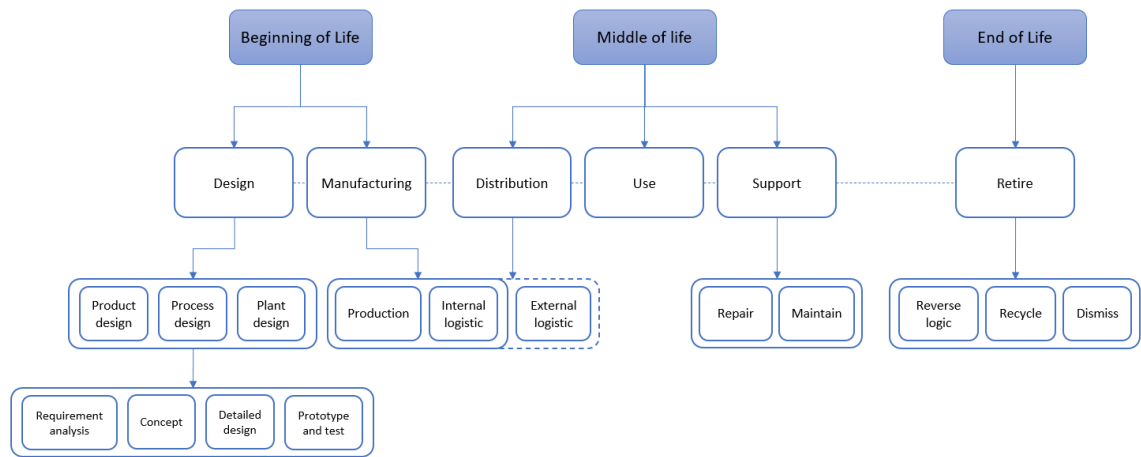


Figure 5. Product life cycle phases, adopted from (Terzi et al., 2010).

To manage products properly cornerstones of PLM need to be considered. Those are product-specific processes and its management, skilled people working around it, and product related data. (Grieves & Tanniru, 2008). PLM provides collaboration around key factors combining process, people, and data together and embedding it with technology. (Gmelin & Seuring, 2014; Terzi et al., 2010). Products and processes tend to improve, change and refine during life cycles when they are produced. PLM applications don't just store data and information, but they also collect and enable it to be used at the right place and time when needed. (Pasley & MacCarthy, 2020). One of the latest innovations has been combining PLM and Internet of Things (IoT) together. Combining both would offer an efficient way to work with existing and real-time information. Predictive maintenance, prototype testing and remote monitoring are good examples where this is already noticed to work properly. Previously, that was done by selecting and handpicking the right data. (Barrios et al., 2022). Another significant development step is including digital twin in PLM. Especially the manufacturing industry is starting to take advantage of its different abilities to enhance its operations. Digital twin allows companies to simulate real-time working conditions and it supports companies' intelligent decision making by giving cost effective solutions, quantitative analysis methods and ability to observe product and its impacts during complete life cycle. (Lim et al., 2020).

There are still problems with PLM strategies, implementation, and daily operations about PLM applications. Digital data is usually too fragmented which aggravates reusing data across the life cycles. This needs to be done manually which generates extra work. Using the same data in sequent life cycle phases from NPD to disposal happens properly only if there is a regulatory requirement, for example in nuclear facilities. (Barrios et al., 2022).

2.3.1 Life cycle thinking and management

In life cycle thinking the focus is beyond traditional thinking about products and processes. Environmental, social, and economic perspective is covered from cradle to grave so that choices support long term targets. According to UNEP-SETAC (2017) life cycle thinking *“is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle.”* Products tend to have different impacts during different life cycle stages. This is why it is important to closely consider the entire life cycle to achieve truly sustainable products. (Mani et al., 2010). Life cycle thinking is recognized and used in many sustainable design strategies, for example in Design for Excellence (DfX) and in SPD. (Chang et al., 2014; Hallstedt et al., 2013).

The life cycle thinking approach is presented in figure 6. It presents how products' life cycle begins from raw material extraction from natural resources without forgetting energy generation and consumption. As the product life cycle continues it goes through design and production, packaging, and distribution, use and maintenance. Eventually it reaches the point where materials and energy can be reused, recovered, recycled, disposed of, or extracted from the cycle. (UNEP-SETAC, 2017).

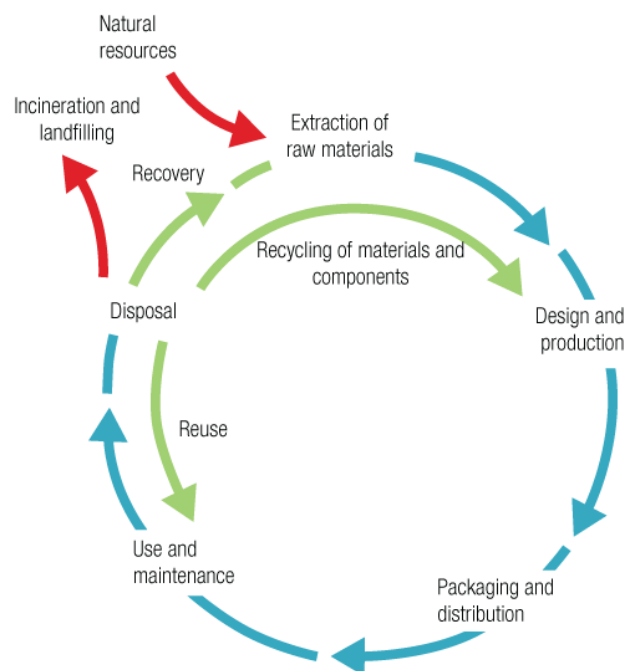


Figure 6. Life cycle thinking according to (UNEP-SETAC, 2017).

Among manufacturing companies' Circular Economy (CE) has gained wide interest. CE is a framework which enables companies to align their long-term goals and sustainability related goals together. The end goal of CE is to separate resource consumption from wealth and welfare creation (Stahel, 2019, pp. 14). According to Diaz et al. (2021) CE has become an essential part in sustainable development as it works like an umbrella capturing various activities like R-strategies to help companies develop more sustainable products. In NPD lies a structural problem since usually development starts from existing products and to best leverage CE that could act as a barrier. To solve that, during the first phases of NPD more emphasis should be given towards CE such as in planning and concept development. Companies should also see CE as a socio-technical challenge and develop collaborative solutions. (Gbededo et al., 2018). It is presented that companies should maintain some level of integrity to the product after producing it and R-strategies are well supporting that. (Diaz et al., 2021). To support that, according to Mani et al. (2010) extended producer responsibility is gaining interest among producers and consumers.

R-strategies originates from 3R's which are reduce, reuse, and recycle (Chang et al., 2014; Shetty, 2016). R-strategies doesn't limit to those "R's" since there are several other suitable "R's". Reike et al. (2018) presents comprehensive framework of 10 different "R's" which are listed below.

- Refuse
- Reduce
- Resell/Reuse
- Repair
- Refurbish
- Remanufacture
- Repurpose
- Recycle
- Recover (energy)
- Re-mine

Recent studies also show that including R-strategies in design phase is too late since product designers are not the decision-makers. Sustainability definitions and specifications should be addressed earlier, and designers implement those in practice.

(Diaz et al., 2021). They also include different drivers for implementing R-strategies. First being regulations, such as REACH EC 1907/2006. Also, requirements of certain certificate can act as a driver. External pressure such as customer demand or the impact of optional due diligence adopted by competitors drives companies to adopt R-strategies. Companies can internally implement proactive sustainability policies and proactively complete internal development projects which act as an incentive to implement R-strategies and other sustainability measures. Lastly, if there is possibility to economically benefit from that such as it supports corporate level competitive strategy to entry specific markets like after sale services, R-strategies were implemented. (Diaz et al., 2021).

2.3.2 Life cycle assessment

Concerns about environmental issues started to attract more attention in the beginning of 1970s and Life Cycle Assessment (LCA) was developed. It is a quantitative tool to measure product environmental impacts, energy and material used during all life cycle phases and it can offer valuable information about product and the production process. (Mani et al., 2010). LCA is defined in International Standards Organization (ISO) standards ISO 14040 and ISO 14044. Inputs, outputs, and environmental impacts of products' entire life cycles are presented in the first mentioned and the operational side is covered in latter one. Therefore, LCA has become a popular and relevant analysis tool for companies' aiming for SPD. (Chang et al., 2014; Sala et al., 2016).

LCA can be used to identify and improve products environmental performance during any life cycle phase (Chang et al., 2014; Dangelico & Pujari, 2010). It can be used to inform companies or their stakeholders about product related environmental questions. LCA helps companies in selection of right Key Performance Indicators (KPIs) measuring environmental performance or measuring techniques like LCA checklists. In addition, it can be helpful in marketing since LCA can be used when making an environmental claim, implementing an ecolabel scheme, or producing an environmental product declaration. Johansson et al. (2021) underlines that in design phase LCA is one of the most important analytical tools to exist.

LCA consists of four different phases which address the environmental aspects and impacts during all different life cycle phases. The first LCA phase is the goal setting and scope definition phase. There, as its name suggests, the goal and the scope of the study are defined. More specified system boundaries, main methodological choices and the

intended use of the study are made. The scope of LCA can differ significantly depending on the wanted results and goal of the LCA. The second phase of the LCA is inventory analysis phase. There data related to the study is collected and calculated to quantify inputs and outputs of the system. Inputs consist of used energy, raw materials and other used physical things when outputs are such as products, co-products, waste, and emissions. Usually during this phase when data is collected new limitations or possibilities are found because the system is becoming more familiar. After that comes the third phase which is the impact assessment phase. There the purpose of life cycle impact assessment is to offer additional information to help evaluating earlier results from life cycle inventory analysis to better understand results environmental importance. The last phase of LCA is the interpretation phase. In this phase results from earlier phases are combined and reviewed to match the goal and the scope. Results should be addressed with some uncertainty, and it is good manners to double check them. (ISO, 2006a; ISO, 2006b; Mani et al., 2010; Sala et al., 2016).

Chang et al. (2014) suggests that NPD and LCA development should keep the same pace because of the vague measurements of environmental impacts. In figure 7 LCA in NPD is presented with typical problems, corresponding solutions and different LCA tools to utilize in different stages of NPD. Companies should actively use assessment results to improve product and operations and not just use them to report or retrospectively check their performance (Held et al., 2018). Concept design stage refers to a point where different possibilities are evaluated and lack of concrete inputs to LCA might become an issue. Usually, assumptions are made to support mathematical models in quantifying customers and technological requirements. After the completion of the first prototype designers keep evaluating more specifically different options in part design stage. Most likely better solutions in material selection can be found for example. The purpose of process design stage is to evaluate different manufacturing processes until they are decomposed to material and energy flows to enable decision making. Even if there are many analytical evaluation methods which provide valuable data to managers and designers, still there are challenges in decision making. The overall performance and success are determined in this stage. Therefore, comprehensive analysis of the whole product life cycle must be reviewed, and no environmental issues can be neglected. Especially when external pressures from eco-organizations and regulators are increasing. (Chang et al., 2014).

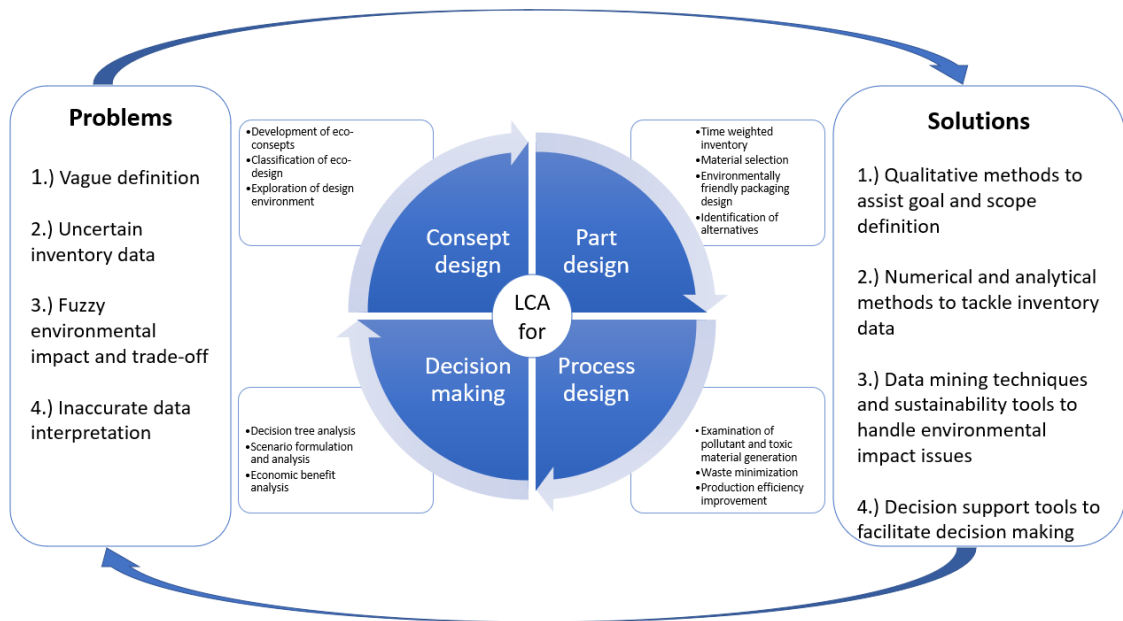


Figure 7. LCA in NPD process and typical characteristics adapted from (Chang et al., 2014).

Conceptual framework which combines PLM and different life cycle assessment methods and management strategies in SPD environment is presented in figure 8. It shows the importance of pressure which acts as a trigger for SPD and collaboration which supports that. Interconnection between PLM and different assessment strategies are important since right and precise quantified data is needed for assessment methods. Those methods provide valuable results which are then stored in it as well as when results are needed, those are easily obtained there. (Gmelin & Seuring, 2014).

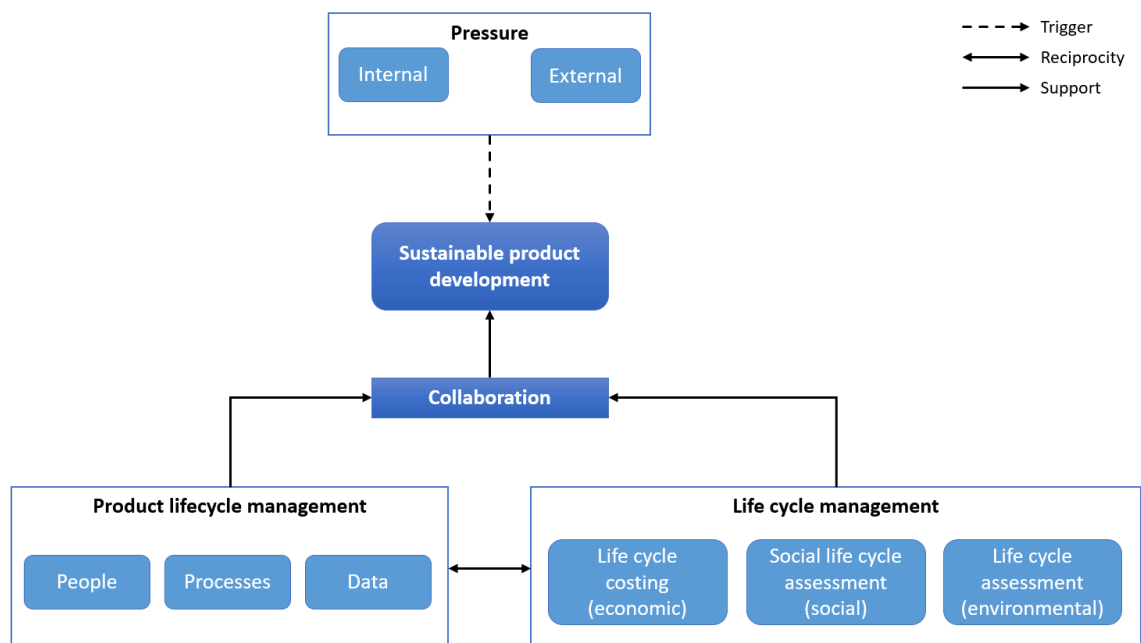


Figure 8. Life cycle focused SPD adapted from (Gmelin & Seuring, 2014).

2.4 Sustainability in product development

Mani et al. (2010) recognizes the need for integrating effective evaluation tools in NPD process. Whereas, according to Watz & Hallstedt (2022) there is a wide variety of different tools and methods for SPD. Still implementation to practice remains low. This may be consequence from overflow of different sustainability implementation methods in NPD (Held et al., 2018). Lack of accessing life cycle data has also been confirmed to be a major obstacle for SPD (Diaz et al., 2021). As said by Shetty (2016) that including sustainability into NPD, it only doesn't benefit environment, but it also offers new business opportunities.

Diaz et al. (2021) describes that SPD process diverts R-strategies to product requirements, where Chang et al. (2014) continues that LCA results can be improved by considering R-strategies in the beginning of SPD process. This is significant since most of the products' environmental impact are determined in this phase. A sustainable approach also lowers the risk related to the product when it is comprehensively evaluated. For instance, the risk for potential supply chain malfunction or the possibility to find prohibited raw materials lowers. All these added to the concerns about rising energy costs and increasing pressure from legislation, firms see SPD as a great opportunity (Ganji et al., 2017; Shetty, 2016). According to Watz & Hallstedt (2020) SPD means that during early phases of NPD strategic sustainability perspective is considered and implemented into practice. Shetty (2016) states that NPD process is about developing more durable products which contain less parts and are packaged and recycled easily while having good quality and possibility to continuously improve product.

SPD is not something that companies can just think and at once implement into action. It requires long and perseverance involvement about many activities and different strategies to pursue towards targets. Companies need to have long-term targets which steer the overall direction of the company. Those are strategic level targets. To support strategic level sustainability targets, companies have tactical level sustainability targets. Tactical level sustainability targets consist of several absolute sustainability targets which are made by individual persons in day-to-day activities. (Hallstedt, 2017). Held et al. (2018) states that in manufacturing industry companies have favored too much short-term goals and neglecting the importance of long-term goals where dieselgate is good example of this. According to Watz & Hallstedt (2022) companies which have established

sustainability policy and company-specific sustainability definition covering all TBL dimensions connected to product innovation process are more likely to success in SPD. This is also aligned with findings by Driessen et al. (2013) who founded that green company policy has major influence on green product innovation. It also requires systematically implemented analytical methods and tools which defines and enables to evaluate different possibilities without making trade-offs in the operational management system. Lastly it requires people with sufficient competence to enable the right decisions.

2.4.1 Triple bottom line – Sustainability dimensions

Triple Bottom Line (TBL) consists of economical profitability, social responsibility and respect for the environment, or any combination of these three dimensions (Arslan & Kisacik, 2017; Elkington, 1999). This concept is universally accepted in business context as sustainability (Abbas et al., 2014). Companies utilize many different strategies to integrate TBL into organizational context and operations (Mani et al. 2010; Rodrigues et al., 2016a). To be truly sustainable, the TBL must be implemented in products every life cycle stage including services (Wang et al., 2021). TBL dimensions are presented in figure 9. Sustainability is truly achieved when all three dimensions are fulfilled together with respect to their interconnections. (Mani et al., 2010; Shetty et al., 2015). TBL dimensions have different requirements which companies must implement into their operations to achieve sustainability. Companies' ability to meet the requirements of environmental dimension can be measured in emissions into air and ground as well as in consumption of energy, water, and materials. In addition, use of dangerous or hazardous materials and in biodiversity or environmental issues over full product life cycle are measured in environmental dimension. Company's internal activities such as capability to provide decent labor practices, opportunities to develop new skills, and offering occupational health services are used in measuring social performance. Also, external activities such as how well companies follow regulations and political decisions, having code of conduct, working only with responsible suppliers and partners are important to achieve social dimension. Profit and revenue are well known ways to measure economic performance. To expand the area of evaluation, different KPIs should be considered such as capital used to NPD, shareholders remunerations and size of market share are just a few to name. (Rodrigues et al., 2016a).

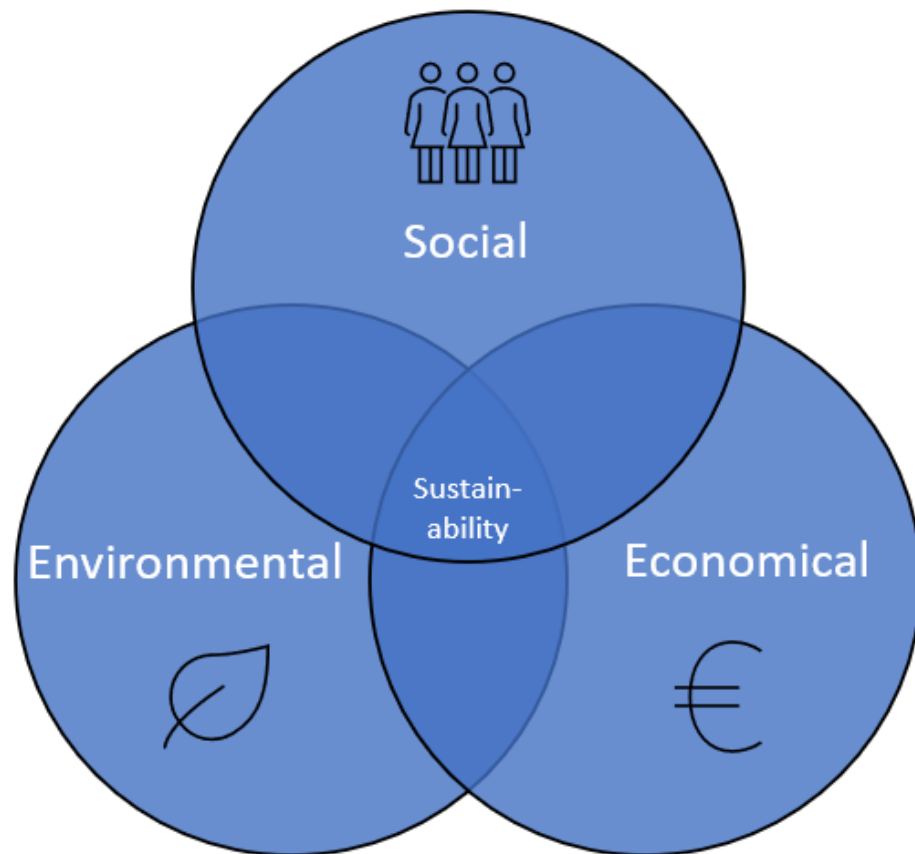


Figure 9. Triple bottom line dimensions adapted from (Arslan & Kisacik, 2017).

According to Diaz et al. (2021) that when you need to do tradeoff between different TBL dimensions, economical dimension was never sacrificed, and social dimension were easiest to be neglected. Economic dimension is also dominated in amount of KPIs measuring its success. Gbededo et al. (2018) states that there is imbalance with different TBL dimensions and that social dimension is most likely to be neglected and its interdependencies with others is the most deficient. This might be due to its uncertainty and intangibility. Where environmental dimension is lacking in clear metrics to evaluate its success in NPD. They also present their concerns that too often different dimensions are looked at separately and in sequential order. When the most effective way is to evaluate interdependencies simultaneously which is supported by Baumgartner & Ebner (2010). There is still ambiguity about how to efficiently work with different TBL dimensions and how to measure it. (Chapas et al. 2010; Rodrigues et al., 2016a).

Looking from TBL perspective it would be advantageous to share innovations and new solutions which have remarkable environmental or social advantages Chapas et al. (2010). Unfortunately, this has major conflict of interest with companies' economic performance. Diaz et al. (2021) stated that there is lack of incentives to share information.

2.4.2 Design for Excellence

Companies face increasing pressure to embrace sustainable acts in NDP (Shetty, 2016). DfX is systematic manner to address product functionalities and requirements in early phase during NPD process covering full product life cycle. DfX can include several variable factors such as manufacturing, environment, or sustainability. Benefits of having recognized and specified goals will enable to develop best practices and likely to achieve desired goals. (Lehto et al., 2011). As a qualitative method DfX is used to help goal and scope definition in LCA and many sources address that DfX and LCA are commonly used tools in SPD. (Alblas et al., 2014; Chang et al., 2014; Chapas et al., 2010; Mani et al., 2010; Shetty, 2016). According to Lehto et al. (2011) including DfX into operations it will offer several benefits in different perspectives such as in cost, quality, services, delivery, and flexibility.

To create more sustainable products Design for Environment (DfE) is a commonly used approach. It allows to systematically consider TBL objectives in NPD over full product life cycle. (Gremyr et al., 2014). DfE treats sustainability factors such as R-strategies, energy and material efficiency and use of hazardous materials as design objectives rather than as constraints and obstacles (Alblas et al., 2014). To enable cost-effective and controlled way to develop more sustainable products, companies need to allow feedback loop from service phase back to design phase (Wang et al., 2021). According to Shetty (2016) completing only eco-efficiency acts is not enough to achieve sustainability. companies need to include it in all TBL dimensions during NPD. In literature DfE and eco-design are used in interchangeable manner. (Johansson et al., 2021). Principles and guidelines for DfE presented by Chang et al. (2014) are listed below.

- Include life cycle thinking to be part of the NPD process
- Resource efficiency and effectiveness evaluations of the overall process
- Choose the right metrics to indicate product life cycle performance and success
- Implement systematic design methods portfolio
- Utilize evaluation methods to monitor design performance and trade-offs
- Leverage software to improve DfE process
- See nature as an opportunity to develop new products

Gremyr et al. (2014) highlights the importance of reducing uncontrollable noise factors from NPD process which is called robust design methods. Noise factors generate

deviation which may appear in lack of quality, environmental damage or in increase of operational costs. Inferior products may produce dissatisfaction among customers. Robust design methods support SPD by minimizing deviation in NPD which increases the performance in all TBL dimensions. Capturing customer expectations is crucial and method such as concurrent engineering can be very helpful when tasks are simultaneously and systematically completed together with all stakeholders. (Makovec et al., 2014).

DfE and LCA have a lot of similarities in requirements and capabilities. Literature manifests that only deploying sustainable methods such as DfE and LCA aren't enough to achieve SPD. Defining clear scope, setting concrete target about sustainability within the company and having high quality information and data available, are cornerstones for efficient DfE. Successful implementation requires strong and committed management. However, if basics of NPD are lacking within the company, then the focus should be on those before moving into implementing sustainability. (Alblas et al., 2014).

2.4.3 Success factors of sustainable product development

Mani et al. (2010) states that there is lack in measuring tools and methods to support SPD. Whereas according to Rodrigues et al. (2016a) to enable decision making and effective management it is crucial that the metrics to measure sustainability are defined and set into action. As said by Alblas et al. (2014) it is important that companies understand first what sustainability means in their case and after that start measuring it and adjusting their operations. Held et al. (2018) list different indicators to assess SPD such as energy and resource consumption, global warming and acidification potential, amount of generated waste as well as percent share of biodegradable packaging, products designed with R-strategies and suppliers chosen for environmental or social reasons. Also refusing to cooperate with partners who don't fulfill all TBL dimensions of sustainability.

Extensive research about different KPIs measuring TBL dimensions performance in NPD is conducted by Rodrigues et al. (2016a), where they identified 787 different KPIs. Research results show major dominance of economic indicators, which were 74,2% of all KPIs. Social KPIs were 19,2% of total and KPIs measuring environmental performance were only 3,2% which is alarming. In addition, 3,4% of indicators were bi or tri dimensional. These results show that companies are still measuring NPD success with economic performance and other TBL dimensions are left aside or not given the same value. This is the result of the uncertain nature of NPD process and because companies

value hard data and facts when making decisions. In figure 10 a handful of those KPIs are presented and linked to corresponding NPD stage. Some KPIs are described as generic activity which means that it is not possible to target to specific NPD stage or it occurs during whole NPD process like environmental budget. (Rodrigues et al., 2016a).

Different qualitative and quantitative methods are presented in table 2 where they are divided according to the purpose of use. To benefit from having these KPIs and different methods to analyze, assess and to even forecast it is necessary to consider how to implement those in practice. Hallstedt (2017) introduces eight key elements to implement successfully implement sustainability perspective which are listed next:

- Verifying organizational support from upper management
- Introducing sustainability efficiently in early phases of NPD
- Utilize and include stakeholders in early phase of NPD
- Include all TBL dimensions across full product life cycle
- During innovation process assign responsibility for sustainability implementation
- Enable systematic knowledge sharing and competence building within sustainability to benefit in future NPD projects
- Enable different tools in decision making to support common assessment tools
- Enable backcasting perspective and use tools supporting that

Key Performance Indicator	TBL Dimension	Product Development Phase					
		PLA	CD	SD	DD	TR	PR
External acquisition of R&D	Economic						
Considerations of sustainability aspects in project scope	Social, Environmental and Economic						
Degree to which the product meets the environmental legislation requirement	Environmental						
Purchase intent rate prior to market introduction	Economic						
Legislation and environmental demands	Environmental						
Considerations for improving sustainability at the end-of-life	Social, Environmental and Economic						
Expected reuse for products	Economic						
Lead time from agreement of requirement to manufacture	Economic						
Number of engineering change orders	Economic						
Number of unique ideas	Social						
Improvement potential of selected concepts	Economic						
Drawings "first-time pass"	Economic						
Number of design defects detected at development stages	Economic						
Economic feasibility in detailed design	Economic						
Planned versus actual formal test procedures attempted/completed	Economic						
Manufacturing process safety	Social						
Launched on time and in budget	Economic						
Customer satisfaction level	Social						
Environmental budget	Environmental and Social	Generic activity					
Attracted foreign researcher	Social						
Number of products with eco-label	Environmental						
Environmental information availability and accuracy	Environmental						
<p>* PLA: Planning; CD: Concept development; SD: System-level design; DD: Detail design; TR: Testing and refinement; PR: Production ramp-up</p> <p>** Product development phases and KPIs changed to match with Ulrich and Eppinger (2016).</p>							

Figure 10. Example sustainability KPIs for each NPD phase and its combinations adapted from (Rodrigues et al., 2016a; Rodrigues et al., 2016b).

Table 2. Tools and methods used in SPD according to (Held et al., 2018).

Analysis methods in SPD	Assessment and decision methods in SPD	Prediction, creativity and auditing methods in SPD
QFD (Quality Function development)	LCA (Life Cycle Assessment)	Trend Analysis
FMEA (Failure Mode and Effect Analysis)	LCC (Life Cycle Costing)	Eco-TRIZ
Guideline for improvement of NPD	S-LCA (Social Life Cycle Assessment)	EHS-Audit (Environment, Health and Safety)
Framework for strategic sustainability development	LCSA (Life Cycle Sustainability Assessment)	EMAS (Environmental Management and audit Scheme)
A practical road map for integration of sustainability issues	WSLC (Whole System & Life Cycle Method)	
	PCF (Product Carbon Footprint)	
	PWF (Product Water Footprint)	
	COMPASS (Companies and Sectors Path to Sustainability)	
	MIPS (Material-Input Per Service Unit)	
	CSPD (Checklist for Sustainable Product Development)	
	SAM (Sustainability Assessment Model)	
	Geocybernetic Assessment Matrix	
	Sustainability Measurement Method	
	Integrated Multimodal Decision Making	
	Multicriteria Decision Making	
	Scenario Method	

2.4.4 Comprehensive approach to sustainable product development

To maximize the effect of introducing sustainability criteria in NPD it is crucial that it is included from the very beginning and aligned throughout the process (Hallstedt, 2017). This could offer companies many benefits which have been recognized in literature before. Shetty (2016) lists that implementing and then actively improving it increases product innovation, quality, safety, and revenue growth. It also improves overall energy efficiency which currently is popular topic, enables product differentiation which supports competitive advantage among competitors (Johansson et al., 2021).

Gbededo et al. (2018) proposes comprehensive framework in figure 11 which provides sustainability practitioners a road map to integrate all three sustainability aspects in traditional NPD process. First, goal and scope are set, and objectives and boundaries are defined in both product and manufacturing process level. It is important to take manufacturing process into consideration in SPD since there are many possibilities to improve products business and sustainability performance (Shetty, 2016). During the second phase traditional NPD and sustainability are put in action to achieve a partial sustainable part of final output, while different elements are evaluated. New sustainable solutions are developed with iterative processes and continuously analyzing different possibilities. Those are then moved forward to model database which act as an input for discrete-event simulation where different TBL dimensions are analyzed and optimized for the best possible solution. Social aspects go through social impact analysis which deploys social impact coefficient which is an aggregated weighted value. Sustainable products and processes are not immediately achieved but through collected feedback and progressively developing better and better solutions sustainability is achieved which in product context means that it is produced with eco-efficient manufacturing process, conserves natural resources, is eco-efficient during use phase, is not dangerous and it is seen as an incentive for promoting social values. (Gbededo et al., 2018).

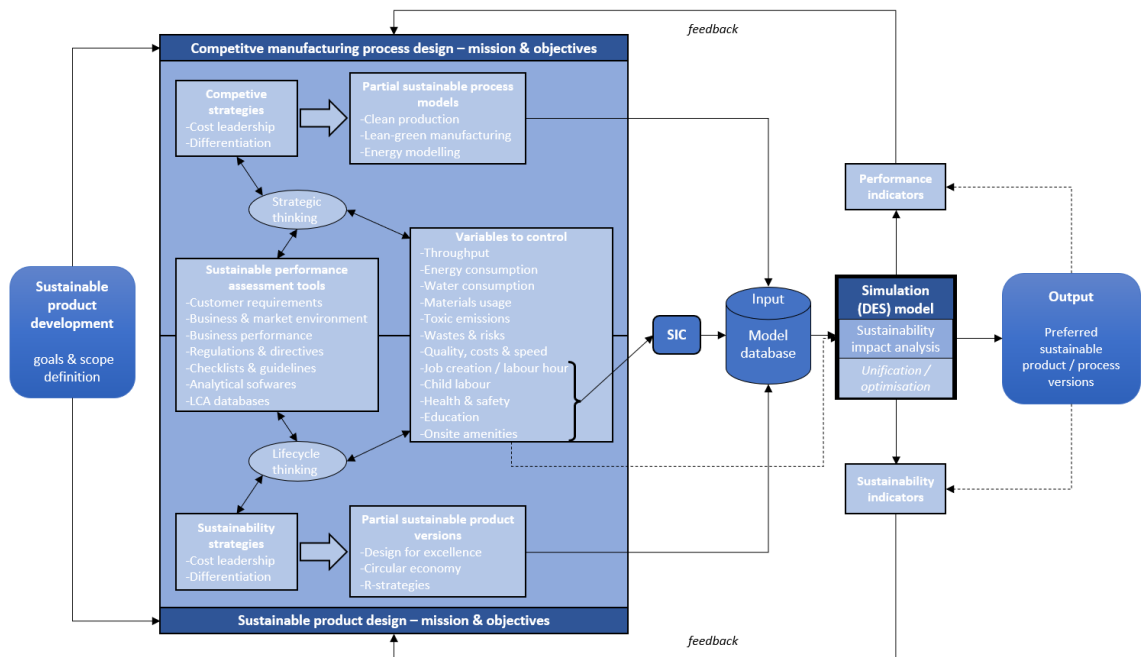


Figure 11. Comprehensive framework for integrating sustainability into traditional NPD adapted from (Gbededo et al., 2018).

2.4.5 Sustainable product-service systems

Product manufacturing and developing companies need to address product related problems after products are transferred to end-user. Sustainable product-service systems aim to develop products that consider all TBL dimensions and in addition to that develop service functions to cover all essential needs (Shetty, 2016). According to Baumgartner & Rauter (2017) moving from product selling-system to product service-system can allow companies to reduce products' environmental and social impacts. In addition, Wang et al. (2021) said that including service in sustainability is needed to achieve sustainable product and that should be done simultaneously with NPD. All life cycle phases should be considered to reduce environmental and social issues to enable economic benefits. That is illustrated in figure 12 where the full product life cycle is considered from design to EOL phase. All TBL dimensions of sustainability are addressed with different tools to support SPD and service. Interaction between SPD and service and the classification of life cycle stages improves overall sustainability performance and thus this framework is useful. (Wang et al., 2021).

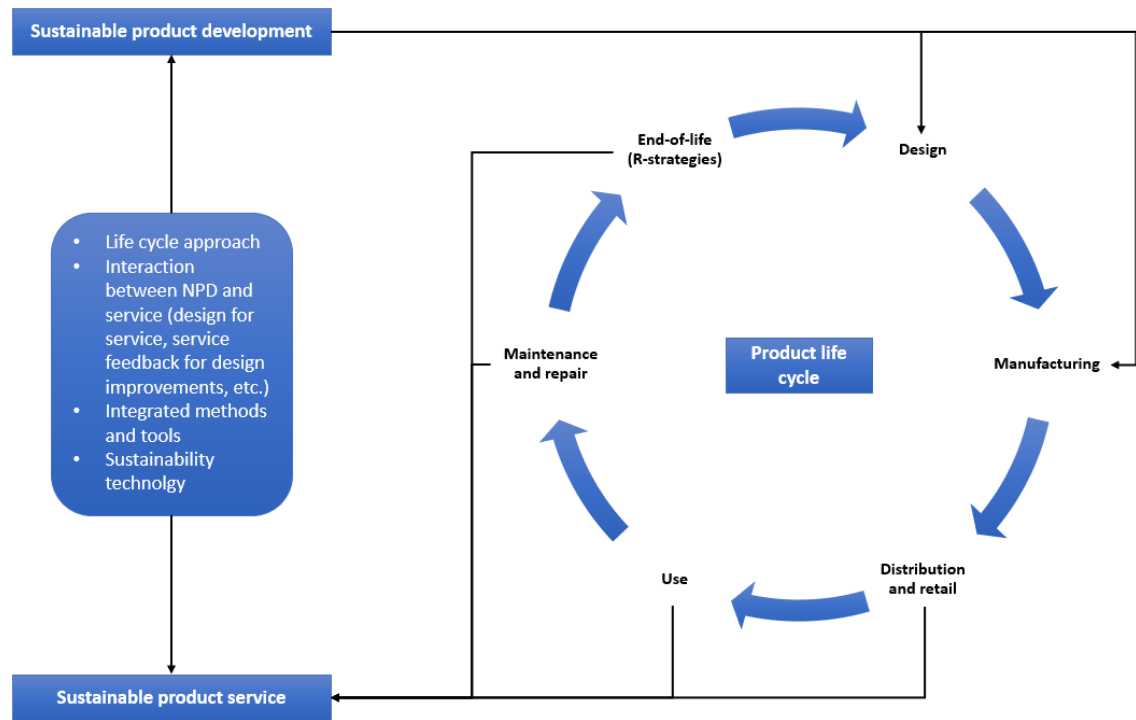


Figure 12. SPD and service approach adapted from (Wang et al., 2021).

2.4.6 Success factors and enablers for sustainable product development

Sustainable and green products should not be seen as an additional cost to companies. It should be an opportunity to differentiate from others and create win-win solutions both for companies and for their customers. (Johansson et al., 2021). Also, customers are reluctant to pay extra for sustainable alternatives nor are manufacturers willing to invest in sustainable if there is not significant cost, quality, and functionality improvements. (Held et al., 2018). However, Dangelico & Pujari (2010) have found out that in some product categories customers are willing to pay extra from sustainable alternative. Movement towards more sustainable approaches to develop new products can be internal or external and different drivers for that exists a lot in this environment (Gmelin & Seuring, 2014). Therefore, as said by Mani et al. (2010) proactive approach to sustainability is seen as a significant objective in the manufacturing industry.

Held et al. (2018) performed research in German automotive sector and results indicated that greatest drivers for sustainability were laws and politics in fear of financial penalties and customers satisfaction. Competitive advantage and cost reduction were given second most attention. Public image and corporate strategy supported future long-term market orientation were given third most attention. Other drivers such as supply chain social responsibility and employee satisfaction were not given so much attention. Another

research about SPD success factors was performed by De Medeiros et al. (2014) and they found out that SPD success consists of factors which consists of variables which are measured. The first factor is knowledge of market, law and regulation which is measured with variables such as customer expectation fulfillment, complying with laws and regulations, and in overall knowledge about factors that drive sustainability buying. The second factor is interfunctional collaboration and its variables are such as level company's different internal operations integration and external integration with different stakeholders. The third factor is innovation-oriented learning and its variables could be measured in development of a set of green competences. The last factor is investments in research & development which is logically measured in investments for diverse SPD methods and investment in qualified human resources. These are all in line with findings by Watz and Hallstedt (2022) who presented a list of consolidated improvement actions. Dangelico & Pujari (2010) also confirms that compliance with regulations is driving companies to more sustainable NPD avoiding risks, money losses and damage to company image. Alblas et al. (2014) divides factors into internal and external. Internal factors are such as monetary savings, quality improvement, risk reduction and boost in social image. External factors are given growing interests which are laws and regulations, customer demand for more sustainable products and pressure from non-governmental organizations.

Watz & Hallstedt (2020) defined five key elements to successfully implement sustainability into NPD considering early requirement management and organizational maturity. First being the power of sustainability power, which contains implantation of different policies and how companies follow them. Second is the scope of sustainability policy which indicates how broadly it has been implemented. Third being the sustainability implementation particularly in NPD process. Fourth is contextual selection of sustainability criteria included in NPD projects and the last one is the decision board's sustainability capability. Having these key elements considered within the company, it will enhance the company's SPD performance and sustainability maturity.

Companies' ability to implement those in action can be reactive or proactive or something between those two definitions. Alblas et al. (2014) said that taking a proactive and entrepreneurial approach to sustainability in NPD will help achieve it and that implementation of SPD is not possible in companies which don't accept uncertainty and lack innovative capabilities. They also discovered that most of the companies which they

interviewed were reactively acting towards sustainability. That means most of the time companies were waiting for clear indicator to do something rather than doing something beforehand to prevent that escalating.

2.4.7 Sustainable product development and risk management

Literature has proven many examples of why sustainability in NPD is important, and those statements have been confirmed by companies in practice. According to Banerjee & Gupta (2017) banks and investors are increasingly assessing sustainability performance for lending money. In addition, following sustainability measures can benefit companies by paying less fines if they accidentally break regulations. Those added to benefits in risk management company's overall cash flows are less volatile. Dangelico & Pujari (2010) and Johansson et al. (2021) lists following benefits when implementing SPD such as increase in resource and return on investment efficiency, new sales and market opportunities, positive corporate image, and competitive advantage due differentiation from competitors. Implementing SPD also increases products overall quality and safety and lowers product-related risks such as unexpected supply chain malfunctions or possibility to find hidden unwanted toxic materials (Shetty, 2016).

2.5 Sustainable development

Corporate sustainability activities have been increasing constantly and companies are starting to show more interest towards it, mostly because of relentless pressure from non-governmental organizations, authorities, and governments. Companies are struggling to implement sustainability into their operations due to its complexity and lack of understanding in basic principles of sustainability. This sometimes leads to greenwashing where companies are pretending to take sustainability measures. (Baumgartner & Ebner, 2010; Baumgartner, 2014). This shouldn't be the case, since according to Held et al. (2018) to implement sustainability into NPD, corporate strategy plays significant role. This also agrees with findings by Diaz et al. (2021) who found out in their research that if corporate culture and management processes are not aligned, sustainability strategies likely fail. Therefore, to enable SPD in companies should manage corporate strategy and sustainability together.

Sustainable development and its interconnection with corporate sustainability is presented in figure 13 where all different TBL dimensions interact together. This also

strengthens the finding that it is important to consider all different TBL dimensions together and how they interact without forgetting external influence and stakeholders. TBL pillars crossing over corporate sustainability square into sustainable development box shows that corporate sustainability has positive effects on society in long-term. (Ebner & Baumgartner, 2006; Baumgartner & Ebner, 2010). In addition, Dyllick & Hockerts (2002) names three key elements of corporate sustainability which are integrating all three TBL dimensions, incorporating both short and long-term goals, and consuming income not the capital. These are in line with other findings and to conclude all this Baumgartner & Rauter (2017) defines sustainable development as a development of economic, environmental, and social dimensions so that they meet present needs and allow future generations to fulfil their essential needs.

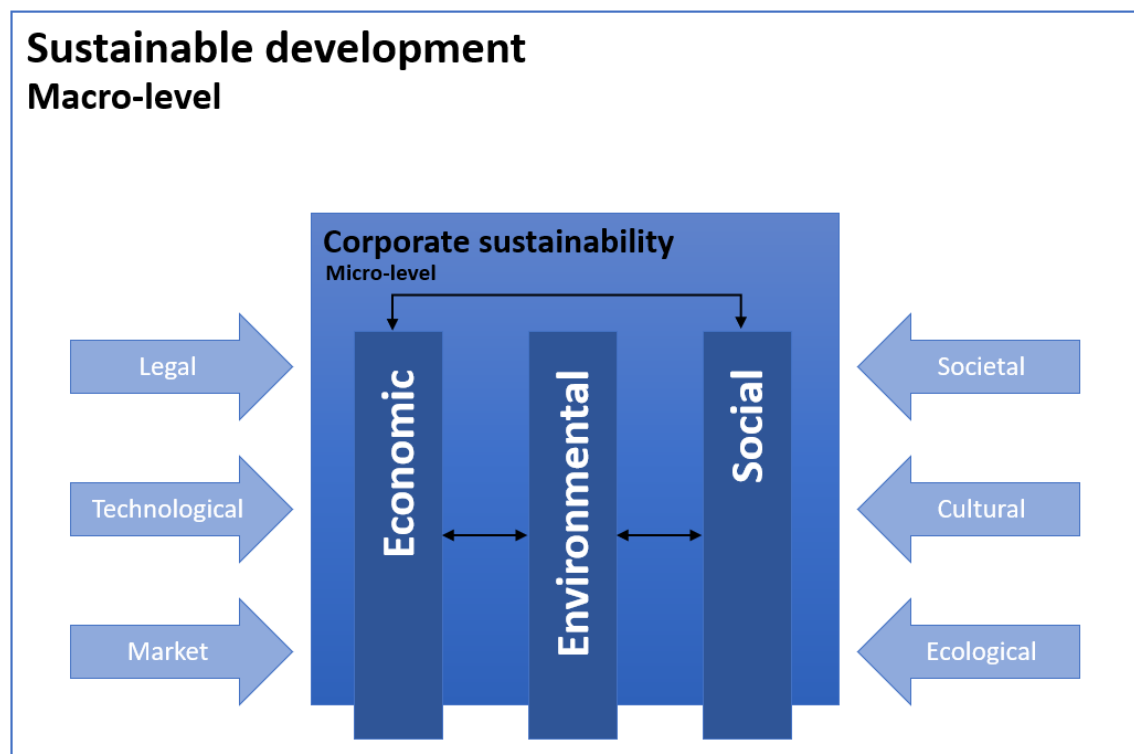


Figure 13. Sustainable development adapted from (Ebner & Baumgartner, 2006).

Companies can have internal or external approach into corporate sustainability strategy. In introverted strategy companies focus on risk mitigation such as legal other external regulations and standards. This is a basic level strategy, and its purpose is to minimize and avoid different risks. Extroverted strategy, however, focuses on legitimating, which means that it tries to enhance external relationships and not just follow them. Extroverted strategies can be differentiated between conventional and transformative approach. Conventional extroverted strategy focuses on communicating its commitment into

sustainability and by that it tries to stand out from its competitors. In this strategy lies the risk for greenwashing. Transformative extroverted strategy is similarly focusing on positive communicating of sustainability commitment, but it also tries to truly influence basic sustainability measures about corporate sustainability. Next strategy is conservative strategy which is focusing on efficiency and better processes. Conservative strategy is focusing on internal aspects of sustainability. This means that companies following this strategy are focusing on finding the right technology and solutions for increased sustainability without forgetting health and safety measures of employees. The last strategy is visionary strategy, which is comprehensive and groundbreaking approach focusing all TBL dimensions to improve operations and to offer unique solutions. It can be divided into conventional and systematic approach where the conventional visionary strategy is focusing on market impact and the systematic visionary strategy is focusing on continuous improvement of sustainability and leveraging both outside-in and inside-out perspectives to achieve competitive advantage. (Baumgartner & Ebner, 2010).

According to Held et al. (2018) corporate strategy and management behavior have a clear impact to SPD. Also, corporate sustainability management can have positive influence in productivity, process efficiency, risk management, and it helps developing more sustainable products. These usually lead to better financial performance, improvements in reputation and legitimacy, and competitive advantage in markets. (Baumgartner & Rauter, 2017). It is important that companies report and communicate their sustainability activities thus it can increase their corporate accountability, transparency, and to show their commitment into sustainability (Tsalis et al, 2020).

2.6 Synthesis of the literature review

The purpose of the literature review was to answer the first research question which is: **What are the requirements for sustainable product development and how it differs from normal product development?** Literature review also included the latest insights about different measures and techniques which to utilize to achieve SPD.

Several different solutions to enable SPD appeared in literature review. However, this could be a major challenge for companies due to the high uncertainty of NPD process, lack of systematic measurability of sustainability and challenges in implementing sustainability. If companies do not make changes in their operating model, they can face

several troubles such as losing competitive advantage when competitors are launching more sustainable products, getting loans with worse terms when banks and investors are demanding sustainability measures or completely lose business when some material becomes prohibited. This is important also because most of the product performance related matters are decided during NPD phase and those can have long lasting consequences.

Six key requirements for SPD are presented in figure 14 which are: baseline operations, sustainability scope and targets, sustainability policy and strategy, strategic implementation of sustainability, tools and practical implementation of sustainability, and personnel skills and sustainability management. Those forms an exhaustive framework covering versatile aspects of SPD and how companies can achieve it. To maximize the benefits first companies must ensure that their baseline operations are at sufficient level and after that shift focus into defining clear and measurable sustainability scope and targets. Those should form a backbone for company's sustainability policy and strategy which defines how company is pursuing into sustainable acts and decisions. To execute sustainability measures in NPD companies need to implement it into its operations at a strategic level to support practical level implementation which occurs in day-to-day activities. Finally, to ensure that sustainability measures are used and developed further, personnel skills need to be developed and sustainability managed appropriately.

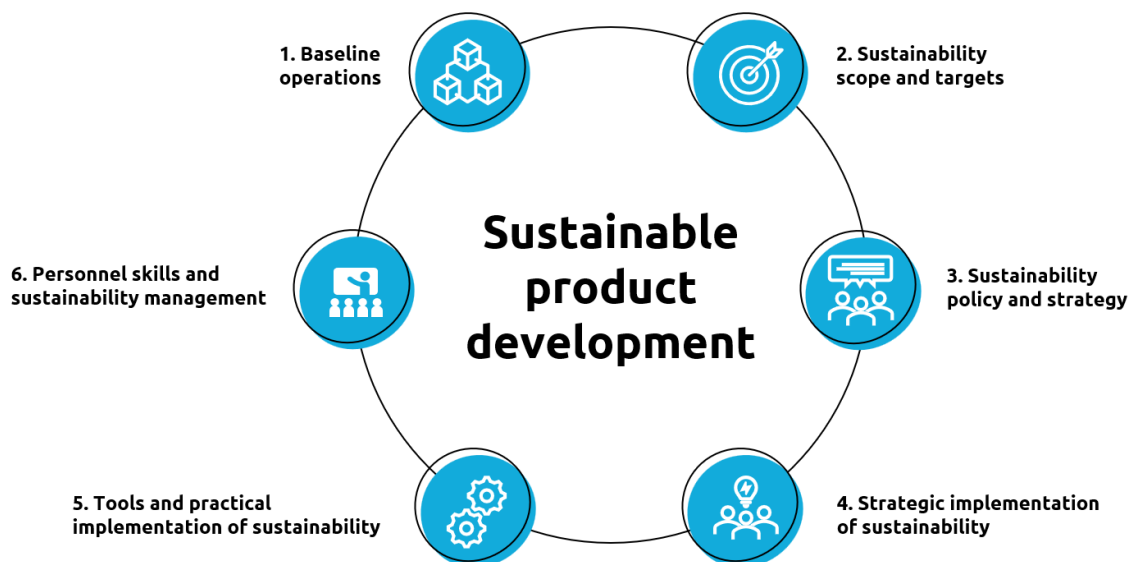


Figure 14. Requirements for SPD.

To address how SPD differs from normal NPD, in figure 15 is presented SPD process and its components. The backbone of the SPD is a normal NPD flow chart which in this case is adapted from Ulrich & Eppinger (2016). This process flow chart part can be some other such as stage-gate model by Cooper (1990) and literature didn't show anything against that it can be even company specific process flow chart. Also, the pressure has similarities since normal NPD and SPD usually need driving factor to make it happen. It can be internal, external or combination of both (Gmelin & Seuring, 2014). The difference consists of these three reasons. First, TBL dimensions affect the entire SPD process. Meaning that every sustainability dimension needs to be included into SPD process from the beginning to the end. TBL dimensions must be considered together with respect to interconnections (Baumgartner & Ebner 2010). Secondly, SPD proactively considers all product life cycles from sourcing to disposal. This two-way communication enables continuous and iterative improvement with acquired feedback (Gbededo et al., 2018; Hallstedt, 2017; Wang et al., 2021). Thirdly, by understanding the requirements of SPD (Shetty, 2016). Requirements of SPD may vary a lot depending on the context, but overall maturity of basic processes and baseline operations must be achieved before starting to focus into SPD more specifically. In addition, generic NPD performance has been usually measured in financial performance such as product units sold or revenue gained from new product. SPD performance in turn can be measured from every TBL dimension and the final performance is usually measured in combination of multiple different factors.

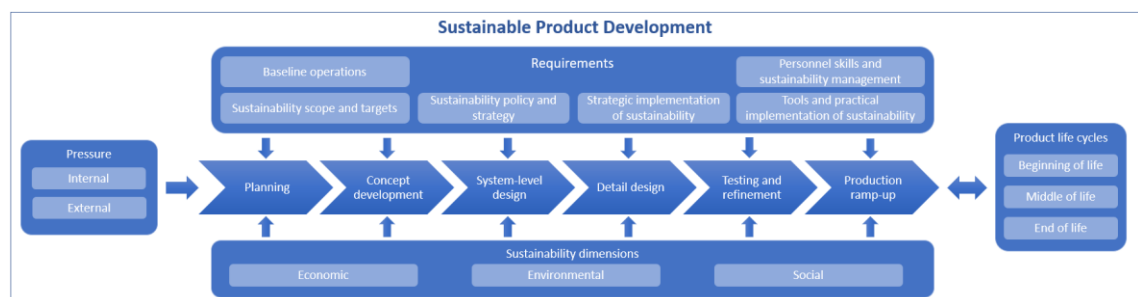


Figure 15. SPD process

3 SUSTAINABILITY MATURITY MODEL

This chapter introduces the sustainability maturity model, its fundamentals, requirements and content. Maturity models are used to evaluate companies' performance in specific area. This maturity model is based on the literature review findings and aims to evaluate companies' overall sustainability performance and more specifically sustainability performance in NPD.

3.1 Maturity model

Maturity models in general are used to evaluate companies and their operations against best practices, recognize the biggest improvement areas and based on those produce development plans (Mani et al., 2010). Maturity models have been applied in a wide range of different fields. For example, in quality management, NPD, and operational excellence. (Fraser, 2002; Isoherranen et al., 2016). To evaluate sustainability performance, another possible method is to incorporate the Dow Jones Sustainability Index (DJSI), which is commonly used to evaluate companies' sustainability performance. It assesses many functions and activities beyond NPD, because of that it might not be the most suitable benchmark for assessing sustainability in NPD. Also, DJSI is not suitable for small and medium size enterprises since participation in it is expensive and it requires extensive efforts within the company. (Hynds et al., 2014). Therefore, we can assume that maturity model would be the right solution to use in this research. Most of the maturity models can be divided into maturity grids, capability maturity models, and to Likert-like questionnaires. Maturity grids contains descriptive text in each element which makes it practically easy and compact way to assess companies. (Fraser et al., 2002).

Sustainability maturity models have been developed in literature before. Watz & Hallstedt (2020) developed profile model for management of sustainability integration into design requirements for engineering design (PROSEQ) which is revised in their later research. (Watz & Hallstedt, 2022). Second sustainability maturity model developed in academic literature is presented by Baumgartner & Ebner (2010). Third sustainability maturity model is developed by Innovation Research Interchange (Hynds et al., 2014) and fourth by Eisner et al. (2022) where they present a comprehensive self-assessment tool that incorporates sustainability and digitalization together. All presented sustainability maturity models have similarities in their scope and goals.

3.2 Sustainability maturity model framework

This research aims to develop a comprehensive framework which addresses sustainability performance in company's overall level and particularly in NPD. Goal of this maturity model is to help companies in manufacturing industry to objectively evaluate and benchmark their sustainability performance in NPD, provide concrete improvement points based on their performance, and indirectly increase and build sustainability awareness. Therefore, maturity grid model was chosen for this and it is presented in appendix 2. Fraser et al. (2002) points out that maturity models usually consist of these following components which may or may not be included into each model. Those are maturity levels with descriptive name to it, several maturity dimensions and descriptions to each dimension which are evaluated by maturity levels, elements within every maturity dimension and precise description for every indicator. Eisner et al. (2022) further developed that structure presented in table 3. These three key topics and five design questions should be addressed during framework design.

Mani et al. (2010) have summarized the following steps when utilizing maturity model evaluation to improve company's operations and performance:

- Substantial review on the latest insights and research addressing the topic
- Identify initial framework for the maturity model
- Identify the essential dimensions and elements for the maturity model
- Identify the maturity levels in the maturity model
- Identify the right questions and competences for each level
- Collect data by surveys or observing the evaluated target
- Assess and implement model

Table 3. Key topics and questions of a maturity model according to (Eisner et al. 2022).

Topic	Question
Maturity Levels	How many levels are applied?
	What are the names of the maturity levels?
Maturity dimensions	How many dimensions are required for the maturity model?
	In how many elements is the dimension structured?
Maturity indicators	What activities and descriptions do the levels include?

3.2.1 Sustainability maturity model levels

There is always demand and need for quantifying NPD and sustainability performance. According to Fraser et al. (2002) there are typically 3-6 different descriptive levels to assess maturity in maturity models. It is good to notice that there is no clear rule on how to identify each level and some degree of arbitrary exists. Maturity grid models provide descriptive text for each level and element which makes it easy to compare with different respondents but when the number of levels is increasing it becomes hard and difficult to build and combine because of its complexity. Eisner et al. (2022) Continues that maturity levels points out the level of progression and the current state in each specific dimension.

According to Watz & Hallstedt (2020; 2022) sustainability performance can be presented in four different maturity levels which are compliance, systematic, ambitious, and strategic. Also, Baumgartner & Ebner (2010) have defined four different maturity levels to illustrate sustainability performance which are beginning, elementary, satisfying and, sophisticated/outstanding. In model developed by Hynds et al. (2014), maturity levels are defined similarly and they are named beginning, improving, succeeding, and leading. Eisner et al. (2022) presents in turn six different levels which are initial, rudimentary, elementary, industry average, outstanding, and visionary. Even if there is some variance in level structuring there can be noticed similarities within every model. Companies' measures towards sustainability rise gradually and at the highest level all TBL dimensions are included in every evaluating aspect during a product's full life cycle.

This maturity model consists of four levels to present sustainability performance and they are named compliance, elementary, succeeding and outstanding. Names are derived from Baumgartner & Ebner (2010), Eisner et al. (2022), Fraser et al. (2002), Hynds et al. (2014), Isoherranen et al. (2016), and Watz & Hallstedt (2020; 2022). Including more levels would make this maturity model more complex and it is justified to use four levels because it is done before by Baumgartner & Ebner (2010), Hynds et al. (2014), and Watz & Hallstedt (2022). It is worth noticing that Watz & Hallstedt (2020) had five levels in their initial model but changed it to four level model later in Watz & Hallstedt (2022).

At the first level processes are not defined or standardized and the company is trying to integrate basic operations to gain sufficient qualifications to move forward. The first level is called compliance level and according to Watz & Hallstedt (2020; 2022) sustainability measures are given low priority and scope covers regulatory compliance. Management

lacks sustainability knowledge and is reluctant to make changes. Corporate sustainability culture is not established which appears as a lack of development opportunities, incompetent use of different IT-systems, and absence of clear sustainability targets and policy. Companies show bare minimum social aspects, for instance laws and regulations are followed to avoid risks for the company but controversial acts and confusion about corporate policies exists. Decisions are made on ad hoc basis and mostly the economic point of view is considered. Some sustainability measures might be implemented into NPD process but utilizing sustainability and leveraging it in NPD is completely lacking. Incentives or motivation to internally develop sustainability exist to some degree. (Fraser et al., 2002; Baumgartner & Ebner, 2010; Baumgartner & Rauter, 2017).

The second level is elementary level where some improvement measures have been taken. Sustainability is respected in basic processes and companies are collaborating with the most important stakeholders. Sustainability scope is mostly focusing on environmental improvement, but social considerations are still missing. Companies can provide concrete targets for the most key factors concerning their sustainability strategy. (Eisner et al., 2022; Watz & Hallstedt, 2022). Some tools are used to enable more precise measurement methods and reporting when benefits are clearly visible. To develop personnel skills and enable sustainability management certain measures have been taken. (Baumgartner & Ebner, 2010; Watz & Hallstedt, 2020).

The third level is named succeeding which indicates good improvement in every aspect of company operations and usually all TBL dimensions are included. The thing that usually separates companies from third and fourth level is execution details and how different operations and functions interact. Internal and external stakeholders are included and communication is well established. Companies have set concrete targets which are aligned with overall sustainability strategy. Different methods and measures have been implemented to improve sustainability performance such as corporate strategy which supports sustainability in all dimensions and right methods to analyze sustainability performance in practical. Companies are enabling sustainability improvement by internally developing their employees and giving them different incentives which are supporting sustainability. (Baumgartner & Ebner, 2010; Eisner et al., 2022; Isoherranen et al., 2016; Watz & Hallstedt, 2022).

According to Hynds et al (2014) at the fourth level which is called outstanding sustainability is completely implemented within company and it is seen as a guideline how company does business. The company is well known by its stakeholders that sustainability affairs are taken seriously. Sustainability activities are transparent and systematically considered through all TBL dimensions in its operations from overall process level to day-to-day activities. Companies have set clear and concrete targets which are quantified and easy to measure. Targets are aligned with the company's overall strategy and measurements are used to monitor how well the company is performing. Companies are continuously evaluating and improving their own performance with acquired results. In NPD companies have established well defined process which includes a holistic life cycle approach and it considers sustainability issues from every TBL dimension. Meaning that sustainability is well implemented throughout company in strategic and practical level without overlapping and employees are encouraged to pursue towards more sustainable culture which is supported by several activities. Maturity levels used in this maturity model are presented in figure 16. (Baumgartner & Ebner, 2010; Eisner et al., 2022; Isoherranen et al., 2016; Watz & Hallstedt, 2022).

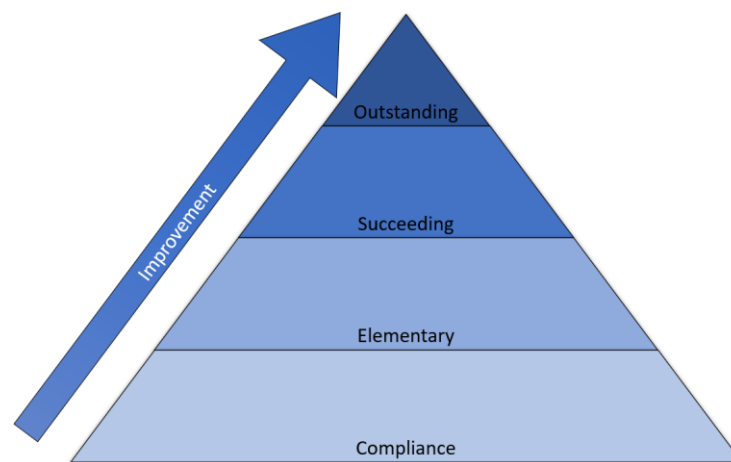


Figure 16. Sustainability maturity levels.

3.2.2 Sustainability maturity model dimensions and elements

Dimensions in maturity models describe what is being evaluated. Main dimensions of this model are derived from literature review and they are corresponding to the requirements of SPD since they provide comprehensive outlook of contributing factors. Each of the six main dimensions are divided into five elements to cover that dimension comprehensively. (Eisner et al., 2022; Fraser et al., 2002). Dimensions and elements of maturity model are presented in table 4 with short descriptions and references where they were obtained.

Table 4. Maturity model dimensions and elements with descriptions.

Dimensions and elements	Description	References
Baseline operations		
Process definition	How well is company's NPD process defined	Bacon et al. (1994); Baumgartner & Rauter (2017); Isoherranen et al. (2016); Watz & Hallstedt (2022)
Process structure	How well is NPD process structured	Cooper (1990; 2017, p. 188-193); Marzi et al. (2020); Ulrich & Eppinger (2016, p. 12-16)
Stakeholder management	Level of stakeholder engagement	Alblas et al. (2014); Baumgartner & Rauter (2017); Gmelin & Seuring (2014); Kiron et al. (2013); Majava et al. (2014)
Success factors	Clarity of success factors	Bacon et al. (1994); Brown & Eisenhardt (1995); Cooper (2019); Held et al. (2018); Kiron et al. (2013)
Opportunity identification	Ability to identify need for NPD	Chang et al. (2014); Dangelico & Pujari (2010); Johansson et al. (2016); Marzi et al. (2020); Miroshnychenko et al. (2017); Shetty (2016)
Sustainability scope and targets		
Operational responsibility	Overall sustainability compliance	Alblas et al. (2014); Baumgartner & Ebner (2010); Chapas et al. (2010); Diaz et al. (2021); Johansson et al. (2021); Watz & Hallstedt (2022)
Scope definition	Accuracy of sustainability scope	Alblas et al. (2014); Diaz et al. (2021); Eisner et al. (2022); Luan et al. (2022); Watz & Hallstedt (2022;2020)
Target setting	Policies in target setting	Alblas et al. (2014); Dangelico & Pujari (2010); Diaz et al. (2021); Held et al. (2018); Hynds et al. (2014)
Scope of targets	Target utilization in NPD	Alblas et al. (2014); Baumgartner & Rauter (2017); Dangelico & Pujari (2010); Diaz et al. (2021); Mani et al. (2010); Watz & Hallstedt (2020)
Target measurability	Capability in target measurability	Chapas et al. (2010); Dangelico & Pujari (2010); Eisner et al. (2022); Johansson et al. (2021); Mani et al. (2010); Rodrigues et al. (2016a)
Sustainability policy and strategy		
Vision and mission	Alignment with vision and mission	Alblas et al. (2014); Baumgartner (2014); Hynds et al. (2014); Luan et al. (2022); Pujari et al. (2003)
Impact to product development	How sustainability strategy and policy are affecting NPD	Alblas et al. (2014); Baumgartner & Rauter (2017); Gbededo et al. (2018); Tsalis et al. (2020); Watz & Hallstedt (2022; 2020)
Sustainability optimism	Attitude towards sustainability and its possibilities	Baumgartner & Rauter (2017); Chapas et al. (2010); Held et al. (2018); Johansson et al. (2021); Miroshnychenko et al. (2017)
Identifying process	Maturity of sustainability criteria identification process	Baumgartner (2014); Hynds et al. (2014); Eisner et al. (2022); Hallstedt (2017); Watz & Hallstedt (2022)
Sustainability in decision making	Extent of sustainability considerations in decision-making	Baumgartner & Rauter (2017); Chang et al. (2014); Rodrigues et al. (2016a); Watz & Hallstedt (2022)
Strategic implementation of sustainability		
Sustainability dimensions	Involvement of sustainability in NPD process	Baumgartner & Ebner (2010); Chapas et al. (2010); Driessen et al. (2013); Held (2018); Hynds et al. (2014); Watz & Hallstedt (2022; 2020)
Decision boards capability	Capability of decision makers in NPD	Baumgartner & Rauter (2017); Hynds et al. (2014); Watz & Hallstedt (2022; 2020)
Life cycle approach	Scope of life cycle approach	Baumgartner & Rauter (2017); Chapas et al. (2010); Dangelico & Pujari (2010); Hynds et al. (2014); Mani et al. (2010); Watz & Hallstedt (2022)
Gradual and consistent improvement	Utilization of continuous improvement	Alblas et al. (2014); Baumgartner & Rauter (2017); Held et al. (2018); Marzi et al. (2020); Wang et al. (2021)
Corporate sustainability strategy	Corporate sustainability strategy used	Alblas et al. (2014); Baumgartner & Rauter (2017); Chapas et al. (2010); Hallstedt (2017); Held et al. (2018); Hynds et al. (2014)
Tools and practical implementation of sustainability		
Checklists and guidance	Utilization of checklist and guiding questions in NPD	Diaz et al. (2021); Gbededo et al. (2018); Gremyr et al. (2014); Mani et al. (2010); Watz & Hallstedt (2022)
PLM utilization	Ability to benefit from PLM	Barrios et al. (2022); Diaz et al. (2021); Främling et al. (2013); Lim et al. (2020); Pasley & MacCarthy (2020)
Analysis and assessment methods	How well sustainability performance is quantified	Chapas et al. (2010); Diaz et al. (2021); Gbededo et al. (2018); Hallstedt (2017); Held (2018); Hynds et al. (2014); Mani et al. (2010)
Data utilization	Data quality and use in NPD	Alblas et al. (2014); Diaz et al. (2021); Eisner et al. (2022); Hallstedt (2017); Terzi et al. (2010)
Sustainability reporting	Sustainability reporting policy	Baumgartner & Ebner (2010); Baumgartner & Rauter (2017); Held et al. (2018); Hynds et al. (2014); Laurent et al. (2019)
Personnel skills and sustainability management		
Employee skills	Employees overall skills and knowledge	Alblas et al. (2014); Dyllick & Hockerts (2002); Isoherranen et al. (2016); Watz & Hallstedt (2020)
Employees motivation and incentives	Motivation towards sustainability and incentives	Baumgartner & Ebner (2010); Dangelico & Pujari (2010); Dyllick & Hockerts (2002); Laurent et al. (2019); held et al. (2018)
Sustainability awareness	Employee and company sustainability awareness	Baumgartner & Rauter (2017); Dangelico & Pujari (2010); Held et al. (2018); Watz & Hallstedt (2022)
Knowledge management	How sustainability knowledge is shared within company	Alblas et al. (2014); Baumgartner & Ebner (2010); Baumgartner & Rauter (2017); Hallstedt (2017); Watz & Hallstedt (2022)
Sustainability training	Sustainability development opportunities	Baumgartner & Ebner (2010); Baumgartner & Rauter (2017); Eisner et al. (2022); Rodrigues et al. (2016a); Watz & Hallstedt (2022)

The first dimension is baseline operations. It describes how well companies have established their basic operations which supports and enables SPD such as process definition, structure, and stakeholder management which is key to achieve effective collaboration. Identifying right success factors and to proactively find new opportunities to start NPD process enables companies to fully benefit from them.

Second dimension deals with sustainability scope and targets by describing how companies are considering sustainability in their operations and how clearly it is defined. In addition, to having a clear and well-defined scope it is important that scope is supported by short and long-term targets which are prioritized, covering all TBL dimensions and measurable by quantified metrics.

Earlier dimensions form a backbone for third dimension, sustainability policy and strategy which defines how a company is pursuing into more sustainable operations. It consists of alignment with company's vision and mission which guides company's high-level decisions, and from then ability to affect NPD. Attitude towards sustainability describes how company sees sustainability as an opportunity and not just as an extra cost. To have an effective sustainability strategy companies need to develop ways to identify sustainability criteria to address for each project and product. In addition, sustainability should be considered in decision making with facts and knowledge.

Maturity models fourth dimension is strategic implementation of sustainability which means how well companies are involving sustainability to be part of the NPD process, extent of sustainability considerations in decision-making and how well companies are considering full end-to-end life cycle during NPD. Company's culture to develop its operations to be more sustainable and overall corporate sustainability strategy affects how well it is performing in strategic implementation of sustainability.

In addition to strategic implementation of sustainability companies need to execute and manage sustainability measures in day-to-day level and the fifth dimension is tools and practical implementation of sustainability. In the manufacturing industry that means how well companies are utilizing different solutions and applications to improve their day-to-day operations. Companies can improve their performance by fully leveraging PLM, analysis and assessment methods, and different means to utilize data in the best possible way. Sustainability reporting in turn can be a positive asset if it is done right and many stakeholders are demanding that.

Lastly the sixth dimension, which is personnel skills and sustainability management. It describes how well companies are ensuring that sustainability measures are utilized and developed. Overall skills and knowledge are the foundation for further development which need to be motivated to increase sustainability awareness. Employers' responsibility is to develop effective ways to manage all that information and to provide new development opportunities.

3.2.3 Sustainability maturity model indicators

Indicators in maturity models indicate and justify a specific maturity level of each evaluated element. Indicators can be numerical data or textual descriptions depending on the evaluated element and how its fulfillment can be addressed. Fraser et al. (2002) states that indicators are descriptions of each element and how it should be performed to at each maturity level. Indicators of maturity models can be also used as a checklist within companies. (Eisner et al., 2022). In this maturity model each indicator was designed as a single choice answer for corresponding question about that specific element. Qualitative indicators are the latest insights relevant for this maturity model derived from academic literature and research.

Dimensions, elements and indicators are then constructed together to form an evaluation tool. In table 5 are presented corresponding appearance of baseline operations which describes companies' activities supporting SPD. After that companies' ability to perform in defining clear and measurable sustainability scope and targets are evaluated by table 6 and following that table 7 is used to evaluate sustainability policy and strategy which defines how company is pursuing into sustainable acts and decisions. Following that companies' ability to implement sustainability into action is evaluated at strategic level by table 8 and at practical level by table 9. Lastly personnel skills and sustainability management are measured by table 10.

Table 5. Maturity levels of baseline operations.

Element	Process definition	Process structure	Stakeholder management	Success factors	Opportunity identification
Compliance	Product development process has not been defined or documented and there is no consistency in process.	There are no clear phases or stage-gates before moving into the next phase or the entire process is just seen as an unstructured process.	Product development is working in its own silo and collaboration with internal and external stakeholders is limited.	Success factors of product development process have not been defined or identified. Reference data from previous projects are not utilized.	New product development project needs rise from reacting to obligatory requirements e.g., some material is becoming prohibited or unavailable.
Elementary	Product development process has been defined and documented to some extent. Performance is measured and assessed in a limited way.	Company has partially adopted or is trying to adopt some framework which consists of different stages to support the overall product development process.	Collaboration with internal stakeholders and with some external stakeholders e.g., legislative and investors. A full product life cycle perspective is not considered.	Some success factors have been identified but not mapped clearly. Mistakes from previous projects are documented and proactive measures implemented to prevent them happening again.	New opportunities arise from reacting to stakeholder demands e.g., customer need, legislation or competitor launching new product. New opportunity identification is sufficient to give stability and time to react.
Succeeding	Product development process is fully defined and documented. Organizations have composed descriptions and instructions of different tasks.	Company has adopted a framework where it is clearly defined what needs to be done before moving into the next phase. Clear inputs and outputs of phases.	Internal and external stakeholders are included in the product development process. Cross-department functions are effective, supplier and customer involvement are sufficient.	Success factors have been identified and mapped and measured. Feedback from finished projects is documented but not implemented systematically.	Company is taking measures to identify risks before they actualize and occur. Product development process is working both reactively and proactively.
Outstanding	Product development process is fully defined and documented. Process definitions and metrics are derived from customer requirements and from the strategic objectives of the company which are continuously improved.	Product development process phases are aligned with other processes, agile methods adopted into product development to fully capture stakeholder requirements with iterations.	Stakeholder involvement is high, company is working with iterative cycles with multiple stakeholders from every product life cycle phase from material sourcing to product disposal.	Success factors are visible, well known and aligned throughout the whole company. Success factors have been divided into measurable variables. Previous and ongoing projects are continuously evaluated, new success factors are identified and implemented into action.	Product development process is seen as a proactive method to find new business opportunities and to react to tightening environmental regulations. New opportunities and risks are continuously evaluated.

Table 6. Maturity levels of sustainability scope and targets.

Element	Operational responsibility	Scope definition	Policies in target setting	Scope of targets	Target measurability
Compliance	Company does not consider sustainability matters in its operations or performs in grey areas in some measure.	Sustainability scope is not defined or existing.	Sustainability targets are not defined.	Sustainability targets do not exist, or they are generic sustainability targets which do not concern product development.	Sustainability targets are not defined or cannot be measured.
Elementary	Company is not doing anything which can be defined controversial. Regulatory compliance is ensured and economic dimension is mainly considered in the operations.	Sustainability scope exists, but it is unclear or not manageable.	Improving in defining target but targets are set by force e.g., by owner, members of legislation, stakeholders or market pressure. Targets are individual and not aligned together or with overall processes and their measurability.	Environmental sustainability targets exist. In general targets are fuzzy and not aligned with each other. Targets give minor support to product development.	Sustainability targets are mostly in qualitative format. If targets are quantified, they don't occur systematically, and measurability is not defined clearly. KPIs are utilized irregularly in product development.
Succeeding	Environmental dimension is also included into considerations within operations in addition to the economic dimension. Social dimension e.g., wellbeing is considered. Dimensions are looked at separately and in sequential order.	Sustainability scope is clear and managed, but it is narrowed down and focuses on tangible key elements which are important to company operations.	Sustainability targets are clear and prioritized, set to measure success of support product development performance and aligned with company's overall targets and processes.	Both short-term and long-term sustainability targets have been defined and implemented which are concerning product development and sustainability extensively but not fully supporting each other.	Quantified sustainability targets are part of company's operating model. Quantified targets are set and defined mostly throughout the company. KPIs are set to measure overall sustainability success in product development process.
Outstanding	Environmental, economic and social dimensions are considered within operations together, interconnections are evaluated, and company's operations can be justified from every point of view.	Sustainability scope is clear, well managed and it covers all needed aspects of company operations.	In addition, Sustainability targets are set proactively, and larger targets are broken down into smaller objectives. Targets are continuously evaluated to enable decision making.	Company has long-term sustainability targets which steer overall performance, mid-term targets supporting those and short-term sustainability targets supporting day-to-day activities. Accountability has been established for sustainable product development and targets fully support them.	Company has clear, continuously evaluated and transparent quantitative sustainability targets which guides company's actions and are known by stakeholders. KPIs covering all sustainability dimensions are set to every stage of product development process.

Table 7. Maturity levels of sustainability policy and targets.

Element	Vision and mission	Impact to product development	Sustainability optimism	Identifying process	Sustainability in decision making
Compliance	Sustainability does not fit into company's vision and mission.	Sustainability means regulatory compliance; sustainability scope and targets are lacking and/or provide little guidance to product development.	Sustainability is mostly seen as an additional cost to products and thus not included voluntarily into product development.	Not used or sustainability criteria are not identified beyond regulatory compliance and thus not included in the initial requirement specification.	Usually only financial cost in the present moment. E.g., when selecting materials giving material price major weight factor over its quality or origin.
Elementary	Sustainability partially fits into company's vision and mission, mostly due to external pressure.	Sustainability has been identified and it is appreciated within the company to some extent as it provides minor guidelines for product development. Economic and environmental dimensions considered.	Sustainability is critically approached and included in product development only when clear benefits are available.	Process is not systematically implemented; sustainability criteria can be occasionally identified beyond regulatory compliance and selection can be part of the initial but not necessarily in the final selection criteria.	More factors included into decision making. E.g., quality, environmental impact and avoiding conflict materials. Full life cycle approach still lacking.
Succeeding	Company has adopted sustainability into its vision and mission. It is both internally and externally driven.	Company appreciates sustainability, and it provides medium guidance and direction to product development. Mostly all dimensions considered.	Sustainability is approached with an open attitude, and it is seen as a possibility, but the company is still figuring out how to perform it.	Identifying process is established and sustainability criteria are always included beyond regulatory compliance in both initial and final selection criteria.	A wide range of different factors which are considered in decision making. In addition, social impact and different life cycle phase impact assessed but e.g., lacking in holistic life cycle assessment from sourcing to disposal.
Outstanding	Vision and mission are based on sustainability and it is internally driven.	Sustainability is valued at a company, and it provides major guidance and direction to product development within all dimensions.	Sustainability is seen as an opportunity to differentiate from competitors, create new market opportunities and create win-win solutions both for companies and for their customers.	In addition, identifying process is systematically approached e.g., sustainability criteria's to address are approached with backcasting method including all sustainability dimensions and it is integrated to be part of development and designing processes.	A holistic total cost of ownership approach to include all affecting factors including full product life cycle assessment from sourcing to disposal to capture every sustainability dimension.

Table 8. Maturity levels of strategic implementation of sustainability.

Element	Sustainability dimensions	Decision boards capability	Life cycle approach	Gradual and consistent improvement	Corporate sustainability strategy
Compliance	Sustainability point of view is not included in product development.	No specific competence or skills required and occasional ad hoc sustainability statements when needed.	Full product life cycle is not considered during product development phase. Products are created for current needs and after it becomes obsolete company's focus shifts to the next product.	Company makes improvements only when it is required by laws and regulations.	Focus on legal and other external standards concerning environmental and social aspects to avoid risks for the company.
Elementary	Economic dimension exclusively included in product development.	Sustainability expert is included on the decision board and to proceed in the product development process sustainability performance must be addressed.	Need for a life cycle approach has been identified but there is a lack of concrete measures. Individual performers can utilize some of the r-strategies e.g., thinking about product recyclability or contamination of the product during when it's used.	Company is making improvements irregularly, mostly when major economic benefits are available. Culture for continuous improvement doesn't exist within the company.	Company tries to differentiate itself from competitors by focusing on the external relationship, few visible sustainability measures and positive sustainability-related communication. Therefore, it seems appropriate to engage sustainability more than it is required by law.
Succeeding	Environmental and economic dimensions included into product development and social perspectives might be assessed. Dimensions are looked in separate and sequential order.	Decision board is aware about sustainability. Sustainability is included in decision making and to proceed in the product development process sustainability performance must be addressed and documented.	Different life cycle stages are considered e.g., r-strategies, supplier evaluations by their environmental performance and collaboration with end-users. Full product life cycle is reviewed on the surface level during product development.	Company has developed multiple practices to improve its sustainability performance. Operations are regularly assessed to find improvement areas which results are then implemented.	Focus on internal measures such as eco-efficiency, cleaner production, cost efficiency and very well-defined processes. Commitment is crucial in the investment in appropriate technology, sophisticated health and safety for employees and above all ecological sustainability.
Outstanding	All (economic, environmental and social) dimensions are included in the product development process. Different dimensions are looked together, and interconnections are considered.	Decision board is educated about sustainability. Sustainability is included into decision making, decisions must be based on actual data from sustainability assessments and to proceed in the product development process must be able to demonstrate that all dimensions of sustainability are addressed and documented.	Systematically and continuously considering different product life cycles. Product life cycles have been divided into different phases and sub phases which are reviewed thoroughly during product development while systematically collecting data and feedback from end-users.	Company is outstandingly improving its operations in many ways from day-to-day activities to C-level strategy. Improvement points are systematically scouted, and feedback is evaluated from many sources. Company has an established culture for continuous improvement.	Proactively focusing on sustainability issues within all business activities, competitive advantages are derived from differentiation and innovation, market leader in sustainability issues. Based on an internalization and continuous improvement of sustainability issues inside the company.

Table 9. Maturity levels of tools and practical implementation of sustainability.

Element	Checklists and guidance	PLM utilization	Analysis and assessments methods	Data utilization	Sustainability reporting
Compliance	Checklists are used for ensuring regulatory compliance. E.g., stage-gate model in operation management system.	PLM is used internally within single department for simple tasks e.g., creating manufacturing drawings and BoMs.	Quantitative methods to assess sustainability performance are not utilized.	Data is not correct and available from external sources, or it is manually entered, stored on many different platforms or only in individual employees' computers and thus not accessible widely or leveraged.	Sustainability issues are not considered either in a distinct sustainability report or in the annual report. Reporting is not based on actual facts and its only existing to polish company image.
Elementary	Checklists and guiding questions are used to evaluate overall sustainability performance in product development. E.g., ensuring that environmental assessment scores meet the requirements.	PLM is utilized internally with different departments enabling cross-organizational collaboration for faster data utilization and minimizing design errors and overlapping work	Life cycle assessment (LCA), life cycle costing (LCC) or some other method is used to quantify environmental or economic performance during every life cycle phase.	Company's internal data (e.g., 3D-models, sales data) is in tolerable state, but flaws with external data (e.g., material background data, end-users' improvement points). Employees can access data easily making it a positive asset.	Only the most important sustainability issues are communicated in company's communication channels or in a distinct sustainability report or in the annual report.
Succeeding	Checklists and guiding questions are used to evaluate overall sustainability performance and to guide designers' decisions in detail level to develop truly sustainable products.	PLM is utilized with stakeholders e.g., sourcing and end-user to improve visibility and to reduce ambiguities, reducing cycle times and to enable real-time monitoring with external stakeholders.	All dimensions of sustainability are included, also social which performance is evaluated and quantified e.g., by using social-life cycle assessment (S-LCA) or conflict resource analysis.	Overall quality of the data is good, it is easily accessible when needed and data is shared with clients and stakeholders in collaborative space to identify priorities giving it a competitive advantage to the company.	One-way communication of sustainability issues in corporate communication channels or in a distinct sustainability report or in the annual report. Goals and measures are additionally defined and communicated e.g., assessment reports.
Outstanding	Checklists and guiding questions are integrated into every phase of the product development and to the interfaces of different processes	In addition, PLM is paired with other intelligent solutions for example AI, additive manufacturing or digital twin.	In addition, assessments are used to evaluate trade-offs and alternatives affecting sustainability performance in every sustainability dimension from beginning of life to end of life decisions. E.g., material selection, environmental pollution during use and its recyclability.	In addition, product development data is automatically collected and analyzed to continuously improve operations and processes thus significant competitive advantage obtained	Two-way communication and consideration of sustainability issues, and in a distinct sustainability report or in the annual report. Additionally, goals and measures are defined and communicated. All stakeholders are aware of the company's sustainability policy and measures.

Table 10. Maturity levels of personnel skills and sustainability management.

Element	Employee skills	Employees' motivation and incentives	Sustainability awareness	Knowledge management	Sustainability training
Compliance	Employees manage only their particular part of the process without understanding the previous, next or parallel part of the process.	Employees motivation is not focused or it has a negative impact to achieve sustainability. Lack of incentives to achieve sustainability. Top management is not concerned about sustainability.	Company and employees are not aware of sustainability and sustainability related issues. Company doesn't have any sustainability experts.	Systematic approach towards (sustainability) knowledge management doesn't exist, and experience is concentrated to one person within company and best practices are not systematically shared.	No specific sustainability development and training measures are set.
Elementary	Employees have a basic understanding of the company's different tasks and processes. Employees are not always aware of what inputs and outputs they need to deliver.	Variation in employee motivation and incentive measures to improve motivation are set to achieve sustainability. Top management has taken actions to achieve sustainability.	In company level sustainability awareness is recognized and within employee's sustainability awareness differs a lot. Company has hired sustainability experts or staff.	Best practices are shared irregularly, and hidden knowledge exists. Specific (sustainability) knowledge management activities exist such as sharing knowledge in working teams and gathering databases to transfer and save (sustainability) knowledge.	Certain sustainability development and trainings measures are set.
Succeeding	Employees can perform in several positions but don't always understand cause-effects and relationships between different tasks. Employees have a good understanding of different tasks and operations.	Incentive measures to improve motivation and to achieve sustainability are set in most areas of the company. Top management shows leading example to achieve sustainability.	Company knows what sustainability means in their case and most of the employees are aware of sustainability. Some employees might lack knowledge of what sustainability means in that position. Sustainability personnel included at managerial or middle management level.	Best practices are documented, shared continuously and implemented systematically within the company; external knowledge is acquired extensively. Company has laid focus on organizational learning and culture for improving by sharing knowledge.	Multiple sustainability development and training opportunities are offered. Most of the employees are trained regarding sustainability. The company has access to third party training platforms.
Outstanding	Employees are aware of cause-effects relating to their task which allows them to make sustainable decisions and they know what their inputs and outputs are. Employees can perform well in several positions and have comprehensive knowledge of different tasks and operations.	Multiple monetary and non-monetary motivating incentives are set to achieve sustainability. Top management has taken an active and leading role showing example to achieve sustainability. Those have established internalized change behavior into sustainability.	Company is very conscious about sustainability. All employees are aware of sustainability and know what that concretely means in that company and in that position where that employee is working. Sustainability executive is included at company C-level.	Best practices are documented, shared continuously and implemented systematically within the company; external (sustainability) knowledge is acquired extensively. The company has laid focus on organizational learning and culture for improving by sharing knowledge.	Multiple sustainability development and training opportunities are offered. Every one working in a company is trained regarding sustainability. Trainings are generated based on customer requirements and the company's strategic goals.

4 EMPIRICAL RESEARCH

The purpose of this chapter is to answer the second research question: **What is the current state of sustainable product development and how companies are performing in it?** Research methods, review of the maturity model capabilities and the analysis of the survey are presented in this chapter.

4.1 Research process

Empirical research is aligned with the synthesis of the literature review which were discovered during literature review. Requirements for SPD are acting as a background for empirical research. To conduct empirical research two different methods are utilized. First data is collected with online survey and analyzed to find insights. Secondly selected and interested participants were interviewed to find more detailed answers. The whole research process is described in figure 17, where process steps and outputs of each process step are presented.

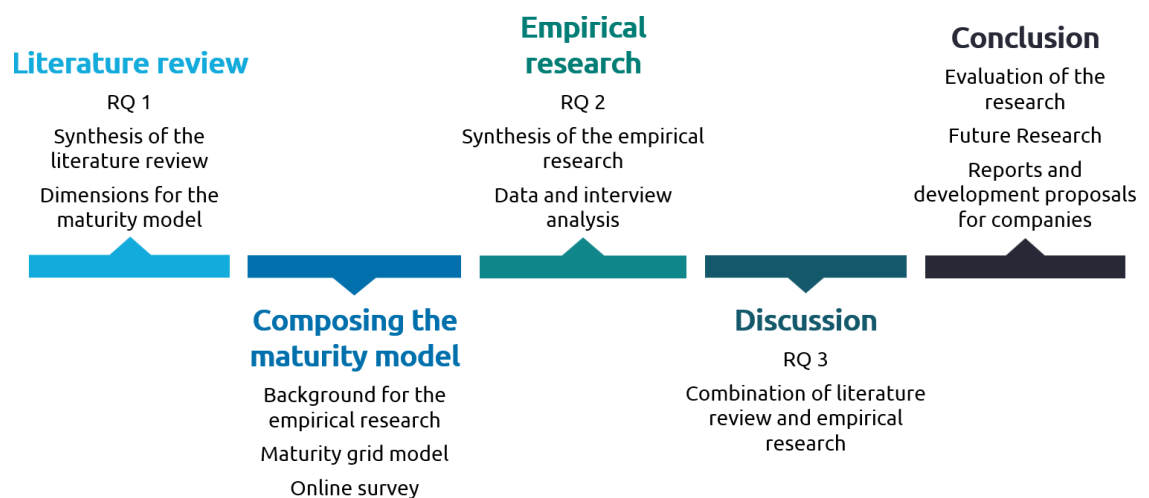


Figure 17. Research process.

Maturity model and its contents are more discussed in chapter 3., Sustainability maturity model. Sustainability performance in NPD is multidimensional so because of that this research utilizes both qualitative and quantitative methods. This research is neither case study nor action research because this research involves multiple companies, sustainability performance is part of wider entirety than one project and the maturity model is not iteratively developed with companies. This research is utilizing a

constructive research approach since it is combining acquired knowledge from literature review which is then used to build maturity model. Then the empirical research results are tied back together with theoretical knowledge from literature review. (Oyegoke, 2011).

Online survey was chosen to be the main empirical method for this research and interviews were given minor significance as the intention in the interviews was to debrief the survey and to possibly catch up some missed information. The data analysis process is more precisely presented in figure 18 which follows framework provided by Bryman & Cramer (2012) with little modifications when it comes to analyzing interviews.

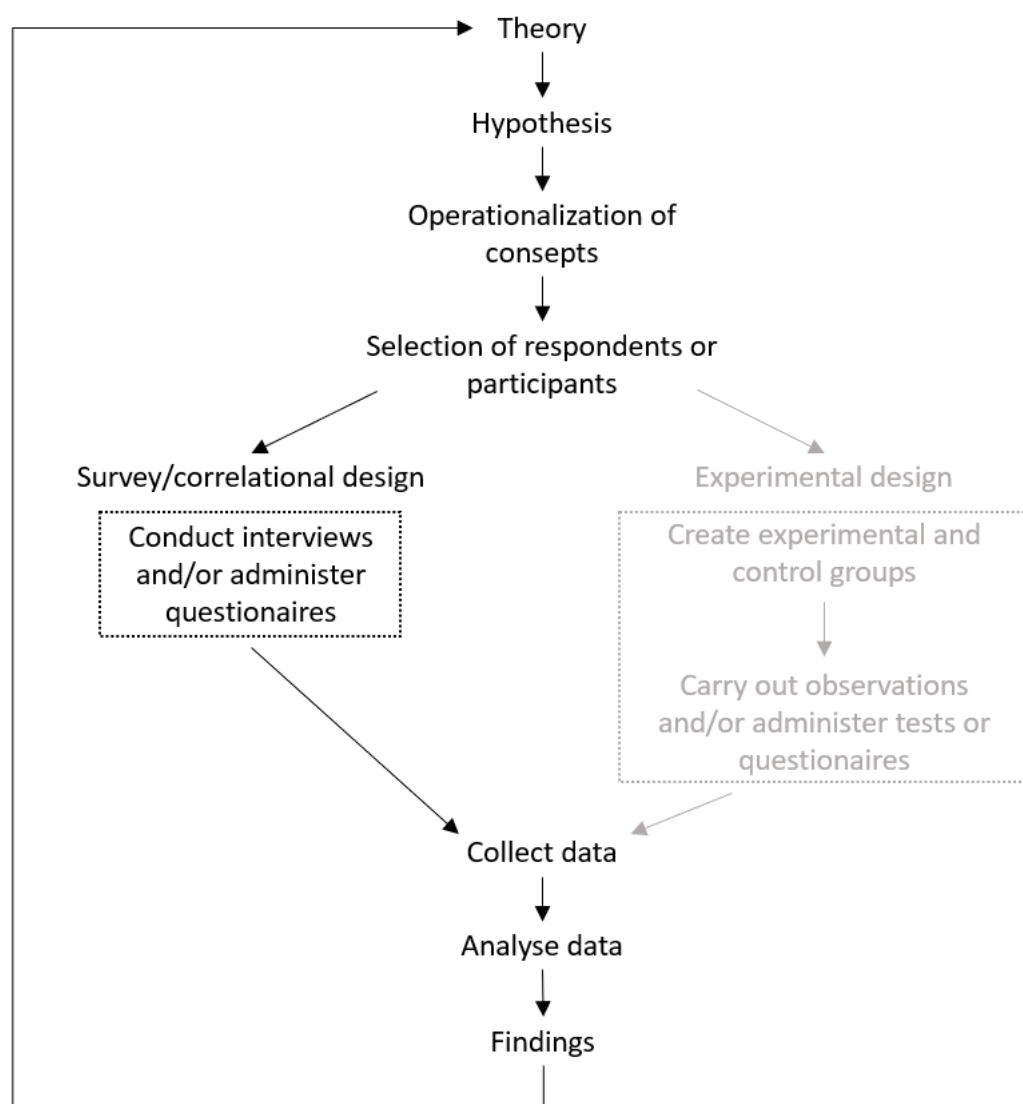


Figure 18. Data analysis process adapted from (Bryman & Cramer, 2012).

Process starts from formulating theory around the research and then based on theory, which is in this case literature review, hypotheses are made which are further tested. First hypothesis H_1 is following: *companies have challenges in implementing sustainability* and the second hypothesis H_2 is following: *large companies have better sustainability performance than smaller companies*. In operationalization phase different measures are developed to measure validity of the hypotheses. Next step is to decide who are the relevant people to be interviewed and to approached regarding the survey. Since aspects of the setting are not manipulated and then those results observed, this doesn't follow the experimental design path. Survey and correlational design are therefore followed since no manipulation of variables exists within the research. Online survey and interviews are then conducted to collect data for further purposes. Then data is analyzed to test hypothesis and to find insights. Lastly the findings are linked back to theory to demonstrate causality meaning that one variable causes impact to another variable. This is described by utilizing independent variable and dependent variable. (Bryman & Cramer, 2012).

4.2 Data gathering

Data for this research was collected by an online survey based on the developed maturity grid model in Google Forms platform. Online survey consists of 30 questions and they are presented in appendix 1. Survey questions were derived from synthesis of literature review and they are divided into six main dimensions and each main dimension consists of five questions corresponding to maturity model element. At the end of the online survey there were three open questions where respondent may answer or may not answer to gain more detailed information and to ensure that no relevant insights or thoughts were missed. Considering that the model is very exhaustive those questions were additional and not mandatory.

In addition, three survey respondents were invited to interview to discuss more detailed about the survey and about their company's sustainability performance. Interviews were semi-structured interviews. First we went through the research process and the topic. Then the maturity model and its dimensions were explained and after that we went through the answers. Participants were asked questions from every dimension and its performance to gain more details. Also, questions about specific topics such as analysis method implementation to other design applications and digitalization were asked to

describe their actual actions. Lastly, we discussed the topics freely to ensure that their point of view was captured as broadly as it is possible. Interviews lasted between 30 to 60 minutes and those were recorded and transcribed to gather every detail.

Respondents for this online survey were gathered from case company's internal contact lists and by searching from open sources with relevant keywords. The used keywords consisted of relevant topics and roles from target companies which are publicly listed manufacturing companies operating in Finland. Keywords used for relevant topics were "sustainability", "R&D" (Research and Development), "development", "product development" and "environment". Keywords for finding relevant roles were "manager", "director", "chief", "head of" and "vice president". A combination of internal and open-source search led to finding 197 potential respondents which were collected into systematically updated contact list. In addition, participants from one Small and Medium-sized Enterprise (SME) were asked directly to take part in the survey.

Draft emails to map out the interest of respondents and to request them to participate in online survey were sent as a first-round email. It was noticed that this approach doesn't work when gathering as many respondents as possible and it was changed to an approach where all necessary information and survey link were directly sent to participants. This approach worked better and in total three rounds of emails were sent to selected respondents.

In total 14 companies participated in this online survey. Participated companies with additional information are listed in table 11. All companies have significant business activities in Finnish manufacturing industry and they are one of the market leaders in their industry type. All participating companies manufacture or designs physical products and thus NPD plays a significant role in their businesses. Companies are defined based on their product type and size. Small and Medium-sized Enterprise (SMEs) are companies which revenue must be under 50 MEUR, balance sheet total under 43 MEUR and they have fewer than 250 employees (Statistics Finland, 2022). The second bucket is midcap enterprises. Companies' revenue in midcap is between 50 – 1000 MEUR and they have 251 – 4500 employees. Last bucket is large-sized enterprises which revenue is over 1000 MEUR and they have over 4500 employees.

Table 11. Participated Companies.

Company	Product type	Company size
A	Large machines	Large
B	Large machines	Large
C	Electrical equipment	Large
D	Large machines	Midcap
E	Large machines	Large
F	Large machines	Large
G	Electrical equipment	Midcap
H	Electrical equipment	Midcap
I	Large machines	Large
J	Electrical equipment	Midcap
K	Large machines	Large
L	Electrical equipment	Midcap
M	Small machines	Large
N	Small machines	SME

To keep respondents anonymity exact figures of company size and employee numbers are not presented in this research. Neither the exact industry nor product type. This was a requirement from many respondents since we are talking about current and hot business problems where companies are reluctant to give out such information.

In total 47 responds to the online survey were obtained. It is considered sufficient in this type of research. Respondents were in total from 14 different companies. Average working experience of respondents from related fields was 17,23 years, where minimum was 1 year and maximum 38 years. List of all online survey respondents with descriptive information are presented in table 12. Descriptions are minimal because respondents wanted to stay anonymous and the possibility to link answers to companies was minimized. All respondents who were interviewed in Microsoft Teams are also mentioned in it. Respondents' company's size and product type is presented in table 11 and most of the respondents were from heavy product manufacturing companies but some respondents participated from electrical industry.

Participants titles were simplified to the level of responsibility and the more descriptive endings were removed. Respondents were from various roles in companies such

Specialist, Manager, Head of business unit, Director, Vice President and Chief X Officer. Two of the respondents wanted to stay untitled. Including respondents from various roles in companies enabled to develop holistic picture about sustainability performance in product development in Finnish manufacturing industry. Managers was significantly the most represented title because they stand for a major part of the respondents approached. Segmentation of respondent's titles is presented in figure 19.

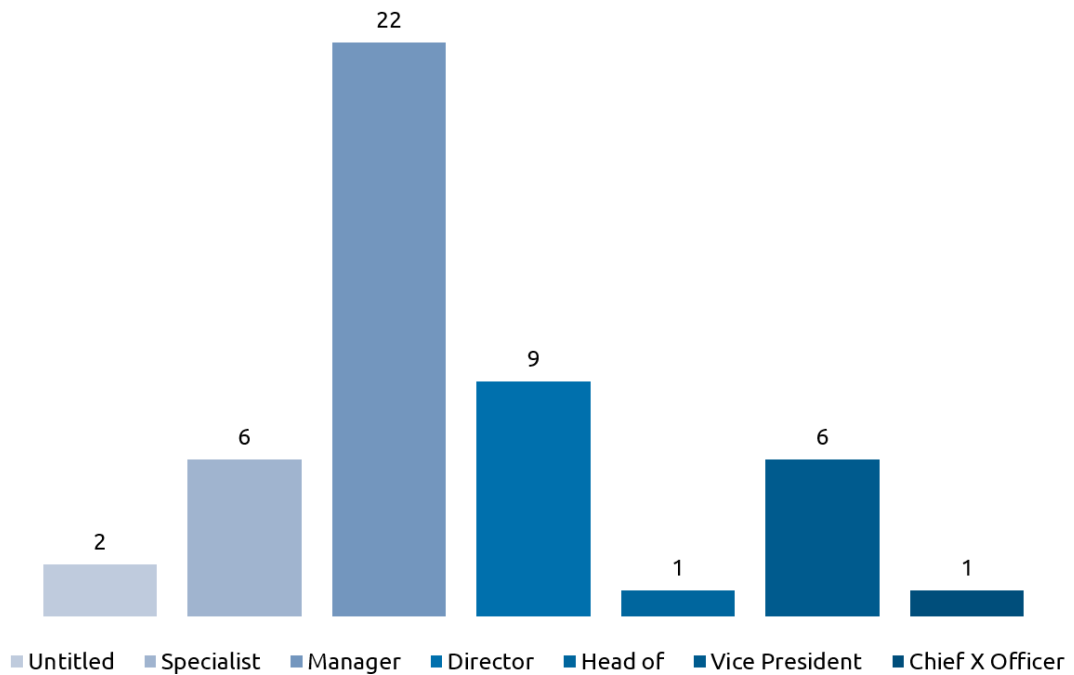


Figure 19. Respondents by their titles, n=47.

Table 12. Survey respondents.

Company	Experience	Title level	Date interviewed
A	30	Vice President	-
B	16	Manager	9.11.2022
A	13	Specialist	18.11.2022
B	5	Manager	-
C	20	Head of	-
B	1	Specialist	4.11.2022
B	5	Director	-
D	10	Manager	-
E	5	Manager	-
B	2	Specialist	-
F	20	Manager	-
B	20	Manager	-
B	32	Director	-
B	12	Director	-
B	22	Manager	-
G	10	Manager	-
B	10	Director	-
H	14	Manager	-
I	38	Director	-
I	35	Director	-
H	24	Manager	-
E	15	Vice President	-
A	6	Manager	-
J	20	Manager	-
D	24	Chief X Officer	-
N	4	Specialist	-
K	20	Manager	-
N	1	Specialist	-
K	20	Vice President	-
J	18	Manager	-
B	20	Manager	-
M	26	Manager	-
L	20	Manager	-
B	14	Manager	-
B	23	Untitled	-
B	28	Untitled	-
I	20	Vice President	-
F	30	Director	-
B	15	Director	-
L	21	Director	-
L	10	Manager	-
B	25	Manager	-
J	30	Manager	-
B	19	Vice President	-
D	2	Manager	-
J	4	Specialist	-
M	31	Vice President	-

4.3 Data and interview analyses

The collected data was analyzed quantitatively and qualitatively, and the results are presented in the following chapters corresponding to each question section in an online survey. Interviews which were held with few respondents were transcribed and used to supplement the online survey results.

Collected numerical data was cleaned before it was analyzed in Microsoft Excel. Qualitative written data collected with the online survey was structured and themed so that the essential themes stood out. Conducted interviews were transcribed, and essential themes were gathered to enable the analysis. Similar results stood out from all three different analysis types which strengthen the accuracy of the results.

Tool for analysis and reporting were built into Microsoft Excel where maturity levels were calculated for all companies and for every dimension and element. Values in the following tables have been calculated with the following formulas. Maturity level of each maturity element is arithmetic mean of given or selected answers in Excel and the calculation is performed by using formula 1.

$$E_k = \frac{1}{n} \sum_{i=1}^n x_i, \quad (1)$$

where E_k is the maturity level of individual maturity element,
 x_i is the score of the answer and,
 n is the number of selected or given answers

Maturity level of each maturity dimension is arithmetic mean of maturity elements within that dimension. The calculation of the maturity level of the maturity dimension is performed by using formula 2.

$$M_D = \frac{1}{n} \sum_{k=1}^n E_k, \quad (2)$$

where M_D is the maturity level of individual maturity dimension,
 E_k is the maturity level of individual maturity element and,
 n is the number of maturity elements within the dimension

The total maturity level of the maturity model is arithmetic mean of maturity dimensions within the maturity model. The total maturity level of the maturity model is calculated using formula 3.

$$M_{tot} = \frac{1}{n} \sum_{D=1}^n M_D, \quad (3)$$

where M_{tot} is the maturity level of maturity model,
 M_D is the maturity level of individual maturity dimension and,
 n is the number of maturity dimension within the model

4.3.1 Overall scores

Company specific scores and total averages are presented in table 13. Maturity levels for every dimension and the overall maturity level for each company are presented in corresponding lines. Mean values for respondents' basic information, individual dimension and total maturity level of sustainability performance in product development are presented at the bottom line. On average ~3 persons from each company answered the survey with an average of 17,23 years of working experience in related field. Assessments between companies are not shown in this thesis, but each participated company received a company-specific report presented in appendix 3.

Overall sustainability maturity level in product development score was 2,86 which is appropriate and describing the reality in Finnish manufacturing sector. The best performance was at the baseline operations dimension 3,14 and the worst performance was at the tools and practical implementation of sustainability dimension 2,36. Performance of each dimension is looked more detailed in the upcoming paragraphs. Abbreviations in table 13 stand for dimensions in the maturity model. It is worth noticing that in this research we are focusing on the collective results and there is no intention to evaluate differences between companies' performance because there is much variation in the number of respondents per companies and the number of respondents per companies remained low except company B where 17 individual respondents answered to the online survey. Therefore, to make some division between respondents, companies are evaluated by their size according to table 11.

First looking at the results from table 13 and comparing them to company size according to table 11 we can observe that larger companies are performing better than smaller companies. Large-sized companies (A, B C, E, F, I, K and M) had combined mean value of 2,98 in total sustainability maturity level where midcap companies (D, G, H, J and L) had 2,75 and SMEs company N had only 1,68. This indicates that larger companies are performing better in sustainability related matters in NPD. In large-sized companies overall sustainability maturity score being 2,98 which is just below succeeding, indicates also that the overall performance is well established and they have been doing right things for a long time but room for improvement exists and in particular dimensions where scores are lower than the overall score. The score of midcap companies which was 2,75 indicates that they are on the right tracks regarding sustainability when defining it but their level of execution is lacking. Overall score of the SME company N which is 1,68 indicates that they are not giving much emphasis towards sustainability and their level of execution in sustainability is low when most of the time is invested into running and developing company's different operations.

Table 13. Company specific scores.

Company	Avg. exp.	n	BLO	SST	SPS	SIS	TPIS	PSSM	Total
A	16,33	3	3,20	3,40	2,93	3,27	2,53	3,07	3,07
B	15,82	17	3,26	3,14	3,04	2,87	2,29	2,88	2,91
C	20,00	1	3,00	3,60	3,80	3,40	3,00	3,20	3,33
D	12,00	3	3,20	3,20	3,20	2,67	1,93	2,27	2,74
E	10,00	2	3,40	3,90	3,60	3,60	3,30	3,00	3,47
F	25,00	2	2,70	3,40	3,50	3,10	2,50	2,90	3,02
G	10,00	1	3,20	3,40	3,00	3,00	2,80	3,00	3,07
H	19,00	2	3,20	2,90	3,10	2,50	2,10	2,50	2,72
I	31,00	3	3,27	3,40	3,40	2,93	2,87	3,07	3,16
J	18,00	4	3,20	3,00	3,05	2,65	2,30	2,60	2,80
K	20,00	2	3,00	3,50	3,40	3,10	2,70	3,40	3,18
L	17,00	3	3,40	2,53	2,67	2,40	2,33	2,20	2,59
M	28,50	2	2,60	2,50	2,10	2,20	2,00	1,90	2,22
N	2,50	2	2,20	1,60	1,60	1,70	1,30	1,70	1,68
Average	17,23	3,36	3,14	3,10	3,02	2,81	2,36	2,73	<u>2,86</u>

*Average values do not add up, they have been calculated from complete data set.

When observing the results from figure 20, three key things can be observed. First it illustrates that the overall performance of companies is dependent on company size except for baseline operations where midcap companies had the best performance. However, sample sizes were limited which could cause bias. Secondly, regardless of the company size in the first three dimensions, performance is better than in the latter three. This indicates that companies have taken the initiative towards SPD but are still experiencing challenges in execution. And thirdly, the biggest difference between large-sized and midcap companies is in strategic implementation of sustainability and in personnel skills and sustainability management. The maturity of larger and more well-established company separating companies from each other.

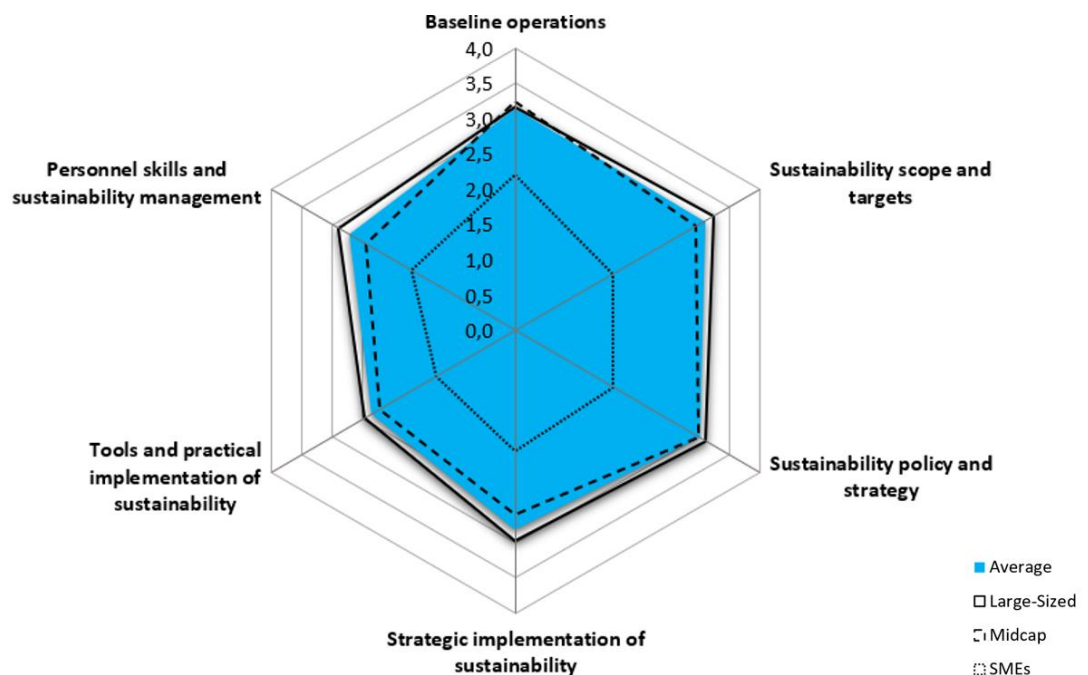


Figure 20. Overall performance of different company sizes.

4.3.2 Baseline operations

The first dimension within the model is baseline operations which describes how well companies have established their basic operations which supports and enables SPD. Mean values and performance for each participated companies are presented in table 14. The overall performance of all companies which is 3,14 was highest in this dimension. The total score of large-sized companies was 3,16 which is way above the level of succeeding. Midcap companies scored better than large-sized companies having a total mean value of 3,25 and all midcap companies scored over 3. As expected, SMEs had the worst performance of 2,20. This was clearly the best scored dimension for SMEs.

First and the best scored element within this dimension is process definition with overall score of 3,40. Based on this score we can say that in most cases companies have fully defined their NPD process and have composed instructions for different tasks. Next step to further develop their performance would be aligning and deriving continuously improved process definitions and metrics from customer requirements and from company's strategic objectives.

Overall performance in process structure element was 3,19. It is clearly above the succeeding level. Most of the companies have established clear NPD framework such as stage-gate or equivalent which gives clear inputs for each phase as well as states which need to be completed before moving into next phase. To achieve the highest level companies need to further develop their capability to include customer voice in the development process. This can be achieved by utilizing iterative agile methods where customers are included into development process to fully capture their needs.

“Stage-gate model is utilized and basic conditions regarding that are in order, but sustainability matters are still in the beginning and we are slowly waking up to them.”

Stakeholder management had an overall score of 3,11. This one is also above the succeeding level. Companies are collaborating internally with other departments and externally with their suppliers and customers. At the highest level companies would need to involve stakeholders from products every life cycle phase.

Success factors were clearly the worst performing element in the first dimension with an overall score of 2,70 being the only one that did not achieve a succeeding level. Companies have identified success factors to some extent and implemented them to prevent them happening again. To develop in this element companies would need to establish clear and visible measures to evaluate their performance from previous projects and use obtained results to continuously improve their performance.

Opportunity identification was scored with an overall score of 3,32 which is over succeeding level. Companies are proactively finding new opportunities to develop their products and do not wait until some material becomes prohibited for example. Companies are evaluating competitors' performance as well as trying to respond to customer demand. At the highest level companies would see NPD process as a continuous and proactive method to find new business opportunities.

The best performance was demonstrated within this dimension. Most of the companies have established good and sufficient foundations for enabling SPD. The biggest improvement point in this dimension would be to systematize and enable continuous improvement in previously discussed elements and emphasis towards success factors should be given more. As said by Brown & Eisenhardt (1995) that in addition to mergers and acquisitions NPD is a pivotal way to diversify, adapt and match the fast growing competitive markets. Therefore, to identify success factors and then utilizing them is essential for companies. But when companies want to maximize the invested assets to improve sustainability better results can be found in other dimensions.

Table 14. Company specific scores in baseline operations.

Company	Process definition	Process structure	Stakeholder mgmt.	Success factors	Oppor. ident.	Total
A	3,33	3,67	3,00	2,67	3,33	3,20
B	3,35	3,24	3,12	2,94	3,65	3,26
C	3,00	3,00	3,00	3,00	3,00	3,00
D	3,67	3,33	3,33	3,00	2,67	3,20
E	4,00	3,50	3,00	3,00	3,50	3,40
F	2,50	3,00	3,00	2,50	2,50	2,70
G	4,00	3,00	3,00	3,00	3,00	3,20
H	4,00	3,00	3,00	3,00	3,00	3,20
I	3,67	3,00	3,00	3,00	3,67	3,27
J	3,50	3,50	3,50	2,00	3,50	3,20
K	3,50	3,00	3,00	2,50	3,00	3,00
L	4,00	3,33	3,00	3,00	3,67	3,40
M	3,00	3,00	3,00	1,50	2,50	2,60
N	2,00	2,00	3,00	1,50	2,50	2,20
Average	3,40	3,19	3,11	2,70	3,32	3,14

*Average values do not add up, they have been calculated from complete data set.

4.3.3 Sustainability scope and targets

The second dimension is sustainability scope and targets. It describes companies sustainability measurability in their operations and how clearly it is defined. Results for participated companies are presented in table 15. The overall performance for all companies was 3,10 which is second best performance of all dimensions. The overall

score of the large-sized companies was 3,25. Midcap companies scored 2,95 which is slightly below the succeeding level and the score of the SMEs was 1,60 which is significantly lower than others.

The first element of sustainability scope and targets is operational responsibility with an overall score of 3,40 which is significantly above the succeeding level. Based on that we can say that companies are including all three TBL dimensions to their operations and understand that including considerations in addition to their financial performance is important. At the highest level, the whole TBL framework is looked at, and interconnections to different dimensions are considered. Based on the analysis some of the companies are close to achieving that.

Second best performance within this dimension was observed in scope definition element with overall score of 3,34. It is also significantly over the succeeding level. It shows that companies have defined clear and managed sustainability scope covering all essential elements of company's operations and in some cases above that. In the outstanding level companies would have sustainability scope covering all aspects of company's operations and based on the results companies are expanding their targets coverage.

The overall score of the target setting was 2,98 just below the succeeding level. Meaning that the sustainability targets are mostly clear, prioritized and set to measure sustainability performance in NPD. They are also aligned with the company's overall targets and processes. Large and in some cases fuzzy targets can be into smaller and measurable objectives which supports company's decision making. Alblas et al. (2014). This particular problem arose also during the in-person interviews.

“Targets towards sustainability are existing but they are more or less vague.”

The scope of targets had an overall score of 3,06 which is also above succeeding. Short and long-term targets have been defined and set to support both NPD and sustainability objectives. Analysis shows that clear coupling with different targets is missing. In a perfect situation companies would have long-term targets to steer their overall performance, mid-term targets supporting them and short-term targets supporting day-to-day activities. Companies would also have established clear accountability for SPD which is supported by targets. (Hallstedt, 2017).

Target measurability is the worst performing element within sustainability scope and targets dimension with overall score of 2,70 which is only one under the succeeding level. Based on the analysis companies have established qualitative targets in NPD and quantified targets are increasing in companies and partially used to measure success. There is still a clear need for more uniform utilization of quantified targets and KPIs. Further development to this would be to utilize continuously measured targets to guide the company's actions and decisions.

“We would need more clearer targets to enable execution to really capture the points which needs to be improved.”

Overall performance of this dimension was above succeeding and it was second highest of all dimensions. Based on the scores companies have formed and defined a clear scope for sustainability and they are quite aware about what sustainability should mean in their operations. The biggest improvement point in this dimension would be in the target setting. Large targets could be divided into smaller and easily quantified targets as well as KPIs could be set to measure sustainability performance. Compared to other dimensions, companies are showing good maturity in this dimension and in the previous dimension, meaning the improvement points companies should focus on are in the other dimensions. Also, the root cause for problems in this dimension could be somewhere outside the company border and when trying to improve performance here it could become difficult.

“Practical problems exist for example our suppliers cannot tell their emission factors and numbers for their products.”

Table 15. Company specific scores in sustainability scope and targets.

Company	Operational respon.	Scope definition	Target setting	Scope of targets	Target measur.	Total
A	3,33	4,00	3,33	3,33	3,00	3,40
B	3,35	3,41	2,94	3,12	2,88	3,14
C	4,00	4,00	3,00	4,00	3,00	3,60
D	3,33	3,33	3,00	3,67	2,67	3,20
E	4,00	4,00	3,50	4,00	4,00	3,90
F	4,00	3,50	3,50	3,00	3,00	3,40
G	4,00	4,00	3,00	3,00	3,00	3,40
H	3,50	3,50	3,00	2,50	2,00	2,90
I	3,67	3,33	3,67	3,67	2,67	3,40
J	3,50	3,25	3,00	3,00	2,25	3,00
K	3,50	4,00	3,50	3,00	3,50	3,50
L	3,00	2,67	2,33	2,33	2,33	2,53
M	3,00	2,50	2,50	2,50	2,00	2,50
N	2,50	1,50	1,50	1,50	1,00	1,60
Average	3,40	3,34	2,98	3,06	2,70	3,10

*Average values do not add up, they have been calculated from complete data set.

4.3.4 Sustainability policy and strategy

Sustainability policy and strategy dimension evaluates how companies are pursuing SPD in their operations and how companies are considering different sustainability aspects in their operations. Scores for participated companies and overall scores of this dimension are presented in table 16. The score of this dimension was 3,02, just above the succeeding level. The performance of large-sized companies was the best as expected with an overall score of 3,11. Midcap companies had almost as good performance than large-sized with overall score of 3,00 but SMEs had significantly lower overall score of 1,60.

The first element within this dimension is vision and mission. This element's overall score was 3,21, clearly above the succeeding level and second best in this dimension. Based on the scores, companies vision and mission are both internally and externally driven. It can be also noticed that it is becoming more driven by companies own values and motives rather than externally by pressure which is caused by competitors or legislation. Some improvements could still be performed in that field.

Impact to product development was scored also above the succeeding level with an overall score of 3,06. This implies that sustainability gives medium guidance to NPD and it is appreciated within companies. Mostly all TBL dimensions are considered when considering sustainability in NPD. To improve in this element companies would need to give more value to sustainability in NPD and it should be guiding the overall process.

“Our goal is that the sustainable product development is not a separate thing but instead it would be automatically part of the product development process.”

Sustainability optimism was clearly the highest scored element in this dimension with an overall score of 3,55 and it is the best scored element in whole maturity model. Based on the results companies are approaching sustainability with an open attitude and it is seen as an opportunity to differentiate from the competitors. The high score in this element is partially explainable by the question since it is not very concrete and describes what companies are trying to achieve. But to further increase their performance here companies would need to see sustainability more as a new way to create market opportunities and win-win solutions for both the company itself and for their customers.

The worst performing element in this dimension was identifying process with overall score of 2,55. Meaning that companies are still figuring out to how to systematically implement and establish ways to include sustainability criteria to be part of the process. Companies are not utilizing backcasting method to figure out what sustainability criteria should be addressed as expressed by Watz & Hallstedt (2020).

“At the practical level strategy is not clearly defined, it is more discussed in the higher level.”

The performance of sustainability in decision making element was also under succeeding level with 2,70. Based on that performance rating companies include factors considering different aspects in NPD. Companies are not only considering the financial costs of the product when developing them albeit it is given superior weight value over other factors. It is shown that companies are including environmental considerations in their decision making but considerations about social aspects are still lacking as well as including considerations comprehensively across product life cycle. To even improve their performance companies should take a holistic total cost of ownership approach to truly capture all TBL dimensions in considerations across whole product life cycle.

The overall score of the sustainability policy and strategy dimension was 3,02 which is above succeeding level. Results show that companies are including sustainability in their operations and know how it should be considered but it is considered as a separate function rather than part of operations and processes. Also, low scores in the last two elements implies that companies are figuring out how to effectively benefit from sustainability. The worst performance in the identifying process element shows that companies are not including sustainability criteria in NPD. As Hallstedt (2017) said that including sustainability criteria to support decisions in the early phases of the NPD is key element to efficiently introduce sustainability perspective in NPD.

Table 16. Company specific scores in sustainability policy and strategy.

Company	Vision and mission	Impact to PD	Sust. optimism	Identifying process	Sust. in DM	Total
A	3,00	2,67	3,33	2,67	3,00	2,93
B	3,29	3,18	3,65	2,41	2,65	3,04
C	4,00	4,00	4,00	3,00	4,00	3,80
D	3,67	3,67	3,67	2,67	2,33	3,20
E	3,00	3,50	4,00	3,50	4,00	3,60
F	3,50	4,00	4,00	3,00	3,00	3,50
G	3,00	3,00	3,00	3,00	3,00	3,00
H	3,00	3,50	3,00	3,00	3,00	3,10
I	3,67	3,67	4,00	3,33	2,33	3,40
J	3,50	3,00	3,75	2,25	2,75	3,05
K	3,50	3,00	4,00	3,00	3,50	3,40
L	2,67	2,33	3,33	2,33	2,67	2,67
M	2,50	2,00	2,00	2,00	2,00	2,10
N	2,00	1,00	3,00	1,00	1,00	1,60
Average	3,21	3,06	3,55	2,55	2,70	3,02

*Average values do not add up, they have been calculated from complete data set.

4.3.5 Strategic implementation of sustainability

Companies capability to involve sustainability to be part of the NPD process and to execute different strategies is measured by strategic implementation of sustainability dimension. Scores for this dimension are presented in table 17. The total score for strategic implementation of sustainability dimension was 2,81 which is slightly below the

succeeding level. Large-sized companies had the best performance with an overall score of 2,96, where the performance of midcap companies was scored 2,60 and SMEs 1,70. The difference between large-sized and midcap companies is significant.

The first element is sustainability dimensions. The overall score of this element was 3,02 which is just above the succeeding level. It indicates that companies are including economic and environmental perspectives to NPD and social perspectives to some degree. Dimensions are still looked in separately and in sequential order. To get better performance in this element companies would need to give more attention to social perspectives of the NPD as well as consider all TBL dimensions without forgetting their interconnections.

Performance in decision boards capability was the worst in this dimension with an overall score of 2,26. Companies include sustainability experts in their decision making board and sustainability performance must be assessed during decision making process. Results indicate that the overall sustainability knowledge within the people making decisions are lacking and clear documentation of sustainability assessment is not established within companies. In addition, companies do not show initiative towards including data-driven sustainability decision making support covering all TBL dimensions.

The life cycle approach had an overall score of 2,74 meaning that companies are approaching a succeeding level. Clear need for holistic life cycle approach has been identified but there is lack of concrete measures. Some of the methods might be used by individual performers such as R-strategies or assessments about supplier environmental performance. Comprehensive model and systematic way to assess all stages of product life cycle is missing from companies operating model. Based on the results companies are lacking measures to collect data from various stakeholders to enable environmental and social assessments of their products.

“Perhaps our perspective for extending the product life cycle has been when we have a really strong maintenance business and retrofit services to extend the products life cycle as long as possible and after that we give the customer information how to dispose the equipment and encourage reuse and recycling, but we do not have very precise information about what really happens to our equipment after decommissioning them.”

Gradual and consistent improvement reached almost succeeding level with an overall score of 2,96. Based on that companies have developed practices to improve its sustainability performance by finding improvement points and then improving performance with observed results. From the results we can observe that systematic ways to improve own performance by obtained results and feedback is still missing.

Corporate sustainability strategy element was scored above succeeding level with overall score of 3,06. Companies have established good baseline for external sustainability visibility and they also focus internally on different sustainability trends such as eco-efficiency, pursuing cleaner production, and cost-efficiency. Companies sustainability strategy supports companies to take actual measure towards sustainability. Based on the results companies have not yet established a strategy which tries to proactively focus on sustainability issues. Companies should strive to gain a competitive advantage from differentiation and sustainable development innovations.

When interpreting the strategic implementation of sustainability dimension scores, we can notice that the overall score is below the succeeding level being 2,81. This implies that companies are experiencing challenges in implementing sustainability at a strategic level but they have recognized the need for it and taken steps towards it. Scores of sustainability dimensions and corporate sustainability strategy elements being over succeeding level confirms that companies are implementing sustainability in higher company level and are performing moderately in it. Lower scores in more concrete strategic elements implies that companies are facing challenges in more practical activities which are looked more detailed in following chapters. The worst performance was observed in decision boards capability element within this dimension which is also looked more detailed in following chapters. Also, the gap between large-sized and midcap companies performance was significantly high in this dimension.

Table 17. Company specific scores in strategic implementation of sustainability.

Company	Sust. dimensions	DB capability	Life cycle approach	Gradual & con. impro.	CSR	Total
A	3,33	2,67	3,67	3,33	3,33	3,27
B	3,00	2,41	2,53	3,06	3,35	2,87
C	4,00	3,00	3,00	3,00	4,00	3,40
D	3,00	1,67	3,00	2,67	3,00	2,67
E	4,00	3,50	3,00	4,00	3,50	3,60
F	3,00	3,50	2,50	3,00	3,50	3,10
G	3,00	3,00	3,00	3,00	3,00	3,00
H	2,50	1,50	3,00	3,00	2,50	2,50
I	2,67	2,33	3,00	3,00	3,67	2,93
J	3,25	1,75	2,75	3,00	2,50	2,65
K	3,00	3,00	3,00	3,00	3,50	3,10
L	3,00	1,33	2,33	2,67	2,67	2,40
M	2,50	1,50	2,50	2,50	2,00	2,20
N	2,50	1,00	2,50	1,50	1,00	1,70
Average	3,02	2,26	2,74	2,96	3,06	2,81

*Average values do not add up, they have been calculated from complete data set.

4.3.6 Tools and practical implementation of sustainability

Tools and practical implementation of sustainability dimension also measures companies' ability to implement sustainability into its operations but in more detailed level. Scores for this dimension are presented in table 18 and the overall score for this dimension is 2,36 which is clearly the worst performing dimension. Large-sized companies had an overall performance of 2,48 which is also clearly below the succeeding level. Midcap companies had an overall performance of 2,23 and SMEs 1,30. All company types had the worst performance within this dimension.

The first element of tools and practical implementation of sustainability dimension is checklists and guidance. The overall score of this element was 2,13 which is just above elementary level. Also compared to other elements of the maturity model, the overall score was the second worst of all. This is surprising because the importance of guidance has been identified before in similar research such as Watz & Hallstedt (2020). Checklists to give guidance are utilized to a minor extent mostly to evaluate and ensure overall

sustainability performance in NPD. There exists high potential for improvement if companies would utilize those in detail level to ensure that sustainability is truly considered throughout NPD.

PLM utilization element overall score was 2,23, also below the overall sustainability maturity score. Based on the results companies are utilizing PLM internally with different organizations enabling cross-organizational collaboration. This is still elementary and limited mostly to creating manufacturing drawings and BoMs. In addition, collision checks are made in large models. There are still a lot to improve, for example enabling PLM utilization with external stakeholders in real time and pairing PLM with other intelligent industry applications such as digital twin.

Analysis and assessment methods had the worst overall score of all elements being only 2,04 which is just above elementary level. Based on the score we can interpret that in addition to economic dimension companies are assessing environmental dimension with quantitative tools such as LCA. Results do not support that companies are quantifying performance of social dimension with S-LCA but analyses about conflict materials are carried out. Companies also lack the ability to use or combine different analysis and assessment methods together to evaluate trade-offs affecting sustainability performance in every sustainability dimension.

“How to guide technology and product development with the help of carbon footprint analysis, and it is challenging because at the beginning we do not have accurate information about the product's materials when we are planning a new technology or product. There is no initial data on which to base the analysis and this is such a big bottleneck and a big challenge and I would make it the biggest challenge in our company.”

“The system is not necessarily the solution for an easier carbon footprint calculation, there is a lot to do with it as you mentioned the data and how it is collected and how good the access to information is, and when little by little the library accumulates that there are suppliers and you have received data from them and you can then scale it.”

Data utilization element a had slightly better performance than latter ones with an overall score of 2,51. Results indicate that companies are not facing as many problems with internal data as with external data. Internal data such as 3D-models and sales data are in

tolerable state and easily accessible by employers making it a positive asset. On the other hand, external data such as supplier environmental data or the ability to collect data at all for external stakeholders are causing difficulties to companies.

Sustainability reporting had the best performance in this dimension with an overall score of 2,87. It indicates that companies are communicating broadly all sustainability matters and issues through their annual report or in a distinct sustainability report. Goals and measures are additionally communicated, and assessment reports may be published to demonstrate their sustainability commitment. Usually, all this communication is one-way and to further develop it including two-way communication and broader sustainability communication with stakeholders are something to consider.

The first thing that can be noticed when interpreting the results of tools and practical implementation of sustainability dimension is that it is the worst performing dimension with an overall score of 2,36. It confirms other findings that companies have difficulties implementing sustainability in their operations, particularly in daily practical activities. Three of the lowest scored elements in the maturity model were in this dimension and they were analysis and assessment methods, checklists and guidance and PLM utilization. Two of the latter mentioned are directly evaluating companies' ability to use and benefit from applications provided by external vendors. Checklist and guidance element is evaluating how companies are ensuring that concrete actions are executed within NPD process such as that environmental assessment scores meet the requirements. Clearly the best performance was observed in sustainability reporting dimension which is concrete action highly visible external stakeholders.

“Many applications vendors market that their products are very compatible, they reduce the workload and that everything works easily. Also, it is noticed that in many applications' sustainability features have not been what was promised, or they were not compatible with our needs or other applications.”

Table 18. Company specific scores in tools and practical implementation of sustainability.

Company	Checklists & guidance	PLM utilization	A & A methods	Data utilization	Sust. reporting	Total
A	2,33	2,33	2,67	2,67	2,67	2,53
B	2,00	1,94	2,00	2,47	3,06	2,29
C	3,00	3,00	3,00	3,00	3,00	3,00
D	1,33	1,67	2,00	2,00	2,67	1,93
E	4,00	3,00	2,50	3,00	4,00	3,30
F	2,00	3,00	2,00	2,50	3,00	2,50
G	3,00	2,00	2,00	3,00	4,00	2,80
H	1,50	2,00	2,00	2,50	2,50	2,10
I	2,33	3,33	2,67	2,33	3,67	2,87
J	2,00	2,50	1,75	2,50	2,75	2,30
K	2,00	2,50	2,50	2,50	4,00	2,70
L	3,33	2,00	1,67	2,67	2,00	2,33
M	1,50	2,50	1,50	3,00	1,50	2,00
N	1,00	1,50	1,00	2,00	1,00	1,30
Average	2,13	2,23	2,04	2,51	2,87	2,36

*Average values do not add up, they have been calculated from complete data set.

4.3.7 Personnel skills and sustainability management

The last dimension in this maturity model is personnel skills and sustainability management. It describes how well companies are ensuring that sustainability measures are utilized and developed. All results for this dimension are presented in table 19 where we can observe that overall score for this dimension was 2,73. Overall score for large-sized companies was 2,91 which is near succeeding level. Midcap companies had an overall performance of 2,45 and SMEs 1,70. The gap between large-sized companies performance and midcap companies performance was clearly highest in this dimension.

Employee skills had an overall score of 3,02. It is the first and the best scored element of the personnel skills and sustainability management dimension. It is the only element within this dimension to be scored over succeeding level. Based on the scores employees in the companies which responded to the survey can perform in several positions and have good understanding about different tasks and operations which the company are

performing. Employees do not always understand the cause effects and relationships between different tasks and operations which restricts companies sustainability capabilities to some degree. Having knowledge about other tasks and operations as well as being completely aware of cause-effects related to specific positions would help employees make more sustainable decisions when inputs and outputs for each task are clear.

The overall score of employees' motivation and incentives was 2,57. It shows that companies have taken initiative in motivating their employees to support sustainability but methods may vary a lot and those may be unclear sometimes or completely lack in some areas. Results indicate that clear internal change culture towards sustainability is not existing in companies that responded to the survey. Monetary or non-monetary incentives and an active leading example for top management which would support sustainability actions are lacking.

Sustainability awareness was scored slightly below the succeeding level with an overall score of 2,89. It indicates that companies and employees are aware of what sustainability means in their operations at a higher level. Employees might lack knowledge of what sustainability concretely means in that position. Personnel responsible for sustainability have been hired at many levels of company hierarchy to increase sustainability performance and awareness. However, the results show that comprehensive and concrete sustainability awareness is lacking from companies.

The overall score of knowledge management was 2,53 which is between elementary and succeeding level. It indicates that the best sustainability practices are being shared but not in a systematic and a continuous way. Therefore, hidden knowledge exists. Also, the capability of documenting sustainability knowledge is not utilized at its full potential. Both of those restrict sustainability knowledge management. Results show also that external sustainability knowledge is not acquired to the extent possible.

The last element of the sustainability maturity model is sustainability training and its overall score was 2,62. This indicates that sustainability development and training opportunities are offered to employees and most of the companies have a training platform where sustainability skills can be developed. Scores also indicate that the training used by companies is general and not tailored for specific company needs.

The overall performance of personnel skills and sustainability management dimension was the second worst of all, being 2,73. Results indicate that companies are lacking in supporting sustainability to be included in company's operations and in every employee's day-to-day activity. One interesting finding is that the gap between large-sized companies performance and midcap companies performance was clearly highest in this dimension. If midcap companies want to look for improvement points matters considered within this dimension would be good point to start. Also, based on the interviews held we can say that large-sized companies have acted in matters considered within this dimension.

"I would say that there is good talent on the personnel side, and I think that we have recently had more people on the sustainability side, and there is cooperation between different functions, so it has been well developed recently."

Table 19. Company specific scores in personnel skills and sustainability management.

Company	Employee skills	Emp. moti. & incentiv.	Sust. awareness	Knowledge mgmt.	Sust. training	Total
A	3,00	3,00	3,33	3,33	2,67	3,07
B	3,12	2,59	2,94	2,71	3,06	2,88
C	3,00	3,00	3,00	3,00	4,00	3,20
D	2,67	2,00	2,67	2,33	1,67	2,27
E	3,50	2,50	3,50	3,00	2,50	3,00
F	3,00	2,00	3,00	3,50	3,00	2,90
G	3,00	3,00	3,00	3,00	3,00	3,00
H	3,00	2,50	3,00	2,00	2,00	2,50
I	3,33	3,33	3,33	2,33	3,00	3,07
J	3,25	2,75	3,00	2,00	2,00	2,60
K	3,00	3,50	3,50	3,50	3,50	3,40
L	2,67	2,33	2,00	2,00	2,00	2,20
M	2,50	2,00	2,00	1,50	1,50	1,90
N	2,50	1,50	2,00	1,00	1,50	1,70
Average	3,02	2,57	2,89	2,53	2,62	2,73

*Average values do not add up, they have been calculated from complete data set.

4.3.8 Open questions

In the end of the online survey were two additional and optional open questions. The intention of these questions was to gather views which might have been missed in the actual questionnaire and to get more detailed answers. In the first open question respondents were asked to describe shortly their biggest pain points in SPD. In the second question respondents were asked what the most important driver or incentive is to pursue more SPD.

Answers to the first open question are structured with a PLM thinking structure; process, people, data and technology. From the tree map in figure 21 we can observe that most answers were under the process section. In total 12 answers were in the process section and six of them were themed as understanding sustainability.

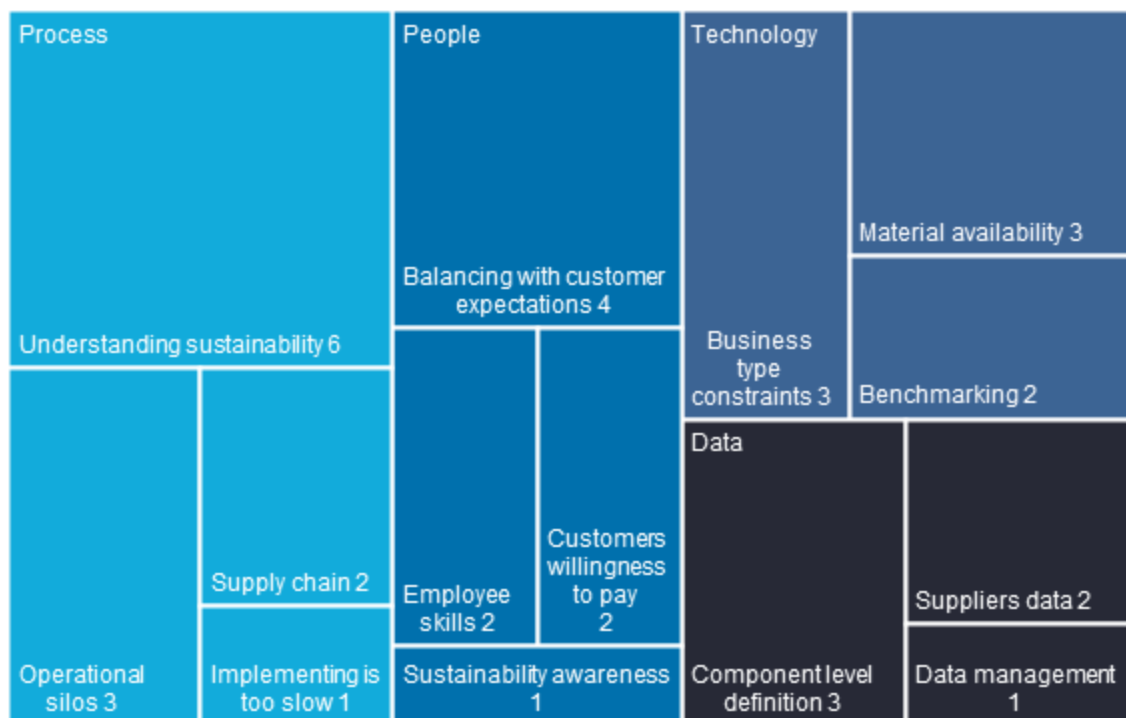


Figure 21. Tree map of biggest pain points and challenges in SPD, total answers 35.

“Product development cycle is a really fast and somewhat paced process so it's not necessarily a linear process, so things may change a lot and then, in a way, when do we determine the point that we can now do a life cycle assessment, i.e., whether the specs are fixed enough that you can do it and give it to the product development team that then controls the overall product design.”

In the process section four different themes stood out. Supply chain, operational silos, implementing is too slow and understanding sustainability. The last mentioned were the most common theme to stand out from the answers. Respondents had similar thoughts about it across the field; *“Understanding and recognizing what is the most important way to improve sustainability.”*, *“Understanding all sustainability aspects and their impact over the whole life cycle.”*, *“Wider understanding of what actually is included in sustainability, as it's too often summarized as emissions.”* and *“Lack of knowledge; tradeoffs between performance/price and sustainable design.”*. Answers implies that companies are currently figuring out the most effective ways to address sustainability in their all operations and not just in one thing and after that how to implement sustainability into action. The operational silo's theme stood out three times, and the answers were similar. One respondent described the situation well: *“Sustainability is still developed as a separate process and not included in every new product development.”*. From the answers we can conclude that companies are seeing sustainability still as a separate thing and not considering its interconnections with other functions as much as it could be possible. One reason for that could be because of long value chains capabilities of other company functions could remain obscure as one respondent said: *“You cannot design effectively if you don't know the capability of manufacturing site. Product development is not a separate function - it is just a part of the chain and overall performance defines the final figures.”*. This could result in slow implementation as one respondent answered it being the biggest pain point. Considerations about supply chain considered also long value chains as one respondent said that their biggest pain point is: *“Including suppliers in Asia.”* Another thing mentioned was the challenges in supply chain environmental footprint calculation.

“Long value chains in companies cause challenges, and then when many goals are set, they conflict with each other,..., multi-criteria optimization is quite challenging in decision making and when there are many conflicting goals, what is the main goal that guides the design?”

In the people section, balancing with customer expectations was the most common theme in this section. Especially respondents were considering different needs of stakeholders from different organizations, how to balance with them and how that should be reflected in their own performance. One respondent summarized as follows: *“Especially external stakeholders want many different things in terms of sustainability. This makes it very*

challenging to prioritize and focus on what matters.”. One concrete thing stood up which was costs as one respondent explains: “In global competitive situation we often have to evaluate things product cost as the most important factor which causes conflict of interest between sustainability policies. The price is always the most important thing to customers and what they ask first. If our products are too expensive, we do not even get the chance to tell about other features such as how we consider sustainability in our products. In other words, product development is continuous balancing between cost and sustainability. Luckily, most of the western customers are more aware about sustainability and appreciate companies which includes sustainability perspective in their products.”. Another similar theme which stood out in the people section was customer willingness to pay and one respondent described it as follows: “More sustainable products easily cost more, and our customers are not willing to pay any extra. Therefore, there is not that much pressure to develop more sustainable products.”

Answers from both theme groups indicate that costs are still the most important factor to consider but more sustainable alternatives are considered as well. Both manufacturing companies and customers are balancing between which factor to value more and in which quantity. A slightly different theme which also stood out was employee skills. One respondent summarized it well: *“Engineers represent variation of skills, age, attitude and knowledge. They do not always see the big picture how from small pieces with big volumes can be achieved something sufficiently large.”*. Also lack of training was noticed in answers. Those implies that overall skills and attitudes of employees who are involved in NPD activities are limited which then prevents change towards more sustainable way. Resistance to change is a known phenomenon when changes are being made and a receptive audience is not willing to make changes in their habits. The last theme in the people section was lack of sustainability awareness. Only one answer was themed accordingly. In this respondent said that sustainability awareness should be increased, particularly outside the NPD organization to promote new and more sustainable alternatives.

Third section was technology where no single dominant theme appeared. Answers themed as business type constraints were raised three times. Meaning that high safety or standardization regulation from government in their products leaves so little room for improvement that there are no possibilities to improve product sustainability reasonably. Also process production equipment was seen as a business type constraint. Meaning that actual changes in product to be more sustainable are so minor in whole value chain that

company is not giving emphasis into it and it is focusing in improving its capabilities to be more sustainable in hands of end user like one respondent summarizes: *“As we are developing products to processes the real effect is in the end process rather than in our products. If we are able to improve the end process sustainability it makes a huge difference, but with selections in our product structure (material ...) the effect is minor.”*.

When resources are limited companies need to prioritize their actions to maximize their inputs like mentioned above. Another theme within technology tied to resource limitation is material availability, and it was also mentioned three times. Some respondents answered that in their cases there are no sustainable alternatives available for their purposes as one respondent concludes: *“Our products are heavy and mostly steel. The sustainable raw materials are only just getting developed.”*. In this case companies are forced to find ways to be sustainable from somewhere else since heavy manufacturing materials need to be manufactured from materials such as steel. There lies a huge opportunity for material development which is currently taking place. (Outokumpu, 2022). Two respondents named benchmarking being the biggest pain point in their operations to achieve sustainability. Companies are ignorant about what are the suitable metrics or best available technologies in markets and there the lack of benchmarking is creating challenges for the companies. In the perfect world this would have already happened but because sustainability is such an emerging area those do not exist yet. Evaluations based on maturity models are great sources to companies to obtain benchmarking data about their peers as well as development proposals based on their actual performance.

Last section of pain points were data. Most answers were themed with challenges in component level definition. This means that there are challenges in collecting and utilizing sustainability data in every component level. One respondent describes it as follows: *“Quite a lot of work to review at component level that sustainability targets are met at each supplier. Processes & resources are in place, but workload is pretty big.”*.

When we are talking about modern large machines there could be tens of thousands of different parts and to define sustainability levels for all and maybe to different alternative parts it is going to be challenging task. Another theme was suppliers' data, and both are linked together. *“A common problem is to get reliable and transparent information about the social and environmental impact of components and materials.”*. Global companies have long value chains which are causing such issues. Therefore, managing supplier requirements is important to reduce disorder. The last theme in data was data

management. When large amounts of data exist, it is necessary that it is maintained and handled properly otherwise its utilization becomes difficult. The importance of managing supplier requirements stood out also during the interviews.

“The supplier requirements are strict with us, and we have certain principles and points that the supplier must commit to in order to cooperate, it is really strict with us.”

Answers to the second open question are divided into internal and external drivers. Figure 22 shows that external drivers are more utilized than internal, which implies that there are still improvement points in SPD because according to literature review the more mature SPD is the more internally driven it is.

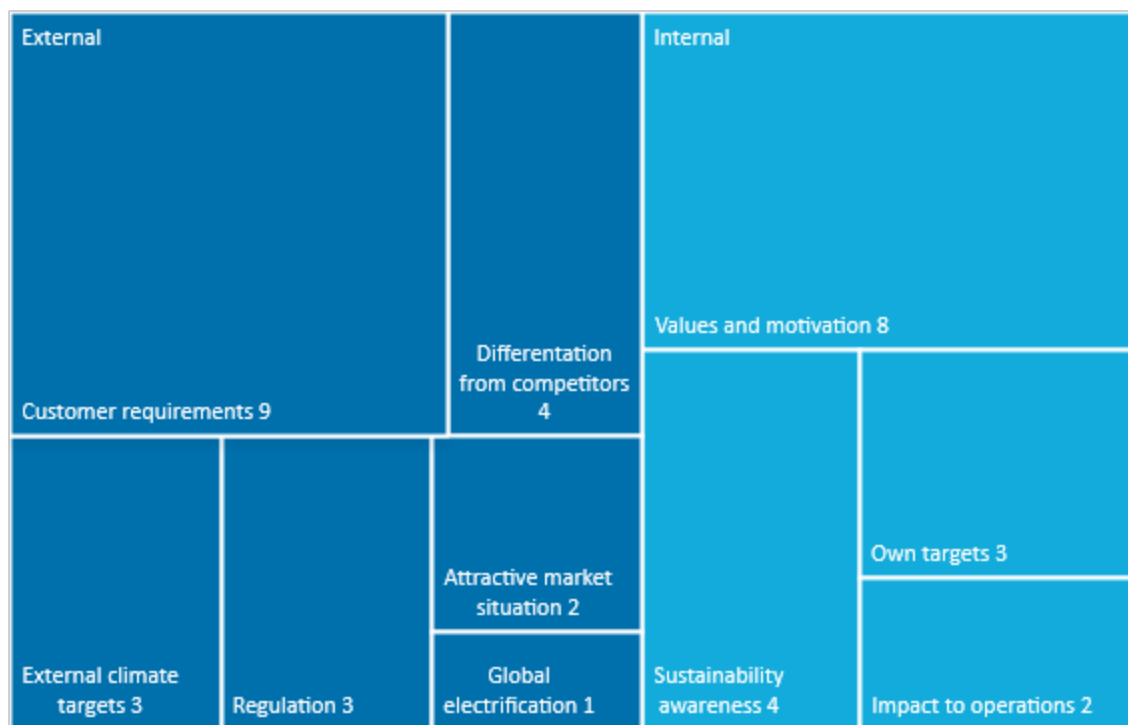


Figure 22. Tree map of drivers and incentives in SPD, total answers 39.

The most common driver for companies to pursue towards SPD were customer requirements. The manufacturing and other industries are dependent on customers, and the business is based on selling products to them. If customers stop buying products and other services from the company, it is going mean serious consequences for that company. Therefore, it is important to understand customers and provide goods they need to succeed in a competitive market situation. Another external theme which is tied to competitive market situation is differentiation from competitors. NPD is strongly supporting this and

including sustainability is a good way to differentiate from competitors. It is known that manufacturing in Finland and in other developed countries is more expensive than in developing countries and companies need to find other ways to differentiate than price as one respondent replied to what is the biggest driver to SPD. Companies are also seeing that current market situation is starting to value more sustainable products which drives companies to develop them as one respondent said: *“Having a clear need from the market which we can fulfill to gain competitive advantage.”* This was recognized only by two of the respondents where the specific customer request was recognized nine times, meaning that the markets for sustainable products are still emerging. The whole different driver to companies is tightening pressure from non-governmental organizations. It appeared only three times and for reference in the research by Held et al. (2018) laws and regulations to avoid penalties were the most answered option.

“The legislation is changing quickly in the area of harmful substances, and we are observing that closely as the list of harmful substances is getting longer and longer.”

Companies are also committing to external climate targets such as science-based emission targets. By committing into external targets companies can display their sustainability motives when for example banks and investors are demanding concrete sustainability actions (Banerjee & Gupta, 2017). The last theme which emerged from the answers was global electrification. This was pointed out only by one respondent but there lies potential in global electrification when the need for technology increases.

From the internal driver's company's own values and motivation stood the most clearly. *“We want to help our customers to meet their goals on sustainability.”* was said by one respondent and it describes clearly how companies can help clients by offering them value adding goods. Similar to this is sustainability awareness where external pressure is formed into internal factor which then drives sustainability. This can also appear as a request from the company's own employees as one respondent said that their own employees are starting to demand and request sustainability. This can be supported by setting own internal sustainability targets and by including sustainability into the process. Impact to operations was the last theme within this analysis. Some respondents said that including sustainability in NPD is connected to profit earning and thus want to promote it in their own actions.

4.4 Synthesis of the empirical research

The purpose of empirical research was to answer the second research question: **What is the current state of sustainable product development and how companies are performing in it?** Also, online survey answers and selected answers from the held interviews are presented. Data was collected so extensively that rough prioritization was made so that only the most relevant answers to this research were analyzed.

Based on the empirical research combined sustainability maturity level from all responded companies was 2,86 out of 4,00. It can be considered as a realistic current state description of Finnish manufacturing sector since the sampling consisted of 47 different respondents from 14 different companies. Score implies that companies are showing good performance through different dimensions and have set foundation for truly SPD process. However, difficulties can be seen and the biggest difficulties are in the detail level how companies are implementing sustainability in their operations and that confirms the first hypothesis to be true.

The second hypothesis is also confirmed to be true. Company size has a positive effect on sustainability performance and the biggest differences separating large-sized companies from midcap companies were in the strategic implementation of sustainability and in the personnel skills and sustainability management dimensions. This can be explained by the overall maturity and greater resources in larger companies. SMEs had significantly worse performance. Typically, in SMEs focus is in running the core business and after that has reached the needed maturity focus shifts to process development such as sustainability development. Lesser resources reflect straight in the capabilities how companies can offer different incentives and development opportunities.

Qualitative research revealed that companies are still valuing external drivers more than internal drivers. Shift towards internally driven SPD can be noticed when comparing results to Held (2018) where external drivers were even more dominant. In addition, pain points were identified which are presented in table 20 with corresponding dimension and percentage of all answers. Clear ignorance about sustainability is evident in qualitative answers which also appears as low scores in the dimensions which characterizes concrete actions towards SPD. A single dominant pain point was not identified which implies that there is no clear industry-specific pain point albeit companies are facing similar issues.

Table 20. Identified pain points, corresponding dimension and percentage of answers.

Pain point	Dimension	% of all answers
Understanding sustainability	SPS	17,14 %
Balancing with customer expectations	BO	11,43 %
Component level definition	TPIS	8,57 %
Material availability	SIS	8,57 %
Business type constraints	SPS	8,57 %
Operational silos	BO	8,57 %
Suppliers data	TPIS	5,71 %
Supply chain	TPIS	5,71 %
Employee skills	PSSM	5,71 %
Benchmarking	SCT	5,71 %
Customers willingness to pay	SPS	5,71 %
Slowness of implementation	SIS	2,86 %
Sustainability awareness	PSSM	2,86 %
Data management	TPIS	2,86 %

*Abbreviations in tables stand for sustainability maturity model dimensions

However, understanding sustainability and balancing with customer expectations being the most answered pain points implies that there is still a lot of uncertainty and considerations what to prioritize in their operations. These findings are in line with Baumgartner & Ebner (2010) when they highlighted that many companies pursue towards more sustainable operations, but their intentions remain unclear and it seems that clear strategy and knowledge is missing. This then reflects as poor results in strategic implementation of sustainability, tools and practical implementation of sustainability and in personnel skill and sustainability management dimensions which are more describing actual actions and measures taken by companies. Also, low scores in identifying process and in analysis and assessment methods dimensions corresponds the biggest identified pain points. This indicates that there are demand for more research about sustainability and sustainable operating models in NPD which are still developing.

Three of the next four forthcoming pain points were concrete issues which considered one entirety. Both component level definition and material availability are linked to external stakeholders and without effective communication and clear requirements those can become a big challenge. A company's own performance can cause challenges both internally and externally if emphasis towards sustainability is not given. Collaborating

with the company's external stakeholders emerged in several pain points which increases its importance even further. Previous pain points had similarities to some extent but the nature behind each is different. Therefore, companies need to put emphasis towards it because many pain points are connected to collaboration with external stakeholders such as clients and suppliers.

Performance of each dimension and element in online survey are listed in figure 23. By visualizing the performance we can observe different things easier such as how badly companies are performing in tools and practical implementation of sustainability dimension.

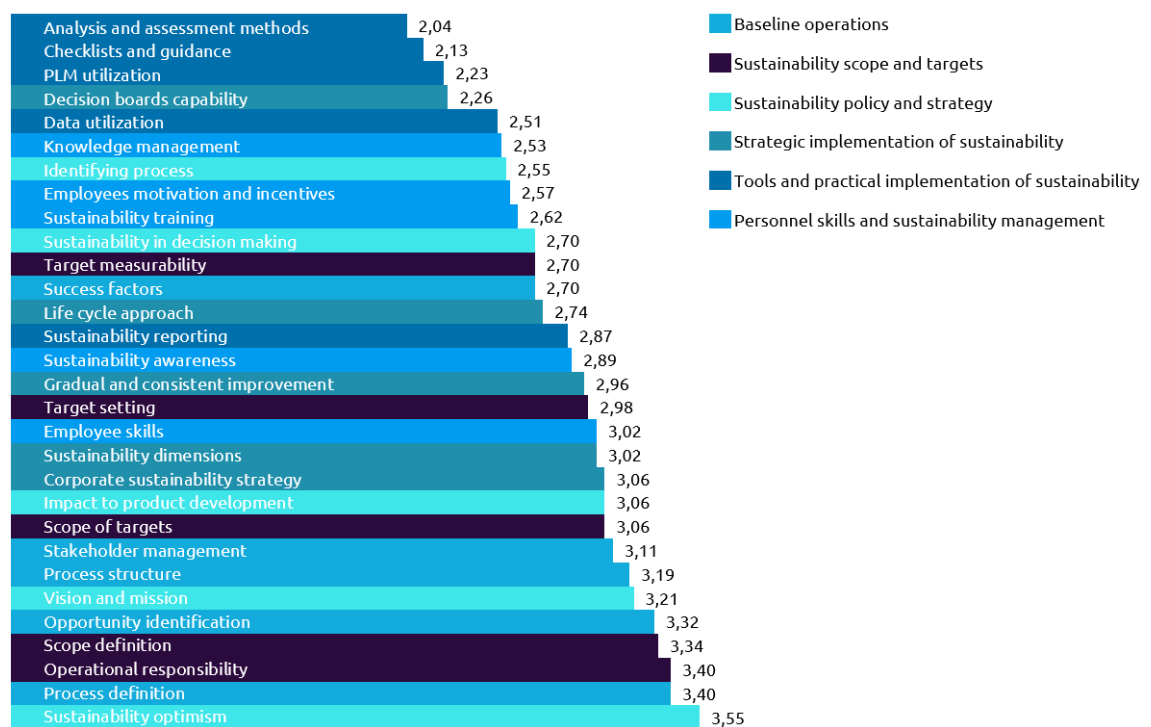


Figure 23. Performance of maturity model elements.

5 DISCUSSION

The purpose of this chapter is to answer the third research question: **How could companies improve their sustainability performance in product development?** The answer to this is derived by combining both literature review and findings from empirical research.

5.1 Differences and requirements for sustainable product development

To assess the question of how companies could improve their sustainability performance in product development we need to set mutual understanding what SPD is and how that could be achieved. This also enables to develop measures for evaluating the performance of different companies though they have differences in their operations. Based on the literature review six key requirements stood up which companies need to recognize and consider within their actions:

- Baseline operations
- Sustainability scope and targets
- Sustainability policy and strategy
- Strategic implementation of sustainability
- Tools and practical implementation of sustainability
- Personnel skills and sustainability management

This framework considers broadly different aspects of sustainability around NPD process. Each of the six key requirements consists of five actions which can be measured. Measuring itself is important when trying to improve sustainability performance (Rodrigues et al., 2016a). Baseline operations consider both the company's NPD process and its supporting functions. Considering sustainability outside its conventional boundaries is important because they lay the foundation for it. (Alblas et al., 2014). Defining clear scope and targets are important for four reasons. It helps to avoid fuzzy results (Chang et al., 2014), enables to use DfE and LCA effectively as well as it makes managing sustainability in NPD easier when sustainability investments and initiatives can be justified (Alblas et al., 2014) and according to Watz & Hallstedt (2022) it makes easier to achieve intended outcomes. Policy and strategy for how those targets are going to be achieved is at least important as the clear targets because it makes managing the SPD

easier. Fast changing regulation requires companies to have clear, proactive and innovative sustainability strategy to respond to upcoming changes and challenges. (Chapas et al., 2010). Good sustainability strategy in NPD enables companies to separate from competitors (Baumgartner & Rauter, 2017) and create new market opportunities (Chen & Chang, 2013). Also, according to Driessen et al. (2013) sustainable company policy has major influence on sustainable product innovation. Watz & Hallstedt (2022) pointed out that sustainability policy and success of implementation are connected together and in addition many studies recognizing sustainability implementation being such a major pain point. Also, the overall complexity of implementation caused that it was considered both from strategic and practical implementation. (Alblas et al., 2014; Baumgartner, 2014; Hallstedt, 2017). Literature points out that in particular accessing life cycle data is creating a major barrier for practical level implementation of sustainability where for the strategic level handling overall complexity creates challenges. (Baumgartner, 2014; Diaz et al., 2021). To ease the implementation eight key elements which need to be considered are presented in chapter 2.4.3 by Hallstedt (2017). Lastly, as mentioned by Watz & Hallstedt (2022) to improve sustainability performance it is important that sustainability continuity within company and employee development is considered.

Companies also need to recognize the characteristics of SPD if they want to improve their performance in it. There are similarities to normal NPD such as linear process like presented by Ulrich & Eppinger (2016) and the pressure that creates the need for NPD (Alblas et al., 2014; Gmelin & Seuring, 2014). The three most significant characteristics identified in the literature review were:

- SPD is proactive and internally driven
- SPD considers whole product and process life cycle
- SPD performance is considered from all TBL dimensions and with respect to interconnections

As said by Hallstedt (2017) and Wang et al. (2021) it is important to consider things proactively rather than wait until is time to react. This allows companies to work without strict deadlines or pressure from external stakeholders which limits product capabilities and innovations. (Luan et al., 2022). Also, according to Alblas et al. (2014) SPD is truly internally driven and achieving it is impossible in companies which do not accept

uncertainty and lack innovative capabilities. SPD approach considers product and process life cycle from the very beginning when the raw materials are extracted from the soil to the end when it is completely decommissioned. Every TBL dimension must be considered during the process with respect to interconnections. (Baumgartner & Ebner, 2010). Also, it is important to establish two-way iterative feedback loop with stakeholders to enable sustainability and to find the pain points (Baumgartner, 2014) and to understand that SPD performance is measured as a combination of all TBL dimensions and their performance. (Gbededo, 2018; Rodrigues et al., 2016a).

5.2 Improvement of current pain points

Empirical research allowed to obtain comprehensive outlook about the sustainability performance in product development in Finnish manufacturing industry. Overall sustainability maturity level being 2,86 indicates that room for improvement exists especially in execution level. Performance of each dimension and element are visualized in appendix 3. Obtained results enable us to indicate prevailing situation and by combining them with findings from literature and the qualitative part of the empirical research, interdependencies and cause effects between different factors can be identified.

Both of the hypotheses were confirmed to be true. Based on the quantitative analysis companies have challenges in implementing sustainability when the scores of both implementation dimension are lower than the average sustainability maturity level. It was also observed that company size has a positive effect on SPD performance.

In figure 24 identified pain points are plotted to the diagram where curved lines separate the area into three different areas describing the magnitude pain points. The vertical axis describes the percentage of each pain point from all answers. Percentages are shown in table 20 and the value range has been set between 0-20%. In table 20 pain points are divided into maturity model dimensions which best describes it and horizontal axis describes the performance of each dimension. This arrangement allows us to visualize the results and connect two different survey types to find the most advantageous improvement points.

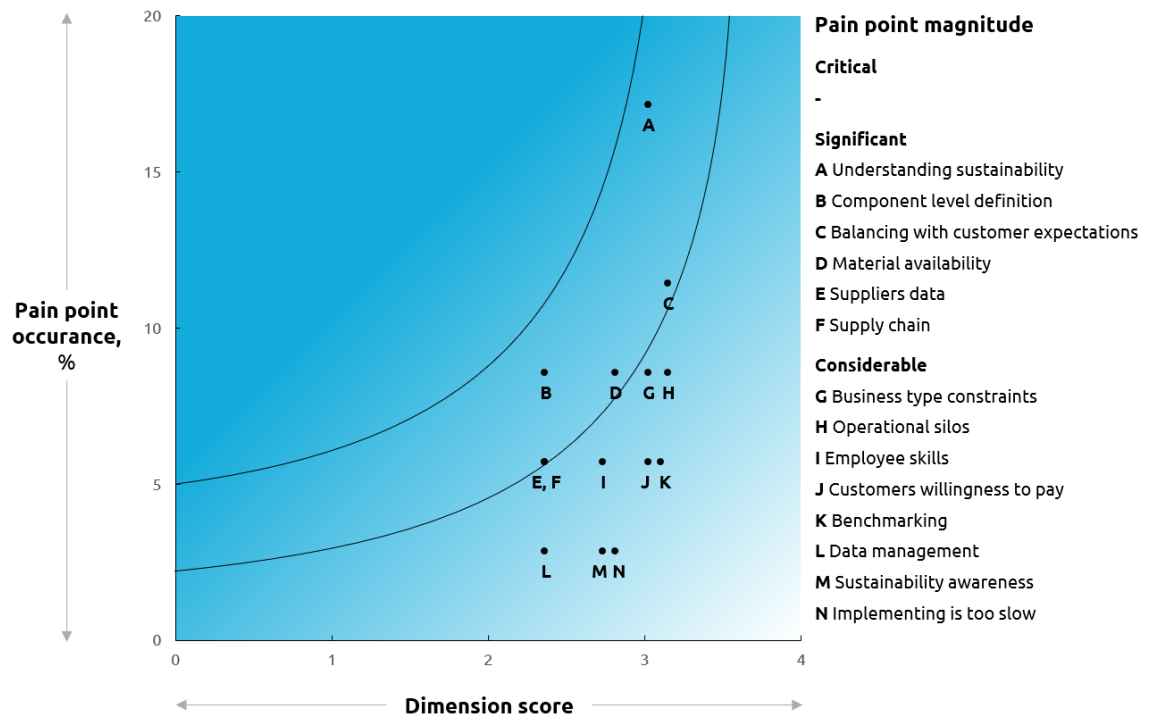


Figure 24. Magnitudes of identified pain points.

The best performance was observed in baseline operations dimension which does not make it the most obvious improvement area for mature organizations where foundation for SPD has been set. On the other hand, smaller and immature organizations most likely set their focus first in the topics which are discussed within this dimension because due to limited resources they cannot affect everything at once and it would be most beneficial to start here. As stated by Alblas et al. (2014) companies should first obtain an understanding of what sustainability means in their operations and products, which is the biggest pain point. Chang et al. (2014) emphasizes that the overall concept should be designed before the actual product design which also corresponds to the biggest identified pain point understanding sustainability. First acquiring sufficient knowledge and understanding would decrease challenges appearing later. Also, as stated by Chen & Chang (2013) and Majava et al. (2014) that matching customer need is crucial for NPD success. To capture those quality function deployment method could be utilized to translate customer needs into specified technical requirements (Diaz et al., 2021). This creates the need for requirements management systems for the companies. Collaborative design methods such as concurrent engineering and agile could be used to capture customer requirements and to obtain better understanding about what sustainability measures are needed and important. (Cooper, 2017, p. 188-193; Makovec et al., 2014). Increasing performance in baseline operations would also affect two other pain points

which were identified. Both balancing with customer expectations and operational silos were pointed out many times. As mentioned before, also in this situation utilizing concurrent engineering and agile sprints where customer expectations could be integrated to the product development would benefit companies to find balance in customer expectations. Also given the fact that customer requirements were the biggest driver to pursue towards SPD, utilizing collaborative design methods seems beneficial. Seeing sustainability as a separate function was also pointed out during the interviews and to improve it companies need to set internal sustainability policy which supports sustainability in its operations. Company's values and motivation were pointed out to be the biggest internal driver towards SPD but more emphasis into it should be given. Also, the need for enabling systematized and continuous improvement and understanding how to utilize previous success factors were recognized as improvement points in this dimension.

Sustainability scope and targets were the second highest scored dimension. Literature pointed out several times how important it is to define clear and measurable goals to enable SPD (Alblas et al., 2014; Watz & Hallstedt, 2022). However, the biggest challenges and improvement points are in target measurability and in target setting. Literature also shows that there is a clear need to develop more indicators to measure environmental and social dimension performance. (Rodrigues et al., 2016a; 2016b). Literature also shows that economic dimension is dominating other TBL dimensions which are more likely neglected during NPD process. Component level definition which is considered to be the second most significant pain point is connected to sustainability scope and targets and targets albeit it is placed to another dimension. Benchmarking which is considering capability of sustainability measurement but in higher level is not considered to be as critical as component level definition because it is not achievable before companies can define and measure sustainability performance in component level. Challenges in component level definition were also discussed during the interviews, and there the root cause was the supplier's inability to provide sustainability data. Both the company's own and external targets were considered moderate drivers for companies to pursue towards SPD, which indicates that companies have clearly taken the initiative but are not established at the needed level. Results indicate that decisions and measures taken in sustainability scope and targets dimension are causing challenges in more concrete level at tools and practical implementation of sustainability dimension. Companies need to develop systematized measures to assess the whole NPD process from all TBL

dimensions as presented in chapter 2.4.3 and require strict supplier requirements to enable component level definition. Also dividing large and fuzzy targets into smaller and more easily measurable goals would help companies to increase their performance.

The performance of the sustainability policy and strategy were also over the succeeding level like the previous two dimensions. It is important that companies define their strategy how sustainability targets are going to be achieved and how sustainability is concerned because according to Driessen et al. (2013) having a company level sustainability policy has a major influence on product innovation. Also, according to Baumgartner (2010) sustainability issues are pursued without a clear strategy when Held et al. (2018) discovered proper corporate sustainability strategy being a major success factor in SPD. Based on the results companies are willing to include sustainability in NPD and in other operations but their main concerns are how to include it beyond regulatory compliance. This indicates that companies seek ways to effectively benefit from sustainability which corresponds to the most answered pain point. The worst scores in this dimension were observed in identifying process element which also indicates and corresponds that companies should improve their capabilities to identify and understand sustainability better. Baumgartner (2014) and Hallstedt (2017) suggest that backcasting method could be used to improve that. It also helps to define companies strategy to success in SPD. Drivers to support latter such as attractive market situation and impact to operations were recognized but in minor quantity. Results also indicate that sustainability concerns lack in decision making which was also stated by Watz & Hallstedt (2022). This could be assessed by utilizing total cost of ownership when considering trade-offs and different options in NPD. Also, including considerations from both short- and long-term strategies and effects to the operations is important and introducing sustainability criteria to support decision making in early phases of NPD when it is most effective. (Baumgartner & Rauter, 2017; Hallstedt, 2017; Held, 2018). Business type constraints emerged to be considerable pain point and it has been identified before by Driessen et al. (2013). When product itself leaves so little room for improvement then the improvement points must be sought somewhere else. Customers' willingness is something that internal processes cannot much affect. Promoting sustainability awareness would be a viable option to justify higher prices related to sustainable products which was also identified to be pain point. Diaz et al. (2021) states that sustainability and strategy should be considered together to maximize its efforts.

Challenges in implementing sustainability were recognized already during the literature review and therefore two separate dimensions were developed to evaluate it. In addition, according to Watz & Hallstedt (2022) different tools to support SPD exist in large amount but the implementation to action remains low which emphasizes the importance of the issue. Results support previous claims when the scores of the strategic implementation of sustainability dimension are lower than the more conceptual dimensions which were discussed previously. Results also indicate that implementation has advanced further in higher conceptual level than in more concrete level. Based on the results companies should give more emphasis towards increasing the decision boards sustainability capabilities by offering them tailored sustainability trainings which is also emphasized by Watz & Hallstedt (2020). Also, the need to make sustainability more systematically concerned and to enable data-based decisions was recognized. To the improve previously mentioned topics actions must be taken on a more practical level when the lack is reflected in other dimensions This could be done by including R-strategies in consideration. Two different pain points emerged from the answers to match this dimension. Lack in material availability was recognized as a significant pain point, and the literature explored did not offer any concrete improvement points. Therefore, then the emphasis must be shifted to elsewhere such increasing material life cycle by offering life cycle services which emerged during the interviews. Also, identified internal and external drivers support that. Long value chains in large companies make implementing sustainability a slow process and that is something which companies need to be prepared for. To speed up the process external expert consultancy and allocating extra time to planning could benefit companies. Lastly, the gap between the performance of large-sized and midcap companies was significantly high in this dimension. This implies that midcap companies should find improvement points within this dimension.

The second dimension to assess the implementation is concerning utilization of tools and practical implementation of sustainability. From the start, it was clear that many challenges are in this dimension, and this was also confirmed by the results. This dimension was clearly the worst performing one and during the interviews, challenges concerning tools and practical level implementation appeared. Four of the pain points were connected to this dimension which is the most of all and the three lowest scored elements were in this dimension. Those findings also strengthen the assumption that companies suffer from challenges in implementation. More precisely companies are suffering from the capability to utilize different tools to enable SPD such as checklists,

PLM and LCA. The potential of discussed tools to support SPD has been identified in the literature several times Diaz et al. (2021), Gremyr et al. (2014), Mani et al. (2010). However, according to Watz & Hallstedt (2022) implantation of different tools does not guarantee increased SPD performance if other requirements are not set in place. This was also confirmed by one respondent during the interviews. Different incentives to support performance of this dimension were observed in small amounts. Increasing performance in utilization of different tools would increase the capability to measure internal and external targets but these drivers are not seen powerful enough. From the identified pain points it is clearly visible that companies are facing challenges with data and especially data coming from external sources. Of all pain points the second most significant pain point was component level definition. This can be also confirmed with significantly low scores in analysis and assessment methods element. Other pain points within this dimension are closely related to it, meaning that there lies a huge amount of potential. Within these challenges the problem usually exists outside of the company borders meaning that affecting into it might feel difficult. As one respondent said, to respond into this challenge managing and demanding strict supplier requirements is crucial because if suppliers are not able to provide sustainability data on component level, managing own products becomes impossible. Therefore, when acquiring new suppliers this needs to be considered and negotiated properly. Current suppliers can be persuaded to change and improve their operations. Diaz et al. (2021) pointed out that clear absence of feedback loops exists between stakeholders from different life cycle phases of the product. Enabling this could provide feedback on needed sustainability issues. Also, according to Kiron et al. (2013) collaborating with external stakeholders can be beneficial to maximize sustainability effects. To enable efficient data utilization companies must set their data requirements high, collect it from all life cycle phases and enable its systematic use with suitable application. (Chang et al., 2014; Pasley & McCarthy, 2020; Watz & Hallstedt, 2022).

The importance of giving sustainability training to employees cannot be underestimated. Straight connection to profit earning can be hard to justify but according to Luan et al. (2022) new opportunities can be proactively created when employees are trained and their sustainability awareness increases. In addition to Rodrigues et al. (2016) by offering sustainability training companies can increase their social TBL dimension performance which is usually the worst performing dimension. Results indicate that companies cannot offer their employees incentives to strive for more sustainable choices which restrict the

sustainability potential. There are also clear indications that companies could support their employees more to achieve that by enabling sufficient knowledge management and by offering suitable training. Similar answers were identified to be pain points within this dimension but as shown in figure 24 they are not the most crucial. Results indicated that the biggest difference between large-sized and midcap companies was in this dimension. Midcap companies which identify that their sustainability maturity could be developed, the most likely development points may exist in this dimension. Many third-party representatives offer sustainability training which companies could easily utilize. Sustainability awareness was the second most answered internal incentive towards SPD which indicates that companies understand the need for sustainability trainings but as previously mentioned the challenges in connecting it to profit earning could slow that down.

5.3 Consolidated improvement points

The purpose of discussion was to answer the third research question: **How could companies improve their sustainability performance in product development?"** Answer to this was derived by combining both literature review and findings from empirical research. Identified pain points with corresponding improvement points are presented and discussed more detailed in chapter 5.2 Improvement of current pain points.

Development proposals are formed based on the literature review, interviews and both combining quantitative and qualitative empirical research. Most relevant improvement points to this research and characteristics of SPD are gathered to figure 25, SPD development framework. Results also indicate that sometimes the experienced pain points and challenges are connected to other dimensions and the challenges reflect to another dimension. Therefore, it is important to consider sustainability holistically and as a combination of multiple things rather than as one large thing or project.

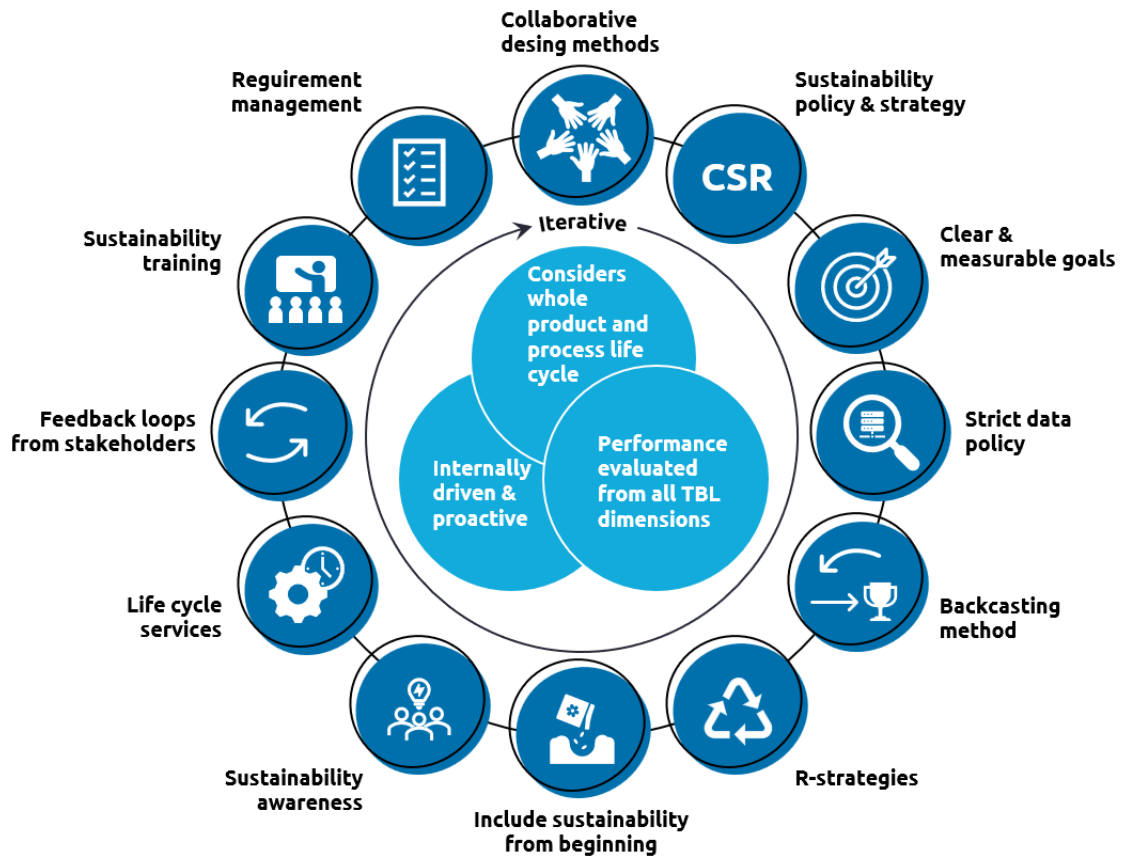


Figure 25. SPD development framework.

6 CONCLUSION

High uncertainty of the NPD process and fuzzy strategies to pursue towards SPD makes this very interesting and current topic to research. Manufacturing companies cannot neglect sustainability issues in NPD because it is one of the most important operations within this type of companies and the requirements are increasing. We are living in critical times when regulations and markets are changing quickly which causes companies to find new ways to succeed and SPD will support that.

The objective of this research was to understand what sustainability means in product development, how could companies improve their performance in it and answer to three research questions was formed. The first research question was: **what are the requirements of sustainable product development and how it differs from normal product development** and answer to that was derived from literature review. The second research question was: **what is the current state of sustainable product development and how companies are performing in it** and answer to it was formed based on the empirical research. Third research question was: **how could companies improve their sustainability performance in product development** answer to it was generated by combining the findings from literature review and the empirical research.

This research provides both managerial and scientific implications. Companies can benefit from this research by utilizing the identified improvement points, benchmark their performance against industry average and find information about how they should pursue towards SPD. Scientifically this research provides new maturity model which can be further utilized, current state analysis about the SPD performance in Finnish manufacturing companies and it verifies previous findings about SPD.

To get even more accurate results answering this survey could have taken place as a team workshop exercise to eliminate single-respondent bias. Structured survey also forces the respondent to choose one pre-made answer which limits the results. The topic for future research would be to utilize this maturity model in process development project when its capabilities and limitations emerge. Also, topic for future research could be set around every identified pain point but especially it would be beneficial to research the possibilities to enable component selection based on real time sustainability and to research how to effectively define company-specific sustainability requirements.

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APPENDIXES:

Appendix 1. (1), Online survey questions

Background

- I. Company name
- II. Role in company
- III. Experience in related field

Baseline operations

1. How well is your overall product development process defined?
2. How is your overall product development process structured into different phases or stages?
3. How internal and external stakeholders are managed within product development?
4. Have you identified or mapped your product development success factors?
5. How do you identify opportunities or possibility to start new product development project?

Sustainability scope and targets

1. How broadly sustainability compliance is considered within your company?
2. How is overall sustainability scope defined within your company?
3. Have your company set a policy in sustainability target setting?
4. How broad are your company's sustainability targets and how they support product development?
5. Have your company set metrics to measure sustainability targets?

Sustainability policy and strategy

1. How does sustainability fit into the overall company vision and mission?
2. How are company's overall sustainability policy and strategy affecting product development process?
3. How is sustainability approached as an opportunity in product development?
4. Do you have a process for identifying and selecting which sustainability criteria to address in product development?
5. How broadly different sustainability factors are considered when making decisions in product development?

Strategic implementation of sustainability

1. What sustainability (environmental, social, economic) dimensions are included in your product development process?
2. What is product development decision boards awareness about sustainability and how it is reflected in decision making?
3. Are you considering full end-to-end life cycle during product development?
4. Is your company continuously improving sustainability performance in product development?
5. What best describes the corporate sustainability strategy which is used in your company?

Tools and practical implementation of sustainability

1. Are you using checklists or guiding questions to ensure that sustainability is considered in product development?
2. How well your company is leveraging product lifecycle management (PLM) opportunities?
3. Are you utilizing analysis and assessment methods or tools to quantify sustainability performance?
4. What is overall data quality in product development, how it is accessible and how it is leveraged?
5. How well are sustainability measures reported in your company?

Personnel skills and sustainability management

1. What are employees overall knowledge of company's operations and individual tasks?
2. How motivated are company's employees to achieve sustainability targets and how top management supports it?
3. What is overall awareness regarding sustainability within your company?
4. How (sustainability) is knowledge management addressed in your company?
5. Does your company offer sustainability development and training opportunities to its employees?

Open questions

- I. Shortly describe your biggest pain points in sustainable product development.
- II. What are the most important drivers or incentives (internal and/or external) to pursue for more sustainable product development?
- III. Development and improvement ideas or something else?

Appendix 2. (1), Sustainability maturity grid model

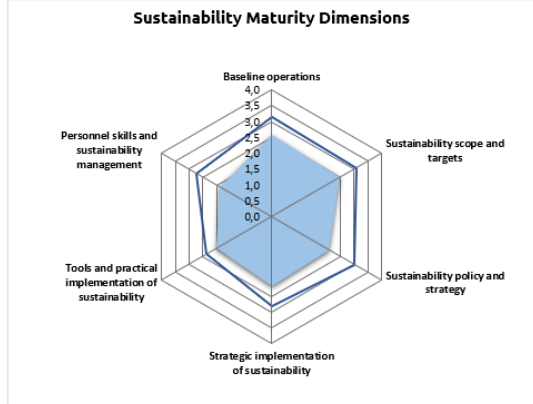
Sustainability Maturity Grid Model					
Element	Maturity level				Score
	Compliance	Elementary	Succeeding	Outstanding	
Baseline operations					
Process definition	Product development process has not been defined or documented and there is no consistency in process.	Product development process has been defined and documented to some extent. Performance is measured and assessed in a limited way.	Product development process is fully defined and documented. Organizations have composed descriptions and instructions of different tasks.	Product development process is fully defined and documented. Process definitions and metrics are derived from customer requirements and from the strategic objectives of the company which are continuously improved.	3 Succeeding
Process structure	There are no clear phases or stage-gates before moving into the next phase or the entire process is just seen as an unstructured process.	Company has partially adopted or is trying to adopt some framework which consists of different stages to support the overall product development process.	Company has adopted a framework where it is clearly defined what needs to be done before moving into the next phase. Clear inputs and outputs of phases.	Product development process phases are aligned with other processes, agile methods adopted into product development to fully capture stakeholder requirements with iterations.	3 Succeeding
Stakeholder management	Product development is working in its own silo and collaboration with internal and external stakeholders is limited.	Collaboration with internal stakeholders and with some external stakeholders e.g. legislative and investors. A full product life cycle perspective is not considered.	Internal and external stakeholders are included in the product development process. Cross-department functions are effective, supplier and customer involvement are sufficient.	Stakeholder involvement is high, company is working with iterative cycles with multiple stakeholders from every product life cycle phase from material sourcing to product disposal.	3 Succeeding
Success factors	Success factors of product development process have not been defined or identified. Reference data from previous projects are not utilized.	Some success factors have been identified but not mapped clearly. Mistakes from previous projects are documented and proactive measures implemented to prevent them happening again.	Success factors have been identified and mapped and measured. Feedback from finished projects is documented but not implemented systematically.	Success factors are visible, well known and aligned throughout the whole company. Success factors have been divided into measurable variables. Previous and ongoing projects are continuously evaluated, new success factors are identified and implemented into action.	2 Improving
Opportunity identification	New product development project needs rise from reacting to obligatory requirements e.g., some material is becoming prohibited or unavailable.	New opportunities arise from reacting to stakeholder demands e.g., customer need, legislation or competitor launching new product. New opportunity identification is sufficient to give stability and time to react.	Company is taking measures to identify risks before they actualize and occur. Product development process is working both reactively and proactively.	Product development process is seen as a proactive method to find new business opportunities and to react to tightening environmental regulations. New opportunities and risks are continuously evaluated.	3 Succeeding
Sustainability scope and targets					
Operational responsibility	Company does not consider sustainability matters in its operations or performs in grey areas in some measure.	Company is not doing anything which can be defined controversial. Regulatory compliance is ensured and economic dimension is mainly considered in the operations.	Environmental dimension is also included into considerations within operations in addition to the economic dimension. Social dimension e.g., wellbeing is considered. Dimensions are looked at separately and in sequential order.	Environmental, economic and social dimensions are considered within operations together, interconnections are evaluated, and company's operations can be justified from every point of view.	3 Succeeding
Scope definition	Sustainability scope is not defined or existing.	Sustainability scope exists, but it is unclear or not manageable.	Sustainability scope is clear and managed, but it is narrowed down and focuses on tangible key elements which are important to company operations.	Sustainability scope is clear, well managed and it covers all needed aspects of company operations.	4 Leading
Target setting	Sustainability targets are not defined.	Improving in defining target but targets are set by force e.g., by owner, members of legislation, stakeholders or market pressure. Targets are individual and not aligned together or with overall processes and their measurability.	Sustainability targets are clear and prioritized, set to measure success of support product development performance and aligned with company's overall targets and processes.	In addition, Sustainability targets are set proactively, and larger targets are broken down into smaller objectives. Targets are continuously evaluated to enable decision making.	1 Beginning
Scope of targets	Sustainability targets do not exist, or they are generic sustainability targets which do not concern product development.	Environmental sustainability targets exist. In general targets are fuzzy and not aligned with each other. Targets give minor support to product development.	Both short-term and long-term sustainability targets have been defined and implemented which are functioning in product development and sustainability extensively but not fully supporting each other.	Company has long-term sustainability targets which steer overall performance, mid-term targets supporting those and short-term sustainability targets supporting day-to-day activities. Accountability has been established for sustainable product development and targets fully support them.	1 Beginning
Target measurability	Sustainability targets are not defined nor cannot be measured.	Sustainability targets are mostly in qualitative format. If targets are quantified, they don't occur systematically, and measurability is not defined clearly. KPIs are utilized irregularly in product development.	Quantified sustainability targets are part of company's operating model. Quantified targets are set and defined mostly throughout the company. KPIs are set to measure overall sustainability success in product development process.	Company has clear, continuously evaluated and transparent quantitative sustainability targets which guides company's actions and are known by stakeholders. KPIs covering all sustainability dimensions are set to every stage of product development process.	2 Improving
Sustainability policy and strategy					
Vision and mission	Sustainability does not fit into company's vision and mission.	Sustainability partially fits into company's vision and mission, mostly due to external pressure.	Company has adopted sustainability into its vision and mission. It is both internally and externally driven.	Vision and mission are based on sustainability and it is internally driven.	3 Succeeding
Impact to product development	Sustainability means regulatory compliance; sustainability scope and targets are lacking and/or provide little guidance to product development.	Sustainability has been identified and it is appreciated within the company to some extent as it provides minor guidelines for product development. Economic and environmental dimensions considered.	Company appreciates sustainability, and it provides medium guidance and direction to product development. Mostly all dimensions considered.	Sustainability is valued at a company, and it provides major guidance and direction to product development within all dimensions.	2 Improving
Sustainability optimism	Sustainability is mostly seen as an additional cost to products and thus not included voluntarily into product development.	Sustainability is critically approached and included in product development only when clear benefits are available.	Sustainability is approached with an open attitude, and it is seen as a possibility, but the company is still figuring out how to perform it.	Sustainability is seen as an opportunity to differentiate from competitors, create new market opportunities and create win-win solutions both for companies and for their customers.	3 Succeeding
Identifying process	Not used or sustainability criteria are not identified beyond regulatory compliance and thus not included in the initial requirement specification.	Process is not systematically implemented, sustainability criteria can be occasionally identified beyond regulatory compliance and selection can be part of the initial but not necessarily in the final selection criteria.	Identifying process is established and sustainability criteria are always included beyond regulatory compliance in both initial and final selection criteria.	In addition, identifying process is systematically approached e.g., sustainability criteria to address are approached with backcasting method including all sustainability dimensions and it is integrated to be part of development and designing processes.	2 Improving
Sustainability in decision making	Usually only financial cost in the present moment. E.g., when selecting materials giving material price major weight factor over its quality or origin.	More factors included into decision making. E.g., quality, environmental impact and avoiding conflict materials. Full life cycle approach still lacking.	A wide range of different factors which are considered in decision making. In addition, social impact and different life cycle phase impact assessed but e.g., lacking in holistic life cycle assessment from sourcing to disposal.	A holistic total cost of ownership approach to include all affecting factors including full product life cycle assessment from sourcing to disposal to capture every sustainability dimension.	2 Improving

Appendix 2. (2), Sustainability maturity grid model

Strategic implementation of sustainability					
Sustainability dimensions	Sustainability point of view is not included in product development.	Economic dimension exclusively included in product development.	Environmental and economic dimensions included into product development perspectives might be assessed. Dimensions are looked in separate and sequential order.	All (economic, environmental and social) dimensions are included in the product development process. Different dimensions are looked together, and interconnections are considered.	3 Succeeding
Decision boards capability	No specific competence or skills required and occasional ad hoc sustainability statements when needed.	Sustainability expert is included on the decision board and to proceed in the product development process sustainability performance must be addressed.	Decision board is aware about sustainability. Sustainability is included in decision making and to proceed in the product development process sustainability performance must be addressed and documented.	Decision board is educated about sustainability. Sustainability is included into decision making, decisions must be based on actual data from sustainability assessments and to proceed in the product development process must be able to demonstrate that all dimensions of sustainability are addressed and documented.	3 Succeeding
Life cycle approach	Full product life cycle is not considered during product development phase. Products are created for current needs and after it becomes obsolete company's focus shifts to the next product.	Need for a life cycle approach has been identified but there is a lack of concrete measures. Individual performers can utilize some of the r-strategies e.g., thinking about product recyclability or contamination of the product during when it's used.	Different life cycle stages are considered e.g., r-strategies, supplier evaluations by their environmental performance and collaboration with end-users. Full product life cycle is reviewed on the surface level during product development.	Systematically and continuously considering different product life cycles. Product life cycles have been divided into different phases and sub-phases which are reviewed thoroughly during product development while systematically collecting data and feedback from end-users.	4 Leading
Gradual and consistent improvement	Company makes improvements only when it is required by laws and regulations.	Company is making improvements irregularly, mostly when major economic benefits are available. Culture for continuous improvement doesn't exist within the company.	Company has developed multiple practices to improve its sustainability performance. Operations are regularly assessed to find improvement areas which results are then implemented.	Company is outstandingly improving its operations in many ways from day-to-day activities to C-level strategy. Improvement points are systematically scored, and feedback is evaluated from many sources. Company has an established culture for continuous improvement.	3 Succeeding
Corporate sustainability strategy	Focus on legal and other external standards concerning environmental and social aspects to avoid risks for the company.	Company tries to differentiate itself from competitors by focusing on the external relationship, few visible sustainability measures and positive sustainability-related communication. Therefore, it seems meaningful to engage more in sustainability than it is obliged to do by law.	Focus on internal measures such as eco-efficiency, cleaner production, cost efficiency and very well-defined processes. Commitment is crucial in the investment in upgrading technology, sophisticated health and safety for employees and above all ecological sustainability.	Proactively focusing on sustainability issues within business activities, competitive advantages are derived from differentiation and innovation, market leader in sustainability issues. Based on an internalization and continuous improvement of sustainability issues inside the company.	3 Succeeding
Tools and practical implementation of sustainability					
Checklists and guidance	Checklists are used for ensuring regulatory compliance. E.g., stage-gate model in operation management system.	Checklists and guiding questions are used to evaluate overall sustainability performance in product development. E.g., ensuring that environmental assessment scores meet the requirements.	Checklists and guiding questions are used to evaluate overall sustainability performance and to guide designers' decisions in detail level to develop truly sustainable products.	Checklists and guiding questions are integrated into every phase of the product development and to the interfaces of different processes.	2 Improving
PLM utilization	PLM is used internally within single department for simple tasks e.g., creating manufacturing drawings and BOMs.	PLM is utilized internally with different departments enabling cross-organizational collaboration for faster data utilization and minimizing design errors and overlapping work.	PLM is utilized with stakeholders e.g., sourcing and end-user to improve visibility and to reduce ambiguities, reducing cycle times and to enable real-time monitoring with external stakeholders.	In addition, PLM is paired with other intelligent solutions for example AI, additive manufacturing or digital twin.	2 Improving
Analysis and assessment methods	Quantitative methods to assess sustainability performance are not utilized.	Life cycle assessment (LCA), life cycle costing (LCC) or some other method is used to quantify environmental or economic performance during every life cycle phase.	All dimensions of sustainability are included, also social which performance is evaluated and quantified e.g., by using social-life cycle assessment (S-LCA) or conflict resource analysis.	In addition, assessments are used to evaluate trade-offs and alternatives affecting sustainability performance in every sustainability dimension from beginning of life to end of life decisions. E.g., material selection, environmental pollution during use and its recyclability.	3 Succeeding
Data utilization	Data is not correct and available from external sources, or it is manually entered, stored on many different platforms or only in individual employees' computers and thus not accessible widely or leveraged.	Company's internal data (e.g., 3D-models, sales data) is in tolerable state, but flows with external data (e.g., material background data, end-users' improvement points). Employees can access data easily making it a positive asset.	Overall quality of the data is good, it is easily accessible when needed and data is shared with clients and stakeholders in collaborative space to identify priorities giving it a competitive advantage to the company.	In addition, product development data is systematically collected and analyzed to continuously improve operations and processes thus significant competitive advantage obtained.	3 Succeeding
Sustainability reporting	Sustainability issues are not considered either in a distinct sustainability report or in the annual report. Reporting is not based on actual facts and its only existing to polish company image.	Only the most important sustainability issues are communicated in company's communication channels or in a distinct sustainability report or in the annual report.	One-way communication of sustainability issues in corporate communication channels or in a distinct sustainability report or in the annual report. Goals and measures are additionally defined and communicated e.g., assessment reports.	Two-way communication and consideration of sustainability issues, and in a distinct sustainability report or in the annual report. Additionally, goals and measures are defined and communicated. All stakeholders are aware of the company's sustainability policy and measures.	2 Improving
Personnel skills and sustainability management					
Employee skills	Employees manage only their particular part of the process without understanding the previous, next or parallel part of the process.	Employees have a basic understanding of the company's different tasks and processes. Employees are not always aware of what inputs and outputs they need to deliver.	Employees can perform in several positions but don't always understand cause-effects and relationships between different tasks. Employees have a good understanding of different tasks and operations.	Employees are aware of cause-effects relating to their task which allows them to make sustainable decisions and they know what their inputs and outputs are. Employees can perform well in several positions and have comprehensive knowledge of different tasks and operations.	3 Succeeding
Employees motivation and incentives	Employees motivation is not focused or it has a negative impact to achieve sustainability. Lack of incentives to achieve sustainability. Top management is not concerned about sustainability.	Variation in employee motivation and incentive measures to improve motivation are set to achieve sustainability. Top management has taken actions to achieve sustainability.	Incentive measures to improve motivation and to achieve sustainability are set in most areas of the company. Top management shows leading example to achieve sustainability.	Multiple monetary and non-monetary motivating incentives are set to achieve sustainability. Top management has taken an active and leading role showing example to achieve sustainability. Those have established internalized change behavior into sustainability.	3 Succeeding
Sustainability awareness	Company and employees are not aware of sustainability and sustainability related issues. Company doesn't have any sustainability experts.	In company level sustainability awareness is recognized and within employee's sustainability awareness differs a lot. Company has hired sustainability experts or staff.	Company knows what sustainability means in their case and most of the employees are aware of sustainability. Some employees might lack knowledge of what sustainability means in that position. Sustainability personnel included at managerial or middle management level.	Company is very conscious about sustainability. All employees are aware of sustainability and know what that concretely means in that company and in that position where that employee is working. Sustainability executive is included at company C-level.	3 Succeeding
Knowledge management	Systematic approach towards (sustainability) knowledge management doesn't exist, and experience is concentrated to one person within company and best practices are not systematically shared.	Best practices are shared irregularly, and hidden knowledge exists. Specific (sustainability) knowledge management activities exist such as sharing knowledge in working teams and gathering databases to transfer and save (sustainability) knowledge.	Best practices are documented, shared continuously and implemented systematically within the company. External knowledge is acquired extensively. Company has laid focus on organizational learning and culture for improving by sharing knowledge.	Best practices are documented, shared continuously and implemented systematically within the company. External (sustainability) knowledge is acquired extensively. The company has laid focus on organizational learning and culture for improving by sharing knowledge.	3 Succeeding
Sustainability training	No specific sustainability development and training measures are set.	Certain sustainability development and trainings measures are set.	Multiple sustainability development and training opportunities are offered. Most of the employees are trained regarding sustainability. The company has access to third party training platforms.	Multiple sustainability development and training opportunities are offered. Everyone working in a company is trained regarding sustainability. Trainings are generated based on customer requirements and the company's strategic goals.	3 Succeeding

Appendix 3. (1), Company-specific report

Sustainability Maturity Dimensions	avg	
Baseline operations	2,60	3,14
Sustainability scope and targets	2,50	3,10
Sustainability policy and strategy	2,10	3,02
Strategic implementation of sustainability	2,20	2,81
Tools and practical implementation of sustainability	2,00	2,36
Personnel skills and sustainability management	1,90	2,73

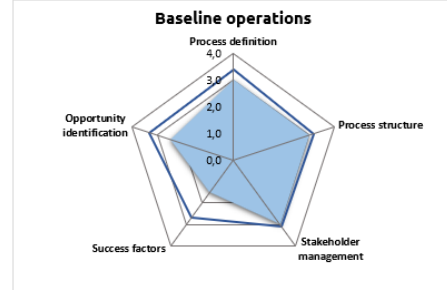


Company M

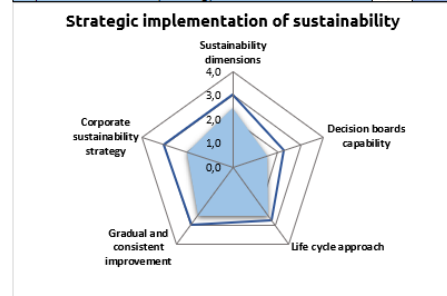
Company-specific sustainability maturity level
2,22

Average sustainability maturity of all companies
2,86

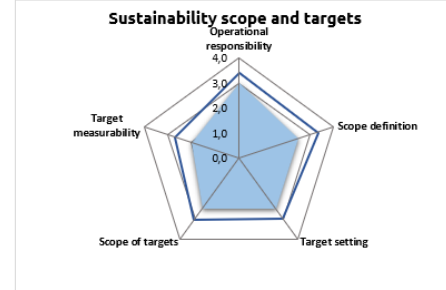
Baseline operations	avg	
Process definition	3,00	3,40
Process structure	3,00	3,19
Stakeholder management	3,00	3,11
Success factors	1,50	2,70
Opportunity identification	2,50	3,32



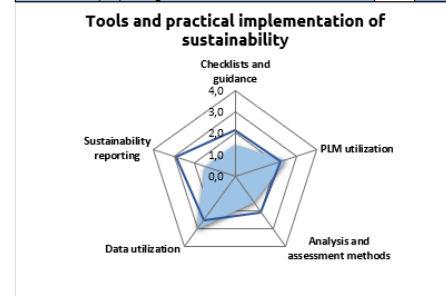
Strategic implementation of sustainability	avg	
Sustainability dimensions	2,50	3,02
Decision boards capability	1,50	2,26
Life cycle approach	2,50	2,74
Gradual and consistent improvement	2,50	2,96
Corporate sustainability strategy	2,00	3,06



Sustainability scope and targets	avg	
Operational responsibility	3,00	3,40
Scope definition	2,50	3,34
Target setting	2,50	2,98
Scope of targets	2,50	3,06
Target measurability	2,00	2,70



Tools and practical implementation of sustainability	avg	
Checklists and guidance	1,50	2,13
PLM utilization	2,50	2,23
Analysis and assessment methods	1,50	2,04
Data utilization	3,00	2,51
Sustainability reporting	1,50	2,87



Sustainability policy and strategy	avg	
Vision and mission	2,50	3,21
Impact to product development	2,00	3,06
Sustainability optimism	2,00	3,55
Identifying process	2,00	2,55
Sustainability in decision making	2,00	2,70



Personnel skills and sustainability management	avg	
Employee skills	2,50	3,02
Employees motivation and incentives	2,00	2,57
Sustainability awareness	2,00	2,89
Knowledge management	1,50	2,53
Sustainability training	1,50	2,62

