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Understanding the Role of Environmental Tools in Concept Development

Master's thesis in Management and Economics of innovation

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Abstract

Early-stage product development decisions shape a product's environmental impact, while later changes are costly and constrained. To address these early-stage constraints, along with responding to regulatory pressure, companies have introduced environmental tools for use in early concept development. However, these life cycle assessment-based tools remain underused and poorly integrated in industrial decision-making. The purpose of this study is to investigate how environmental tools are perceived and used in concept development, with the aim of understanding the conditions that enable or constrain its decision-making relevance. An exploratory, embedded single-case study design was applied using a mixed-method approach in a large automotive manufacturer to examine a matrix-based environmental decision-support tool inspired by Multi-Criteria Decision Analysis (MCDA) and the Pugh matrix. Data was collected through observations and unstructured interviews to build contextual understanding, followed by surveys distributed to engineers and project leaders to capture patterns in perception and use. Semi-structured interviews were then conducted to explore identified issues in depth, where the analysis was guided by the Gioia methodology. The data sources were compared through a thematic analysis to identify similarities and differences which will ultimately lead to change management recommendations. The identified results indicate that while environmental considerations are acknowledged as important, the environmental tools are typically introduced late in the concept development process after concept decision is made, and are used more for documentation than for guiding concept selection. Sustainability is deprioritized compared to other product features like cost and quality. Barriers that hinder the tool's usage include exchanging material data from suppliers, misalignment between engineers and leaders, unclear ownership and lacking leadership support. Based on the results change management recommendations were provided, e.g. strengthening leadership and communication, and improving integration with existing workflows. The results of this qualitative life cycle study will advance understanding of how environmental tools can be effectively used in concept development and contribute to research by showing that limited early use is driven more by organizational embedding, timing and alignment with decision-making structures than by tool capability. The study further advances current discussion on the practical meaning of LCA by reframing the challenges as a socio-technical integration problem.

Keywords: Environmental tools, Sustainability, Concept development, Change management, Life Cycle Assessment (LCA).

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1. Introduction

Environmental product decisions should be considered as early as possible in the product development process, since decisions made in early product development have a major influence on a product's environmental impact (Charter et al., 2001). According to McKinsey (2022), early design decisions can shape a large share of a product's lifetime emissions, and later changes tend to be more costly. This shows the importance of considering environmental aspects early in product development.

Companies' efforts to meet external sustainability expectations are a part of a broader European transition and it aligns with the European Union's (EU) Green Deal initiative. This initiative was launched in 2019 as a new growth strategy to become the first climate neutral continent by 2050 (European Commission, n.d.). To make sure everyone understands how to reach the objectives, the EU introduced a common definition for sustainable investments. The targets defined within this definition are the integration of sustainability into risk assessments and increased investments in sustainable activities, among other things.

Despite the development of eco-design tools, several studies show that systematic adoption in product development remains limited. Rossi et al. (2016) identify barriers related to methodological complexity, lack of resources and difficulties in adapting tools to industrial practice. Clark and de Leeuw (1999) highlight similar challenges in the adoption of LCA, including limited management commitment, lack of expertise and problems related to data and integration. Knight and Jenkins (2009) further show that eco-design techniques are not automatically embedded in existing development processes and need to be compatible with established ways of working.

In studies of Swedish vehicle manufacturing companies, Poulikidou et al. (2014) found that environmental aspects were not always systematically integrated into product development, and that cost and performance requirements often had stronger position in decision-making. Their results also show that the use of environmental tools varied between companies and frequently relied on specialists rather than being embedded in everyday engineering work. These findings indicate that the existence of environmental tools does not ensure their use in practice. There is therefore a need to better understand how environmental tools are perceived and used by design engineers in the concept development, as well as what factors influence their application.

Even though many environmental tools exist, their early phase usage in product development seems weak. There is a lack of evidence of decision influence in early concept selection, limited clarity on when early use provides value, and insufficient guidance on organizational embedding mechanisms. This study examines an internally developed environmental tool within a large global automotive OEM to gain deeper insight into current practices and the conditions that affect the use of environmental tools in early product development.

The aim of this study is to support increased use of environmental management tools in the initial phases (concept development) of product development. This is achieved by building knowledge and understanding of how existing environmental tools are perceived and used in the concept development phase at Volvo Group Trucks Technology & Industry Division, which drives innovation in areas such as electric vehicles and aims to enable zero-emission transport.

Based on the aim of the study, the research questions are:

1. How are environmental tools perceived during concept development?
2. How are environmental tools used during concept development?
3. What barriers and enablers influence the use of environmental tools in early product development?
4. What actions can management take to better support and increase the use of environmental tools in concept development?

In recent years, Volvo Group Trucks Technology & Industry Division (TTI) has introduced a set of environmental tools intended for use by design engineers to take larger environmental considerations in concept development, i.e. early phases of product development. These tools consist of relatively small checklists combined with simplified Life Cycle Assessment (LCA) elements. Their purpose is to support design engineers to make better environmental decisions up front and throughout the sustainability journey between changes in product generations. The study has both practical and academic significance. As mentioned, companies are introducing environmental tools that are not being used efficiently. However, there is a need for them to be used, partly due to the external pressure. Because of this, there is a significance in increasing the knowledge for companies of how these tools can be utilized. For the academic standpoint, literature today shows that many tools exist, but little is known about their real usage in concept development. The insights will contribute to filling a gap in literature while offering the case company actionable knowledge to strengthen sustainability integration in early product development.

This study applies an exploratory, embedded single‑case study design. A mixed‑methods approach was used across three phases. First, observations, training sessions and unstructured interviews were conducted within the case company to develop contextual understanding of the product development process and the tool. This was followed by conducting surveys, one for leaders and one for engineers, aimed at capturing patterns in perceptions, sponsoring and actual tool use, which will answer the first two research questions. Finally, semi‑structured interviews were carried out to explore remaining questions in depth, particularly barriers, enablers and managerial factors influencing tool adoption. Together, these methods enabled triangulation of data and supported analysis of both intended and actual use of the tool in concept development.

2. Theoretical Framework / Literature review

This chapter presents the theoretical background for the study. It describes early product development, how decisions are made in concept development and theory about environmental tools, since these are central aspects of the study. Theory related to barriers and enablers for the use of environmental tools is also included to show what is already known. Finally, change management is introduced to give a perspective on how to implement change.

2.1 Early product development

The study will focus on what Cooper (1990) calls the homework phase, which includes the early stages of product development. The homework phase covers the pre-development that leads up to the following development phase. This phase includes the most pivotal activities and decisions, which is important since if these decisions are taken later, it would cost more to "right the wrongs". Consequently, these early phases of product development offer the best opportunities to include environmental considerations into the finished product. Therefore, strong homework leads to better outcomes. More specifically, this study will focus on concept development.

This phase is characterized by high uncertainty and limited data availability. Limited data availability together with the design freedom of the phase is what Bhander et al. (2003) calls the eco-design paradox (figure 1).

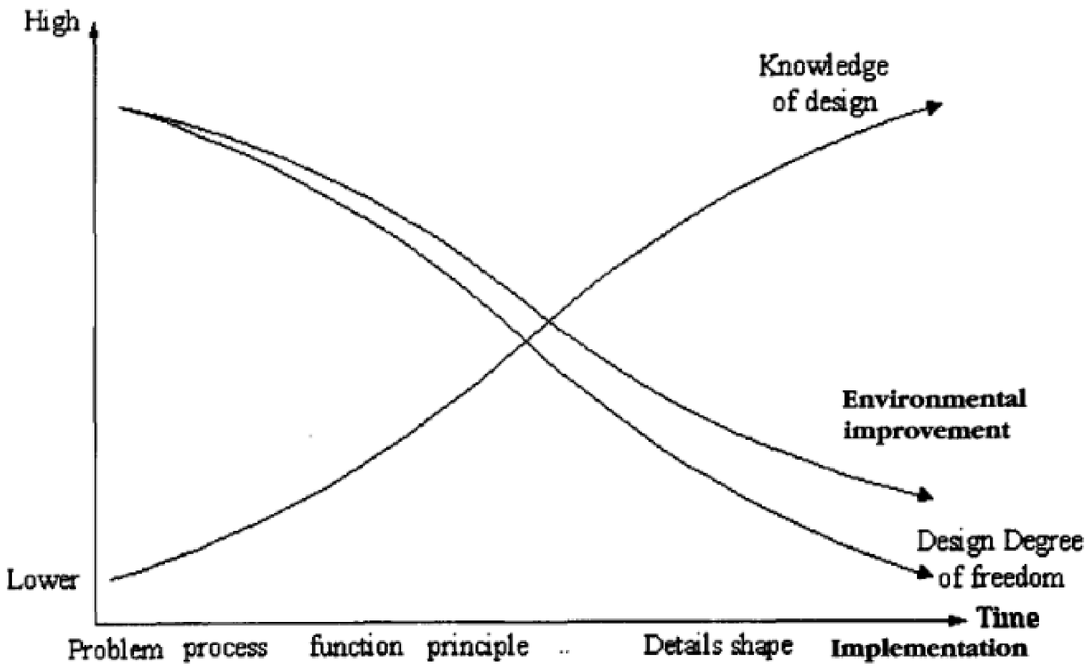


Figure 1. Eco-design paradox (Bhander et al., 2003)

2.2 Project management

This section describes how product development projects are structured and managed. It includes different approaches such as stage-gate, agile development and a hybrid approach.

2.2.1 Stage-gate model

Companies use stage-gate models in product development for various reasons. The stage-gate system serves as a framework for risk management, structuring decision-making and allocating resources efficiently throughout product development and the product lifecycle. Cooper (1990) describes the process as a structured way of moving an idea to a product through stages and gates.

The slow and structured ways of the stage-gate system can be advantageous for some and a limitation to others. The transparent and structured approach leads to consistent decision-making across projects, which is particularly important in large corporations for them to stay true to their identity, maintain organizational alignment and avoid silos caused by different processes being used across departments (Cooper et al., 2002).

The core structure of the stage-gate system is that it is built around stages and gates. The stages represent different phases within the divided product development timeline. Each stage is intended to involve cross-sectional workflows where specific tasks are due to be completed, leading engineers to the end of the stage where a gate is positioned (Cooper, 1990).

The gates function as decision milestones, which could mean start and/or stop (go/kill). What is meant by this is that during the gates, the critical decisions must take place. The decisions concern whether the project should move forward, be recycled (requiring certain activities to be redone), be put on hold or even be discarded (Cooper, 1990).

The basis for the decisions stems from the work that cross-functional teams have committed to meet the predefined project outputs, as well as from the data generated by decision-support tools, such as the environmental tools this study focuses on. It is important that the data produced from these tools is accurate and that the tools have been used efficiently, since the upcoming decision could determine the survival of the project (Cooper, 1990).

The decisions can be based on multiple different qualitative and quantitative criteria, which traditionally were connected to financial, technical and market strategic fits. Evaluation matrices and structured scorecards are commonly used mechanisms to support the systematic comparison of alternatives at gate reviews, and these criteria are often organized in checklists or matrix-based formats (Cooper, 1990).

The criteria may be of different importance. There are must-meet criteria, which are the most critical and may include political or regulatory requirements that a company must fulfill. Should-meet criteria are of lower importance, which could be internal goals and are typically those that gets compared and prioritized among concepts (Cooper, 1990).

One common limitation to the stage-gate process is that it is very time-consuming, which some large organizations are taking advantage of where new initiatives must take time for everything to remain stable and structured.

Though with some pros, other cons are non-avoidable. This further leads to bureaucracy and documentation-intensive processes. Another limitation is that a mindset of "following the protocol" can be advocated (Anderson, 1996; Grönlund et al., 2010), where teams do what is necessary to pass the gates instead of proactively explore. Cooper et al. (2002) and Walrave et al. (2022) means that this can be due to the customizable aspect of the system, which may enable adaptability, but it also adds complexity to an already heavy and slow process.

2.2.2 Agile Development

The agile development method has its origins from the software development "world" which is characterized by high uncertainty, partly because of the everchanging requirements (Walrave et al., 2022). The method even assumes that the requirements will change and therefore is built up in iterative loops, compared to the sequential stage-gate method with its predefined requirements (Walrave et al., 2022). Cooper and Sommer (2018) mean that agile development arose as a response to the previous and slow methods. Collaboration is emphasized and used within the product cycles.

The method is characterized by its iterative approach, and it is built up by sprints which are timeboxes of different lengths (Cooper & Sommer, 2018). These timeboxes usually start and ends with planning meetings where the team sits down and creates a task plan (Cooper & Sommer, 2018). The team structure distinguishes itself from the traditional setup with the usual project manager. Instead, a product owner, which is a part of management, represents the stakeholder's expectations and needs. Depending on the type of agile method used, the team usually includes a dedicated development group where roles as the Scrum Master may exist. The group is set up by cross-functional individuals that will be able to cover what the project requires, which leads to teams including design-, engineering- and testing individuals. When the agile development method was developed, the idea was that a team should only focus on one project at a time. Unfortunately, this has become more difficult as many manufacturing companies today are under-resourced, making it difficult to have each team work on only one project at a time (Cooper & Sommer, 2016).

Agile development offers in theory many different strengths such as faster response to customer needs together with faster time-to-market. It also promotes better collaboration through improved team communication (Cooper & Sommer, 2016). There are limitations with the method as well, such as the short time horizon often used with the method. Cooper and Sommer (2018) imply that manufacturing organizations that originate from a long history of plan-driven structures, like the stage-gate model, are used to comply with milestones. Walrave et al. (2022) means that it can become a clash between logics which may lead to misalignments with stakeholders who expect to see results within a timebound plan. The stages may also be difficult for management to govern (Cooper & Sommer, 2018).

2.2.3 Hybrid agile/stage-gate approach

The stage-gate and agile development methods differ in several ways, and each offers specific advantages and disadvantages (Walrave et al., 2022; Cooper & Sommer, 2018). As mentioned earlier, companies increasingly combine the two to leverage their strengths and reduce weaknesses, creating development processes that better fit their needs (Cooper & Sommer, 2016, 2018).

In hybrid models, the fundamental structure of stages and gates remains essential, as the go/kill decision points prevent unnecessary resource spending (Cooper, 1990; Cooper & Sommer, 2016). The stages also provide an overview of project progress, enabling managers and engineers to understand the project's current position and to identify the recommended activities for each phase (Cooper, 1990). These activities are, compared to the traditional stage-gate model, more flexible and less detailed (Cooper & Sommer, 2016, 2018).

Cooper and Sommer (2016) demonstrate that agile sprints can be embedded within stage-gate stages, increasing collaboration while still maintaining the level of governance required by many large manufacturing firms. This means that companies can preserve the control offered by stage-gate while gaining opportunities for agility (Cooper & Sommer, 2016, 2018). However, to prepare a business case with time and cost estimates that stakeholders can jointly approve, the project cannot be overly flexible or shortsighted. Hybrid models typically solve this by creating a schedule with only the necessary amount of detail to provide an approximate plan that can be accepted (Cooper & Sommer, 2018).

Unlike the traditional stage-gate model, which often locks activities and requirements early (Cooper, 1990), hybrid models intentionally keep decisions open during the early phases. This allows the project to adapt based on data and emerging insights (Cooper & Sommer, 2016; Walrave et al., 2022).

Sommer et al. (2015) identify several benefits for manufacturing firms adopting hybrid models. Improved collaboration and communication increased team morale, which in turn enhanced focus and time prioritization. They also observed increased design flexibility. However, they found that teams sometimes became "disconnected" from the wider organization, and that the bureaucratic environment was difficult to change.

More practical challenges also exist. Many companies struggle with resource allocation, and Cooper and Sommer (2018) show that firms often distribute employees across several projects, preventing teams from dedicating their full attention to a single initiative. As a result, the hybrid model may not be suitable for all project types, and companies should be selective in its application. Less complex incremental projects may not justify the resource demands of hybrid processes. Their study highlights how a large manufacturer such as Danfoss uses the hybrid process only for large transformational and innovative projects in specific parts of the organization. In theory the model is widely applicable, but in practice firms tend to choose carefully where to implement it (Cooper & Sommer, 2018).

The roles originating from agile methods are also incorporated into hybrid models (Cooper & Sommer, 2018). For this study, the most relevant role to mention is the Product Owner, who is responsible for managing the project's "to-do list," or backlog.

2.3 Decision-making in concept development

This section describes how decisions are made during concept development, where several criteria need to be considered at the same time. It introduces methods that structure these trade-offs and support comparisons between concepts.

2.3.1 Multi-Criteria Decision Analysis

Environmental design decisions in early product development cannot be taken in isolation. They almost always affect and are affected by other key factors such as performance, cost and feasibility. For this reason, Multi-Criteria Decision Analysis (MCDA) methods are frequently used. These decisions do not usually focus on optimizing just one criterion, instead they require balancing multiple, often conflicting and contradictory criteria. What may be better for the environment may also cost more than the prior variant (Cinelli et al., 2014).

Working with trade-offs means that there is rarely no best solution. The decision depends merely on the requirements and goals that were established at the start of the project. This is why MCDA tools are frequently used in working with environmental decision-making since it is not the tool itself that decides. Ultimately it is the organization's management where the decisions rest (Baumann and Cowell, 1999).

MCDA enables decision-making based on transparent data. The data could be both qualitative and quantitative, which can become a risk. Subjectivity is a significant and almost inevitable challenge when multiple stakeholders are involved. Further challenges with MCDA include its typical weighted scores, which infer that every criterion is ranked according to how important it is considered to the project (Cinelli et al., 2014). Different stakeholders may assign different levels of importance to the same criteria, reflecting their own priorities. As a result, these differing priorities can influence the scoring process and affect the final decision outcome.

This is especially a challenge in early product development which is characterized by uncertainty, which further implies that norms have not yet been set and stakeholders may not agree on priorities. Therefore, early weighting can be problematic due to limited knowledge (Svanström & Peters, 2013). Another challenge lays with how the results are interpreted since they can be relative, not always absolute. This means that different users can interpret the same result differently (Brunklaus et al., 2009).

2.3.2 Pugh Matrix

Pugh (1991) developed the Pugh Matrix which is a well-established comparative concept selection tool that is a MCDA approach (Cinelli et al., 2014). The method uses a reference concept, against which newly generated concepts are compared and attempt to “outperform”. The evaluation relies on a set of criteria, which may vary depending on the context in which the tool is applied. These criteria may be both qualitative and quantitative, making the Pugh matrix very flexible and adaptable which means it can be set in many environments.

The outcome of the evaluation is based on a scoring method where concepts are rated as much better, better, the same, worse or much worse which corresponds to scores of 2, 1, 0, -1 or -2. Because knowledge is often limited in early development phases, this relative scoring system is highly beneficial (Svanström & Peters, 2013).

Comparison rules can be easily established within the tool, which makes it a good fit for cross-functional teams where normally each team have their own “language”. This transparent and shared structuring is what Baumann and Cowell (1999) implies with conceptual tools such as the Pugh matrix.

Pugh (1991) explicitly designed the tool to be used in the concept design phase, which supports generation, screening and selection. This leads to it being a good fit for Coopers (1990) stage-gate process, as the matrix helps developments move forward with structured decision making through discussion and comparison.

The limitations and challenges of the Pugh matrix are the same associated with MCDA methods mentioned earlier. An additional challenge that can be added to what has not been previously mentioned is that the criteria that can be used with environmental orientation can often be quite complex, and using this tool might oversimplify the treatment of such criteria (Baumann & Cowell, 1999).

2.4 Environmental tools in product development

This section describes environmental tools and their role in product development. It focuses on how they support decision-making and that they do not work on their own.

2.4.1 Environmental tools as decision-support in early product development

Remmen et al. (2007) wrote in the UNEP Life Cycle Management guide that environmental tools should be integrated into business decisions and used proactively, not merely reporting environmental performance. Baumann and Cowell (1999) draw a clear distinction between analytical and conceptual environmental management tools. The distinction lays in what kind of work they do, which is either to calculate environmental impacts or structures thinking and decision-making. They further argue that these tools do not act on their own, which can be interpreted as that their impact relies on how they are interpreted, perceived and further integrated into everyday work.

It is important to use environmental tools in early product development since the phase is characterized by high uncertainty. This means that there are a high number of concept alternatives that further enables a large design freedom (Cooper, 1990). When used correctly, the environmental tools aim to make trade-offs between environmental and non-environmental clear (Cinelli et al., 2014). When these trade-offs are visible, the tool would ideally support comparison between concepts with more informed decision-making.

2.4.2 Life Cycle Management

The environment in which the tools exist must be organized and routinized. Nilsson-Lindén et al. (2015) demonstrate this clearly in their study of a multinational manufacturing corporation as even though competence and tools are available, the teams working in development still struggle to incorporate this because it is not organizationally embedded. They also show that environmental work often exists, but in parallel processes or is initiated too late, when the design decisions are already locked in. Such late use may simply be due to justification or more symbolically rather than in the use of guidance. The underlying causes include a lack of ownership, partly due to unclear responsibilities and misalignment with established workflows.

2.4.3 Requirement driven development

Environmental development is often very requirement driven. This is partly because of the political goals and requirements that have been set up by the European Commission (n.d.). Failure Modes and Effects Analysis (FMEA) is fundamentally a requirement-driven method which assumes that functions and requirements are defined well enough to identify potential failure modes within the system (Kania et al., 2014). Therefore, understanding the requirements clearly is necessary before the analysis can be done. FMEAs focus on requirements and early problem prevention can help guide how early concept evaluation tools are structured.

Concept dashboards aim to structure and visualize key criteria and requirements in a way that supports comparison and continuous visibility (Few, 2006), which is inspired by the requirement-driven logic of FMEA. Rather than performing a more detailed analysis like the Pugh Matrix, dashboards organize and display overall environmental considerations together with other design requirements (Few, 2006).

2.5 Adoption and use: barriers and enablers

This section describes barriers and enablers for the use of environmental tools, with emphasis on why the tools are used or not used in practice.

2.5.1 Barriers to implementation of environmental tools

Rossi et al. (2016) identify several barriers related to the implementation of Life Cycle Assessment (LCA) and simplified LCA methods in industrial contexts. One of them is the need for specific knowledge. This includes knowledge of how to use the tool as well as environmental knowledge required to interpret results correctly. Related weaknesses to this are the need for training and prior experience in using the tool to interpret results. Economic resources are also described as a barrier, including the allocation of financial and personnel resources. In addition, large number of available tools may complicate the selection of an appropriate method.

A barrier related to a full LCA is the time effort required to conduct the analysis, due to the need to handle a high quantity of data along the entire product life cycle. A related weakness to that is the requirement for high quality data and access to supplier information for purchased components. Simplified LCA methods aim to reduce time and data requirements but are limited because the simplification can limit the results due to the not complete data. For checklists and guidelines, Rossi et al. (2016) identify staff experience as a barrier, as these require users to interpret general recommendations and translate them into concrete design actions.

2.5.2 Integration and prioritization of environmental aspects in product development

Poulikidou et al. (2014) study the integration of environmental aspects into product development in four vehicle manufacturing companies in Sweden. The study shows that early consideration and integration of environmental requirements is regarded as important in all companies but not always achieved. Even though product development processes are formalized, Design for Environment (DfE) is not always coordinated and integrated as a natural part of these processes.

The identified drivers for the selection of environmental aspects are regulations and standards, customer demands, company standards and values, market competition, and business opportunities/risks. Regulations are described as having a strong impact on design choices, as they introduce qualitative requirements that must be fulfilled. Poulikidou et al. (2014) also report that the involvement of design engineers in the use of DfE tools is generally low. In several cases, tools are developed and used by environmental specialists rather than systematically embedded withing product development groups. The study also suggests that DfE training, life cycle-based environment requirements, and systematic use of DfE tools were often lacking or insufficiently applied.

2.6 Change management

Change management is a structured approach to move from a current state to a desired future state. It focuses on supporting employees to adopt new processes, technologies or structures. In this study, it is used to understand the results and to support the development of change management recommendations. This section describes two common models used within change management: Kotter's 8-step model and ADKAR. The former is used towards organizational change, and the latter focuses more on individual change.

2.6.1 Kotter 8-step model

John Kotter (1996) introduced his eight steps for change, which are built on eight errors that usually take place during change initiatives. The first step is "establishing a sense of urgency", which is based on the error that many initiatives do not establish enough of it. This is something companies are good at overestimating, namely how much urgency has been created. This can be due to a lack of patience. It can also be due to those responsible having too many managers around them and no leaders, which leads to them becoming paralyzed due to a lack of leadership and too much bureaucracy. Change initiatives require leaders who take the initiative, not merely managers who delegate responsibility at several levels. How this is performed practically is by spreading bad news, such as showing comparison metrics to competition or other vital metrics that show how bad the situation is and how urgent the change is.

The second step is to construct a guiding coalition group with enough power to initiate the change. It is generally necessary that the group comes from outside the current hierarchy, because obviously the current system did not work and it would not be as effective to use the current leaders. If the current system worked, there would be no need for change, and the current people could continue working, but when it does not work, new people are needed.

The third step includes creating a vision with a clear strategy on how to reach that vision. This goes hand in hand with the fourth step, which is to continuously communicate that vision through every channel that is connected and relevant to the initiative. A common error connected to these steps is not as bad as it sounds, since half of the job is done. The error is that the vision has been formulated in detail, but the group has only briefly mentioned it in one initial meeting, meaning they only mentioned it once in a single channel. Some transformations, especially in large organizations, are only feasible if many people are on board with the vision. This can only be accomplished if the vision is continuously communicated through many types of channels for a long time, ensuring that the idea has been hammered into people's heads.

When people have shown their interest, the fifth step begins, which is to empower those people to act on that vision. To achieve this, a clear path must be established, which is an error groups commonly encounter. Obstacles must be removed from the path between the current situation and the vision. These obstacles can exist in people's minds or within the system itself. Therefore, changes must be made to those obstacles that undermine the vision.

The sixth step is to set interim goals along the way for people to feel a sense of accomplishment. These short-term wins may be what’s needed to keep spirits and motivation up through a possibly quite long road. This leads to the seventh error, which is claiming victory in advance. The seventh step is therefore to continue building on the gains already achieved to enable continued results and gains. This can be done through promoting the vision even more, attracting more people who can help implement the vision, or further developing already ingrained people.
The last step involves embedding the change initiative into the foundation of the company. This can be done by explicitly stating the performance boost the change has made.

Figure 2. Phases of the 8-step model (Kotter, 2014)

Three larger phases can be constructed from the 8 steps (Kotter, 2014). The phases are “Creating the climate for change”, “Engaging and enabling the organization” and “Implementing and sustaining for change”. Within the first phase step 1-3 belongs, 4-6 for the second phase and 7-8 for the last phase. See figure 2 for the grouping.

2.6.2 ADKAR

Jeff Hiatt has been widely praised for his ADKAR model within change management, which focuses specifically on how to change people in groups, rather than how to change the technical aspects and larger organizational change (Prosci, 2021). Through his company Prosci change management group, they have helped many companies with new initiatives and implementations. The model consists of five elements, where the first letter of each element together forms the name ADKAR: Awareness, Desire, Knowledge, Ability and Reinforcement.

Dziak (2026) explains the elements and means that it will lead to individuals getting on board with the change, ultimately getting away from resistance that makes individuals go back to previous routines and behaviors. The model will also give individuals confidence and understanding that the grass is greener on the other side.

The first element, and first step of the model, is awareness which is built by leaders who conduct honest two-way communication about what is going to change, why, in what way and the effects of it. This is followed by the second step, which is to build desire by presenting the individual and organizational benefits of the change. Fears are redirected by comforting the people with how everything is thoughtfully planned and set up for success. Change often involves new technologies, which makes the third step extra important, knowledge. This step includes building knowledge through e.g. training, so that the individuals receive the knowledge necessary to successfully change. This is highly connected to the fourth step, ability, which also includes training, but what is different is mainly that this step is more hands-on (Dziak, 2026).

The fifth and final step is reinforcement, which really is the aftermath of the change. In this step the leaders ensure that the change is kept and that individuals do not go back to old habits. During this time feedback on the change should be welcomed to see how the change has been from different perspectives (Dziak, 2026). If the feedback turns out to be unwanted, it may require them to revisit and redo certain steps to ensure the change takes hold. If the change doesn't stick the first time, it can be necessary to work through the steps again.

2.7 Summary of the state of knowledge

To summarize what we know today, the literature shows that early product development is the phase that has the greatest potential to influence environmental outcomes, but the difficulty with this phase is the lack of data, characterized by uncertainty and competition with other criteria. The literature emphasizes the importance and potential of the tools, but it also emphasizes that the tools are underused and underintegrated in practice. It also appears that the tools are used for documentation rather than decision-making, due to their late usage. Barriers and enablers have been identified regarding implementation, but despite these, it is unclear what the perception and actual use of these tools looks like in early product development. This gap motivates this study.

3. Methodology

This chapter describes how the study was structured and conducted. It includes the research design, case study, data collection and data analysis, showing how the data has been collected and analyzed. A case description is also included to explain the context of the study and what is being examined.

3.1 Research design

This study was conducted as an exploratory, embedded single-case study (Yin, 2018). According to Yin (2018), case study research is appropriate when investigating a contemporary phenomenon within its real-life context. This aligns with the aim of examining how an environmental tool is perceived and used in concept development. Exploratory research designs are common in organizational research when the aim is to gain understanding of a phenomenon that is not yet well defined and is guided by research questions rather than hypotheses (Bell et al., 2022).

A mixed-methods approach was used in this study, structured in several phases to address the research questions. Figure 3 provides a visual overview of the research design and its phases. In the first phase, observations and training sessions were conducted within the case company to gain a thorough yet sufficient understanding of their ways of working. Specifically, the product development process and the Sustainability Criteria Evaluation Matrix (SCEM), a matrix-based environmental decision-support tool, were examined (see Section 3.2.4 for further details). The observational data included workshops in which these tools were reviewed together with the supervisor and other professionals in the department. Unstructured interviews were also conducted during observation sessions to further develop an understanding of the case and clarify the intended use of the tool.

After the first phase, a survey was created to capture patterns related to perception and actual use among design engineers and relevant stakeholders. The survey primarily supported RQ1 and RQ2 by examining perception and actual use of the tool in concept development. The final phase consisted of semi-structured interviews, conducted to obtain deeper insights into issues that remained unclear after the previous phases. The interviews enabled exploration of barriers, enablers and other influencing factors, contributing mainly to RQ3 and RQ4. Observations helped build a contextual understanding and supported gap analysis of intended versus actual use of the tool. The data were analyzed using thematic analysis with a focus on identifying patterns across groups. Comparative analysis and the Gioia methodology were used to enable triangulation. Based on what was identified, the recommendations were developed by linking the findings with change management theory. More practical recommendations were developed during workshops together with the Platform sustainability team.

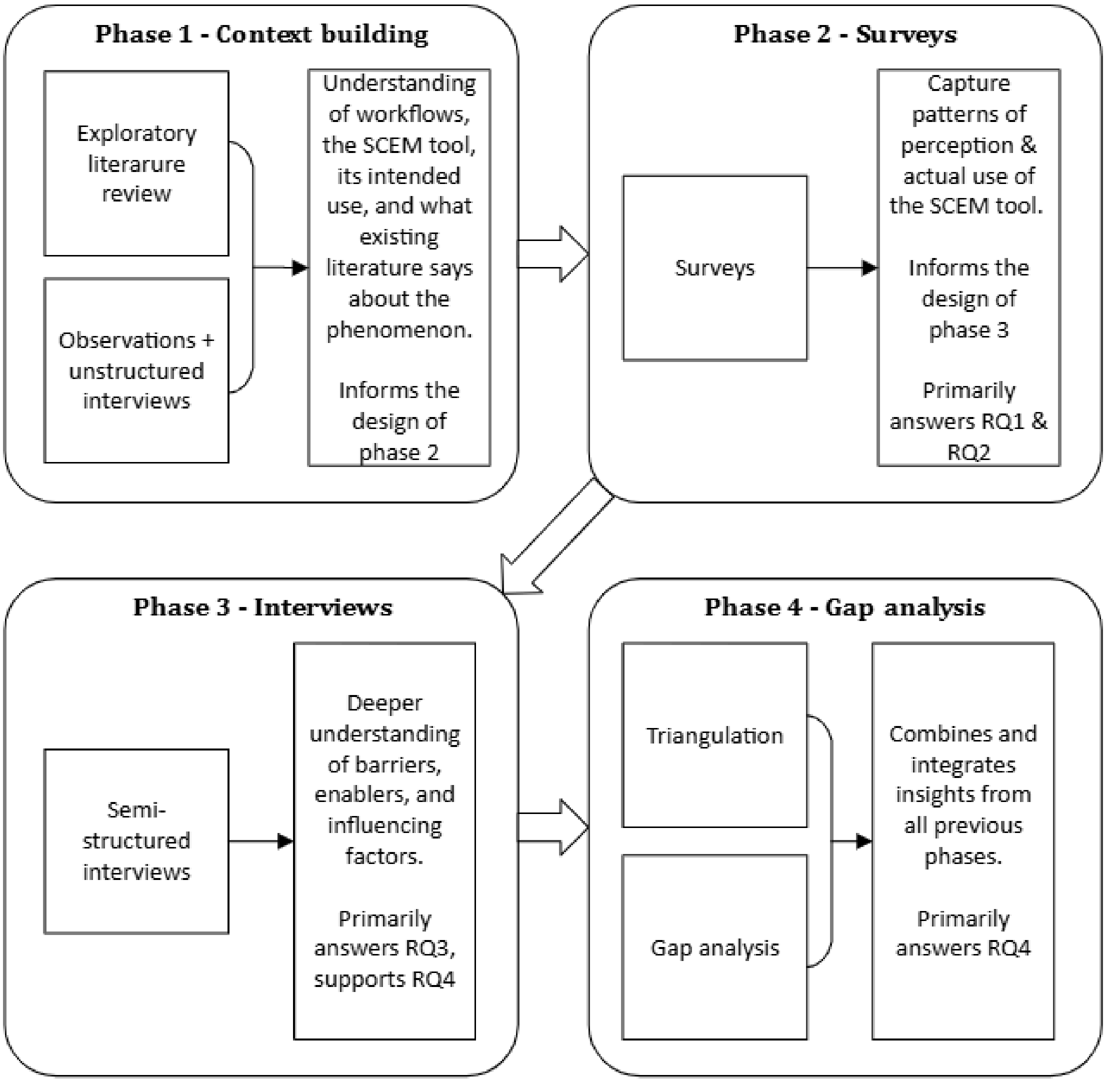


Figure 3. Research Design Phases

3.1.1 Literature review

A narrative literature review was conducted to support this study by developing understanding and enabling triangulation. According to Bell et al. (2022), narrative literature reviews are suitable for exploratory research when the aim is to develop understanding, and the boundaries are not clearly defined from the start. Since this study is exploratory and focuses on understanding rather than testing theory, a systematic literature review was not considered appropriate (Bell et al., 2022).

The literature review included both methodological literature and literature used to establish the theoretical background. Methodological literature related to qualitative research, surveys, and interviews were reviewed to support the design of data collection. This literature also supported considerations related to reliability, validity and replicability (Bell et al., 2022). In addition, literature related to sustainability tools, product development processes, and environmental management was reviewed to develop understanding around the studied phenomenon. The intended use of the studied tool was derived from the case company, while the literature supported the analytical framework for interpreting the empirical findings. This made it possible to do a gap analysis and compare intended and actual use of the environmental tool.

The literature for this study was mainly sourced from online databases, with Google Scholar being the primary search platform. Searches were done by using keywords related to eco-design tools, such as "eco-design tools", "integration of environmental tools in product development", "barriers to eco-design implementation" and "change management". The search words were adjusted and redefined throughout the process as the study developed. In addition to database searches, relevant literature was identified through recommendations from the academic supervisor. Snowballing was also performed to identify potentially relevant studies.

3.2 Case description

Volvo Group is a Swedish multinational corporation founded in 1927 with headquarters in Gothenburg. The company operates globally and is a leading manufacturer of trucks, buses, construction equipment and marine and industrial engines, while also offering financing and service solutions. Committed to shaping the future of sustainable transport and infrastructure, Volvo Group has over 100,000 employees across production facilities in 18 countries and selling its diverse range of products in more than 190 markets under various brands.

3.2.1 TTI

Volvo Group Trucks Technology & Industry Division (TTI) is, within Volvo Group, the central organization responsible for truck product development, R&D, product planning, purchasing and range management across the brands Volvo Trucks, Mack and Renault Trucks. TTI drives innovation in areas such as electric vehicles, aiming for zero-emission transport and focuses on developing and delivering advanced, reliable and safe truck technology to its global customers, with a strong emphasis on sustainability and connectivity solutions.

3.2.2 Roles and Responsibilities

In this study, engineers and leaders are mentioned several times, as these are the ones we have encountered and are the ones that are utilizing the environmental tool. It is important that you as a reader understand what is meant by these roles to understand the context. Engineers are the ones who work most hands-on with tools during the concept development phase. Engineers in this case is used as a collective name for the many different types of engineers who are involved and participate. Examples of more precise job titles could be Design Engineer, Mechanical Engineer and Electrical Engineer. Engineers can have multiple responsibilities whereas many are also component owners.

The leaders mentioned in the study are those who control the projects, i.e. project managers and group managers. They are the ones who control the big picture parts of the project and usually have a couple of engineers with them on their teams, to whom they delegate tasks and inform about what goals exist. The leaders usually do not perform tasks, such as the usage of environmental tools themselves. Leaders can also be product owners, which role is to drive product development over the entire product life cycle and has its origin from the agile terminology (Cooper & Sommer, 2016).

Mostly engineers, along with a few leaders, have been appointed the role of SCEM key user, which has been distributed throughout the organization to make sure that knowledgeable people are close to whoever is operating a SCEM. People are supposed to ask the key users when they need assistance along the way when working with the SCEM. The key users have received particular training so that they have what it takes to help others, and to understand the tool itself. Even more specialized people within the area of sustainability are Sustainability Leaders. These are people assigned to manage the sustainability aspect of a project.

3.2.3 DVP

The backbone of Volvos product development process is called the Develop Product and Aftermarket Product Portfolio (DVP). It explains and outlines how to move forward with product evolutions in a structured flow. It functions as a cross-functional framework that aligns requirements, platforms, strategies and other ways of working. This ensures that foundations such as customer focus, product ownership, sustainability, safety, quality, legal compliance and fast time-to-market are managed consistently across the whole organization. Such a structure is particularly emphasized for large organizations to ensure consistency across projects (Cooper et al., 2002) and the overall structure of the DVP supports risk management and decision making in product development (Cooper, 1990).

DVP combines a stage-gate process, or phase-gate as Volvo calls it, with agile development. This combined hybrid agile/stage-gate approach allows them to benefit from the best features of both worlds, whereas the overall structure and stability of the stage-gate is used to receive clarity and predictability. Zooming inside the stages on the other hand, agile-style development is carried out in cycles which embrace flexibility, speed and adaptability. Thus, the day-to-day work is performed via the agile method, but the overall big-picture structure is more stage-gate. This aligns closely with how literature describes hybrid approaches (Cooper & Sommer, 2016, 2018; Walrave et al., 2022).

The DVP consists of several phases, which may vary in length depending on the scope, size and impact of the project. All development projects go through these phases, but their focus may vary depending on what is required. Governance and synchronization occur at gates, like the typical stage-gate system (Cooper, 1990). This study will focus on the concept development phase within the DVP, which is located after the feasibility study phase and before the solution development phase. The concept development phase is characterized by first and foremost developing alternative concepts, closing knowledge gaps and finally selecting the best option to meet stakeholder- and customer needs.

3.2.4 SCEM

The Sustainability Criteria Evaluation Matrix (SCEM) is an internal decision support tool designed to introduce environmental considerations at an early stage of concept development and is the tool that study focuses on. Its overall purpose is to ensure that key sustainability aspects are evaluated consistently across projects and that new design solutions contribute to the company's long term environmental targets. Its intended role is to provide a structured framework for comparing design alternatives from an environmental perspective. The SCEM is a collection of multiple interconnected tools, but for the simplicity of the study we refer to it as one tool. This is also why the term "environmental tools" have been used for the study.

The SCEM is intended to be applied from the earliest stages of the development cycle, beginning as soon as a reference concept is established. The SCEM should be updated iteratively and revisited before decision gates. This use inside the stage-gate system ensures that sustainability aspects are not considered only at the end of development but are integrated into the evolving design work, which is very similar to what is encouraged in a typical hybrid agile/stage-gate system (Cooper &Sommer, 2016).

The tool supports engineers by enabling them to systematically evaluate how new solutions perform relative to the existing reference-solution. The outputs are utilized in Volvo's broader concept evaluation framework, the concept dashboard. This enables engineers to compare environmental aspects to other criteria, as sustainability decisions are always made in relation to other factors like cost and quality. This comparative logic aligns closely with MCDA, where the sustainability criteria is not optimized in isolation (Cinelli et al., 2014). The usage of a reference-solution is inspired by the Pugh Matrix (Pugh, 1991). More inspiration that came from this are the weighted scores, which indicate the importance of each criteria and can vary depending on the project.

In practical terms, the SCEM is an Excel based matrix, heavily inspired by the Pugh matrix, where the responsible engineer reviews a set of criteria. The Criteria on which the SCEM is built are:

- CO_2 Cradle to gate
- Substances of Concern (SOC) status
- Recycled content
- Recyclability and recoverability
- Design for circularity

The SCEM uses requirement-driven development whereas these criteria include both must-meet and should-meet requirements, which is commonly used in early product development (Rossi et al., 2016). Any solution that fails to meet legal requirements, such as certain Substances Of Concern (SOC), is removed from consideration.

The SCEM does not cover the full life cycle of a product. Its scope is limited to the cradle to gate phase which includes only the point of extraction of the raw materials to when the product leaves the factory. In addition to internal tools that must be used to fill out the SCEM, CO_2 data can also be sourced directly from suppliers. A completed SCEM is the basis for informed decision making with the goal of improving environmental performance of a design compared to the reference project. A total score indicates which solution is best compared to the reference.

The intent is that each new design generation should contribute to incremental environmental improvements while supporting the broader balancing of functionality, cost, manufacturability and sustainability.

Further connecting SCEM to theory, it is obvious that it belongs in the conceptual environmental tools compartment (Baumann & Cowell, 1999). This is because it relies on separate analytical tools to retrieve specific data while structuring comparison and supports discussion. It also fits into this category because it depends on one's own interpretation, which is similar to the MCDA and Pugh Matrix.

3.3 Data collection

Data were collected sequentially through observations, surveys and semi-structured interviews, with the purpose of building understanding step by step and allowing each phase to inform the next.

3.3.1 Observations and unstructured interviews

This study was structured around understanding how concept development processes were carried out in practice. This is aligned with the aim of comparing the environmental tool's intended use with its actual use. To build this understanding, insights into both the product development process and the tool itself were needed. Observations were conducted within the case company as an initial phase for the researchers to get familiar. The researchers were present on site to establish themselves within the organization to observe and attend activities, including selected meetings and internal learning sessions to gain insight into the tool as well as the product development process. In addition, internal documents related to the tool were reviewed to understand its intended purpose, structure and historical developments. The training sessions that were conducted were the ones that Volvos engineers and leaders themselves take when they need more knowledge. The training courses taken covered DVP, SCEM, overall organizational and product specific knowledge together with sessions about engineering culture. Being physically present was essential, which motivated the use of participant observation (Yin, 2018), inspired by Gemba-style practices with the principle of being situated where the work is done (Liker, 2021).

Data collection in case studies is guided by research questions rather than strict protocols (Yin, 2018). Therefore, unstructured conversations were conducted with individuals responsible for the development and management of the tool to clarify the purpose of the tool. Unstructured interviews were also conducted to deepen the understanding of the processes. Field notes were taken continuously throughout the phase and were later thematically analyzed to identify patterns and themes, which developed understanding. The combination of multiple data sources, observations, field notes and interviews, contributed to data triangulation, which strengthens the credibility of insights in complex organizational settings (Eisenhardt, 1989).

3.3.2 Surveys

Surveys were used in this study to capture patterns related to the perception and use of the SCEM. Two separate surveys were developed, the first survey targeted engineers who were expected to have experience using the SCEM. The second survey targeted leaders who did not necessarily use the SCEM themselves but sponsored projects in which it was applied. The engineer-survey formed the basis for the leader-survey, with the questions being adapted to fit the leaders' perspective. The surveys were used as both a qualitative and quantitative data collection tool.

Both surveys were administered digitally via Microsoft Forms. The survey for engineers was distributed to 206 people, while the survey for leaders was distributed to 102 people. The recipients belonged to different commodities/divisions and were located at various sites across the world. More specifically the sites that were included was Gothenburg Sweden, Lyon France, Greensboro USA, Bangalore India and Curitiba Brazil. A total of 14 pilot surveys were conducted for both survey versions (12 engineers and 2 leaders) prior to distribution to test clarity, interpretation and the time required to complete them. A 30-minute session was booked per pilot, which took place online via teams and was filled by the responded first performing the questionnaire in his/her own time. This was followed by an open dialogue where feedback was collected. Based on the pilot feedback, adjustments were made by clarifying unclear questions, adding additional answer alternatives and removing questions that were considered irrelevant or difficult for respondents to answer. Both the pilot versions and the revised surveys used in the study are included in the appendix. The recorded completion time showed that they were completed within 5-10 minutes. The feedback that was received during the pilot testing was gathered without reacting to respondents' answers in a way that could signal judgement. This was intended to minimize perceived evaluation and support validity and reliability.

Sampling, question formulation and administration were designed with regards to Fowler's (2014) Total Survey Design (TSD) method, which states that the quality of the survey data can be no better than the weakest element of the survey design. Consequently, considerable attention was given to ensuring a sufficient sampling frame and formulating clear and non-leading questions. In addition, the surveys were administered in a way that minimized risks such as non-response bias and misinterpretation. All factors were purposefully aligned to ensure validity and reliability.

Bias and representativeness were considered. The aim was to include participants who interacted with or were responsible for the SCEM in comparable ways. However, including only similar groups could lead to shared biases. In both surveys the questions required both objective and subjective responses, which meant that some degree of bias in the data was likely. What is important is that the researchers remain aware of the potential direction of this bias and strive to be as objective as possible when analyzing the data to ensure validity and reliability.

Non-response bias was an additional concern. Individuals who worked continuously with SCEM or perceived it positively were expected to respond at higher rates than those with negative perceptions of the tool. Minimizing non-response bias was therefore important, as excluding more critical perspectives could distort the findings (Fowler 2014).

The questions were written in a way that aimed to ensure consistent interpretation among respondents. Fowler (2014) states that even with well-educated respondents, clear and simple wording is key to effective questionnaire design. No double-edged or ambiguous wording was included to avoid misinterpretations. The survey consisted of a combination of Likert-scale, multiple-choice and open-ended questions. This allowed the survey to capture both structured, comparable responses and more elaborate answers. This approach also supports the study's mixed-methods design, where data from the survey informed the subsequent interview phase.

To reduce social desirability bias (Fowler, 2014), confidentiality was ensured. Although identities and individual responses were visible to the survey administrators for administrative purposes, all analyses were conducted on anonymized data. Names and personal identifiers were not linked to the analytical dataset or reported results. A self-administered survey format was used to limit potential pressure associated with researcher presence.

The surveys were administered according to Dillman's Tailored Design (TDM) (Dillman et al., 2014) to maximize response rates. This included creating a positive perception on the surveys, reducing perceived participation costs and building trust. Respondents were informed about the purpose of the study, survey length and confidentiality. Trust was supported by transparent communication regarding roles and data handling. The contact strategy consisted of an invitation email containing information about the study and the survey together with the survey link. Reminder messages were sent to individuals who had not yet responded, which was the only administrative purpose for which identifiable information was used. Respondents' busy schedules were also considered, and the surveys were therefore designed to take 5-10 minutes to complete, which also supported the aim of maximizing response rates. The initial invitation was sent on a Thursday. The first reminder followed on Tuesday and was reinforced with another reminder on Thursday. To conclude the process, a final reminder was sent on the last day, which was Monday.

86 out of the 206 engineers answered the survey which resulted in a 42% answering rate, which of four engineers responded with explanations that they had nothing to do with the SCEM and therefore will not answer. 37 out of the 102

leaders answered the survey which resulted in a response rate of 36%. The combined response rate ended up being 40%.

3.3.3 Semi-structured Interviews

The interviews were conducted to gain an in-depth understanding of how environmental tools are used during concept development, as well as to explore factors influencing application. Semi-structured interviews were conducted, as this allows for a combination of structure and flexibility as well as focusing on the interviewee's own perspectives. In qualitative research, semi-structured interviews are common as their aim is to explore experiences, perceptions, and practices in depth. They also enable follow-up questions and allow relevant themes to emerge during the interview process (Bell et al., 2022). The interviews built on the survey findings, allowing participants to elaborate on their perception and experience of using the tool. This allowed exploration of barriers, enablers and other aspects influencing the use of the tool.

An interview guide was developed to help structure the interviews and ensure alignment with the research questions. The guide was based on literature on qualitative research interviewing that emphasizes the importance of clear purpose, structure, and thorough preparation. The interview questions were formulated to be relevant to the interviewees' professional context and designed to allow the participants to express themselves in their everyday language (Kvale & Brinkmann, 2015). The interview guide primarily consisted of open-ended questions, which enabled the participants to elaborate on their experiences and allowed the interviewers to ask follow-up questions when relevant (Bell et al., 2022).

When designing the interview questions, attention was paid to avoid leading or directive formulations. In qualitative research, leading questions may influence responses and reduce opportunities for reflection, which can negatively affect the quality of the data (Kvale & Brinkmann, 2015). The interview guide therefore focused on neutral and open-ended questions that encouraged reflective and experience-based responses. These formulations were intended to support participants in describing their experiences without being steered toward predefined answers.

Closed questions such as yes/no questions were generally avoided as they tend to limit depth and reflection in exploratory qualitative interviews (Kvale & Brinkmann, 2015). However, such questions were used for clarification, verification and as transition to open-ended follow-up questions. This approach aligns with recommendations for semi-structured qualitative interviewing, where closed questions may serve supportive function but should not dominate the interview (Bell et al., 2022).

One of the first questions of the interview was a situational question, asking participants to recall an experience related to the studied phenomenon. According to Kvale and Brinkmann (2015), beginning with situation-based questions can facilitate spontaneous and rich descriptions. This also allowed the interviewer to reflect on the response and ask follow-up or critical questions, to encourage the interviewee to elaborate and reflect on the situation.

Five pilot interviews were conducted before the main interviews to test and refine the interview guide. The focus was on the overall structure, how the questions were interpreted and whether the interviews could be completed within 30 minutes. Four out of the five pilot interviews were conducted face to face while the fifth was conducted online via Microsoft Teams. Since the online interview made transcription easier, the main interviews were conducted online as well. Pilot interviews are recommended in qualitative research to evaluate how the interview questions are interpreted, check the flow and duration of the interview as well as identify potential improvements in question formulation. It can also help the interviewers practice analyzing the interview data to help create the real interview outline (Kvale & Brinkmann, 2015). The data collected during the pilot interviews were considered relevant to the research questions and were therefore included in the analysis.

For the main interviews, a controlled sampling approach was used to ensure coverage across different sites, divisions and roles. Invitations were sent out to individuals in the same contact list that was used for the survey. This includes engineers who presumably have been in contact with the SCEM and leaders who presumably have sponsored projects where the SCEM has been used. Interview invitations were not based on whether individuals had responded to the survey and no consideration was given to their actual survey responses. The goal of the selection was to be as randomized as possible while still achieving variation across different geographical sites, organizational divisions and roles in terms of engineers and leaders.

All the main interviews were conducted individually and held online via Microsoft Teams. Each interview lasted around 30 minutes. The interviews were audio-recorded with participant consent and transcribed using Microsoft Teams own transcription function. The interviewers also took notes during the interviews which were later compared with the transcribed material to ensure accuracy. Interviews conducted in Swedish were translated into English using AI-based translation tools. 28 main interviews were conducted whereof 20 were engineers and eight were leaders. This results in a total of 33 interviews including the pilot interviews that were analyzed in this study.

3.4 Data analysis

The collected data has been analyzed based on the survey results, interview data and observations. The different data sources have been analyzed separately and the connected to give a combined understanding of the findings.

3.4.1 Survey analysis

The surveys were conducted in Microsoft Forms which automatically generated tables and graphs based on the responses. These outputs were reviewed to get an initial overview of patterns related to perception and use of the tool. To enable more detailed analysis, the survey data was also exported to Microsoft Excel where additional tables and graphs were created. These graphs compare responses across different background variables such as division and experience of the SCEM. The analysis focused on identifying patterns across groups rather than individual responses, the patterns were then used to highlight areas of interest to inform the interview guide.

3.4.2 Interview analysis

The interview data was analyzed using an approach named Gioia methodology. The method provides a structured way to move from raw interview data to themes and patterns, which builds qualitative rigor through a strong structure. It is done by developing first-order concepts, these are categorized into second-order themes, these are then categorized to aggregate dimensions (Gioia et al., 2013).

In this study, the interview transcripts and notes were reviewed iteratively to identify quotes and statements related to the research questions. The interviewers included time references in their notes to make it easier to locate the quotes in the transcriptions. Relevant expressions were then collected in a separate document. Since many expressions were repeated or similar, these were reduced to as few quotes as possible while still covering all relevant phenomena and topics. The remaining quotes functioned as raw data and were grouped into first-order concepts. The first order concepts were compared and combined into second-order themes. The final step was then to aggregate the themes into broader dimensions related to barriers and enabler of SCEM use. This helped create a data structure aligned with Gioia methodology, but further and additional analyses where made as well.

3.4.3 Triangulation

The data collected from observations, surveys and interviews were compared to strengthen the analysis. The purpose was to compare results from the different data sources and see how they relate to each other. For example, patterns identified in the survey were compared with the interview results to see if they were similar, explained in depth or even differed. Since the interview guide was based on the survey results, there were many similarities between them which could strengthen the validity of the data. Interviews allow for more in-depth discussion which also enabled patterns from the surveys to be clarified and understood better.

To reduce individual bias, the findings were discussed with the academic supervisor and the supervisor at the case company. A workshop with the sustainability team was also conducted where the results were presented and discussed. These discussions and the workshop provided additional perspectives and helped refine the interpretation of the data.

3.5 Validity and Reliability

According to Bell et al. (2022), validity concerns whether a study investigates what it intends to investigate, while reliability relates to the transparency och consistency of the research process. In this study, validity was strengthened through triangulation, combining observations, surveys and interviews. It also followed a sequential design, allowing findings from one phase to inform the next, which made it possible to explore emerging issues further rather than interpreting responses in isolation. Follow-up and clarifying questions were used during interviews to reduce the risk of misunderstanding, and pilot testing was performed for both surveys and interviews to improve clarity.

Reliability was strengthened by systematic documentation of all stages of the research process. Both researchers attended the interviews, which were audio-recorded and transcribed. The material was then discussed and analyzed to ensure similar interpretation by the researchers. If any differences in perceptions occurred, the interviewee was contacted for clarification.

3.6 Limitations

Explicit emphasis is placed on the use of the Sustainability Criteria Evaluation Matrix (SCEM) tool, which is Volvo Groups internally developed version of Pugh's evaluation matrix (Pugh, 1990). The study examines only the case company's (Volvo Group) internal situation and excludes external stakeholders, given that the research is conducted in partnership with the company.

4. Findings

This chapter presents the findings and analysis from the surveys and interviews. The survey results are interpreted to identify patterns in perception, use and awareness of the SCEM. The interview data is analyzed using Gioia inspired approach to identify barriers and enablers for the use of the tool.

4.1 Survey

The survey questions and results can be found in the appendix. The survey for engineers is included in Appendix A and the survey for leaders in Appendix B. Some selected graphs are shown in the text as well. For all Likert-scale questions, neutral (middle) responses were analyzed as neither left nor right. Additional detailed results are included in Appendix C.

Respondents showed varying levels of awareness and understanding of the SCEM. It is shown that engineers are aware and confident in both the purpose and usage of the SCEM (question 6 and 8), they also indicate that they receive support and are aware of the key user network (question 17 and 18). Leaders show far less understanding, as seen in question 6 and 7, as many are not aware of the purpose and required input data of the SCEM. Question 5 further shows that they consider themselves to have low experience with the tool. See comparison between the understanding of the purpose of the tool in the figures 4 and 5.

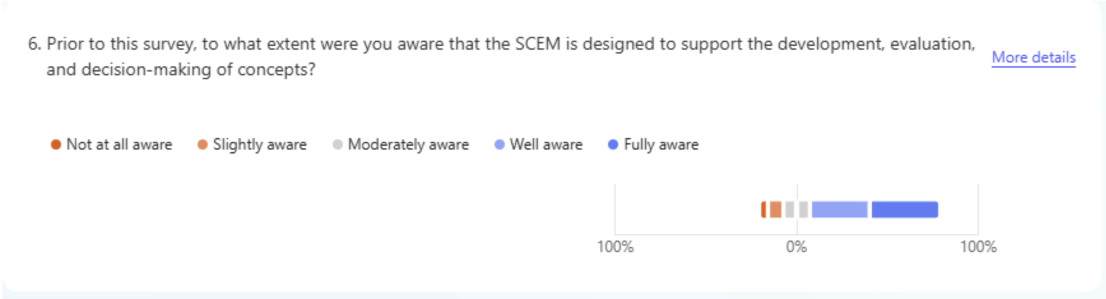


Figure 4. Engineers' understanding of the tools' purpose

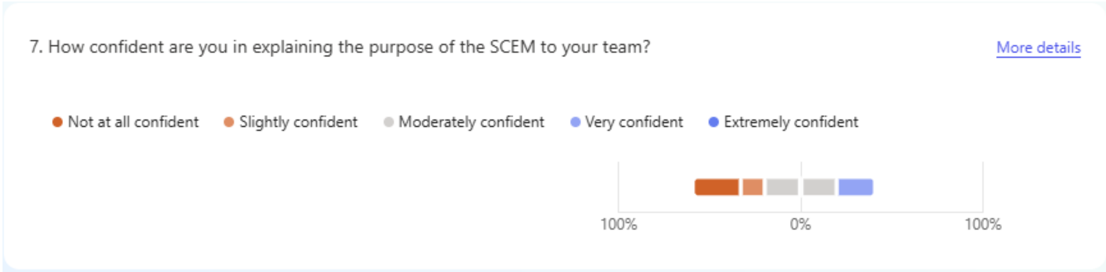


Figure 5. Leaders' understanding of the tools' purpose

In terms of how the SCEM is actually used in concept development, engineers answer that environmental performance is considered in early concept development (question 9). However, this contradicts findings showing that the SCEM is rarely used while concept alternatives are still being explored and compared (question 12)(see figure 6). This suggests that decisions have already been made by the time the SCEM is used. Question 11 further indicates that the SCEM is primarily used for documentation/reporting rather than decision support. Leaders seem to be aware of this, as shown in question 8, where they answer that the SCEM is rarely, or even never, used when still exploring and comparing concepts. The answers for question 10 indicate that leaders do not necessarily track or follow the SCEMs usage.

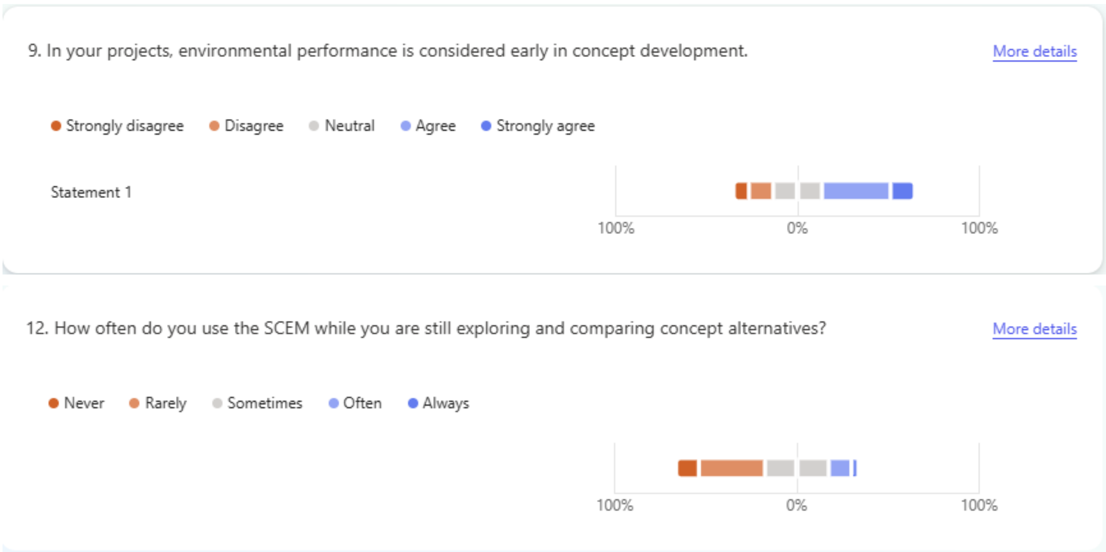


Figure 6. Comparison between Q9 and Q12 answers in the survey for engineers

The results from engineers' question 10 and leaders question 9 regarding when SCEM is first picked up generated the following results: Both groups agree on that it is picked up around “point 5” (see figure 7), which resembles the start of the “evaluating concept” phase. But what differentiates them is that the leaders are more optimistic and believe that it is used from “point 5” and earlier while the engineers think that it is used from “point 5” and onward. This indicates a difference between actual and intended use in the process.

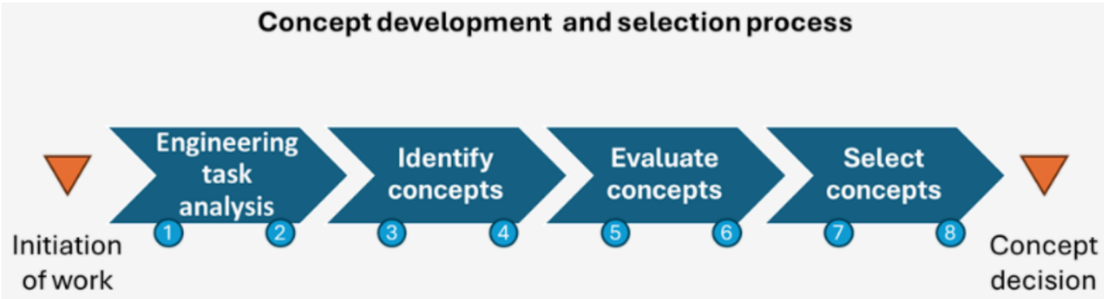


Figure 7. Concept development and selection process

Regarding the perceived value and impact of the SCEM, engineers are unsure of how the SCEM fits their way of working with comparison of concept alternatives in early product development (question 14), but presumably they believe that the purpose of the SCEM motivates them to use it (question 7). Leaders believe that the SCEM is valuable for improved decision-making in concept development (question 13). At the same time, they indicate that the results from the SCEM do not influence concept selection (question 14).

When it comes to time and effort, most engineers generally believe that the work required to perform the SCEM is reasonable in relation to the benefits, which show an acceptance of the workload required (question 13). The same question for the leaders indicates that they are more uncertain and give a vague result, although they are leading towards agreement (question 12).

When examining leaderships support for environmental tools, engineers are not fully convinced that leadership actively supports such tools (question 16). This aligns with and can be due to leaders’ own low confidence, experience and understanding of the SCEM (question 5, 6 and 7).

Looking at the results for the three largest barriers, both engineers and leaders agree on cost targets and data availability from suppliers (question 15 for both groups). Engineers additionally believe that time availability is among the three where leaders instead would add individual experience and confidence to the list. The final open-ended question for both engineers (question 19) and leaders (question 16) put further emphasis on these barriers. Both groups recommended that improvements in data accessibility through automation and collaboration between tools could help ease of use. This indicates that the use of the tool is not optimal today and that duplicate work is occurring, which reinforces and could be the source of the time barrier. Recommendations from both groups about strengthening training and awareness further build on the case that lacking experience and confidence are barriers between both groups. Engineers also recommend management alignment, which implies the lack of clear guidelines from management and strengthens that they are unsure about leadership support. Leaders on the other hand, forward this message via recommendations that higher management should clarify ownership. Leaders would also like to improve the visibility of sustainability benefits, which could incentivize the use of SCEM and strengthen both understanding and confidence in the tool by making its impact more explicit. The most common recommendation from both groups was about improving supplier collaboration, which has been confirmed many times as one of the largest barriers.

4.1.1. Detailed survey findings

This section presents selected findings from the additional comparative charts. All relevant survey questions were compared across different respondent groups, such as SCEM-experienced levels and divisions. Only the comparisons that show noticeable differences, or where differences were expected but did not appear, are included here.

The first chart in appendix C.1 shows the results for awareness level (question 6) grouped by how many SCEMs the respondents have completed. The Likert-scale shows that the group with six or more SCEMs is almost entirely in the "fully aware" category, with only a small share in "well aware". The awareness level decreases as the number of performed SCEMs goes down.

The second chart in appendix C.1 shows the results for confidence level (question 8) grouped by how many SCEMs the respondents have completed. The chart shows that the confidence level is highest among the most experienced respondents and decreases as the experience goes down. See figure 8.

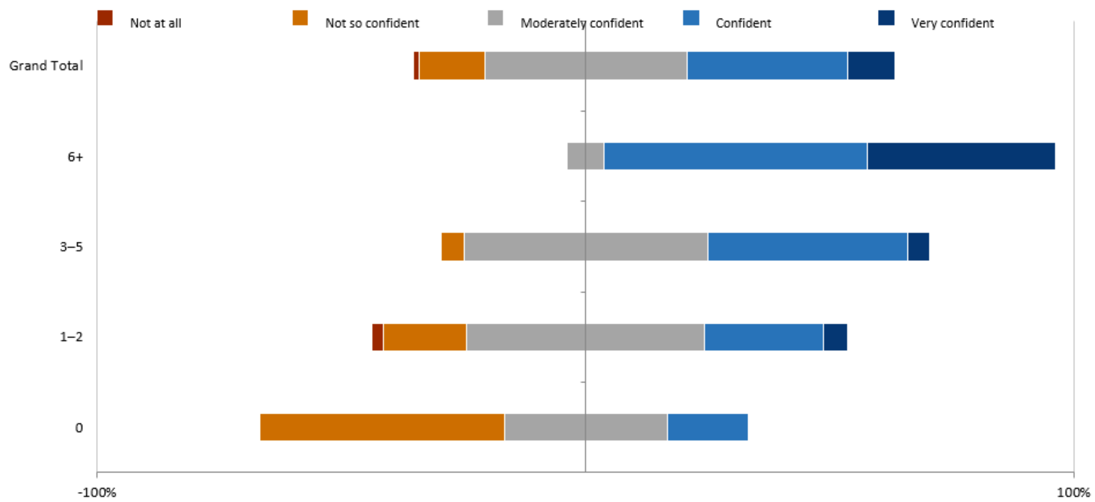


Figure 8. Relationship between the number of times engineers have used SCEM and their confidence in using the tool.

Another chart in Appendix C.1 shows the result for the time and effort required to use the SCEM, where all the respondents who have performed at least one SCEM have most of the answers on 'neutral' and 'agree'. However, the respondents that have not performed a SCEM have a perception that the required time and effort are high compared to those who have completed at least one.

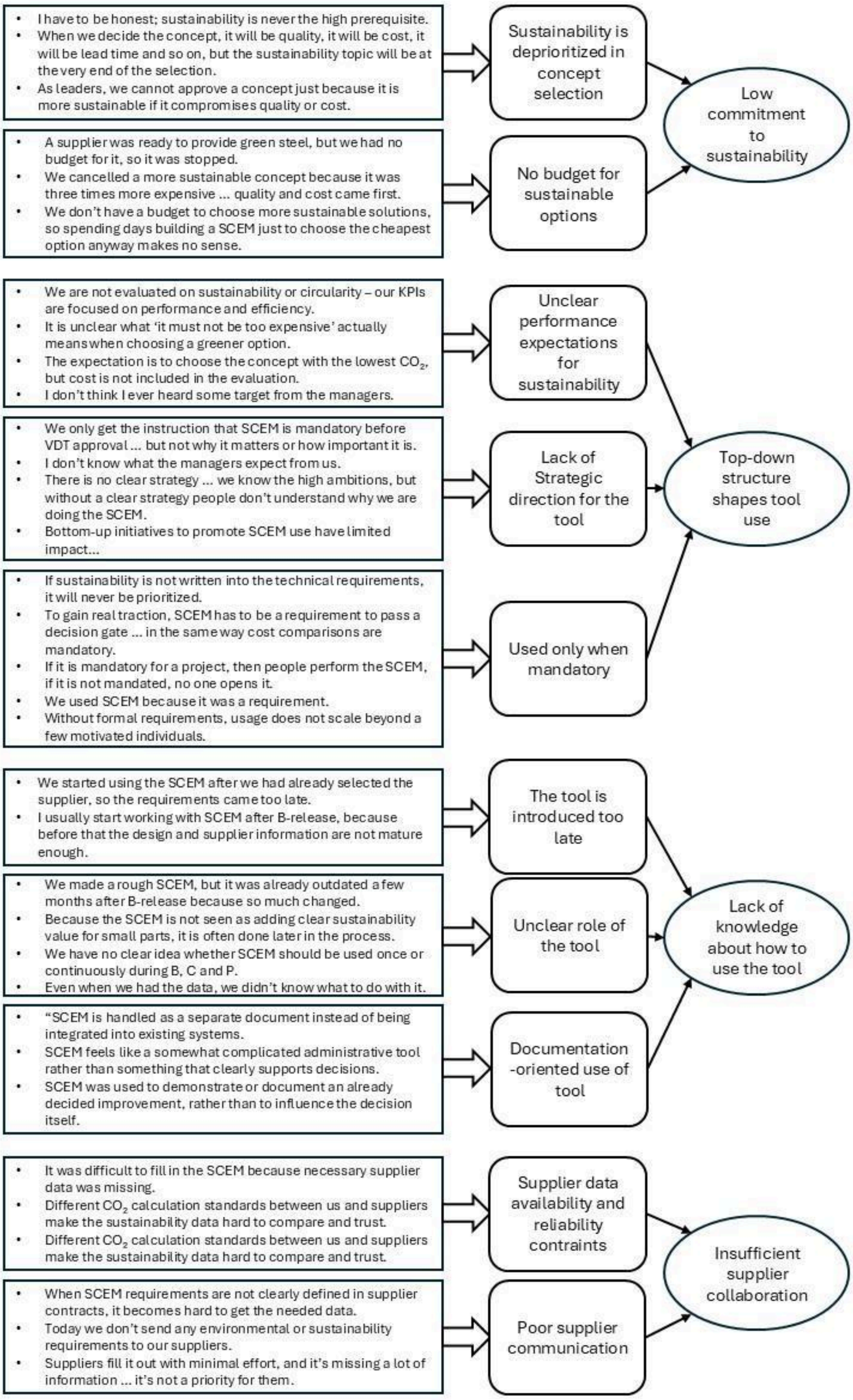
The next chart in appendix C.1 shows the results for question 16, grouped by how many SCEMs the respondents have completed. It asks to what extent respondents agree or disagree that environmental tools such as SCEM are actively supported by project leadership. The total distribution of answers shows that the 'agree' and the 'neither agree nor disagree' have the most answers, which is reflected in the bars for respondents who have completed at least one SCEM. Respondents who have not completed a SCEM deviate from the other groups, they generally disagree that SCEM is actively supported by project leadership.

Looking at appendix C.2, the charts show how the answers differ between respondents with different levels of engineering experience, measured in years of working in engineering roles. Charts 1, 2 and 3 (question 6, 7 & 8) show that the least experienced engineers (0-5 years of experience) are the most aware of the purpose of the SCEM tool, are the most motivated by the purpose of using it and are also the most confident in using it. Chart 4 (question 9) shows that engineers with 6+ years of experience agree that environmental performance is considered early in concept development, while the group with 0-5 years' experience disagrees on the same statement. This may indicate that more recently graduated engineers are more exposed to sustainability topics and therefore show higher awareness.

Appendix C.3, shows a comparison between the two biggest divisions in the question regarding when in the process the SCEM tool is first picked up. Although the answer alternative with most answers is 5 in both divisions, the distribution of the rest of the answers differs. For the Chassis division, the majority of the answers apart from the '5' answers is at '6' or higher, which means later in process. And for the Cab division it is the other way around, the majority of answers apart from the '5' answer is at '4' or lower, which means earlier in the process.

4.2 Interviews

This section presents the findings from the conducted interviews. The interview data has been analyzed using a Gioia inspired approach as described in the methodology section. In short, the analysis structures interview statements into themes and broader dimensions to show patterns and connections. The results from the Gioia analysis show that several barriers affect the use of the SCEM, but also some enablers to its usage were identified. The barriers are related to top-down organizational factors, tool-related barriers, data and supplier-related barriers as well as time and workload constraints. The enablers are mostly connected to the support from sustainability leaders, while allocated time and practical experience are other identified enablers. The following part presents these findings more in detail.



I have to be honest; sustainability is never the high prerequisite.
When we decide the concept, it will be quality, it will be cost, it will be lead time and so on, but the sustainability topic will be at the very end of the selection.
As leaders, we cannot approve a concept just because it is more sustainable if it compromises quality or cost.
Sustainability is deprioritized in concept selection
A supplier was ready to provide green steel, but we had no budget for it, so it was stopped.
We cancelled a more sustainable concept because it was three times more expensive ... quality and cost came first.
We don't have a budget to choose more sustainable solutions, so spending days building a SCEM just to choose the cheapest option anyway makes no sense.
No budget for sustainable options
Low commitment to sustainability
We are not evaluated on sustainability or circularity – our KPIs are focused on performance and efficiency.
It is unclear what 'it must not be too expensive' actually means when choosing a greener option.
The expectation is to choose the concept with the lowest CO_2, but cost is not included in the evaluation.
I don't think I ever heard some target from the managers.
Unclear performance expectations for sustainability
We only get the instruction that SCEM is mandatory before VDT approval ... but not why it matters or how important it is.
I don't know what the managers expect from us.
There is no clear strategy ... we know the high ambitions, but without a clear strategy people don't understand why we are doing the SCEM.
Bottom-up initiatives to promote SCEM use have limited impact...
Lack of Strategic direction for the tool
Top-down structure shapes tool use
If sustainability is not written into the technical requirements, it will never be prioritized.
To gain real traction, SCEM has to be a requirement to pass a decision gate ... in the same way cost comparisons are mandatory.
If it is mandatory for a project, then people perform the SCEM, if it is not mandated, no one opens it.
We used SCEM because it was a requirement.
Without formal requirements, usage does not scale beyond a few motivated individuals.
Used only when mandatory
We started using the SCEM after we had already selected the supplier, so the requirements came too late.
I usually start working with SCEM after B-release, because before that the design and supplier information are not mature enough.
The tool is introduced too late
We made a rough SCEM, but it was already outdated a few months after B-release because so much changed.
Because the SCEM is not seen as adding clear sustainability value for small parts, it is often done later in the process.
We have no clear idea whether SCEM should be used once or continuously during B, C and P.
Even when we had the data, we didn't know what to do with it.
Unclear role of the tool
Lack of knowledge about how to use the tool
"SCEM is handled as a separate document instead of being integrated into existing systems.
SCEM feels like a somewhat complicated administrative tool rather than something that clearly supports decisions.
SCEM was used to demonstrate or document an already decided improvement, rather than to influence the decision itself.
Documentation -oriented use of tool
It was difficult to fill in the SCEM because necessary supplier data was missing.
Different CO_2 calculation standards between us and suppliers make the sustainability data hard to compare and trust.
Different CO_2 calculation standards between us and suppliers make the sustainability data hard to compare and trust.
Supplier data availability and reliability contraints
When SCEM requirements are not clearly defined in supplier contracts, it becomes hard to get the needed data.
Today we don't send any environmental or sustainability requirements to our suppliers.
Suppliers fill it out with minimal effort, and it's missing a lot of information ... it's not a priority for them.
Poor supplier communication
Insufficient supplier collaboration

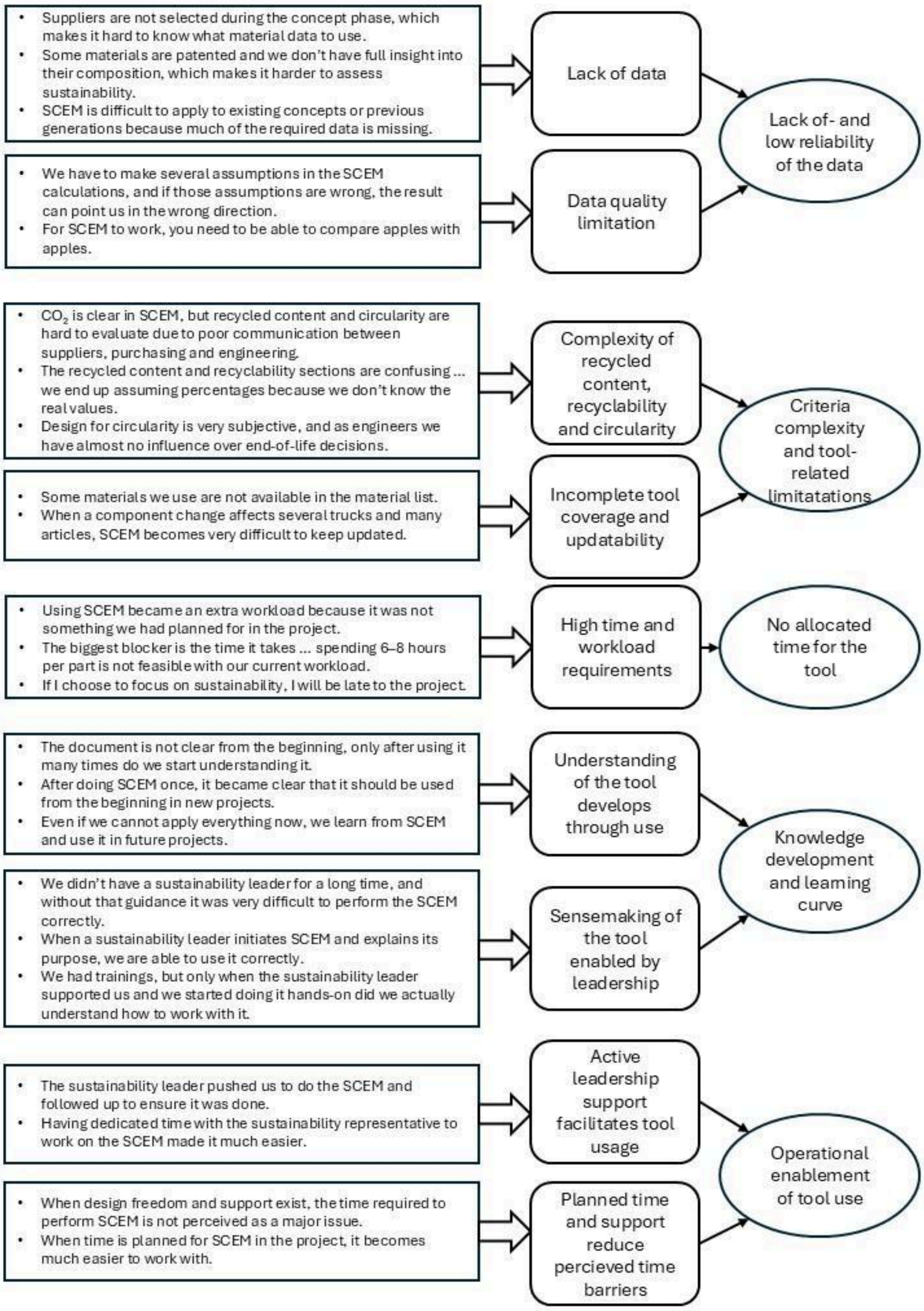


Figure 9. Gioia analysis

4.2.1 Barriers to tool use

Barriers to SCEM use have been identified from the interviews and structured in the Gioia figure. The barriers are categorized into four areas: Top-down organizational barriers, Tool-related barriers, Data and supplier-related barriers and Time and workload constraints.

4.2.1.1 Top-down organizational barriers

A central barrier is how sustainability and the SCEM tool are handled from a top-down perspective. Many of the interviewees described how sustainability is not prioritized in concept selection. Decisions are instead first and foremost cost and quality, but also durability and lead time are considered before sustainability. Even when more sustainable alternatives are identified, they are often rejected due to increased cost of the concept. This is closely linked to the budget constraints, where sustainability trade-offs are made when for example cost or quality is affected. Interviewees explained that there is often no budget for more sustainable solutions. As a result, investing time in environmental tools can feel unnecessary if the final decision is expected to favor the most cost-efficient option anyway.

The interviewees also described a lack of strategic direction related to the SCEM. While sustainability ambitions are high, there is no clear strategy for how the tool should be used, how the results should influence decisions or what success looks like in terms of KPI's. This relates to the unclear performance expectations described by several engineers. Without clear targets linked to the use of the SCEM and sustainability in general, it is difficult to understand how sustainability should be weighted relative to other requirements.

As a result, the use of the SCEM is shaped by formal requirements rather than strategic intent. According to the interviewees, the tool is used because it is part of a checklist, in other words a mandatory task to pass a decision gate. This is also one of the reasons the tool is picked up too late in the process and used more as documentation of already made decisions rather than to influence them. The documented SCEMs are then used to pass a gate in the concept development phase. Although some individuals claim to take their own initiatives, bottom-up initiatives alone were described as insufficient. If it is not explicitly required to use the SCEM, it is rarely used.

Several interviewees mentioned that the commitment and leadership communication have reduced compared to the first time they heard about the tool. Others mentioned that it has never been any talk or "hype" about it in their teams. The ones that have not heard about the tool have not been in presence of any sustainability leaders. This indicates that the introduction of the tool has taken place in various ways across the organization. The consistency in informing and keeping the relevance and preaching about the importance of the tool has shown to be low, which is not ideal in change management literature. Many engineers mentioned that they follow what leaders and management signals as important, which further shows the importance in informing and reminding people about what is important. Leaders themselves highlighted the importance of sustained top-down pressure. Some explicitly stated that their enthusiasm drops when sustainability out of nowhere disappears from weekly meetings and KPIs. Some leaders acknowledge that only providing the SCEM as a bottom-up adoption is unrealistic without mandates coming from above.

4.2.1.2 Time and workload constraints

A barrier related to the previous one is the barrier connected to time and workload. SCEM was frequently described by the interviewees as an additional task that is not planned in their projects. Performing the SCEM can require multiple hours per part, which is difficult to combine with an already high workload. Interviewees explained that prioritizing sustainability work can lead to delays in their projects, creating a direct trade-off between SCEM use and project delivery.

These constraints were particularly strong in contexts with limited resources and no clear sustainability leaders to support. The use of the tool was also described as constrained due to limited business benefits of sustainable solutions. This made it difficult to justify allocating time to the tool, resulting in SCEM being applied late, if even at all. The SCEM tool is a part of a checklist to be done before production-release, however the managers can still approve a concept without a performed SCEM if they regard it as unnecessary. As a result, sustainability work was described as something that competes with other priorities, and projects are planned according to business benefits which makes SCEM somewhat a secondary activity.

4.2.1.3 Tool-related barriers

Another barrier that emerged from the interviews is related to the tool itself and how it is integrated into everyday work. Several interviewees described that SCEM is not integrated into their existing systems like for example KOLA and is instead handled as a separate document. In practice this means that the tool is just filled in, saved, buried and never to resurface again. The view that SCEM is mainly used as a documentation task appeared frequently in the interviews, and several engineers asked for a more automated, living document that is easier to update and integrated with existing systems.

Tool coverage and updatability were also mentioned as limitations, for example some materials used in practice are not available in the material list. And when a component change affects several trucks, it is hard to keep the SCEM updated.
The results indicate that there is no real issue in the tool's capability itself. Among the criteria included in the SCEM, recyclability and circularity are the most complex and the most difficult to find reliable data for. This is largely due to the fact that for these criteria the users are very much dependent on the suppliers for correct and reliable information. The criteria can sometimes be quite subjective, which makes the data difficult to work with as well, especially since it is retrieved in collaboration with the supplier. The interviews have shown that for those who use the SCEM as its intended use, gets the most out of the tool and encounters few practical problems with the tool itself. However, these

challenges are more connected to knowledge about sustainability rather than barriers to using the tool itself.

However, usability limitations still affect adoption and perceived burden. As findings from the survey also hinted at, the fact that the SCEM is not automated and "talks" with other databases is a recurring issue that means that it takes an unnecessarily long time to retrieve and send data between tools.

4.2.1.4 Data and supplier-related barriers

Barriers related to data availability and data quality were also very prominent and most of them were connected to supplier involvement. A common theme among the interviews was the challenge of getting necessary data from suppliers. There were many dimensions to this problem, but to summarize, it was either availability, reliability or time related. In some cases, the supplier was not selected yet and therefore it is hard to gather data. In other cases, the supplier provided data, but different calculation methods were used which made the data unreliable and hard to compare with internal calculations. These differences in calculation standards make it hard to compare and evaluate suppliers and consequently, several assumptions are made, which lowers the trust in the result of the SCEM.

From the interviews it also became clear that there were unclear expectations sent towards suppliers from a sustainability point of view. Sustainability requirements are rarely specified in the Technical Requirements (TR) that are sent to the suppliers early on in the process. Without clear requirements, suppliers have little incentive to provide the detailed sustainability data needed to perform the SCEM.

Another issue that was brought up was the difficulty gathering data from previous concepts and solutions. That data is important to enable comparisons between the old and the new concepts and solutions to evaluate the sustainability aspects. Without that data, it is hard to evaluate the new concepts and interpret the results from the SCEM. Several interviewees had started applying SCEM to older concepts in order to create a baseline for comparison. This was described as really challenging and time-consuming, mostly due to the suppliers not having access to all the data nor the incentive to investigate old projects.

4.2.2 Enablers of tool use

Enablers that supported the use of SCEM in practice were also identified during the interviews. These were a lot fewer than the barrier but had a strong impact on the use and understanding of the tool.

4.2.2.1 Knowledge development and learning curve

Several interviewees described that understanding of SCEM developed through practical use. The tool is often first perceived as unclear, but repeated use helped engineers to better understand both its purpose and how it should be used to be effective. Interviewees that had completed the SCEM several times reported that it became easier to apply in projects. While repeated use may also increase awareness of materials and their environmental impact, the findings primarily point to increased understanding of the tool itself rather than environmental expertise.

In addition, sustainability leaders played a key role in supporting this learning process. When sustainability leaders were present and could explain its purpose as well as support performing the tool, the engineers felt more confident in applying the tool. Although all the engineers have access to training and e-learning, they were described as insufficient and the support from sustainability leaders was very important from a learning perspective.

4.2.2.2 Operational conditions of tool use

Another set of enablers relates to the more practical conditions for using SCEM. Yet again, sustainability leaders and their push for usage in terms of support, follow-up and general availability for questions was described as helpful. This support helped reduce uncertainty and worked as a springboard to start using SCEM in projects.

Planned time for SCEM is another enabler that was mentioned during the interviews. In projects where sustainability was a defined target and time was allocated for it, interviewees reported that SCEM was applied earlier and used better according to its purpose. This also highlights the barrier of prioritization and no allocated time for the SCEM. In cases with sustainability focus and allocated time, the tool was more likely to be used as intended, rather than being solely documentation.

Focusing on what distinguishes interviewees who use the SCEM in a way that aligns with its intended purpose the first thing that can be identified is that they have had presence of a sustainability leader who has supported them along the way. This support has been a collaborative type of support that has educated the engineers for upcoming projects. Many especially mentioned that they feel confident in performing their upcoming SCEM on their own, because of this previous help they have received.

This leadership support also influences how the tool is framed within the organization. It can be interpreted from the interviews that in the cases the leadership support exists, the usage of the tool has been talked about as mandatory and not otherwise. It is important that the feeling regarding the tool is that it should be a given thing that you should use it.

4.2.2.3 Ownership as an enabler

Beyond formal leadership roles, ownership also plays a central role in correct usage. As mentioned, sustainability leaders have taken responsibility and provided leadership support because that is their role. It has been shown that other people who have received some sort of sustainability responsibility within their team, like a key user for example, have used the SCEM in a more ideal way than the others, along with promoting its usage and helping others with it. Receiving this role and responsibility makes people care more about what they do and could absolutely be the reason why they have used it in a greater way than the others. Probably because they have received more training and have taken part in sessions where the SCEM has been talked about, along with more general usage. This highlights the necessity of spreading information through as many channels as possible because it really makes a difference.

4.2.2.4 Framing of SCEM

A misconception in the interviews is reflected in how people speak about the SCEM. A clear connection can be made between how people speak about the tool and how they use it. The ones who see it as a documentation oriented tool also describe using it as just "filling it out". In contrast, users who apply it as intended describe it as a tool for discussing and comparing alternatives. One user explicitly described it as helping them to uncover design issues, where in this case glued components prevented disassembly, which they later used as a basis to force suppliers to redesign. This highlights that the perceived usefulness of the SCEM is tied to how it is used and talked about in practice. A documentation mindset limits its value while a more discuss-oriented approach enables it to support design decisions.

5. Analysis and Discussion

This chapter analyzes and discusses the findings in relation to the research questions and previous literature. It also summarizes the answers to the research questions, reflects on the study in relation to its overall aim, presents managerial recommendations and discusses the study's contribution to existing knowledge.

5.1 Key Themes

The analysis and discussion are presented together in sections 5.1.1 to 5.1.6, allowing the analysis to be followed up by discussion in relation to previous literature. The headings represent key themes that emerged from combining patterns identified in the Gioia analysis with findings from the survey and the theoretical framework.

5.1.1 Awareness, Leadership and Change Readiness

Engineers appear to have higher awareness and confidence in the purpose and use of the SCEM than the leaders who sponsor their projects, which is the opposite of what change management literature would predict (Kotter, 1996). A likely explanation is the rollout path. SCEM was diffused through a key-user network inside engineering teams rather than cascaded down from management, so adoption ran ahead of leadership awareness. This may explain why engineers experience leadership as unsupportive, because the leaders may not fully understand the tool themselves. While it is positive that engineers feel confident since they are the ones using the tool, this gap highlights the need to better understand and address the role of leadership in the implementation. This lack of knowledge from the leaders is a known barrier to environmental tool implementation mentioned in the literature (Rossi et al., 2016). Looking at it from the perspective of ADKAR, leaders lack Awareness and Knowledge, which has been a barrier to the implementation of SCEM. Literature also mentions that these tools fail to integrate when the people who are involved with their usage lack understanding, which could be because roles and responsibilities are unclear (Nilsson-Lindén et al., 2015). The leaders are aware of the SCEM intentions, but sustainability is still deprioritized to other criteria. This reinforces that leaders' so-called awareness does not translate into action. This might be because of the lack of strategic direction and unclear KPI:s.

Change management literature shows that lacking leadership can be a major barrier to implementation and active usage of new initiatives (Rossi et al., 2016). This is evident as engineers do not feel that leadership actively supports environmental tools. The case here must not imply that the leaders are opposed to the tool, but rather that they may not have received clear instructions or guidelines to follow. In some cases, leaders appeared to have limited awareness of the SCEM which have led to environmental considerations never taking place in those projects, except for Volvo's overall vision, which is to become 100% fossil-free by 2030. It is essential that the company has this to strive towards, but without clear guidelines across the organization that vision will only be empty words without any meaning.

Leaders appear to have low confidence, experience and understanding of the tool, which may indicate that they need more exposure to it, get constantly reminded and even enlightened of the benefits. It is apparent that the early steps of Kotter's eight step framework (1996) have been absent from the introduction of the SCEM, more specifically clear urgency, a guiding coalition and strong leadership. We assume that it may have been present at times but certainly not consistently and widespread, which may explain why things have unfolded the way they have. No clear strategy and reliance on individuals' initiative rather than system-level change further supports this. SCEM has been rolled out in a way which supports a bottom-up approach of working with sustainability, which again relies on engineers taking initiatives and picking up the tool. With the help of clearer top-down management initiatives we believe that the use of the tool could increase. When management offers instructions and overall clearer information on what they want they can reach a shared understanding of success. This is aligned by what Baumann and Cowell (1999) mean by management needing to guide. "Bottom-up initiatives to promote SCEM use have limited impact" is a quote shown in the Gioia which strengthens the case of lacking a strategic direction for the tool. It further connects to the importance of top-down structures shaping the use.

The decline over time in communication from leaders aligns with what Kotter (1996) believes is a thing that leads to failure in anchoring change efforts. Rossi et al. (2016) also highlight that leadership is necessary when implementing environmental tools. This case further illustrates how initial measures become insufficient if they are followed up with continuous recurring communication.

5.1.2 Timing and Integration of SCEM in Early Development

Environmental aspects are often described as considered early in the process. At the same time, the SCEM is rarely used when concept alternatives are still being explored, which creates a contradiction. One explanation is that environmental considerations are treated more as general awareness or ambition in early stages, rather than being applied in decision-making. This is strengthened by leaders who confirm that the SCEM is rarely used during early exploration. The situation is closely related to the eco-design paradox (Bhander et al., 2003), as when the SCEM is used late in the process there is less room for configuration since then many decisions have already been made. This means that when SCEM gets picked up late it lands in the part of the curve where design freedom is low. Because design freedom is low, the tool can't change anything and then people use it for documentation. Since it is used for documentation, leaders rarely see it influence decisions and then they do not champion it and this reflects in a reinforcing cycle where the tool keeps getting picked up late because it is not fostered by the leaders.

Literature stresses that crucial decisions, like environmental ones, must be made early to have an evident influence (Cooper, 1990). This issue is brought up in literature and is evidently common where environmental tools are used after the design has been locked in instead of shaping early decisions (Nilsson-Lindén et al., 2015). This contradiction observed in the study can be explained by how sustainability is described in practice. Environmental considerations were often described as general ideas, values and ambitions. Awareness of the company's overall sustainability vision may give an impression that environmental aspects are being considered. It is therefore possible that sustainability is taken into account in early stages, but not applied in a structured or tool-based way. At the same time, using the SCEM seems to improve understanding of its purpose and use. It may also make it clearer that it is often applied too late, which challenges the idea that environmental performance is considered early.

The differences among how the two largest divisions adopt the tool reflect how practices and tool usage can vary across large organizations, where divisions have different tasks, priorities and workflows. It also highlights the fact that environmental practices are not always embedded consistently across organizations. This suggests that SCEM is not embedded in a standardized way, but rather shaped by local interpretations, which previous research suggest is because the tools are dependent on how they are integrated into the existing workflow, instead of acting independently (Baumann & Cowell, 1999; Nilsson-Lindén et al., 2015). As a result, the adoption of SCEM has become inconsistent and dependent on local conditions rather than guided by a shared organizational approach. We believe that this inconsistency may be inevitable when further initiatives are rolled out for the SCEM, because of how the teams differ. Moving forward this must be kept in mind and even accepted. However, striving towards establishing at least a general organizational approach is something they should certainly pursue. From a change management perspective, Kotter (1996) and ADKAR place greater importance on how leaders communicate and follow up on new practices, since they have a great impact on the integration and adoption of new tools.

The issue related to the timing of SCEM can be described as a supplier-related paradox. When suppliers are not yet selected, it is difficult to use SCEM since engineers depend on suppliers for data. At the same time, when the supplier is selected it is often too late to influence the concept, which means that the tool loses its impact. This can be linked to the difficulties of limited data availability in early product development (Bhander et al., 2003). This suggests that the tool does not fully fit in the development work, a mismatch between intended use and existing workflow which makes it challenging to pick up the SCEM early in the process (Nilsson-Lindén et al., 2015).

5.1.3 Prioritization, Decision Impact and Organizational Signals

When working with MCDA methods, like the SCEM, it is important to receive prioritization from management to influence decisions (Baumann & Cowell, 1999). However, this does not seem to be the case, as time for SCEM use is often not allocated or planned for in the project. Therefore, the usage of the tool has not been prioritized, it should also be added that in very few projects sustainability had any priority whatsoever, unless it was the reason for starting the projects. In other words, in ordinary projects where general improvements are to be made, very little room is given for sustainability because other criteria are more important. Based on the current situation, all projects must have the goal of improving sustainability levels, or the criteria itself must increase their weight for it to be recognized. Overall, prioritization in the form of allocated time and budget is needed to increase usage.

Regarding the perceived value of the SCEM, there are several observed contradictions. Engineers value the purpose of the tool and feel motivated by it yet feel uncertain of its fit in the early concept comparison workflow. Literature suggests that the influence from these tools depends on clearly defined priorities and early weights, which arguably is difficult to achieve in early phases (Svanström & Peters, 2013). But that does not remove the fact that it is important and could be the cause of the lack of use. It is also known that environmental tools often lack integration into everyday engineering workflows (Poulikidou et al., 2014). Leaders also show a contradiction, as they believe the SCEM is valuable for decision-making, but at the same time acknowledge that the results from the tool do not affect actual concept choices. This may stem from what literature says regarding environmental priorities being ambiguous, which can lead to the output being interpreted inconsistently (Brunklaus et al., 2009). Also, from the constant pressure the leaders are under to always balance and keep multiple features in mind when making decisions, such as cost and other performance requirements (Poulikidou et al., 2014). As a result, some features will be deprioritized, with sustainability often being one of them. Cost and/or quality ultimately is the deciding factor/factors, even when the SCEM highlights more sustainable options. This has led to engineers feeling frustration since SCEM becomes irrelevant. Investments in the SCEM may be perceived as unnecessary if the outcome is strongly driven by which concept is the most cost-effective.

The strength of these priorities may depend on the geographical context of the development. For example, market conditions in regions such as Brazil can further reinforce the focus on cost and quality. Due to the challenging road conditions, it becomes a question of when a vehicle fails rather than if it fails. In such cases, where uptime is crucial, there is even less room left for sustainability which further limits the relevance of tools such as the SCEM.

5.1.4 SCEM Use in Practice

Instead of using the SCEM as a decision-support tool, as it is meant to be used, the SCEM is often applied more as a reporting or documentation tool. Literature suggests that environmental tools risk becoming precisely this, which can be explained by the typical ways of the stage-gate process that regularly pushes teams to do what is needed to pass the gates (Remmen et al., 2007; Anderson, 1996; Grönlund et al., 2010). One explanation is that the SCEM seems to lack follow-up, lack integration with other tools and lack ownership. As a result, it is often treated as a secondary activity rather than a core activity. This reinforces the documentation mindset and may indicate that for large organizations that implement new tools into existing complex stage-gate processes that already have a lot of requirements and tools. This issue is understandable because of the origin of the stage-gate, which originally focused primarily on cost and quality. These priorities can remain deeply embedded in established organizations, making it difficult to introduce new considerations such as sustainability.

The "fill it out"-mindset acts as a barrier and something that limits the effective use of the tool. To move away from this, the SCEM needs to be framed and communicated differently. When supporting users, the help should not focus on how to fill out the SCEM, but rather to discuss and reveal alternatives that can improve the sustainability aspect compared to the reference concept. This shifts the purpose from documentation to exploration, where the tool helps identify improvements. Sustainability leaders may play an important role in this shift by consistent support, since literature suggests that consistent leadership can be an important factor in establishing a different mindset and sustaining positive change.

Time constraints and manual data handling appear to limit the practical use of the SCEM. Automatic data sharing between tools could reduce the need for double work and lower the time required to perform it. This suggest that further development of the software, particularly regarding system integration and usability which could help reduce the effort of using the tool.

5.1.5 Experience, Competence and Perceived Effort

Experience, familiarity and training may have an important role in shaping the perception of the tools' usability and relevance. It aligns with literature such as the ADKAR model, more specifically the *Knowledge* and *Ability* components. This suggests that for adoption to be successful, individuals require both cognitive understanding and practical, "hands-on" experience, where knowledge is developed through training.. The literature on environmental assessment tools also highlights the importance of experience, stating that environmental tools demand specific knowledge and that users require training and prior experience to interpret results (Rossi et al., 2016). Many users felt more confident after their first time using the tool, which often was due to sustainability leaders supporting them the first time.

Sustainability leaders are one of the strongest enablers for SCEM use in practice. At the same time, interviews indicated that group managers with access to these roles sometimes showed lower understanding of the tool compared to those without. This can be linked to the risk of reliance on specialists highlighted in the literature (Poulikidou et al., 2014). However, considering the level of support they provide and the importance of their presence, the benefits seem to outweigh this risk in this case. What is important here is that specialists, in this case the sustainability leaders, should be used as support rather than taking over responsibility.

Time and effort may be perceived as a barrier to SCEM adoption, especially among users with little or no experience. This aligns with Rossi et al. (2016) who highlights that a barrier related to LCA is the time and effort as well as data requirements to conduct the analysis. Although the SCEM is not a full LCA, respondents with no prior experience may associate it with similar characteristics and therefore perceive it as more time consuming and effort demanding.

Perceived leadership support appears to be connected to the adoption and use of environmental tools. Literature consistently emphasizes that leadership and management play a crucial role in adoption and use of new tools, which could be related to this connection between no perceived leadership support and no usage of the tool. This highlights the importance of sustainability leaders acting as champions of the tools past and further usage.

The difference between experience levels, whereas the less experienced reported a more ideal view on the SCEM, may reflect that engineers in early stages of their careers are in a more "learning mindset" and therefore more open to new tools or practices. More senior engineers may rely on established ways of working, which could make them less prone to adopt new tools. The difference in how environmental performance is perceived may also relate to younger engineers having more recent academic exposure to sustainability. Since younger engineers may have been more exposed to sustainability in general, they might have higher expectations of environmental performance. The lower awareness of the SCEM among more experienced engineers appears somewhat counterintuitive. This is not a shock but rather very natural in a mature company and industry, where things have been "as they always have", and established ways of working may be difficult to change. The interviews might have revealed a loophole that improves usage and adoption regardless of seniority and experience. Those who have received a role with the idea of fostering sustainability thinking, such as SCEM key users and sustainability leaders, were shown to carry entire teams because of the ownership and leadership they provided. This might mean that roles carry heavier than experience, at least in terms of taking on new ways of working. We do believe that Volvo should consider the assignment of various sustainability roles to the more experienced, because they have more difficulty in taking on the change compared to the less experienced where their role does not have the same meaning. We believe this can maximize adoption by taking the individual's characteristics into account.

5.1.6 Structural and Contextual Barriers to Adoption

Literature mentions that time can be a barrier especially working in stage-gate processes that are documentation heavy (Rossi et al., 2016; Cooper, 1990). Time availability appears to be one of the biggest barriers, at the same time many believe that the time required to perform the SCEM is reasonable to its benefits. This may indicate that it is not the tool itself that disrupts time, but rather the system. It is famously known that they have a lot on their plates. Leaders are uncertain but lean towards agreeing its reasonable, which implies that they lack perception of this. It is difficult for engineers to determine what is worth pursuing when they lack clear guidance from leadership, likely due to leaders limited understanding. This acceptance from the engineers suggests that workload is not the core barrier, the issue rather lies in priorities, ownership and possibly timing. And that no time was allocated for using the tool, strengthening the sign that this is a system error.

Cost targets, lack of data and the need for experience are all barriers that align with literature as classical barriers in environmental tool adoption (Rossi et al., 2016). Early product development is defined by limited data (Bhander et al., 2003), making this phase naturally difficult. In this case, the tool requires some sort of supplier collaboration to gather the data needed to fill out the SCEM. Supplier collaboration varies across departments and even teams where some only need a line of data compared to others who are totally dependent on them. This further put pressure on the suppliers to provide the right data since it can be very specific. Because of cultural differences and lack of worldwide standardization this kind of environmental data can be hard to retrieve. The difficulty in creating baselines further illustrates this challenge. What makes it even harder and more time-consuming is that some suppliers are dependent on their sub-suppliers, which also must comply with what Volvo engineers are asking for. This challenge adds to the identified barrier that the leaders stated: individual experience and confidence. Because MCDA tools require user competence to interpret results, the lack of experience and confidence reduces reliability and trust (Cinelli et al., 2014), especially when the leaders cannot even be sure that the data they have received from the suppliers can be trusted or not. It is important that this data is correct because it is set against and compared with the reference project. If this turns out to be the wrong data, it means that two completely different types of data are being compared, which gives a completely random result and helps nobody. An action that can be taken here would be directed towards the procurement department, where clearer instructions regarding what data Volvo requires need to be specified in the negotiations while writing a contract with the suppliers.

Organizational context and culture can make it harder to implement the tool in the same way across the organization. The case company strives to implement new initiatives, like the SCEM, in the same way throughout the whole organization. They are committed to their "We are Volvo"-phrase which means that they do things as one identity. This somewhat becomes a problem as all teams have different conditions around the world in the form of different budgets which affects manpower. However, the biggest prerequisites may be how culture affects the way they operate. For example, sustainability is not viewed in the same way in North and South America as in Europe, which if you look at it from a cultural perspective, has reflected their entire upbringing, education and current job. This leaves them with different possibilities to succeed at what is asked of them. It also seems to affect how much resources are put into sustainability, for example fewer sustainability leaders. Since these roles are important enablers for SCEM use in practice, this makes it harder for engineers to use the tool in the intended way. This geographic variation in engagement with SCEM, such as with teams in the US and in Brazil, connects to a dimension that is explicitly absent from both the ADKAR and Kotter’s 8 step model (Prosci, 2021; Kotter, 1996) that the case company might need to keep in mind. It suggests that environmental tool adoption in multinational firms is not only an organizational embedding problem (Nilsson-Lindén et al., 2015) but also a sociopolitical one, where macro-level signals filter into engineering practice. This complicates Volvo's "We are Volvo" uniformity ambition and points toward differentiated implementation strategies. The “We are Volvo” idea of being one singular unit is understandable, but there are clear signs that different focuses may need to be put on different sites because of cultural, political and other conditions.

Differences in team structures also create variation in perceived usefulness. Teams that work with complex products with a lot of different parts explicitly showed frustration regarding completing the SCEM, because it takes a long time to find the data for each part. This further shows the importance in automating the tool, together with these teams having low design freedom, meaning they are very supplier dependent since they design the parts. For the teams that work like this the SCEM might not be as useful and have a harder time being used the intended way compared to the teams with more or complete design freedom as they are the ones pulling the strings by choosing material and shape. This further raises the question of whether the SCEM is applicable everywhere.

For many of the projects that the SCEM has been used in they have already been going on for some time, which means that the SCEM has been a late addition for many. One could argue that the tool hasn't really been given a fair chance of succeeding since it has not been part of the project's initial plans. This would explain why it felt like an extra task for many, a documentation-oriented tool rather than a decision-support and the contradiction of why environmental considerations are taken early on but that the tool was used late. Our study showed that people learned from practical experience, and by having performed a SCEM might have laid the foundations for upcoming projects where the SCEM should be used. People did also indicate that they are aware that the tool should be used earlier. These are all signs that indicate a brighter future for the SCEM, and especially gives us an explanation to why our findings have looked the way they have. This ultimately shows us that the introduction of the tool has not only been structural shortcomings but also transitional, having to do with the timing of the projects. We therefore believe that when the SCEM becomes integrated from the beginning of the projects, the conditions for its success will be completely different.

5.2 Synthesis and Answers to the Research Questions

This section answers the research questions and discusses to which extent the study has succeeded in providing deeper insight into current practices and the conditions that affect the use of environmental tools in early product development.

RQ1. How are environmental tools perceived during concept development?

Both engineers and leaders perceive environmental tools as purposeful and important. Both groups agree that sustainability is deprioritized compared to cost and quality in concept decisions. Their perception differs in other ways, as engineers show high awareness, confidence and motivation to use the tool, while leaders show lower understanding of its purpose and required input.

RQ2. How are environmental tools used during concept development?

A gap exists between the intended and actual use. While environmental performance is alleged to be considered early, the tool itself is rarely used while concepts are still being explored and compared. It is mainly used after concept decisions have been made, functioning as a documentation tool rather than decision support.

RQ3: What barriers and enablers influence the use of environmental tools in early product development?

Barriers were identified in four categories: 1. Top-down organizational barriers such as unclear KPIs, deprioritization, lack of strategic direction. 2. Tool-related barriers such as weak integration with existing systems, subjective and data-heavy criteria. 3. Data and supplier related barriers such as reliability and timing of supplier data. 4. Availability and time/workload constraints such as no allocated time, competing priorities. The main enablers identified were support from sustainability leaders and key users, allocated project time and repeated practical use of the tool.

RQ4: What actions can management take to better support and increase the use of environmental tools in concept development?

Answered below under 5.3 Managerial Recommendations.

The study succeeds in providing deeper insight into current practices and conditions that affect the use of environmental tools in early product development. This is demonstrated by providing a triangulated view of how a matrix-based environmental tool is perceived and used in practice. It supports a view of environmental tools being socio-technical systems that are less dependent on their technical design but more on how they are embedded, supported, prioritized and communicated within the organization. The findings are bound to a single case company and a single tool, which somewhat limits generalizability.

The most supported findings are those that align across all three data sources. These are in particular the gap in awareness/understanding between engineers and leaders as well as the late and documentation-oriented use of the tool relative to its intended purpose. Other findings have a narrower evidential basis and should be interpreted with more caution, as they are indicative rather than conclusive. This could partly be because of the methodological choices: the 40% response rate on the surveys could mean that there is a non-response bias and the Gioia analysis involves interpretive factors.

5.3 Managerial Recommendations

With a deeper understanding of the role environmental tools have in concept development, the following part will discuss how management can increase the use of environmental tools in concept development. The change management recommendations will be based on Kotter's 8 steps together with the ADKAR model which together provide a basis for both organizational and individual change. In other words, the combination of Kotter's 8 steps top-down focus together with the bottom-up ADKAR model forms a comprehensive approach that ensures change from both directions.

Shonhe (2019) synthesized the three larger phases within Kotter's 8 step model together with the five elements of ADKAR, see figure 10 for grouping. This framework will be used as the foundation for the managerial recommendations.

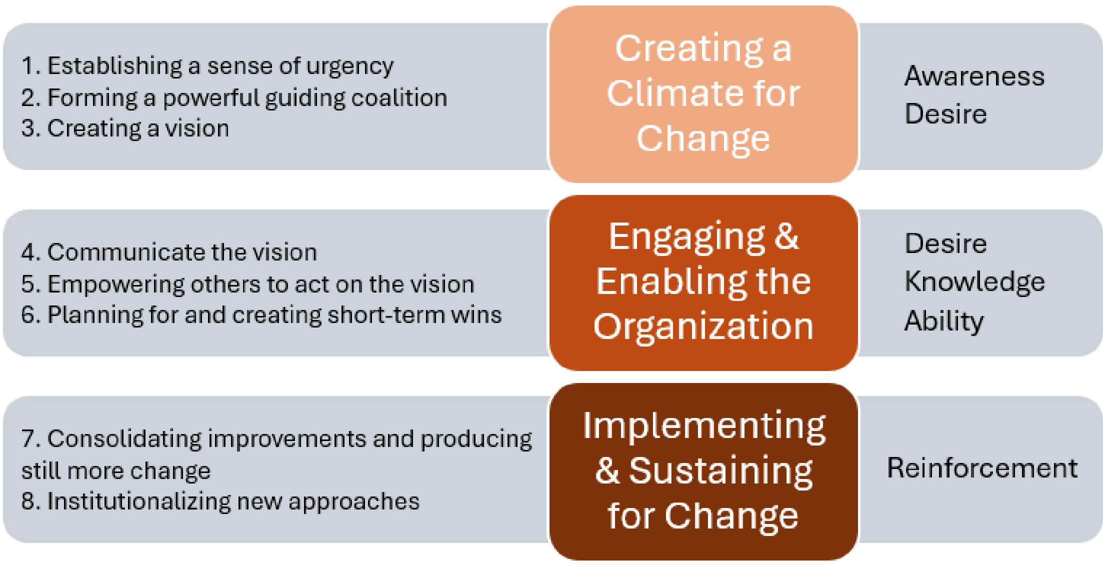


Figure 10. Leading Successful Change. Kotter's 8 step model combined with ADKAR (Kotter, 2014; Shonhe, 2019)

Before jumping into this, it is important to keep in mind that the key is to iteratively have a dialogue between top-down and bottom-up management styles (Smeds et al., 2003). Only using one of the methods will not cover what the situation for the case company requires. It was identified that change was required at both the individual level, in terms of mindset, and the organizational level, in terms of structure and strategy.

5.3.1 Creating a Climate for Change

Enabling a climate for change will require that individuals, which are engineers and leaders in this case, become aware of the situation and feel a desire towards the goal. Because of the prior low urgency surrounding the environmental tool, it has generated low awareness and thus low usage. SCEM is seen as optional and used mainly for documentation, the whole sustainability criteria is deprioritized and leaders are not engaged. To create urgency and change this, they can show the cost of late environmental decisions through the eco-design paradox. This can be done through providing internal examples of this. This shows the risk and possible missed opportunities.

The second step is something that the company already has done well overall, but where there are some areas that can be improved. It is granted that the platform sustainability team form the inner ring of the coalition, whereas the sustainability leaders are the next level of the coalition and lastly the key users become the outer ring. However, there appear to be gaps in this structure as not all teams were covered. Without these "champions" having complete coverage, adoption and usage get inconsistent. To make this coalition more powerful, sustainability leaders, or similar roles, could be expanded or increased in number so that all teams are covered. Anyhow, the platform sustainability team should continue to investigate how this can be expanded and improved.

They need to create a clear vision and strategy that includes when and how the tool should be used, its relation that affects decisions and maybe most importantly what success looks like. To do this, it must become clear for everyone that it is mandatory. KPIs showing what the tool generates could help demonstrate its value. These KPIs are facts that will reduce the confusion about the purpose of the tool, therefore increasing awareness which hopefully leads to higher knowledge and even desire to use the tool.

Another action to be taken is to align environmental tools with existing requirement structures. Since engineers work closely to and strive towards fulfilling requirements, misalignments between the two reduce usability and desire. Looking at the case company's Generic Technical Requirements (GenTR), which provide a framework for what the Technical Requirements (TR) should include in concept development projects. Sustainability is included but very and the structure is not aligned with the SCEM tool, the different aspects of the SCEM are covered but seems a little bit messy. In practice, this makes it more difficult to connect the requirements directly to the SCEM than what it needs to be. One way to improve this is simply by structuring sustainability requirements in the GenTR in a way that matches the SCEM tool. This could be done by for example dividing them into clear sub-requirements such as CO_2 impact, SOC, etc. This would make SCEM more closely connected to the requirements, making it more natural to use the tool in the development process. This aligns with what many interviewees pointed out, that they work towards the requirements sent to them.

5.3.2 Engaging and Enabling the Organization

The second phase builds on making the organization and individual able to succeed. Communicating the vision is the first step of this phase which is particularly important for the organization since communication has been inconsistent in past rollouts. This communication should be present through as many channels as possible. This can be through: weekly/monthly/yearly meetings, gate reviews, internal forums, events etc. Ultimately, the tool itself needs a shift away from a one-time introduction, being presented as an option, to continuous communication where the mandatory element must be pressed. The training must still include the technical and practical focus, but it must move closer to highlighting the benefits from using the tool.

Next step is the fifth out of Kotter's eight steps which is to empower people to act on the vision. The identified barriers must be addressed and eventually removed to clear the path towards the vision. This will be both from top-down and bottom-up initiatives. The bottom-up initiatives are about the tweaks that can be done with the tool itself, such as automating data exchange and making it more compatible with other tools. The criteria Recyclability, Circularity and Recycled content should also be reviewed since several users had difficulties working with them. Supplier collaboration is also something that should be further investigated to enable a smoother way of working for the users. Explicit time must be allocated for SCEM in projects for it not to be perceived as an extra task, but rather as one of the standard tasks of the project. The budget, in terms of money, must leave more space for sustainable solutions. This is overall a mindset that needs to be changed, where people must accept that sustainable solutions often cost more. This can be difficult in an environment where profitability is often prioritized. To reach goals as the Green deal, alterations must be made, and someone has to do them first.

The material list in the SCEM is incomplete and does not match the list of materials in the calculation tool, which is used for calculating CO_2 emissions of components. This inconsistency makes it difficult to perform the analysis. One improvement would be to expand the material list to make it complete and match the list in the calculation tool. Another improvement would be to integrate the calculation tool directly into the SCEM, through for example built-in calculations or an Excel-based solution. This would reduce the double work of first calculating the emissions in the calculation tool and then manually adding the value to the SCEM, whereas now, the material list is incomplete.

Regarding the SCEM tool and its different aspects, two were often mentioned as the most challenging: recyclability and circularity. These aspects were described as difficult to assess, since they are subjective and often depend on assumptions, particularly when data is limited and evaluation relies on individual judgement. One way to address this is to simplify or better structure these aspects, for example by providing clearer criteria, predefined values or some sort of guidance on how to address them. It could also help with some extra emphasis on these aspects in the training materials, since there seems to be a lack of knowledge about them.

An action that can be taken to increase the use of environmental tools is to integrate them into existing workflows and systems. Because when they become separated, they risk being treated as external documentation rather than essential decision-support. When the tool is used late, its influence on concept development decisions becomes limited. Follow-up and continuous work also become difficult due to this. One way to address this is to link SCEM with existing systems such as KOLA, a commonly used system among the engineers themselves. This would support the need for integration between the tool and existing systems. Since full integration is not feasible, this could be done by including requirements related to SCEM in these systems. It would also increase the visibility of the tool which can act as a reminder to use it, specifically to use it earlier and not only when the concept is already chosen. Another improvement would be to treat the SCEM more like how Failure Mode and Effects Analysis (FMEA) is used, which is to update it throughout the development process. This would allow SCEM to be used more continuously and work more as a living document rather than a one-time thing.

A key challenge related to usability is the lack of accessible and reliable data when performing the SCEM. This makes it difficult to rightfully compare concepts and leads to uncertain results. The strong dependency on suppliers makes this issue difficult to address, since the availability and quality of data often depend on external actors.

A way to address this issue is to introduce clearer sustainability requirements earlier in the supplier process. Instead of asking for data later on, these requirements should be set already when selecting suppliers and they should be aligned with the criteria in the SCEM. This would make expectations clearer from the start of the supplier collaboration and hopefully enhance data availability and quality. Today, sustainability requirements are often limited to restricted substances as this is what the engineers receive in their Technical Requirements. This means that for this change to succeed, requirements and targets must be communicated from management to the engineers, then forwarded to the suppliers. The responsibility is therefore not only on the engineers but rather the whole organization.

Another improvement could be to allow suppliers to work more directly with SCEM, which could reduce time, effort and double work. This could reduce the challenges related to supplier data and double work.

The last step of the phase and the sixth of Kotter's model, is to plan and create short-term wins. When the SCEM does not influence decisions, users lose motivation to use the tool. This highlights an issue with the perceived usefulness of the tool, early wins could therefore increase the perceived value and desire. Teams can be rewarded for using the SCEM early. They should further investigate how these rewards could look like.

5.3.3 Implementing and Sustaining for Change

The final phase reflects the organization in its current position, where the focus shifts from initial implementation to sustaining the use of the SCEM. This phase should build on the identified insights and adapt them to different project contexts. Incorporate new factors discovered along the way and share the most effective practices across all teams. It may be relevant that they start looking closer into what factors are successful depending on what different circumstances the teams are operating in. Since teams operate under varying conditions, a more flexible approach may be needed while avoiding strict standardization. This means working with these differences rather than trying to eliminate them, to ensure both practical usability and organizational alignment.

To sustain the use of SCEM, the perceived time and effort required to apply the tool need to be addressed. However, the required time varies depending on how the tool is used and the context of the project. For concepts that consist of many components, performing a SCEM can be time-consuming. The required time is also influenced by factors such as data availability and reliance on suppliers for the data. In addition, there is a difference between using the SCEM as a one-time documentation task and applying it continuously throughout concept development, where the latter requires more time but aligns better with its intended use. If it takes too much time and effort, the tool is difficult to use early in the process which can lead to it being postponed. One way to reduce this effort is to provide suggestions for materials and solutions, this could be based on previous concepts that have been successful. This guidance could help engineers to identify concept solutions faster and reduce the effort required. Another improvement could be to provide more concrete examples in the training and e-learning materials. They should be tailored to the different divisions and more project-specific for engineers to understand more how it works specifically for them in their projects.

Creating a "SCEM library" with a collection of previous SCEMs and concept solutions could serve as support and inspiration. It could be structured in a way that aligns with the tailored training examples, per division, to make it easier for engineers to orient themselves. In addition to this, providing simple guidelines for material choices could also serve as support. For example, highlighting materials with low CO_2 impact, high recyclability and so on. The purpose is to help engineers identify environmentally friendly solutions and make better decisions without having to investigate all alternatives from scratch. This could also facilitate earlier use of the SCEM in the projects since the engineers now have some sort of guidelines from the beginning. Over time, this can help engineers learn how to use SCEM more effectively and contribute to individual change through increased knowledge.

The last step is to ensure that the new changes are embedded within the organization and make them a part of standard practice. For this to happen, the use of SCEM needs to be supported from a top-down perspective, where management understands the tool, expects it to be used and sees value in its results. Bottom-up initiatives alone are not sufficient to sustain changes over time. If the use of SCEM is primarily driven by sustainability specialists, it risks remaining a parallel activity rather than part of the core process. It needs to be integrated into how decisions are made and followed up across the organization.

To summarize how the barriers and the recommendations are connected, a table consisting of barriers, recommendations and expected effect can be found below in table 1.

Barrier	Recommendation	Expected Effect
Sustainability is deprioritized and expectations are unclear	Set clear expectations, targets and KPIs	Increase understanding of what should be achieved with the tool
No allocated time for SCEM	Make environmental assessment mandatory earlier in the process	Earlier use and better influence on decisions
Poor integration with existing workflows and systems	Integrate and/or link the tool with existing systems	Making it a natural part of the process instead of a separate file
Subjective and difficult criteria	Improve training and create guidelines and examples	Help engineers gain confidence and learn about sustainability
Dependence on supplier information	Communicate sustainability requirements earlier to suppliers	Improve data availability earlier in the supplier collaboration
Lack of guidance when performing SCEM	Create a library with previous assessments and project specific examples	Reduce effort and support identifying solutions
Low commitment to sustainability and the tool	Communicate when and how the tool should be used across multiple channels	Increase awareness and making benefits visible

Table 1. Change management recommendations

5.4 Contribution to existing knowledge

The study confirms existing knowledge while also contributing new insights that have not been previously known. The study confirms the late and documentation-oriented use surrounding environmental tools (Nilsson-Lindén et al., 2015), the deprioritization compared to other features such as cost and quality (Poulikidou et al., 2014), classical barriers regarding data, time and knowledge (Rossi et al., 2016). The eco-design paradox (Bhander et al., 2003) is also apparent. The study adds nuance to when, under what conditions and how it becomes possible to use environmental tools meaningfully.

The study has contributed new knowledge primarily connected to perception and usage. The key new finding to literature is the coexistence between the positive perception of environmental tools and the low decision-influence they have. It identifies a paradox in which late use leads to low perceived influence, which in turn reduces leadership engagement and sustains late use. It also shows that the tool is used as a document that is being filled out rather than a tool that helps identify and compare concepts. In addition, it was shown that the ownership that comes with having a sustainability role is a stronger driver of correct tool use than seniority.

6. Conclusion

Environmental tools have a large potential to support environmental decision-making, where early design decisions have a large influence on a product's environmental impact. This study shows that even if environmental tools are perceived as valuable and their purpose is understood, their potential is not fully utilized in practice.

The findings show that environmental tools are often introduced too late in the concept development process to influence concept selection. Instead of supporting comparison and decision-making between alternatives, they are more commonly used for documentation of decisions that have already been made. This reveals a gap between the intended use of environmental tools and how they are used in practice.

The study further shows that this gap is not primarily connected to the limitations of the environmental tools themselves. Instead, their ability to support environmental decision-making depends largely on the organizational conditions in which they are used. This indicates that increasing the impact of environmental tools requires organisations to better embed environmental considerations into everyday engineering work, allowing the tools to fulfill their intended role in concept development.

Overall, this study provides a deeper understanding of how environmental tools are perceived and used in practice as well as the conditions that influence their use in early product development. The findings show that the successful use of environmental tools depend less on their technical capability and more on how they are embedded within the organization. Environmental tools can therefore contribute to more sustainable concept decisions, but only when the organizational conditions allow them to influence decisions when they matter the most.

To finalize, the case company should drive the integration of environmental considerations through a top-down approach, making sustainability a natural part of the development process instead of a separate activity. This would create the conditions needed for the environmental tool to become valuable and fulfill its intended purpose in supporting concept development. Future research should investigate the impact of using environmental tools in concept development and evaluate the outcomes they generate in practice. This study focused on how environmental tools are perceived and used, but did not examine their effects on environmental performance or decision-making. Addressing this gap would provide valuable insights into their actual benefits. Future research could also explore how sustainability KPIs and other performance measures can be developed and used to increase the knowledge about the outcome effects of using environmental tools.

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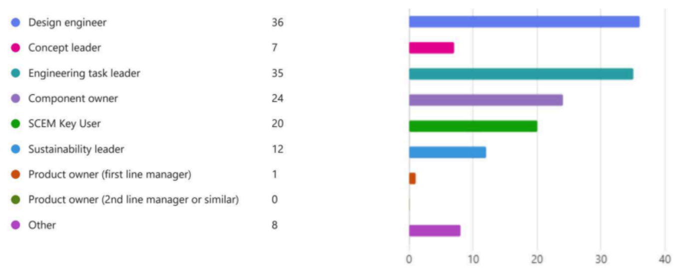
Appendix

A: Survey for engineers

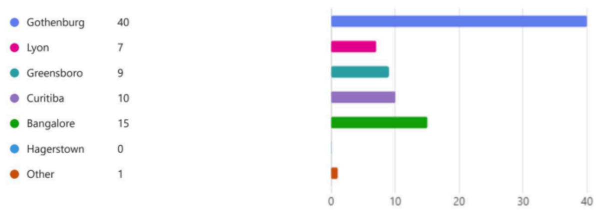
Responses Overview Active

Responses	Average Time	Duration
82	56:26	23 Days

1. Which role(s) best describes your current role? (Select all that applies to you)



2. Which site are you based at?



3. Which commodity/division are you part of?

Cab	42
Chassis	22
EEVC	4
FCEV	0
Function & Software Defined Vehicle - Driver Interaction & Infotainment	0
Function & Software Defined Vehicle - Embedded Platform Factory	4
Function & Software Defined Vehicle - Safe Efficient Driving & Services	0
Function & Software Defined Vehicle - Vehicle Motion and Thermal Management	0
Function & Software Defined Vehicle - Other	1
Powertrain Technology - Base Engine	1
Powertrain Technology - Combustion	0
Powertrain Technology - Complete Powertrain	1
Powertrain Technology - Driveline	0
Powertrain Technology - EATS	2
Powertrain Technology - EATS Diagnostics	0
Powertrain Technology - EMOB EE	0
Powertrain Technology - EMOB ESE	0
Powertrain Technology - EMOB ESS	0
Powertrain Technology - EMOB Other	0
Powertrain Technology - Other	1
Other	4

4. How many years of experience do you have from working in engineering?

82
Responses

Latest Responses
"20"
"5"
"7"
...

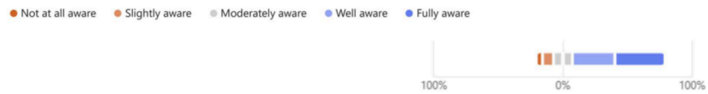
7 respondents (9%) answered 10 for this question.

5. For how many concepts have you used and/or helped performed a SCEM?

82
Responses

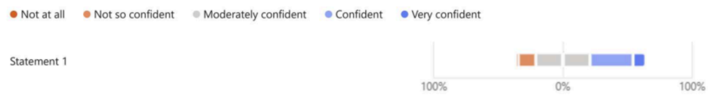
Latest Responses
"1"
"4"
"5"
...

6. Prior to this survey, to what extent were you aware that the SCEM is designed to support the development, evaluation, and decision-making of concepts?



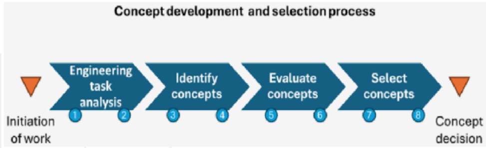
7. To what extent does the intended purpose of the SCEM motivate you to use it?

8. How confident are you in using the SCEM?

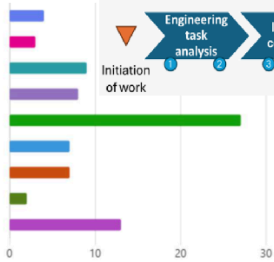


9. In your projects, environmental performance is considered early in concept development.

10. Looking at the picture of the Concept development and selection process, where would you say that you first encounter or use the SCE M in a typical project?

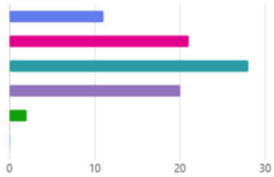


1	4
2	3
3	9
4	8
5	27
6	7
7	7
8	2
After concept decision	13



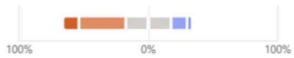
11. Which of the following best reflects how the SCEM is typically used in your experience?

Mainly as input to early concept decisions	11
Mainly as documentation/reporting	21
Both decision support and documentation/reporting	28
SCEM is rarely used	20
Not applicable	2
Other	0



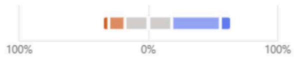
12. How often do you use the SCEM while you are still exploring and comparing concept alternatives?

Never Rarely Sometimes Often Always



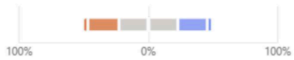
13. The time and effort required to use the SCEM is reasonable in relation to its benefits.

Strongly disagree Disagree Neutral Agree Strongly agree

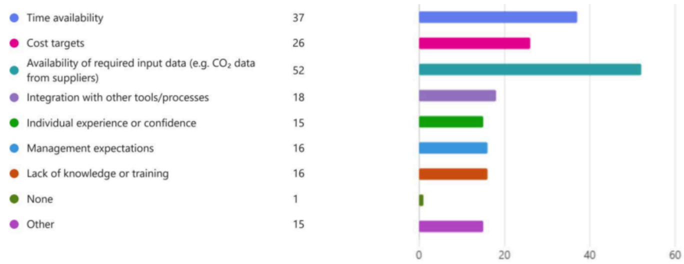


14. To what extent does SCEM fit with how you work when comparing alternative concepts in early development?

Not at all To a low extent To some extent Toa high extent To a very high extent



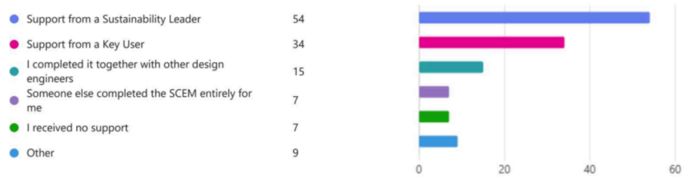
15. What are the main barriers that prevent SCEM from being used early in concept development? (Select up to three)



16. Environmental tools such as SCEM are actively supported by project leadership.

17. Are you aware of where to find the key user/s to contact in case of needing support?

18. What type of support did you receive when using SCEM? (Select all that applies)



19. What changes, if any, would most improve your experience using the SCEM?

43
Responses

Latest Responses
"user friendly tool"
"."
...

22 respondents (51%) answered SCEM for this question.

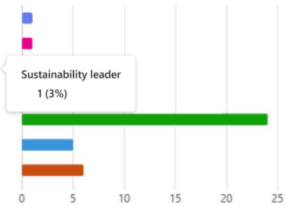
B: Survey for leaders

Responses Overview Active

Responses	Average Time	Duration
37	09:34	20 Days

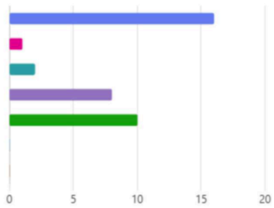
1. Which role(s) best describes your current role? (Select all that applies to you)

Cross Functional Technical Leader	1
Project Manager	1
Sustainability leader	1
Component owner	0
Product owner (first line manager)	24
Product owner (section manager or similar)	5
Other	6



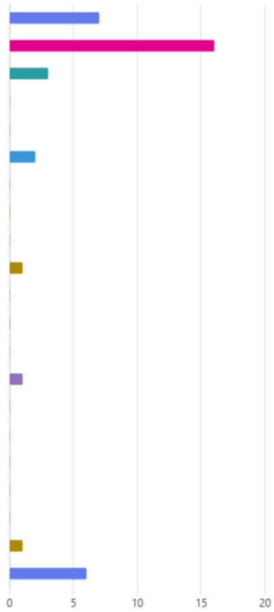
2. Which site are you based at?

Gothenburg	16
Lyon	1
Greensboro	2
Curitiba	8
Bangalore	10
Hagerstown	0
Other	0



3. Which commodity/division are you part of?

Cab	7
Chassis	16
EEVC	3
FCEV	0
Function & Software Defined Vehicle – Driver interaction & Infotainment	0
Function & Software Defined Vehicle - Embedded Platform Factory	2
Function & Software Defined Vehicle – Safe Efficient Driving & Services	0
Function & Software Defined Vehicle – Vehicle Motion & Thermal Management	0
Function & Software Defined Vehicle – Others	0
Powertrain Technology– Base Engine	1
Powertrain Technology– Combustion	0
Powertrain Technology– Complete Powertrain	0
Powertrain Technology– Driveline	0
Powertrain Technology– EATS	1
Powertrain Technology– EATS Diagnostics	0
Powertrain Technology– EMOB EE	0
Powertrain Technology– EMOB ESE	0
Powertrain Technology– EMOB ESS	0
Powertrain Technology– EMOB Others	0
Powertrain Technology– Others	1
Other	6



4. How many years of experience do you have from working in engineering or similar roles?

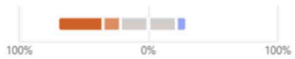
37
Responses

Latest Responses
"15"
"26"
"22"
...

9 respondents (24%) answered 20 for this question.

5. How experienced do you consider yourself in sponsoring projects where the SCEM has been used?

● Not experienced at all ● Slightly experienced ● Moderately experienced ● Very experienced ● Highly experienced



6. How clearly do you understand what input data the SCEM tool requires?

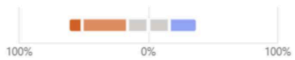
● No understanding ● Limited understanding ● Some understanding ● Good understanding ● Excellent understanding

7. How confident are you in explaining the purpose of the SCEM to your team?

● Not at all confident ● Slightly confident ● Moderately confident ● Very confident ● Extremely confident

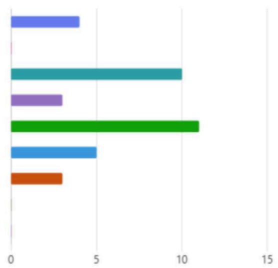
8. To your understanding, how often is the SCEM tool used when engineers in your teams are still exploring and comparing concept alternat ives?

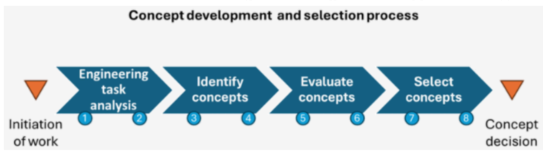
● Never ● Rarely ● Sometimes ● Often ● Always



9. Based on your understanding, at what point in the concept development phase is the SCEM usually first used in the projects you sponsor or lead?

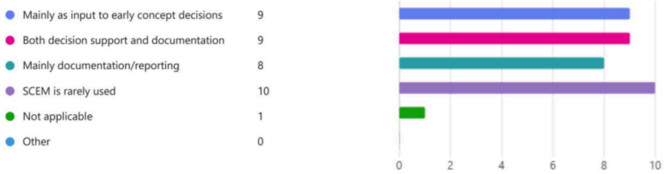
● 1	4
● 2	0
● 3	10
● 4	3
● 5	11
● 6	5
● 7	3
● 8	0
● After concept decision	0





10. Based on your understanding, to what extent is the SCEM tracked or followed in project you sponsor?

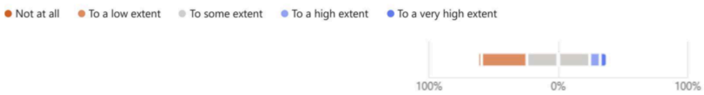
11. Which of the following best reflects how the SCEM is typically applied in your experience?



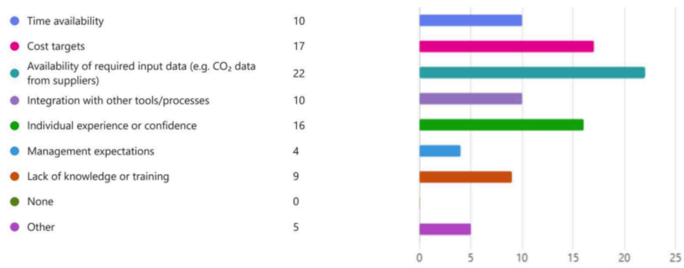
12. Based on your understanding, the time and effort required to use the SCEM is reasonable in relation to its benefit.

13. How valuable do you believe the SCEM is for improving decision-making in concept development?

14. To what extent do the results of the SCEM influence concept selection in your experience?



15. Based on your understanding, what are the main barriers that prevent SCEM from being used early in concept development? (Select up to three)



16. What changes, if any, do you think would improve the usage of the SCEM?

15
Responses

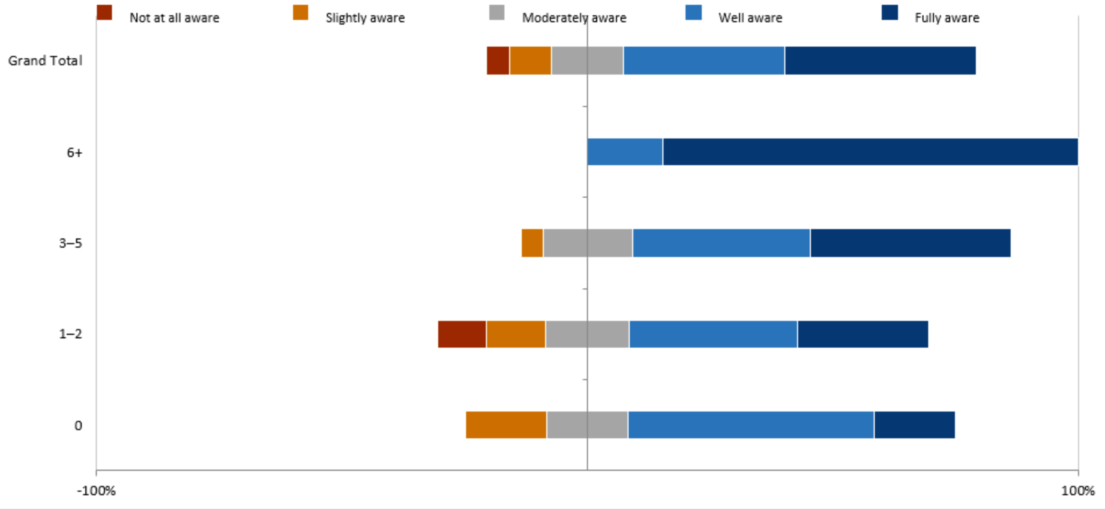
Latest Responses
"The use needs to be requested and the relevant training is needed."
...

6 respondents (40%) answered SCEM for this question.

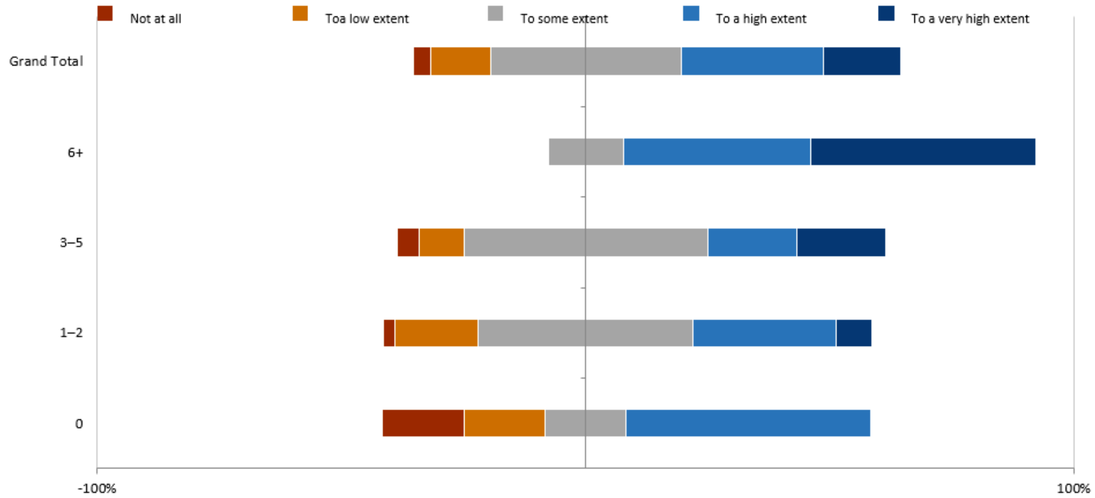
C: Detailed survey findings

C.1 SCEM usage among engineers (For how many concepts have you used and/or helped performed a SCEM?)

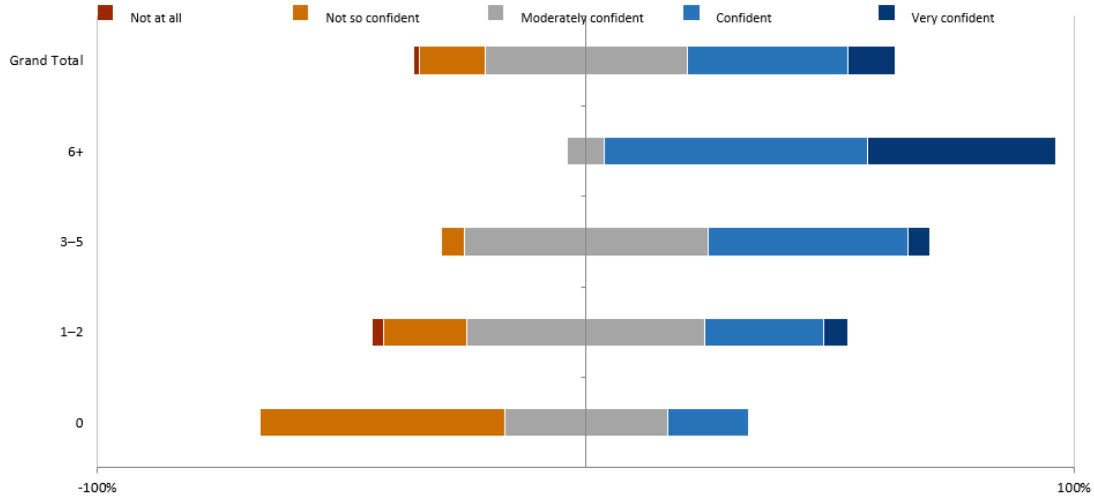
6. Prior to this survey, to what extent were you aware that the SCEM is designed to support the development, evaluation, and decision-making of concepts?



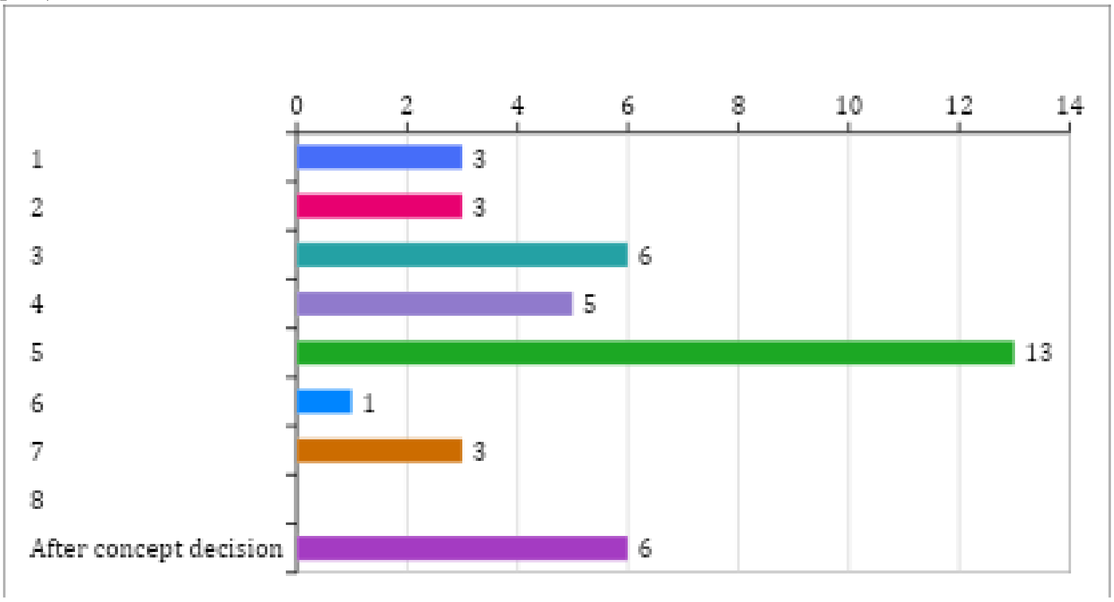
7. To what extent does the intended purpose of the SCEM motivate you to use it?

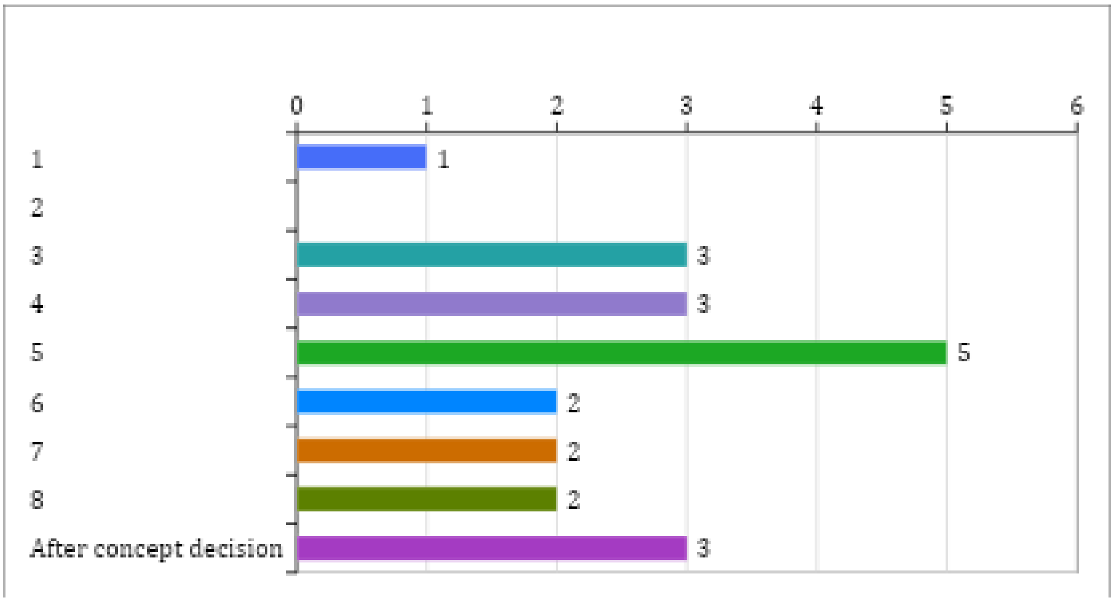


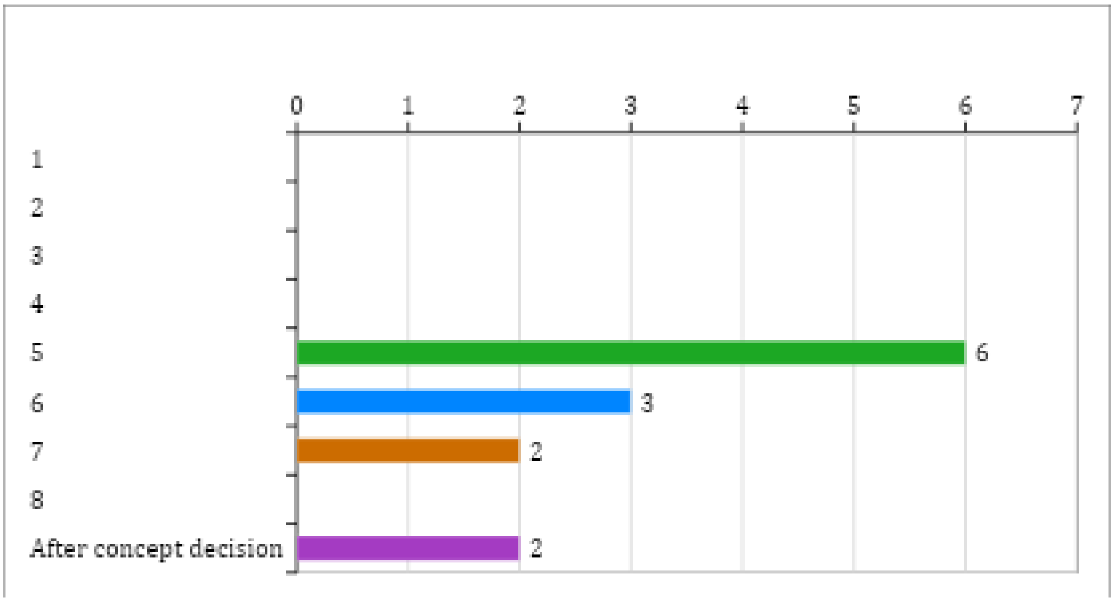
8. How confident are you in using the SCEM?



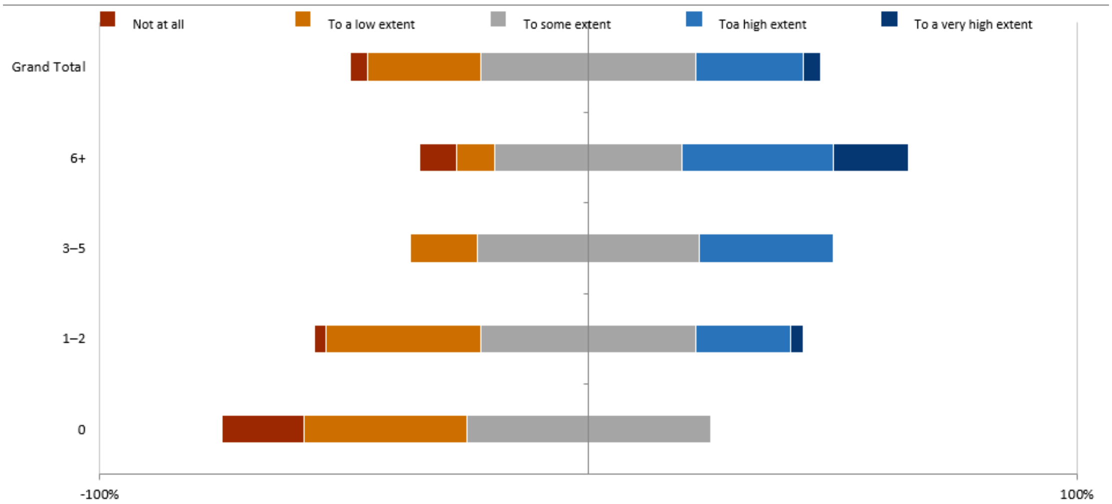
10. Looking at the picture of the Concept development and selection process, where would you say that you first encounter or use the SCEM in a typical project?



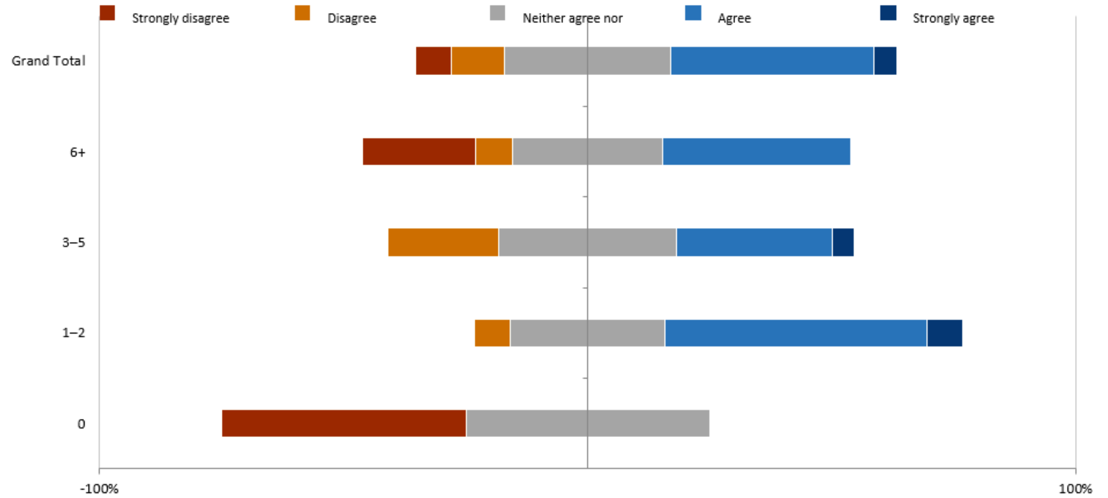




14. To what extent does SCEM fit with how you work when comparing alternative concepts in early development?

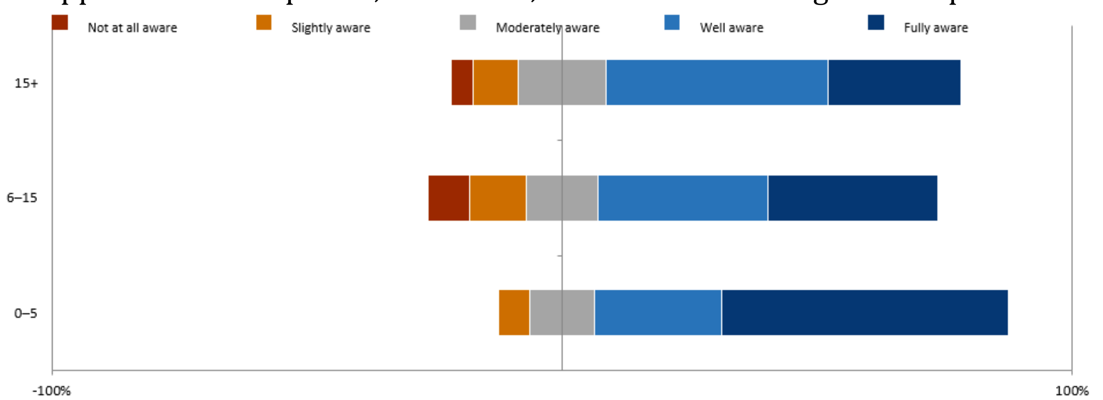


16. Environmental tools such as SCEM are actively supported by project leadership.

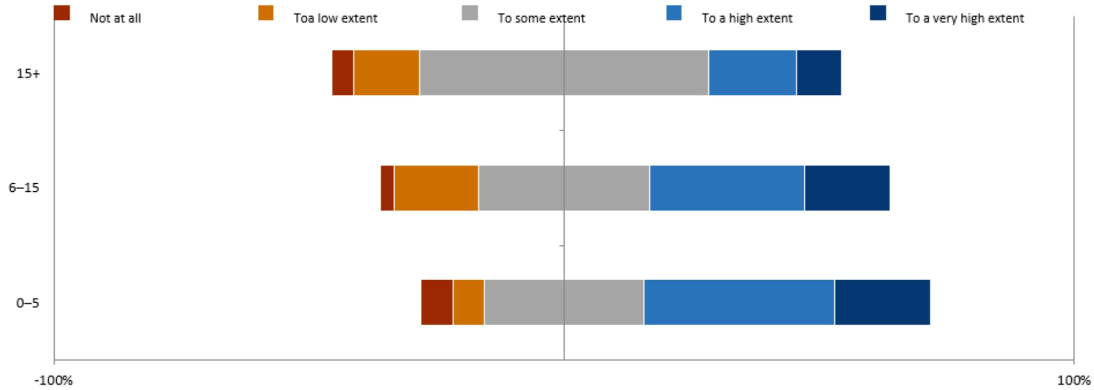


C.2 Experience level among engineers (How many years of experience do you have from working in engineering?)

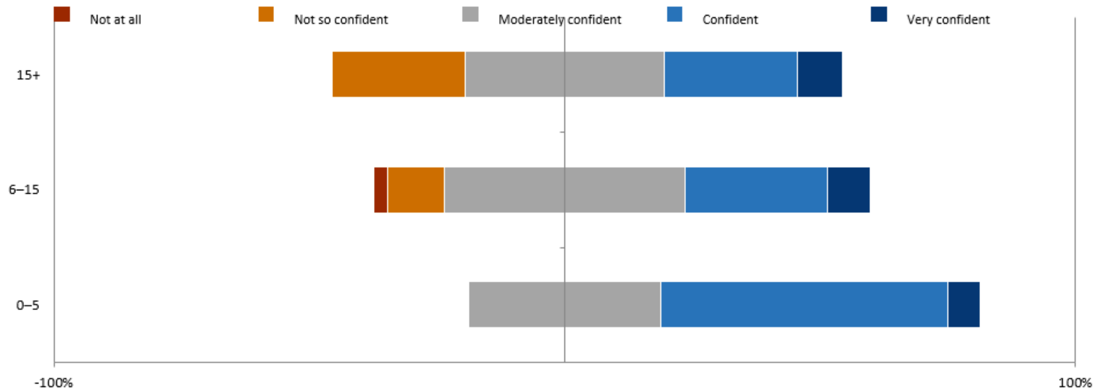
6. Prior to this survey, to what extent were you aware that the SCEM is designed to support the development, evaluation, and decision-making of concepts?



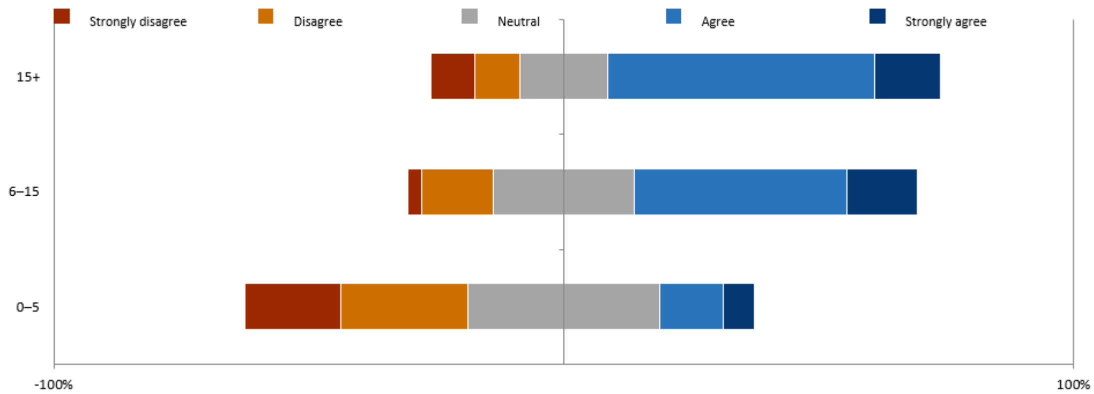
7. To what extent does the intended purpose of the SCEM motivate you to use it?



8. How confident are you in using the SCEM?

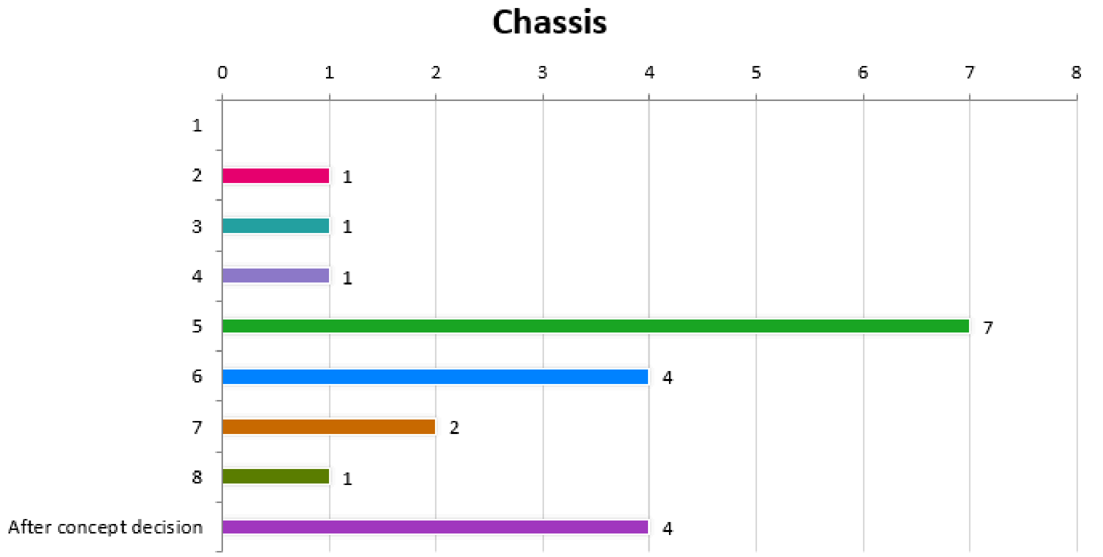


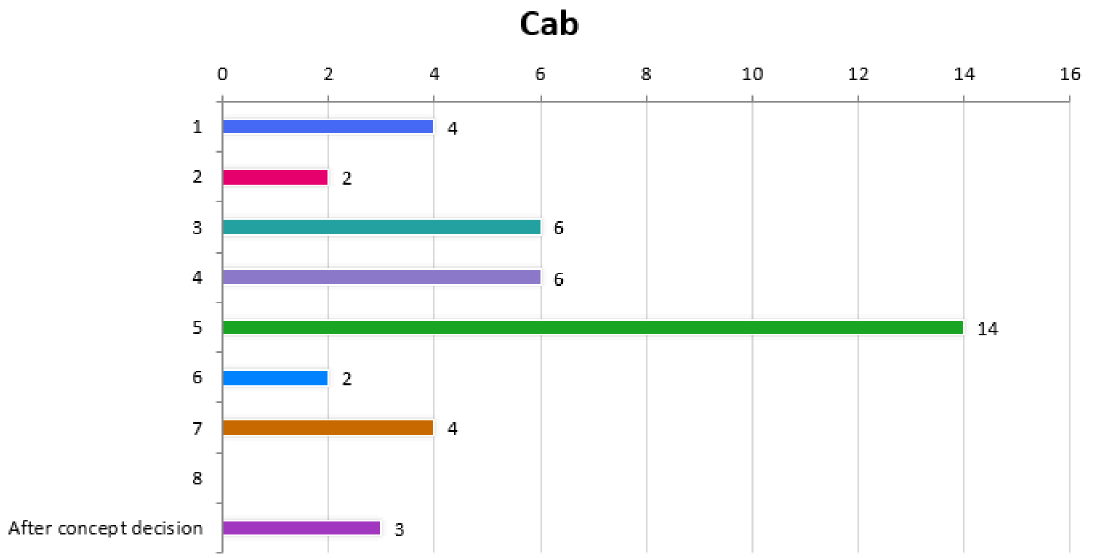
9. In your projects, environmental performance is considered early in concept development.



C.3 Commodity/division that engineers are a part of (Which commodity/division are you a part of?)

10. Looking at the picture of the Concept development and selection process, where would you say that you first encounter or use the SCEM in a typical project?





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