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Utilizing an AI material database for sustainable material selection

A case study within an Automotive company

Master's thesis in Product Development

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Cover: Visualization of AI used for materials selection in automotive industry with Volvo FH truck.

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Abstract

The rising importance of sustainability in the automotive industry has increased the demand for more environmentally conscious decision-making during product development. The materials chosen for a vehicle directly shape its environmental impact, resource efficiency, and sustainability performance across its entire lifecycle. Yet in practice, engineers regularly find themselves working with scattered material information, insufficient sustainable data, tight time constraints, and increasing complexity in evaluating sustainable material alternatives during early-stage product development. While a number of tools and methods have been created over the years to help bring sustainability into engineering workflows, research consistently shows that such tools are often not adopted or used to the extent intended in industrial practice due to challenges related to usability, workflow integration, trust and alignment with engineering needs. This thesis investigates how an AI-enabled Sustainable Material Data Ecosystem (SMDE), developed within an automotive manufacturing context, is perceived and used by engineers in practice, as an industrial case study in collaboration with Volvo Trucks Technology & Industrial Division (TTI).

Empirical data was collected through interviews and user feedback sessions with engineers from different product development domains, and analysed qualitatively to understand what helps and what hinders the practical use of the system within existing workflows. The findings show that the system has genuine potential in terms of enabling more convenient access to material information, helping increase the rate at which alternatives are explored, and being useful for early engineering investigation. However, some issues also emerged during the study, including inconsistent response quality, excessive and irrelevant output, concerns around trusting AI-generated information, and the problem of the system's integration into everyday work along with other existing tools. Overall, results suggest that it is very important to develop AI-based decision support systems specifically according to the industrial needs and workflows of the engineers using it to support successful adoption within product development environments.

Keywords: Sustainable material selection, AI-enabled decision support, Sustainable Material Data Ecosystem, adoption barriers, automotive product development, Retrieval-Augmented Generation.

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This master's thesis was conducted during the spring of 2026 at the Department of Industrial and Materials Science at Chalmers University of Technology. The study was carried out in collaboration with Volvo Group Trucks Technology.

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List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

ASMD	Aerospace Structural Metals Database
AI	Artificial Intelligence
BOM	Bill of Materials
CES	Cambridge Engineering Selector
CMD	Common Material Database
CSD	Corporate Standard Database
DfE	Design for the Environment
EPD	Environmental Product Declaration
GDPR	General Data Protection Regulation
GPT	Generative Pre-trained Transformer
GTT	Group Trucks Technology
LCA	Life Cycle Assessment
LLM	Large Language Model
ML	Machine Learning
MMPDS	Metallic Materials Properties Development and Standardization
PDF	Portable Document Format
RAG	Retrieval-Augmented Generation
RFQ	Request For Quotation
SCEM	Sustainability Criteria Evaluation Matrix
SMDE	Sustainable Material Data Ecosystem
SOC	Substance of Concern
SWOT	Strengths, Weaknesses, Opportunities, Threats
TR	Technical Requirement

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1
Introduction

This chapter presents the background of this research and the need for the master's thesis work to be conducted in the case company. Furthermore, the purpose and aim are described, together with the scope and the intended research questions. Finally, the objectives of this study and a declaration of how AI was used throughout the research process are discussed.

1.1 Background

The world is moving towards sustainability, and every industry is focusing on contributing to global sustainable goals. Among them, the automotive industry is one of the most resource-intensive and environmentally consequential industrial sectors worldwide (Mayyas et al., 2012; Kim and Wallington, 2013). There have been a lot of rapid transformations in the current automotive sector, which are largely driven by regional regulatory pressure, societal expectations, and corporate commitments to sustainability for the global cause. As a result, automotive manufacturers are increasingly looking at how they can reduce this impact at every stage, and material selection has become one of the most important concepts available to them (Mayyas et al., 2012).

Materials play a major role in shaping the overall carbon footprint of vehicles across their life cycles, and the selection of materials impacts the overall contribution of an organisation to their environmental goals. The choice of materials directly influences factors such as vehicle weight, recyclability, energy consumption, durability, and embodied emissions (Mayyas et al., 2012; Ashby, 2013). In response to sustainability demands, many raw material suppliers worldwide are gradually shifting their production processes from traditional to new technologies that are more sustainable. As a result, suppliers continuously introduce advanced and more sustainable materials (Serrano et al., 2021). Although these materials exist in the market, engineers in product development often lack the time, data accessibility, or specialized sustainability expertise needed to evaluate and compare such materials, especially in the early design phase, where critical decisions are made. Further, material-related information is frequently distributed across supplier databases, internal standards, legacy documents, and sustainability reports. As a result, the decision-making process for sustainable material selection in industrial practice can be complex, inconsistent, and highly dependent on individual experience (Mallalieu et al., 2024).

In the past decade, several sustainable design approaches, tools, and digital decision-support systems have been developed to enable sustainability integration into product development processes (Faludi et al., 2020). Although the number of such tools is increasing, previous research shows that the industrial adoption and practical use of such tools are still limited (Vilochani et al., 2024). Several barriers to the effective use of sustainable design methods and tools have been identified in studies. These include poor compatibility with engineering work processes, lack of usability, lack of trust in data, organizational limitations, and lack of integration into existing decision-making processes. Therefore, an understanding of industrial user needs, workflow requirements, and barriers to adoption has become increasingly important in the development of new AI-enabled decision-support systems for engineering applications (Mallalieu et al., 2024).

To address these challenges, a sustainable material data ecosystem(SMDE), which is a sandbox environment enabled by next-generation artificial intelligence (AI) is developed by an automotive company, which serves as the case company for this study. Several raw materials suppliers were collaborated together with other stakeholders in the project to provide more novel sustainability information, improved data quality, and enhanced analytical capability through this ecosystem in order to provide an AI-driven decision support. The ecosystem integrates both structured and unstructured engineering data through a Retrieval-Augmented Generation (RAG)-based artificial intelligence approach, enabling context-specific retrieval of up-to-date material information and AI-supported decision assistance for engineers. The ecosystem aims to allow more informed, sustainability-oriented material selection in product development by integrating supplier sustainability data with internal company knowledge, validation data, and material standards.

1.1.1 Need for the Research

Although the AI-enabled SMDE provides advanced capabilities for retrieving and analyzing sustainability-related material information, the successful integration and adoption of such systems within industrial engineering workflows remains insufficiently understood. Existing research indicates that the usefulness of digital tools and sustainable design techniques depends on their alignment with organizational practices, user expectations, current workflows, and decision-making processes (Mallalieu et al., 2024). In industrial environments, the introduction of new tools and methods is typically accompanied by organizational resistance, workflow adaptation, trust issues, and different levels of user acceptance (Vilochani et al., 2024).

Material selection decisions in the automotive product development process involve a number of stakeholders, engineering disciplines, validation needs, and company specific procedures. Moreover, the selection criteria and decision-making approaches may differ according to the application area, component requirements, project phase, and sustainability targets. Therefore, it is crucial to understand when, how and why engineers might use AI-enabled decision support systems for ensuring practical relevance and long-term adoption in industrial settings (Mallalieu et al., 2024), thus creating a need for this master's thesis to effectively investigate these issues and study the utilization of the AI-enabled SMDE to generate actionable insights into how engineers can be supported in selecting innovative and sustainable materials for automotive components.

The study is conducted as an academic thesis at Chalmers University of Technology during the first half of 2026, under the supervision of the university. The empirical investigation is carried out in collaboration with Volvo Group Trucks Technology (GTT), which serves as the case company and provides access to industrial data and domain experts.

1.1.2 The Case Company

Volvo Group's Volvo Trucks Technology & Industrial Division(TTI) is the global research and engineering division responsible for the development of heavy-duty trucks and related transport technologies. The organization leads activities in product development, advanced engineering, and technology innovation across the Volvo Group's truck brands.

The division is involved throughout the entire product development lifecycle, from concept development and virtual simulations to physical testing, validation, and industrialization. It integrates multiple engineering disciplines, including powertrain systems, vehicle dynamics, materials engineering, and digital technologies, to ensure that products meet performance, safety, and regulatory requirements.

A key focus area of Volvo Trucks Technology is the development of sustainable transport solutions, such as electrification, alternative fuels, and energy-efficient vehicle systems. In addition, the division contributes to advancements in connected and autonomous vehicle technologies, supporting the transition towards safer and more efficient transport systems.

Furthermore, the organization works in close collaboration with suppliers, production units, and other business areas within the Volvo Group to ensure that the developed technologies are scalable, manufacturable, and aligned with market needs.

Given its strong emphasis on innovation, sustainability, and advanced engineering practices, Volvo Trucks Technology provides a highly relevant industrial context for this thesis. The availability of real-world engineering challenges, access to multidisciplinary expertise, and the use of simulation-driven development make it particularly suitable for investigating material selection, performance evaluation, and decision-support approaches in product development.

1.1.3 AI-enabled SMDE

This section describes the AI-enabled material data ecosystem that serves as the proposed solution investigated in this thesis. It provides an overview of the AI-enabled SMDE, the data sources integrated within it, its current capabilities and limitations, forming the necessary context for the evaluation presented in this section. The AI tool evaluated in this study is a RAG system developed as part of a parallel master's thesis at Chalmers University of Technology (Tran and Larsson, 2026). It was built specifically for the AI-enabled SMDE in collaboration with Volvo Group Trucks Technology and AI Sweden.

Unlike a standard large language model, the RAG system does not rely solely on pre-trained knowledge. Instead, it retrieves relevant information in real time from a restricted, domain-specific corpus and grounds its responses in cited source documents. This approach is designed to reduce illusions and improve factual accuracy. A critical requirement in an industrial setting where incorrect material data can have significant engineering consequences. Users interact with the system through a natural language chat interface which supports conversational queries, iterative follow-up questions, and material comparisons while providing source citations alongside each response (Tran and Larsson, 2026).

The RAG tool's knowledge base consists of both structured and unstructured data sources provided by Volvo Group. On the unstructured side, the system indexes internal Corporate Standard Database (CSD, approximately 950 documents) covering material standards, requirements, and specifications, along with external Environmental Product Declarations (EPDs, around 440 documents) and a smaller set of supplier-provided EPDs, primarily in PDF format in both English and Swedish Tran and Larsson (2026).

On the structured side, the tool draws from the internal Common Material Database (CMD), which contains tabular data on physical material properties such as mechanical properties, chemical composition, density, and material identifiers, sourced from supplier data sheets and laboratory tests. A demo dataset of supplier sustainability indicators was also included. Together, these data sources enable the tool to address both technical material queries and sustainability-related questions, reflecting the diverse information needs of the different personas involved in the material selection workflow (Tran and Larsson, 2026). The tool handles queries in both English and Swedish, retrieves information from textual documents (CSDs, EPDs) and structured tabular data (CMD), supports material comparison and alternative material suggestions, and provides source citations with each response for traceability. However, several limitations apply: data coverage is restricted to the sandbox-stage corpus, meaning not all relevant internal and external sources are integrated; the tool operates only on text and tabular data with no support for images, drawings, or figures embedded in documents; occasional illusions have been observed, particularly when relevant data is absent from the knowledge base; and response consistency can vary when sources contain conflicting values or queries are phrased differently.

1.2 Aim

This thesis aims to understand how engineers select materials for automotive components across different stages of the product development process and to investigate how an AI-enabled SMDE can support more practical, informed, and sustainability-driven material decisions, accelerating the integration of sustainable materials within the automotive supply chain, thereby supporting the transition toward sustainable transportation. The study further aims to capture insights from engineers regarding their needs, requirements, and challenges, to identify key barriers and decision-making constraints that influence the adoption of sustainable alternatives, and to evaluate how such an AI-based tool can be integrated into existing workflows to improve the efficiency of sustainable material selection.

1.3 Research Questions

The following overarching research question guides this thesis:

> *How can a sustainable material data ecosystem, supported by next generation AI tools, improve decision-making in the selection of new and more sustainable materials for automotive components?*

To address this, the following sub-questions have been formulated:

1. What processes, workflows, and decision criteria are currently used when selecting materials for different categories of automotive components?
2. Which types of sustainability related data and insights are most critical for material selection in early design phases?
3. At what stages in the engineering and design workflow can a material data ecosystem provide the most valuable decision support?
4. How do engineers perceive the usability, relevance, and reliability of AI based decision-support tools during material selection?
5. What recommendations can be proposed to enhance the integration and practical adoption of AI-enabled decision-support systems within engineering practices?

1.4 Scope

The thesis focuses on early-stage material selection within automotive product development at the case company and how sustainability data and AI-based decision support can assist engineers involved in the material selection process.

This includes:

1. Mapping and documenting current material selection practices.
2. Developing user personas and defining approximately six use cases.

3. Identifying where the material data ecosystem can add value to decision-making.
4. Formulating recommendations for future integration into engineering workflows.

However, there are few delimitations in the scope of this study to maintain focused and feasible outcomes.

1. The study evaluates the AI tool in its current sandbox stage, as developed by a parallel master's thesis; no modifications or improvements to the AI model will be made as part of this study.
2. The research is limited to early-stage material selection within selected departments.
3. The persona development is limited to the design engineers, material experts, buyer and sustainability expert. No other persona regarding supplier or others involved in the material selection workflow are considered.
4. Defining the use cases may not cover all possible scenarios and it is restricted to number of departments which are the CAB US and Chassis Gothenburg of the collaborated company and use cases considered.
5. No physical testing of materials and specific calculations regarding sustainability in the evaluation of the new tool box will be performed.
6. No new sustainability criteria will be developed; only existing criteria from prior studies will be considered.

1.5 Limitations

Despite careful planning, there are certain limitations that may affect the outcomes of the study:

1. The duration of the project limits the number of interviews that can be conducted.
2. The availability and usage of the AI tool are limited, as it is currently in an early sandbox stage and not yet fully accessible across the organization.
3. The availability of data in the AI tool is also limited to certain sources from suppliers and company's internal material management documents.
4. Further, data regarding sustainability, new material performance from testing, and other additional sources are currently being structured for integration into the AI tool.

1.6 Ethical Considerations and AI Usage

All participants were informed about the purpose and the objective of the study prior to the interviews. Participation in this study was voluntary. Both the thesis students signed a confidentiality agreement regarding the protection of data within Volvo Group. To ensure confidentiality, no personally identifiable information was included in the thesis report.

The information gathered from interviews was anonymized, and participants were referred to only by their professional roles rather than by name. Before each interview, participants were asked for their consent to record the interview for transcription purposes, if required.

All collected data, including recordings and transcripts, were stored securely and accessed only by the researchers involved in the project. Any information that could reveal sensitive company knowledge or internal processes was treated confidentially and was not disclosed in the final thesis. Personas and use cases developed during the study were based on aggregated insights from multiple participants and did not represent any specific individual.

The handling and storage of personal data followed the principles outlined in the General Data Protection Regulation (GDPR) to ensure that participants' information was processed responsibly and securely. Final reports and any documents submitted were reviewed in consultation with supervisors at both Volvo Group and Chalmers University of Technology to ensure that no confidential information was disclosed.

2
Frame of Reference

This chapter focuses on presenting the gathered theoretical knowledge relevant for the study from various literature studies on product development and its embedded material selection processes; Existing material databases used for engineering, sustainability considerations in material selections in the industries and the influence of AI in them. Additionally, limitations and barriers in implementing a new design method or decision-making tool in the organizations are described to understand the research gaps.

2.1 Product Development Process

Product development is the broad process through which organisations transform an identified need into a market-ready product, encompassing everything from understanding customer requirements to concept generation, detailed design, manufacturing, and launch. Ulrich and Eppinger (2016) describe it as a sequence of activities involving technical, managerial, and commercial decisions that must be made in an integrated and often iterative manner. Within this, the design process forms the technical core, moving progressively through concept development, system-level design, detail design, and testing and refinement. Decisions made in the early stages, particularly during concept development, tend to lock in a significant proportion of the product's final cost and performance, making early-stage decision quality critically important (Ulrich and Eppinger, 2016). Given this complexity, the product development process does not rely on intuition alone, it draws on a range of structured design research methods to support decision-making, problem-solving, and innovation at each stage.

2.2 Design Research Methods

Design research methods are systematic approaches developed to support designers and engineers throughout the product development process. These methods aim to improve problem-solving, decision-making, communication, and innovation during product development activities. Jagtap et al. (2014) defines design methods as identifiable ways of working intended to improve one or more aspects of product development, including procedures, techniques, guidelines, and tools.

The emergence of design methodologies during the 1960s introduced more systematic and formalized approaches to product development. Early design methodologies focused mainly on engineering-oriented problem solving and structured procedural models. Over time, the increasing complexity of products, systems, and societal challenges expanded the scope of design methodologies beyond purely technical aspects. Gericke et al. (2021) explain that modern product development has become increasingly transdisciplinary, requiring collaboration across multiple disciplines and integration of diverse tools, techniques, and methods.

Design thinking evolved from these developments and represents a broader approach to innovation and problem solving. According to Cross (2023), the meaning of design thinking shifted from traditional design intentions toward understanding how designers think, work, and solve complex problems. Design thinking increasingly emphasized creativity, iterative development, user-centered approaches, collaboration, and systems thinking. It later expanded into fields such as business, management, and social innovation, where design-oriented approaches became important for addressing complex and uncertain challenges.

Design thinking did not remain confined to technical problem solving or business innovation alone. As societal and environmental challenges grew more complex, it gradually expanded to address broader concerns including sustainability and circular economy thinking. As product development increasingly involves environmental, social, and economic considerations, design methods have expanded to support life-cycle thinking and sustainable innovation. Carlsson et al. (2021) explain that modern design approaches must consider users, business requirements, and resource efficiency simultaneously when determining optimal product lifetimes. This demonstrates how design methodologies have evolved from focusing primarily on technical performance toward addressing broader system-level sustainability goals.

Design methods are also increasingly viewed as dynamic rather than static solutions. Lavrsen et al. (2022) describe design methods as evolving throughout a lifecycle involving development, dissemination, adaptation, use, and evaluation. This perspective highlights the importance of continuously adapting methods to changing organizational contexts, technological developments, and user needs. One area where this adaptability is particularly relevant is material selection—a decision that sits at the intersection of technical performance, cost, and sustainability, and one that increasingly demands structured, data-driven approaches to navigate effectively.

2.3 Material Selection in Design

Material selection is a decision that sits quietly inside the design process with impact that influences across multiple stages. Materials play an important and fundamental role in shaping the performance, functionality, and overall character of any product. The choice of materials and its selection process is not only technical, but is a multidisciplinary process that directly influences the characteristics of a product, synthesizing its functionality, usability, and personality. This reflects how materials impact design expressions and user experience which is beyond physical properties of the materials (Ashby, 2004).

Industries consider the material selection process critical because it affects their key product attributes such as strength, durability, weight, cost, and environmental impact, while an inappropriate choice may lead to product failure, increased cost, inefficiencies in product and affects over all customer's satisfaction. These are not limited to a single sector but are relevant across industries including automotive, consumer goods, aerospace and other manufacturing industries more broadly (Ashby, 2011; Farag, 2013).

Moreover, material selection becomes a strategic decision-making process that significantly influences manufacturability and sustainability. Further, requires careful evaluation of multiple criteria, balancing technical requirements, economic constrains, and environmental considerations to ensure that the final product meets both functional and non-functional requirements effectively. As Ulrich and Eppinger (2016) highlights, material and process selection decisions are inherently linked to the larger design decisions being made at each stage and cannot be isolated. Even a preliminary material choice made during concept development can quietly constrain what remains technically and economically feasible in later phases, making early-stage material decisions particularly consequential.

2.3.1 Material Selection Methods in Engineering

Material selection in engineering design is a structured decision-making process aimed at identifying the most suitable material that satisfies functional requirements while optimizing performance objectives. According to Ashby (2013), this process follows a systematic strategy based on constraints, objectives, and supporting data, rather than trial-and-error approaches.

The selection process begins with data gathering, where material properties and process characteristics are compiled into a database. This is followed by defining design requirements, which are expressed as constraints (non-negotiable conditions) and objectives (criteria to be minimized or maximized). Materials that meet the constraints are considered candidates, and these are then ranked based on the defined objectives. Finally, the most promising candidates are validated through detailed documentation and analysis (Ashby, 2013). Ashby formalizes this into four fundamental steps:

1. **Translation** – converting design requirements into material properties, constraints, and objectives.
2. **Screening** – eliminating materials that fail to meet constraints.
3. **Ranking** – ordering candidates using performance indices.
4. **Documentation** – evaluating shortlisted materials in detail (Ashby, 2013).

This structured methodology ensures that material selection is aligned with engineering performance requirements rather than subjective judgement.

Material selection methods can be broadly divided into screening methods and ranking (decision-making) methods, reflecting the two core stages of narrowing down and optimizing material choice. Screening reduces a large material database to a manageable subset by eliminating unsuitable candidates. Key methods include:

1. **Cost per unit property method**: evaluates materials based on cost relative to a critical property, enabling early elimination of economically unfeasible options (Jahan et al., 2010).
2. **Ashby chart method**: uses material property charts (e.g., modulus vs. density) to visually identify feasible material regions and support initial selection (Jahan et al., 2010).
3. **Questionnaire method**: applies structured questions addressing technical, environmental, and economic requirements to filter materials (Jahan et al., 2010)

Across these approaches, screening is consistently identified as a fundamental step, narrowing alternatives before detailed evaluation (Jahan et al., 2010).

Material selection in the automotive industry follows the same fundamental principles but is strongly driven by performance, cost, and increasingly environmental considerations. Automotive design problems typically involve multiple constraints, such as strength, stiffness, manufacturability, and durability, alongside objectives such as minimizing mass, cost, and environmental impact. Within the Ashby framework, these requirements are translated into material indices that guide selection. For example, minimizing vehicle mass—a critical objective for fuel efficiency—is achieved by selecting materials with favorable combinations of density and mechanical properties (Ashby, 2012).

A key characteristic of automotive material selection is material substitution, particularly in the context of lightweight design. For instance, replacing steel with aluminium reduces density but requires compensatory design changes due to differences in stiffness and strength. Ashby demonstrates that such substitutions must consider scaling laws and performance indices to maintain functional equivalence, highlighting that weight reduction is not proportional to density alone (Ashby, 2012).

Additionally, automotive applications increasingly integrate environmental objectives into material selection. Objectives such as minimizing embodied energy, carbon footprint, and resource consumption are incorporated alongside traditional performance metrics. This reflects a shift toward design for the environment (DfE), where material choice is evaluated over the entire lifecycle of the vehicle (Ashby, 2012).

2.3.2 Existing Material Databases and Tools

Material selection in engineering design relies on reliable material property data. Material databases support this process by providing searchable information such as mechanical properties, density, thermal conductivity, and environmental impact. According to Rumor and Andrade-Campos (2022), these databases reduce the need for repeated experimental testing by storing previously verified data . As the range of engineering materials continues to expand, material databases have become increasingly important for systematic and sustainable material selection.

Several general-purpose material databases are widely used in engineering practice. One of the most well-known is MatWeb, a free online database that contains property data for a broad range of materials including metals, polymers, ceramics, and composites. MatWeb allows users to search for materials based on specific property values and also provides links to material suppliers and manufacturers, making it useful both for research and for practical design decisions (Rumor and Andrade-Campos, 2022). Another widely used tool is the Ansys Granta Selector(Ansys, 2021), formerly known as the Cambridge Engineering Selector (CES), which was developed based on the material selection framework introduced by Ashby and Cebon (1993). Granta Selector includes the Material Universe dataset, which contains technical, economic, and environmental data for thousands of engineering materials, and allows users to generate Ashby-style property charts for visual comparison and screening (Ansys, 2021). Total Materia is another commercial database that provides access to over 570,000 materials and more than 25 million property records, covering both metallic and non-metallic materials. It also includes features for sustainability assessment and machine learning-based property prediction, which makes it relevant to more modern approaches to material selection (Total Materia, 2024).

Beyond general-purpose databases, specialized databases are also developed for specific industries and applications. The ASM Handbook series by ASM International is a major reference source in materials engineering. In particular, ASM Handbook Volume 20 focuses on materials selection methods, tools, and information used in engineering design (ASM International, 1997). The Metallic Materials Properties Development and Standardization handbook (MMPDS) is widely used in the aerospace and automotive sectors. It provides statistically derived design allowable data for metallic alloys and is considered a standard reference for structural design (MMPDS, 2022). Similarly, the CINDAS Aerospace Structural Metals Database (ASMD) contains critically evaluated thermal, mechanical, and physical property data for aerospace structural materials (CINDAS LLC, 2022). These specialized databases are important because their data is thoroughly reviewed and validated, making them reliable for safety-critical engineering design decisions.

Despite the wide availability of these tools, important limitations remain. Rumor and Andrade-Campos (2022) found that most databases do not include information on the experimental procedures used to collect the data, making it difficult for users to verify its accuracy. Data needed for finite element simulations, such as constitutive model parameters, is also largely absent (Coudert, 2019). Further highlighted the lack of standardisation across databases, which makes combining data from different sources challenging. These gaps are particularly relevant in sustainable material selection, where environmental data needs to be presented alongside mechanical and economic properties in a consistent format. The development of AI-assisted databases that can predict material properties and integrate sustainability metrics represents a promising direction for addressing these limitations and forms the basis of the approach explored in this study.

2.3.3 Sustainability in Material Selection

Environmental concerns, stricter regulations, and a shift in industry priorities toward reducing carbon footprints have made sustainability an increasingly important factor in material selection in recent years. Materials are closely linked to the environmental impact of a product, as they influence energy consumption, emissions, resource use and end-of-life treatment (Holloway, 1998). Therefore, the selection of suitable materials is not only limited to performance and, cost but should also consider their sustainability throughout the entire lifecycle.

One of the key ways to attain sustainability through material selection is by beginning at the source of raw materials by reducing their environmental impact. This involves the utilization of low-carbon raw materials such as green steel produced using Green Hydrogen instead of fossil fuels which reduces CO_2 emissions during production significantly (Pauliuk et al., 2013). Similarly, recycled materials, such as secondary aluminum and steel from scraps reduce energy consumption and the extraction of virgin materials. In addition, the growing popularity of bio-based materials, which are produced from renewable resources such as jute fibers etc, further contributes to the shift of more sustainable material systems (Joshi et al., 2004).

Recent advances in material science have resulted in lightweight, high-performance and environmentally friendly materials. These developments enable industries to improve energy efficiency in the application phase, such as implementing a light weight material in transportation reduces fuel consumptions and emissions(Luk et al., 2015). In addition, the new technologies in processing and material formulations are making it possible to achieve required mechanical and functional properties while minimizing environmental impact.

Besides such developments, policy initiatives and regulatory frameworks are also driving the shift towards sustainable materials. Governments and international bodies are setting more stricter emission standards, circular economy policies and sustainability goals that are encouraging businesses to adopt greener options (Geissdoerfer et al., 2017). Consequently, companies are increasingly factoring in sustainability metrics like carbon footprint, recyclability and resource efficiency into their material selection processes.

Furthermore, sustainability in material selection in modern engineering design is not only considering how materials are sourced and produced, but it is closely connected to life-cycle thinking such as design for recyclability and circular material flows, where it includes how they perform during, use and how they can be reused, recycled or disposed of at the end of a product's life

2.3.4 AI in Material Selection

Artificial Intelligence (AI) has been gradually integrated into modern engineering design, providing capabilities well beyond traditional computational tools. AI is a collection of techniques that include machine learning (ML), deep learning, and natural language processing that allow systems to identify patterns, make predictions, and support complex decision processes from large amounts of data (Russell and Norvig, 2021). These approaches have been rapidly adopted in materials science and engineering over the last decade, driven by the maturation of ML algorithms and the increasing availability of curated materials databases. We have transitioned from rule-based expert systems to deep learning architectures capable of predicting material properties at the atomic level and even designing new material compositions (Ramprasad et al., 2017). Systematic reviews of data-driven methods throughout the product development lifecycle confirm that ML-based approaches now dominate practice, with deep learning showing a clear upward trend throughout design and implementation stages (Söderberg et al., 2024).

The recent developments in automotive sector clearly demonstrates that how seriously the organizations are investing in AI related projects to understand its practical potential. Driven by the strict emissions requirements, the need for electrification, and increasing international competition, the auto industry has invested heavily in incorporating AI into their research and development processes. According to a recent study conducted by McKinsey in 2024, 75 percent of automotive firms were testing generative AI solutions, while product design and material optimization were cited as some of the key areas being tested by firms, with more than 40 percent allocating up to €5 million to generative AI R&D (Olefir, 2024).

AI addresses a number of fundamental constraints of traditional methods in material selection. Traditional methods, such as Ashby material selection charts and multi-criteria decision analysis tools, are well established, but are largely static and depend on fixed databases and predefined weighting criteria that are difficult to adapt dynamically (Ashby, 2011). On the other hand, AI-driven frameworks can handle extensive and diverse sets of information ranging from mechanical characteristics to environmental impact assessments, costs, and regulation, and derive optimized material selections that cannot be discovered manually. As Ismaeel et al. (2026) have demonstrated, an AI-enabled lifecycle model will be able to accommodate conflicting selection criteria such as energy efficiency and sustainability metrics into an automated ranking system based on certification standards.

Further, in product development, the value of applying AI in selecting materials lies in its ability to handle the multi-constraint nature of real design problems, where performance, cost, weight, sustainability, and manufacturing considerations need to be optimized at once. Under such circumstances, engineers often find it difficult to locate enough material data for their purposes, especially when they include sustainability concerns which adds an additional layer of complexity (Söderberg et al., 2024). However, with AI tools, it is possible to mitigate this problem by training systems using historical design data, detecting conflicts early in the development process, and reducing the need for expert intuition for decisions that may actually be more informed through data. Although there have been several innovations in recent years, the problem of poor data quality, issues with model interpretability, and the lack of representation of sustainability criteria in existing AI models remain significant gaps that further motives the need and development of an AI enabled material data ecosystem as explored in this thesis.

2.4 Implementation of New Tools and Methods

The implementation of new digital tools and methods in product development is associated with both technical and organizational challenges. As companies increasingly adopt tools related to sustainability assessment, life cycle analysis, artificial intelligence, and decision support systems, there is a growing need to integrate these tools into already established engineering workflows and development environments. However, introducing a new method is rarely only a technical activity. It also involves changes in how people work, communicate, and make decisions during product development.

One major challenge concerns integration with existing systems and processes. Product development activities are often supported by interconnected software platforms, databases, and engineering procedures that have developed over long periods of time. Introducing new tools may therefore require changes to data structures, workflows, and communication between departments. Gericke et al. (2021) explain that many methods fail because they do not fit effectively within the broader "method ecosystem" already present inside organizations. As a result, tools that function well in theory may become difficult to apply in practical industrial settings.

Another important issue is complexity and usability. Many methods require specialized knowledge, extensive data input, or significant training before they can be used effectively. If tools are perceived as overly complicated, time-consuming, or disconnected from daily engineering activities, employees may avoid using them or use them only partially. This becomes particularly challenging in fast-paced product development environments where teams operate under strict cost, time, and performance pressures.

The implementation of new methods also depends heavily on organizational conditions. Different engineering disciplines often follow different practices, priorities, and development approaches.

Mechanical, electrical, software, and sustainability teams may all use different procedures for validation, documentation, and data management. Because of this, implementation cannot usually follow a standardized “plug-and-play” approach. Instead, methods often need to be adapted to fit the existing organizational structure and working practices.

Organizational and human factors further influence implementation success. Boks (2006) describes these challenges as the “soft side of ecodesign,” referring to issues such as resistance to change, communication problems, lack of cooperation between departments, and insufficient management support. These challenges can significantly reduce long-term adoption even when technically effective tools are available. In many cases, implementation problems arise not because the technology itself is inadequate, but because the tool does not align with how employees already work in practice.

Literature also highlights the importance of contextual adaptation and organizational learning in the implementation of design methods. Mallalieu et al. (2024) explains that sustainability-related implementation is rarely straightforward, as organizations require not only technical tools but also a shared understanding and competencies related to sustainable development. The authors emphasize that companies often prioritize technical solutions while underestimating the organizational and behavioral changes necessary to support long-term sustainable transformation. Similarly, Lavrsen et al. (2022) describe design methods as evolving systems that develop through adaptation, application, and organizational learning rather than functioning as fixed procedural tools.

Overall, the literature shows that successful implementation depends not only on the technical quality of tools and methods but also on how well they align with organizational processes, employee competencies, communication structures, and existing ways of working.

3

Methodology

This chapter outlines the research methodology adopted to address the key challenges identified in the literature and to achieve the objectives of this thesis. The sections that follow present a structured account of the research approach to ensure that all research questions are effectively addressed, covering how data were collected, the analytical methods applied to process and interpret those data, and the reasoning behind the chosen strategies. In addition, this chapter outlines how the outcomes of the research and data collection are represented and communicated through formats that are relevant and meaningful to the scope of the work, including a requirements list, process mapping, and the identification and evaluation of decision support strategies.

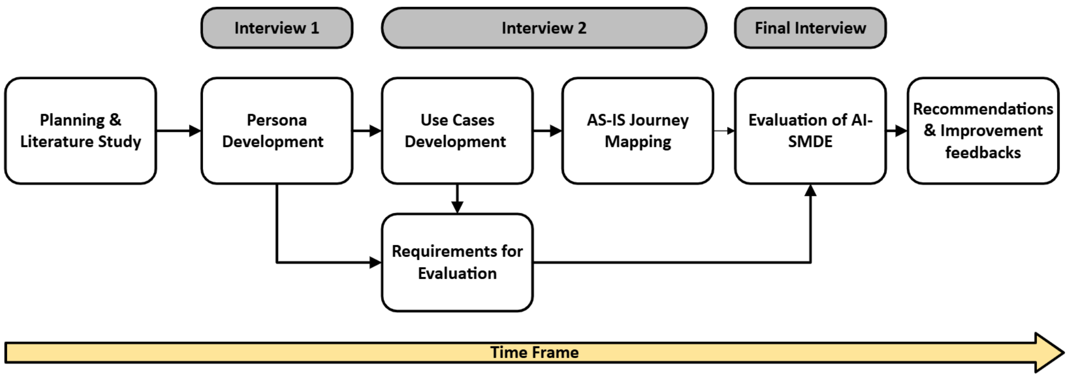

Figure 3.1: Research Methodology

3.1 Research Approach

The research presented in this thesis follows an exploratory, qualitative, and action research approach, deliberately chosen to reflect the nature of the problem being investigated — the introduction and evaluation of a new AI tool within a real organizational context. As discussed in the literature study in chapter 2, there are clear gaps not only in how AI is currently applied to material selection, but also in understanding how engineers actually experience and perceive such tools when they are introduced into a real working environment. Closing those gaps required more than reviewing what already exists in theory; it required going directly into the organization and working closely with the people involved.

An exploratory research methodology was selected because of the nature of the core topic of study, which is the real-world use of a new AI-driven technology tool and its effectiveness and value perception by the engineers in a live engineering firm (Saunders et al., 2019). Rather than measuring outcomes against known benchmarks, the aim was to explore how the tool performs in practice and how engineers experience it.

A qualitative approach was adopted to enable the depth of understanding this required. No surveys or large-scale statistical instruments were deployed; instead, the research engaged with engineers drawn from multiple competencies, experience levels, and locations within the organization, ensuring broad coverage of the material selection workflow without sacrificing the depth that a quantitative approach would have compromised (Bryman, 2016).

What made this study particularly different from a conventional research project was the way the engagement with engineers was structured. Rather than studying the organization from the external position or simply collecting data from it once, the research followed an action research approach, meaning the researcher was actively involved with the engineers throughout, returning to them repeatedly across different stages of the work (Reason and Bradbury, 2008). This also acts as a thread between both exploratory and qualitative methods. This unfolded in three phases: in-depth interviews for persona development, followed by journey mapping and use case development, and finally the evaluation of the AI-enabled SMDE. At each stage, insights obtained from each interview contributed towards the development of ideas for the following interview, creating a genuine iterative dynamic between the researcher and the engineering community that is well-suited to studying how a new tool intervention is understood and experienced in a live organizational setting.

With the research approach established, the next step was determining how data would actually be collected to support each phase of the study. Given the qualitative and action research nature of this work, the data collection methods needed to be interactive, flexible, and capable of capturing the kind of rich, contextual information that engineers carry with them from years of working within the organisation. The following section outlines the specific methods used at each stage of the research, and the reasoning behind choosing them.

3.2 Data Collection

Following the research approach described in the previous section, interviews were adopted as one of the main data collection methods in this study. Interviews are especially appropriate for qualitative and action research as they allow researchers to collect rich and contextualized data directly from participants. Ulrich and Eppinger (2016) talks about understanding the needs of the stakeholders and how to get them. It mentions that to get a good understanding of the needs, you have to interact closely with the people involved in the process because a lot of important information comes through discussion and experience, and not just from documentation. Hence, semi-structured interviews were considered an appropriate method for exploring current practices, challenges, and needs related to sustainable material selection within the organization.

The data collection was carried out in three phases which is illustrated in Figure 3.1. The first step was a 30-minute introductory meeting with groups of engineers and stakeholders from different departments to explain the scope of the research and establish a common understanding of the study. These were followed by individual semi-structured interviews lasting approximately one hour. They were more interactive and conversational in nature to support the development of personas. A second round of one-hour interviews was conducted later to collect information for developing the use cases. A final session was held to evaluate and validate the developed use cases.

The sampling frame for the thesis consisted of engineers and experts from diverse departments within two separate Volvo Trucks Technology premises. The participants were selected based on their involvement in diverse processes related to product development and material selection. A summary of the interview participants, including their roles, locations, and years of experience, is presented in Table 4.1. Some interviews were conducted at the Lundby CampX office of Volvo Trucks Technology, while most sessions were carried out online through Microsoft Teams, depending on participant availability and location.

In line with GDPR, participants were informed of the purpose of the study before each interview and asked for permission to record the session. Interviews generally started with general questions about the participants' roles and responsibilities, and then moved on to more specific and task-related questions related to the research objectives. The sessions were recorded on Microsoft Teams and then analyzed as raw qualitative data. The following section presents the method used for analyzing the collected data.

3.3 Data Analysis

After the interviews were conducted, the raw data collected was transcribed and reviewed, and analyzed to identify recurring themes, user needs, challenges, and workflow patterns in relation to material selection. Qualitative research analysis process is important not only for the interpretation of the collected information but also for the communication and representation of the findings in a structured and understandable way. As discussed in (Ulrich and Eppinger, 2016), different methods and tools can be used for communicating user needs and requirements.

In this research, personas were used for representing user characteristics, while use cases were used for describing processes and workflows as shown in Figure 3.1. The following sections describe the development and application of the personas and use cases used in this study.

3.3.1 Persona Development

Personas are fictional yet research-grounded representations of user archetypes, constructed from real data gathered through interviews and observations, and used to communicate the needs, behaviours, and goals of different user groups in a meaningful and human way (Cooper et al., 2014). In the context of this thesis, personas were developed not to represent a single type of user but to capture the diversity of engineers and stakeholders involved in material selection across the organization. Since material selection is not confined to one department or one type of expertise, it was important to reflect that variety and personas provided a structured way to do so.

Each persona was developed with a consistent set of attributes collected during the interview phase. This includes basic demographic information such as role, department, years of experience, and location within the organization, as well as the tools and systems that the individual currently uses in their day-to-day work. Beyond surface-level details, each persona describes how the individual's material selection workflow functions as part of their department or product, the challenges they encounter along the way, the needs they voiced, and the role of sustainability in their material selection. Additionally, each persona included a direct quote from the interview that captures how that person feels about sustainable material selection in their own words.

The personas together provide a cross-sectional representation of the organization, considering the differences in competencies, experience, and work environment, in order to create a complete picture of the decision-making process for material selection from the perspective of various departments within the company, instead of a single department. The detailed findings and insights drawn from each persona are presented and discussed in section 4.1.

3.3.2 Use case development

A use case is commonly described as an interaction of a user with a system to perform a specific goal, capturing the sequence of actions and the context of that interaction (Jacobson et al., 1992). In the context of this thesis, use cases were adapted to represent real scenarios that engineers encounter in their material selection workflow — situations where they need to find information, evaluate alternatives, or make a decision related to a specific material or component. This could range from identifying a more sustainable alternative for an existing part, to finding a material that meets a particular set of functional and environmental requirements for a new application.

The use cases developed in this study were constructed during the second round of interviews with the engineers, building directly on the insights gathered during the persona development phase. Each use case was structured around a consistent framework: the component or part in question and its function, the specific situation the engineer is facing, the information need driving that situation, and the requirements that any solution must satisfy, including design constraints, sustainability criteria, and other relevant considerations. With this, a set of targeted questions were developed for each use case around the things the engineer would want to know or find out in that use case. This extra layer had two purposes: it gave the engineer a guided starting point when interacting with the AI tool, and it provided a structured basis for evaluating the tool's performance, which is further elaborated in section 4.2.

3.4 Requirements List

Following the completion of the two rounds of interviews and the subsequent data analysis through personas and use cases, the next step was to systematically consolidate all identified needs into a structured requirements list as illustrated in Appendix B. The above-mentioned needs are divided into two broad categories: primary needs, reflecting the challenges, bottlenecks, and gaps that engineers actively experience in their current material selection process; and latent needs, which refer to the potential benefits or features that the organization should ideally have but does not necessarily require the engineers to request. Apart from the above-mentioned needs, another important aspect was the informational needs of engineers, specifically, what data, context, and guidance they require to confidently select and implement a sustainable material for a given component or application.

The requirements were organized into two separate lists, each serving a different evaluative purpose. The first is a general requirements list structured around engineer persona types—covering roles such as the Design Engineer, Material Expert, Buyer, Sustainability Leader, and Simulation Engineer—capturing the distinct needs of each, as well as the needs commonly shared across all of them. This list provides a broad picture of what the AI-enabled SMDE would need to address to be genuinely useful across the organization, which is further discussed in detail in section 4.3. The second set of needs addresses the specific use cases. It details the needs of each particular use case and the person who is responsible for fulfilling these needs. They describe what is expected to be accomplished and what the AI data environment should provide to satisfy these expectations. These two sets of needs together serve as the basis for conducting the evaluation of the AI tool in a structured and traceable manner. This approach makes sure the evaluation is based on actual needs rather than general assumptions which is represented in detail in chapter 6.

3.5 Process Mapping and Decision Support Identification

One of the central objectives of this thesis is to identify where and how a material data ecosystem can most effectively support decision-making in the selection of new and sustainable materials. This directly addresses the research questions guiding the study—particularly the need to understand what processes and workflows currently govern material selection, what decision criteria are applied at different stages, and at which points in the engineering design process, an AI-enabled SMDE can add the most meaningful value to address the research questions 2, 3 and 4. Answering these questions required more than just collecting opinions from engineers; it required a structured way of visualizing and analyzing how work actually flows from start to finish within their roles.

To achieve this, AS-IS journey mapping was used as the primary process mapping method. An AS-IS journey map is a visual representation of the current state of a user's experience, capturing the sequential steps, actions, and pain points a person goes through when completing a task in their existing environment (Kalbach, 2016). In this study, it provided a structured way to trace how engineers from different departments navigate the material selection process step by step, making it possible to see precisely where information gaps arise, where decisions stall, and where an AI-enabled SMDE could intervene most usefully, as mentioned in Figure 3.1 after the use case development.

The journey maps were built on the data gathered across both rounds of interviews and the insights already embedded in the personas and use cases, ensuring that the steps and decision points captured reflect what actually happens in practice. By mapping the current workflow for each engineer persona involved, it became possible to identify the stages where data availability, sustainability considerations, and decision confidence are most lacking. The detailed journey maps and the insights derived from them are presented in chapter 5.

3.6 Evaluation Strategies

With the data collection, persona development, use case creation, requirements listing, and AS-IS journey mapping all completed, the research reached the point where the AI-enabled material data ecosystem needed to be put to the test. The goal here was straightforward but important to empirically evaluate how the tool actually performs in practice, whether it genuinely satisfies the needs and requirements identified through the earlier phases, and whether it can meaningfully support the decision points surfaced through the journey mapping process. This directly serves the thesis objective of empirically evaluating the AI-enabled SMDE, assessing its usability and perceived value, understanding how it changes or improves decision-making, and identifying opportunities for improvement in both the tool itself and how it is used, as mentioned in research question 5.

For this purpose, another round of interviews was performed with the engineers as final interviews, who had worked in the process of development of use cases as illustrated in the Figure 3.1. In contrast to the previous phase of the assessment process, which included interviewing the engineers about their usage of the tool randomly and freely, here the use cases and requirements were used as the background for evaluating the tool and its relevance to the actual workflow of engineers. This way, the process became more structured, and its outcomes were more relevant since they were tied up to particular stages of work and needs of engineers. The criteria of evaluation and the way the AI tool was evaluated are described in the following subsection.

3.6.1 Evaluation Dimensions and Criteria

To evaluate the AI-enabled SMDE in a structured and meaningful way, the assessment was organized around five core dimensions: usability, output quality, perceived value, data trustworthiness, and efficiency impact, with an additional focus on user perception and adoption potential. These dimensions were chosen together to provide a holistic view of how the tool performs not only technically but how the engineers actually experience it and interact with it in a real decision-making context.

As shown in Table 3.1, each dimension is broken down into specific criteria. Usability covers understandability, learnability, interaction effort, interface quality, and response performance. Output quality looks at accuracy, reliability, transparency, logical soundness, relevance, and completeness. Perceived value captures decision confidence, actionability, insight generation, risk awareness, and comparison capability. Efficiency impact addresses time saving and decision speed, while data trustworthiness and adoption potential reflect how much engineers trust the tool and how willing they would be to use it regularly.

Table 3.1: Final Evaluation Framework

Dimension	Criterion	Description
Usability	Understandability	Clarity of outputs, terminology, and logic
	Learnability	Ease of getting started without prior training
	Interaction Effort	Effort required to input data and iterate
	Interface & Visualization	Quality of layout and visual outputs
	Response Performance	Speed and system stability
Output Quality	Accuracy	Technical correctness of results
	Reliability	Consistency across runs and scenarios
	Transparency	Visibility of assumptions and data sources
	Logical Soundness	Structured and rational outputs
	Relevance	Fit to the engineering problem
	Completeness	Sufficiency for decision-making
Perceived Value	Decision Confidence	Improves trust in decisions
	Actionability	Enables direct decisions or next steps
	Insight Generation	Provides new or non-obvious insights
	Comparison Capability	Supports evaluation of alternatives
	Risk Awareness	Highlights uncertainties and assumptions
Data Trustworthiness	Data Granularity	Specific vs generic data
	Data Timeliness	Up-to-date vs outdated data
Efficiency Impact	Time Savings	Reduces time to perform analysis
	Effort Reduction	Reduces manual work
	Decision Speed	Speeds up decision-making

The evaluation was conducted through a combination of methods. In the final round of interviews, engineers worked with the AI-enabled SMDE by using the use cases developed in the previous phases, and their experience was captured through direct observation and guided questions relating to the above criteria. In addition, a structured Microsoft Form was released with seven Likert-scale rating questions, whereby engineers were asked to indicate the extent to which they agreed or disagreed with statements about each evaluation dimension. This mix of observational and self-reported data provided a balanced understanding of the tool's real-world performance. The detailed findings from this evaluation are presented in chapter 6.

4

Findings from Data Analysis

This chapter presents the findings from the three rounds of interviews conducted with engineers from the Cab and Chassis departments. It covers the personas developed in the first interview, the use cases developed in the second interview, the requirements list synthesised across both rounds, and the questions and prompts prepared for the evaluation of the AI tool in the final interview.

4.1 Persona Development

Nine personas were developed from the first round of interviews, with each persona corresponding to one of the nine engineers interviewed. Rather than aggregating multiple participants into a persona, this one-to-one mapping was chosen so that the unique perspective of each engineer could be collected and later traced into the use cases and requirements. The personas are from different departments and cover design engineers, material experts, a simulation engineer, a sustainability leader, and a buyer. The buyer persona is included because they also play a primary role in material selection for a component. An overview of the personas is given in Table 4.1, and the full persona profiles are provided in Appendix A.

Material Expert (Cab) — P1 The associate engineer in cab works with cab interior and exterior plastics and paint systems, solving material application issues for R&D engineers and maintaining the CMD with new test data, typically in the later stages of Product Development (PD). They need a single interface that consolidates material data, simulation results, and historical performance, along with quick early estimates for sustainability and weight-to-strength ratios. The main challenges are difficulty in extracting actual test data from supplier PDFs, the lack of greenhouse gas and end-of-recyclability data, and fragmented, person-dependent storage that causes data loss. Sustainability Criteria Evaluation Matrix (SCEM) is known but not prioritised early, and sustainable alternatives are often blocked by cost (Figure A.1).

Senior Material Expert (Cab) — P2 The expert materials engineer in the Cab team, supporting engineers with material selection, testing, and simulation queries rather than owning components, and proactively exploring sustainable and recycled materials, typically at after design or later stages. They need more accurate and trustworthy early-stage tools, clear comparison metrics for CO_2 and recycled content in a standardised format, and earlier involvement so sustainable options can be considered before suppliers are involved. The main challenges are that existing sustainability calculators are too high-level to trust for early decisions, validation requires time and budget, and supplier-driven material choices limit standardisation. They focus on circularity and end-of-life recyclability for plastics. (Figure A.7).

Senior Design Engineer (Cab) — P3 The Senior Design Engineer works on interior cab parts such as trims, plastic parts, sun visors, curtain rails, and grab panels, is involved in all PD stages, create the Technical Requirement (TR) sent to the supplier, and decide on a tentative material before the supplier is involved. They need testing data, including heat cycling and colour testing, to choose materials with confidence and reliable, sustainable material suppliers capable of high volume with consistent quality. The main challenges are getting old test data, finding pass criteria for component testing in the TR, and comparing supplier-suggested materials against generic requirements. SCEM is known but not prioritized as it is a relatively new tool, and sustainable suppliers are often start-ups not ready for high volume (Figure A.6).

Senior Buyer (Cab) — P4 The Senior Buyer has sourced cab interior plastics components for six and a half years and now works on wheels and tires, getting involved after being released from design engineer by floating a Request For Quotation (RFQ) to five to ten suppliers and selecting best-value suppliers together with the cross-functional sourcing board. They need access to validated sustainable materials that meet technical requirements, early involvement of purchasing and suppliers in the design phase, and realistic cost evaluation, including volume and supplier constraints. The main challenges are that design teams assume sustainable materials are too expensive without evaluating real supplier data, sustainable plastics in the US cost much more than in Europe due to lower volume, and there is limited control over Tier 2 suppliers. Sustainability focus is on the supplier's production process and CO_2 improvements (Figure A.4).

Senior Design Engineer, MUC (Chassis) — P5 The Senior Design Engineer works on the Modular Under Cab (MUC), creates the TR for the supplier, and is involved in all PD stages, designing metal components in aluminium and steel by deciding which parts must remain rigid or deform and recommending suitable manufacturing processes such as sheet metal for crash performance. They need reliable, accurate, and repeatable material data, access to capable suppliers for advanced casting methods such as rheo-casting, and crash analysis data to confidently select materials. The main challenges are uncertainty about SCEM reliability — cast parts from different country suppliers show identical CO_2 values regardless of factory, inconsistent supplier samples, and large time gaps between original selection and current SCEM analysis. Sustainability focus is on weight reduction linked to CO_2, with crash performance ranked above cost and environment(Figure A.5).

Simulations Engineer (Chassis) — P6 The simulations engineer sets up and performs structural analyses using ANSA and Abaqus, defines analysis criteria for durability and crash, applies material properties from material libraries, interprets simulation results, and recommends alternative materials to optimize strength, ductility, and weight. They need detailed material data for plastic behaviour beyond yield, reliable and standardized data to avoid manual adjustments, and a common integrated material database across teams and locations, such as Bangalore and Gothenburg. The main challenges are the difficulty in finding accurate and complete material data in their team's libraries compared with other teams, and the lack of above-yield data, which forces assumptions or the adaptation of data from similar materials, such as different aluminium types. Sustainability focus is on light weighting to reduce CO_2 and on aluminium recyclability (Figure A.8).

Design Lead (Chassis) — P7 The Design Lead manages the design engineers in the Chassis team and is extensively involved in early concept development for new metal component solutions, planning the number of solutions to be developed based on project prerequisites such as variant configuration and road conditions, but is not much involved in detailed design. They need early collaboration of purchasing, suppliers, and engineering teams in the design phase and a better understanding of simulation accuracy and confidence levels for new or less-tested materials. The main challenge is that evaluating cost, performance, and sustainability for one component requires sequential conversations with the cost engineer, simulation engineer, sustainability team, purchasing, and suppliers, which is slow and unsustainable at program scale. Sustainability is emerging in prerequisites at a low level, such as SOC, and recycled content data in early phases is largely up to purchasing and the supplier (Figure A.2).

Senior Engineering Task Leader (Chassis) — P8 The Senior Engineering Task Leader leads engineering tasks in the Steering and Servo team and acts as Scrum master and agile product owner, currently working on pumps and electronic power steering, involved in all PD stages and pre-studies, and responsible for creating and approving TRs for servo line components, although without component ownership. They need early assessment of supplier availability and production scalability, and faster testing and validation methods to reduce the year-long cycle currently needed for material changes in safety-critical components. The main challenges are that material requirements are often defined externally by a central materials department, with changes communicated indirectly through suppliers, market readiness limits material choices, and sustainable suggestions are overridden by cost and budget owners. SCEM is rarely used, and sustainability is deprioritised because material changes cannot be compromised on safety-critical components. "We have SCEM, but it's not the starting point of the project (Figure A.3).

Sustainability Leader (Chassis) — P9 The Sustainability Leader advises on sustainable decisions for the Chassis team without final authority over material selection, influences mainly in early PD through supplier release, reviews SCEM and proposes sustainable alternatives by connecting engineers with material experts, and runs review meetings with platform sustainability and the global sustainability team using the SCEM rollup sheet and Life Cycle Assessment (LCA) guidelines. They need a dedicated budget for sustainable solutions, detailed and precise sustainability data applicable to specific components or manufacturing processes, better collaboration between engineering, purchasing, and suppliers, and standardised supplier data for requesting sustainable options in RFQs. The main challenges are that it is hard to know which sustainable materials exist in the market, unclear whether alternatives work for specific applications, existing tools provide only high-level emission estimates, and supplier CO_2 data is inconsistent due to varying capabilities and LCA tool mismatches. CO_2 is the current quantifiable focus, while circularity, reduced diversity, and Substance of Concern(SOC) are also considered to fulfill Volvo sustainability goals (Figure A.9).

Four patterns emerge consistently across the nine personas. First, cost is described as the dominant constraint at every stage of the workflow, and although sustainability is acknowledged by every persona, it is consistently positioned as conditional on cost, as a secondary criterion, or as a feature that purchasing is expected to reject. Second, the sustainability data that engineers would need to act on — comparable CO_2 figures, recycled content, end-of-life information, and supplier process data — is described as fragmented, inconsistent, and supplier-dependent across both plastics and metals, with SCEM viewed as a useful but high-level estimate rather than a reliable basis for decisions. Third, the phase in which sustainability could most meaningfully influence material selection is consistently identified as early PD, yet this is the phase in which the relevant data is least available and the relevant roles of material experts, the sustainability leader, and purchasing are least involved. Fourth, material decisions in practice depend heavily on supplier readiness, individual expertise, and reuse of previously validated materials, which collectively make it difficult to introduce new sustainable alternatives even when they exist.

Table 4.1: Overview of the nine personas developed from the first interview round.

#	Role	Team	Exp.	PD stage involvement	Sustainability tool/awareness	Primary sustainability driver
P1	Material Expert	Cab	2 yrs	Later stages	Aware of SCEM, low priority early	CO_2 end-of-life recyclability
P2	Senior Material Expert	Cab	3.5 yrs	Later stages	Awareness of SCEM	Circularity, recyclability, recycled content
P3	Senior Design Engineer	Cab	14+ yrs	All PD stages	Aware of SCEM, not prioritised	Recycled content with performance retained
P4	Senior Buyer	Cab	7 yrs	When supplier is involved	Limited direct use	Supplier process CO_2 improvements
P5	Senior Design Engineer	Chassis	20 yrs	All PD stages, iterative	Uses SCEM but questions reliability	Weight reduction linked to CO_2
P6	Simulations Engineer	Chassis	25+ yrs	Design validation and later stages	Not a direct SCEM user	Lightweighting and aluminium recyclability
P7	Design Lead	Chassis	10 yrs	Early concept development	Sees SCEM as a rough calculation	Energy and material source, low-level SOC
P8	Senior Engineering Task Leader	Chassis	7 yrs	All PD stages, technology-led	Rarely uses SCEM	Sustainability deprioritised vs. safety
P9	Sustainability Leader	Chassis	4 yrs	Early PD through Supplier release	Primary SCEM and LCA user	Balance across SCEM criteria, circularity

4.2 Use Case Development

Seven use cases were developed from the second round of interviews, each describing a concrete component-level decision in which the engineer would benefit from access to better material and sustainability information. The use cases were captured through journey-mapping sessions with engineers from across the Cab and Chassis teams selected to cover different decision contexts so that the subsequent evaluation of the AI tool would not be biased toward a single type of query. Each use case is mapped to one or more personas from section 4.1 and includes the actual queries that the engineer would put to a decision-support tool, which were later used as the prompts for the AI evaluation reported in chapter 6. An additional complementary use case from the Sustainability Leader is presented at the end of the section.

4.2.1 Use Case 1 – Side Crash Shield (Chassis)

The side crash shield is part of the chassis of the truck. Its main function is to prevent crash damage to the chassis. The current design uses an aluminium alloy and is suitable for the application, but an alternative material is to be explored for the next design iteration with using a material with low CO_2 emission performance at equivalent or lower stiffness, while the component is still in the early design phase.

Table 4.2: Details of Use Case 1.

Field	**Description**
Provided by	Simulations Engineer (P6) and Design Lead (P7), Chassis
Component	Side crash shield
Current material	VAW6005A+T6 (aluminium alloy)
Need	Identify a sustainable alternative aluminium grade for the next design
Requirements	Similar ductility, minimum required yield and tensile strength, formable, no heat treatment required
Primary query	Suggest alternative sustainable materials to VAW6005A+T6 with similar properties

Guiding questions:

- Report the carbon footprint of these suggested materials.
- Identify grades with similar or 20% lower ductility.
- Compare yield strength, tensile strength, fracture, and elongation against VAW6005A+T6.
- Check whether heat treatment is required.
- Assess how reliable the suggestions are and how they are validated.

4.2.2 Use Case 2 – Chassis Fairing (Cab, Exterior Plastics)

The chassis fairing reduces aerodynamic drag to improve fuel efficiency during highway driving, protects components such as fuel tanks, batteries, and air systems from road debris, water, and dirt, and contributes to the aesthetic design of the truck. It is currently produced from PC/ASA by injection moulding.

Table 4.3: Details of Use Case 2.

Field	**Description**
Provided by	Senior Material Expert (P2), Cab
Component	Chassis fairing
Current material	PC/ASA (injection moulded)
Need	Find a recyclable sustainable alternative that meets strength, testing, and manufacturability requirements, and understand how the AI tool reasons about critical tests, risks, and confidence before production
Requirements	Resistant to road debris, good UV stability, weight not greater than current material, suitable for injection moulding
Primary query	Suggest recyclable sustainable alternatives to PC/ASA with specific grades for the chassis fairing that are strong enough, have good UV stability, are not heavier than the current material, and are suitable for injection moulding

Guiding questions:

- What is the CO_2 footprint and is it recyclable?.
- Rank alternatives with sustainability as one of the metrics, with specific rather than generalised information.
- What are the shrinkage characteristics compared with the current material, and does it include glass?
- Will it be compatible with the existing injection-moulding tooling, and what are the chances of warping after demoulding?
- What are the key properties -chemical resistance, moisture resistance, and thermal stability, compared with the current material?
- Which tests are most critical for this material and application, and which properties need to be validated before production.
- Are there previous test results or similar application data available for this material?

4.2.3 Use Case 3 – Coolant Hose (Cab)

The coolant hose prevents overheating by maintaining the operating temperature and transporting coolant to ensure efficient heat transfer. It is currently produced from PA 612 as a two-layer component by precision extrusion. The objective is to redesign it into a single-layer solution while improving sustainability through weight reduction and lower greenhouse gas emissions, without compromising performance or durability, and to obtain a quick first estimate rather than a detailed analysis.

Table 4.4: Details of Use Case 3.

Field	**Description**
Provided by	Material Expert (P1), Cab
Component	Coolant hose
Current material	PA 612 (two-layer, precision extrusion)
Need	Identify a suitable material to replace the current two-layer coolant hose with a single-layer solution
Requirements	Withstand operating temperature up to 200 °C, endure burst pressure, and remain compatible with ethylene glycol coolant (50:50 ratio)
Primary query	The current material for the coolant hose is PA 612, designed as a two-layer component. The hose is to be redesigned into a single-layer solution; what alternative materials could achieve this while meeting an operating temperature and burst pressure in compliance with the relevant standards

Guiding questions:

- Is the material compatible and resistant to degradation in ethylene glycol coolant.
- Can the material provide the required mechanical strength, flexibility, and barrier properties in a single-layer configuration.
- Among the options, which materials have lower greenhouse gas emissions.
- Can it be processed in the same way as the current material, or does it require changes in manufacturing,
- Compare materials based on cost (price index), weight, and CO_2 emissions to identify the best trade-off.

4.2.4 Use Case 4 – MUC Side Beam (Chassis, MUC)

The Modular Under Cab (MUC) houses many electrical components that must be protected during a crash, and is positioned under the cab of an electric truck. The side beam is one of the main components of the MUC structure and must remain intact during a crash. This use case re-evaluates the material selection for the validated component to identify environmentally improved alternatives while maintaining equivalent mechanical performance, geometry, and manufacturability.

Table 4.5: Details of Use Case 4.

Field	Description
Provided by	Senior Design Engineer (P5), Chassis MUC
Component	MUC side beam
Current material	Steel / Aluminium (cold-formed)
Need	Find a sustainable alternative with better yield strength, higher elongation, and lower weight for a defined design and form factor, while maintaining crash performance
Requirements	The beam must weigh no more than 34 kg for 2 m; thickness and shape can be adjusted if needed, but the material must have higher elongation and yield values
Primary query	Which aluminium material grades offer higher elongation while keeping adequate yield strength for the defined crash performance requirements

Guiding questions:

- Which of these aluminium grades provide the lowest CO_2 (kg CO_2/kg) while meeting the elongation and yield requirements.
- How do the candidate materials rank across SCEM dimensions: CO_2 cradle-to-gate, recycled content, recyclability, and design for circularity.
- Are these material grades compatible with the current manufacturing process.
- How do the identified sustainable alternatives compare with the current material in terms of energy absorption and failure behaviour under crash conditions.

4.2.5 Use Case 5 – B-Pillar Trim (Cab, Interior)

The B-pillar trim covers wires and the seat belt harness from the customer's view and must be scratch resistant with a good surface finish. It is currently produced from a TPO resin (Thermylene XPT R020) by injection moulding. Because it is a high-volume component, substituting it with a sustainable alternative would deliver a meaningful sustainability benefit, provided the alternative satisfies the mechanical and surface-quality requirements expected of interior parts.

Table 4.6: Details of Use Case 5.

Field	Description
Provided by	Senior Design Engineer (P3) and Senior Buyer (P4), Cab Interior
Component	B-pillar trim
Current material	Thermylene XPT R020 TPO resin (injection moulded)
Need	Substitute the standard interior trim resin used in high-volume components with a more sustainable material that meets all required functional and performance specifications
Requirements	Maintain structural integrity under impact; tensile strength and flexural modulus equal to or greater than the baseline; shrinkage rate equal to or lower than the baseline; meet test requirements for surface finish, consistent appearance, scratch resistance, chemical resistance, and impact
Primary query	Provide a list of talc-filled TPO (∼20%) grades that offer comparable mechanical performance (tensile strength, flexural modulus, Charpy notched strength) with lower CO_2 footprint and recycled content

Guiding questions:

- Do these grades match or exceed the baseline tensile strength, flexural modulus, and impact performance.
- What is the verified CO_2 footprint (kg CO_2/kg) for each grade.
- Is retooling necessary for this material.
- Which alternative material meets the sustainability requirements.

4.2.6 Use Case 6 – Steering and Servo Components (Chassis)

Two related components from the Steering and Servo team were captured as a combined use case: the high-pressure servo line and the oil reservoir. Both serve the steering and servo hydraulic system and were raised by the same engineer to evaluate whether sustainable alternatives can be identified for hydraulic components that have safety and packaging constraints. For both components, the engineer wants to identify a suitable alternative material, understand the recycling potential, and obtain a cradle-to-grave CO_2 estimate.

Table 4.7: Details of Use Case 6

Field	**Use Case 6A – High-Pressure Servo Line**	**Use Case 6B – Oil Reservoir**
Provided by	Senior Engineering Task Leader (P8), Chassis	Senior Engineering Task Leader (P8), Chassis
Component	High-pressure servo line (hose)	Oil reservoir (housing and internal components)
Current material	NBR with steel braid	PA6 GF15 / GF30 / GF35
Need	Identify an optimal alternative material, identify recycling potential, and identify alternatives with their trade-offs	Identify an optimal alternative material, identify recycling potential, and identify alternatives with their trade-offs
Requirements	Transmit hydraulic fluid without leakage; flexible enough for assembly; withstand wear and tear; restricted by packaging requirements; avoid PFAS in the BOM; cost cannot be too high for the required quality level	Hold hydraulic fluid without leakage; withstand vibration without deformation; shape restricted by packaging constraints; acceptable cost
Primary query	What is a good alternative material for this use case	What is a good alternative material for this use case

Guiding questions:
- How can these hoses or components be recycled.
- What is the CO_2 output from cradle to grave of these hoses or components.

4.2.7 Complementary Use Case – Sustainability Leader (Chassis)

A complementary use case was contributed by the Sustainability Leader (P9), capturing two short situations rather than a single full component-level decision. These situations were retained because they reflect the kinds of queries that this persona would typically bring to an AI-enabled SMDE, even though the persona does not own components directly.

The first situation concerned a new heat shield being developed at approximately 14 kg as a sandwich solution of steel and polymer. The component is large and the project was at the RFQ stage, so a sustainable option with lower CO_2 was sought for the specific steel grade. The requirement was to find an alternative with lower CO_2 emissions that remains compatible with the deep-drawing process.

The second situation arose during an SCEM review, in which a cast iron part had its recycled content recorded as zero, which was unknown rather than verified. The need in this case was to identify the European average recycled content for cast iron so that the SCEM entry could be updated to a realistic value.

These two situations were used in the evaluation as additional short queries to test whether the AI tool could support the Sustainability Leader's review and reporting work, in addition to the longer use cases provided by the design and material engineers.

Across the seven use cases, three patterns can be observed. The use cases cover a wide range of material families, including aluminium, plastics, polyamides, rubber composites, steel, and cast iron, which shows that sustainability questions are not limited to one material type. The use cases also cover different stages of product development, from early-design exploration to substitution of existing materials, post-validation re-evaluation, and RFQ-stage review, which shows that sustainability-related queries appear throughout the workflow. Finally, the same types of queries appear in most use cases, such as finding alternative materials, checking CO_2 footprint and recyclability, comparing properties, checking manufacturing compatibility, and asking how reliable the suggestions are. These patterns are used as input for the requirements in Section 4.3 .

4.3 Requirements List

The requirement list summarizes the complete set of needs extracted from engineers throughout the first and second interview sessions, along with the process of developing the persona and use cases. These interviews were conducted exploratively so that the primary and latent needs of the engineers were identified by asking the right kind of questions — thus ensuring that not only explicit but also implicit needs are considered while framing the requirements. The needs were categorised by type: data needs capturing what information engineers require to make confident material decisions; output needs reflecting how they want the AI ecosystem to present its results; and organizational and collaboration needs highlighting structural bottlenecks and cross-functional gaps. Additional needs related to testing, supplier engagement, data quality, and budget were also captured as separate categories.

However, apart from the category, needs were mapped according to the engineer personas too. As a result, not only the unique needs of different personas, such as the design engineer, material engineer, simulation engineer, buyer, and sustainability leader personas, but also the needs that were common for certain subsets of personas were identified. Notably, there was a set of needs that almost all engineers who took part in the interviews mentioned, suggesting significant deficiencies in the present approach that transcend functions and departments. These commonly shared needs represent the clearest opportunities for the AI-enabled SMDE to deliver broad and immediate value across the organization.

Interview results revealed that different engineering roles face different challenges when choosing sustainable materials, but some needs were common across teams. The main concern for design engineers was the availability of reliable material data. They often noted the need for accurate information on mechanical properties, crash performance, recycled content, sustainability impacts, and supplier data. Another common theme was the challenge of balancing sustainability requirements with cost and performance early in design decisions.

Material engineers mainly highlighted challenges related to data availability, validation, and accessibility.One of the major trends identified was that of having a centralized database holding information regarding testing, simulations, and sustainable properties. They also stressed the importance of reliable supplier validation data and early involvement in the material selection process to support testing and feasibility assessments of sustainable materials.

For simulation engineers, the main challenge was the limited availability of detailed material behavior data, especially for newer or less-tested materials. Inaccurate or incomplete data reduces confidence in simulation results and affects material evaluation. Similarly, sustainability leaders emphasized the importance of quantifiable and grade-specific sustainability metrics such as recyclability, circularity, and greenhouse gas emissions to support sustainability assessments.

Some frequently occurring patterns were observed in all of the personas. A significant problem noted by participants is that there is an absence of an integrated and standardized set of data about the materials within all departments and suppliers. Participants also frequently mentioned that collaboration between the engineering, purchasing, suppliers and sustainability teams often happens too late in the process. Many users also expressed the need for faster validation methods, more transparency in sustainability data and tools to enable easier comparison and decision-making with less manual effort. Overall, the findings suggest that sustainable material selection depends not only on technical evaluation, but also on effective data management, data reliability, and cross-functional collaboration throughout the development process.

The detailed list of identified user needs collected from interviews across different engineering roles is provided in Appendix B.

4.4 Questions and prompts

The questions and prompts used for the evaluation of the AI tool were derived directly from the use cases. Each use case contributed a primary query reflecting the engineer's core information need, accompanied by a set of guiding follow-up questions to structure the interaction with the tool. These prompts were phrased in natural language to reflect how engineers would realistically interact with a conversational AI assistant.

Across the use cases, several recurring query types were observed. These include identifying and comparing alternative materials, retrieving carbon footprint and recyclability data, comparing mechanical properties against a reference material, checking manufacturing process compatibility, and assessing the reliability and validation of the tool's suggestions. These patterns confirm that sustainability-related queries appear across different material families.

The prompts served as the structured basis for the evaluation sessions reported in chapter 6, where engineers interacted with the AI tool using these queries and assessed the responses against their actual information needs. The complete list of questions and prompts used across all use cases is provided in Appendix D.

5
AS-IS Process

This Chapter discusses how the material selection happening currently in Volvo generally, further exploring how decisions are made by key persona involved in the material section by using as-is journey mapping, followed by explaining some identified pain points or bottlenecks in the current process, and exploring the areas of opportunity for the AI enabled Sustainable Material data ecosystem (SMDE).

5.1 Existing materials selection process

One of the main objectives of this research work is to understand the current material selection workflow in order to answer RQ1 and implement a new tool that can support decision-making, especially for new sustainable materials within the existing process. From the first interview conducted with the participants involved in the research work, an overall understanding was obtained regarding how material selection decisions are initially made for a component during the early design phase and how these decisions continue through the later development phases, as shown in Figure 5.1.

It was observed that, in the beginning, a generic material type is selected to proceed with the initial design iterations of a component. This initial selection is mainly based on important criteria such as previous experience, validated simulation results accumulated over several years, confidence in the material, and manufacturability with suppliers. In addition, technical requirements and Volvo standards are considered, including functional requirements, material properties, and testing requirements. The criticality of the component is also an important factor in the decision-making process. This includes the working environment, application area, crash impact location, component weight, and several other considerations. Based on these aspects, an initial material choice is generally made.

After the initial material selection, the design and simulation setup are explored through several iterations until satisfactory results are achieved for the component with respect to the selected material, its properties, and simulation requirements. Once acceptable performance is obtained, the process moves toward cost estimation of the component, while buyers simultaneously search for suitable suppliers. These activities are often carried out iteratively and in parallel. Suppliers then propose one or more suitable material grades based on the technical requirements, raw material costs, and manufacturability considerations. Finally, when both the cost and performance requirements are satisfactorily achieved, the component proceeds to the next phase of product development.

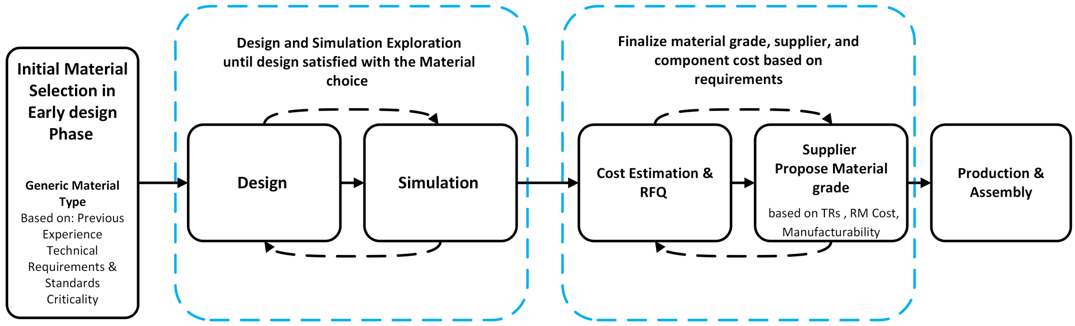

Figure 5.1: High-Level Overview of the Current Material Selection Process

Apart from this approach, there are instances where a specific material grade is directly specified in the technical regulations and manufacturing drawings of a component, or in the Request for Quotation (RFQ) issued to suppliers. This occurs for several reasons — the component may be carried forward from a previous design with no significant changes, meaning the existing material specification remains valid. In other cases, material experts may propose specific sustainable material grades that they have been actively working on and validating in collaboration with suppliers. Some materials have shown proven technical performance in years of simulation and validation work, giving engineers confidence in their suitability. Some components may also need very specific manufacturing techniques, which naturally limits the range of viable material options and leads engineers to prefer well-established grades that they can rely on.

5.2 Decision making workflow

To gain a deeper understanding of how each engineer experiences the material selection process and to identify the key areas where critical decisions are made, an AS-IS Journey Mapping approach was used. This mapping was developed based on the data gathered during the first two meetings with the participants.

Starting with the design engineer, the process for a new component design begins with identifying the component requirements, such as functional requirements, cost targets, sustainability goals, and manufacturing considerations. Based on these requirements, initial design concepts are developed. During this stage, a tentative material type is selected to proceed with the design and simulation activities, as discussed in section 5.1.

Once the design concept is finalized, supplier sourcing and material testing activities are carried out to ensure that the technical requirements are satisfied. At this stage, the material choice may go through several iterations if the physical testing results do not meet the expected performance requirements before moving into production. The detailed journey mapping is illustrated in the Figure 5.2

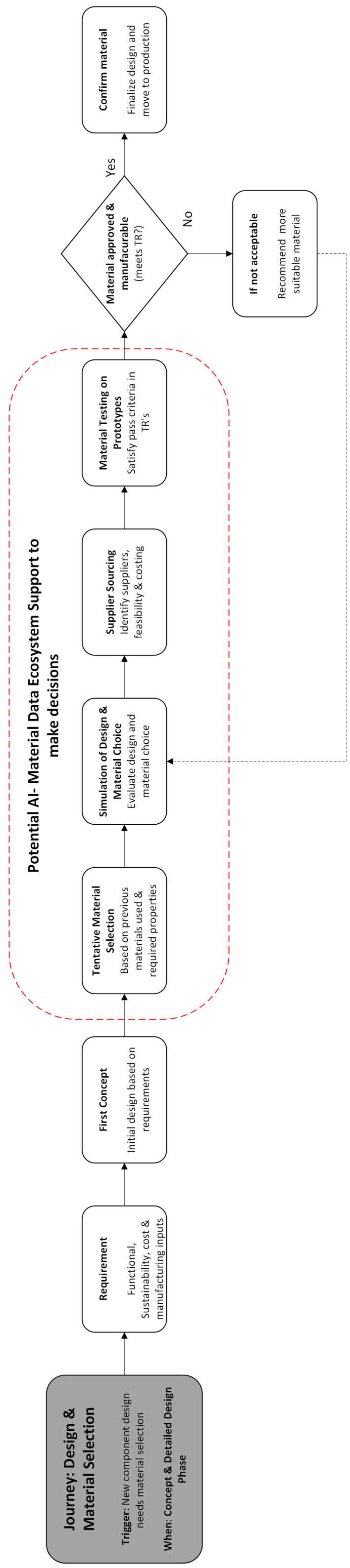

Figure 5.2: AS-IS Journey Mapping of Design Engineer

For material experts, the journey is slightly different. They usually experience two types of situations where they are involved in material selection decisions for components. The first is proactive support during the early-stage material advisory process, where the design engineer approaches them for material suggestions suitable for a particular application. The second is reactive support during late-stage problem solving. This typically occurs during the pre-production phase, when physical component testing reveals failures or mismatches related to the selected material. Another situation arises when a material has already been selected for a component, but a more sustainable alternative is later required. In such cases, the material expert either explores the possibility of implementing the alternative within the same project at a later stage or considers it for future projects. The detailed journey mapping for the material expert is shown in Figure 5.3.

The journey usually begins with understanding the requirements provided by the engineers or analyzing the issue and its context. The material expert then translates these requirements into material-specific needs or identifies the root cause associated with the selected material in the case of reactive support. Following this, they search and review internal tools, company documents, supplier datasheets, and data from previous projects. In reactive support scenarios, they additionally explore suitable replacement options by reviewing new test data, supplier catalogs, and sustainable material alternatives.

After gathering the required information, the available options are screened, compared, and shortlisted. The alternatives are then evaluated to finalize and recommend a suitable material choice, along with the necessary tests that should be carried out for validation. This process is highly iterative and involves continuous collaboration with design, simulation, and test engineers until the final material decision is achieved.

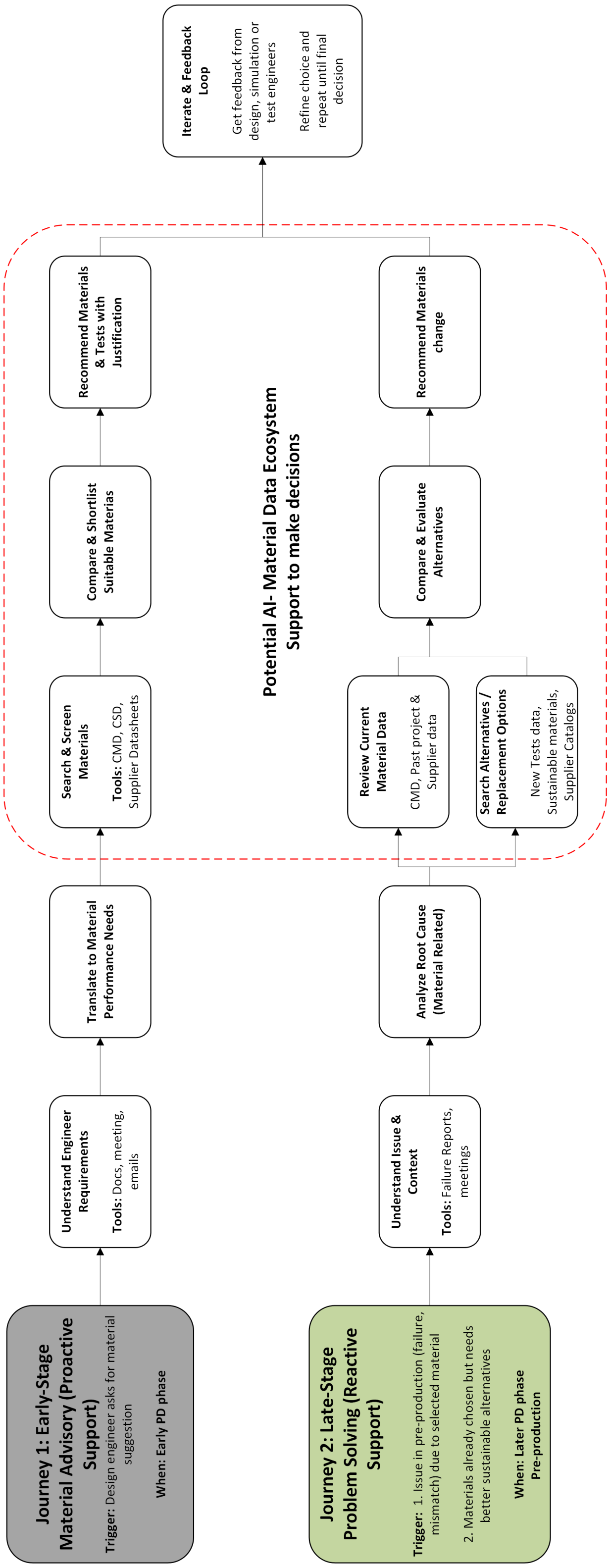

Figure 5.3: AS-IS Journey Mapping of Material Engineer

The simulation engineer works closely with the design engineer during the material selection process. However, their decisions and considerations are somewhat unique, and play an important role, as illustrated in Figure 5.4. The process begins with an understanding of the design constraints and performance related requirements for the tentatively selected generic material type as discussed earlier in section 5.1.

Then the simulation engineer prepares the analysis, including load cases, boundary conditions, and modeling of material properties required for simulation. Then simulations are performed to evaluate durability, crash performance, and other functional requirements such as stress, strain, and failure modes for the chosen material and design geometry. The results are evaluated, and the analysis setup is iterated if needed.

If the material performance is acceptable and satisfies the required criteria, two possible decisions can be made. The first option is to confirm the choice of material and finalize the design. The second is to look at optimization opportunities, such as suggesting a lighter or lower-cost material alternative to reduce weight or cost while still meeting performance requirements. However, if the results of the evaluation do not meet the required performance criteria, a stronger or more suitable material is recommended for further iterations.

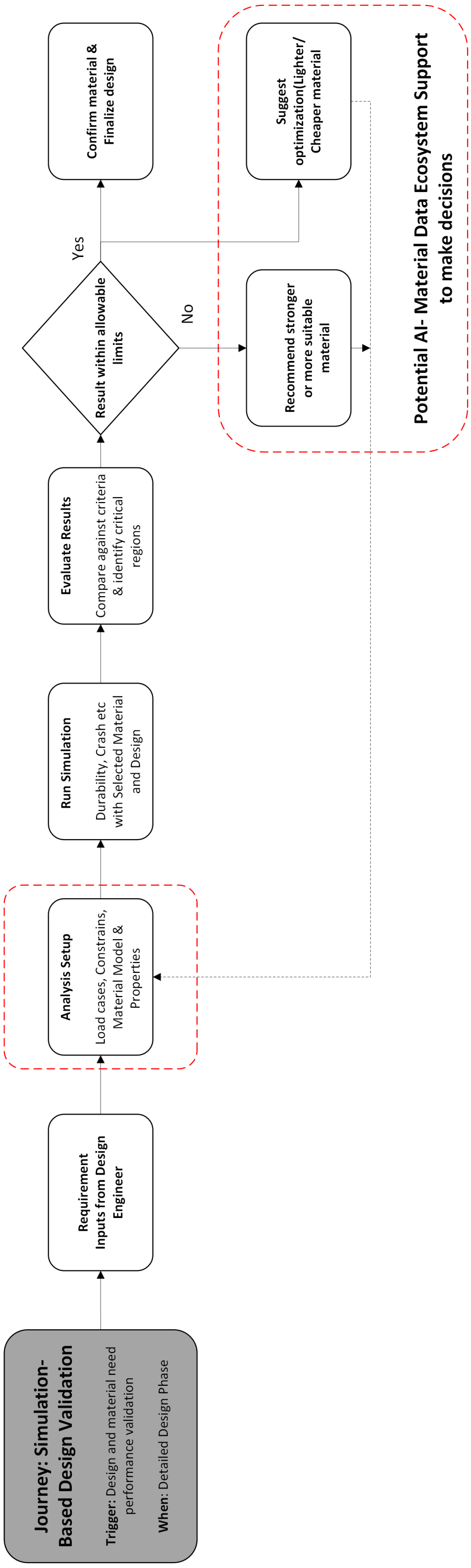

Figure 5.4: AS-IS Journey Mapping of Simulation Engineer

5.3 Identified pain points & limitations

From the overall journey mapping a few pain points in material selection and decision making were noted. A significant challenge is that information about materials is spread across many sources, such as different databases, documents, standards, teams and organizational locations. As a result, engineers spend a lot of time searching for the information they need and verifying that the data is reliable and current.

Another major challenge is the lack of availability of accurate and complete sustainability data, especially for newly introduced materials from suppliers at an early design stage. The available information is often incomplete, inconsistent, or not easily accessible, which complicates the ability of engineers to confidently evaluate and compare sustainable material alternatives during the decision-making process.

5.4 Areas of Opportunities for AI-enabled SMDE

When observing the journey maps of the different engineers, a similar pattern can be identified across all roles. In each journey, there is a stage where engineers actively search for information related to the task they are working on. This often involves searching through internal databases, company standards, supplier documents and catalogs, engineering reports, public databases, international and EU standards, and several other information sources that influence material selection decisions.

For design engineers, there is clear potential for an AI-enabled SMDE to support decision-making during both the early concept phase and the detailed design phase of product development.by providing material-related information such as material properties, suitable suppliers offering new or sustainable materials, and alternative materials that satisfy similar requirements. It can also assist in identifying the types of tests required to validate a material choice according to the technical requirements specified in the component TRs.

A similar pattern can also be observed in the journey of simulation engineers. During the detailed design phase, simulation engineers are responsible for verifying the performance of the selected material and component design. To set up the simulation models, they require access to relevant material data and analysis-related information. Although much of this knowledge is gained through years of experience and many situations become familiar over time, there are still cases where specific material property data or unfamiliar materials need to be explored through databases and technical documents. In such situations, the AI-enabled SMDE could provide useful support. Furthermore, based on the simulation results, simulation engineers may need to recommend stronger material alternatives with improved performance. In other cases, when the performance is higher than required, they may look for lighter or lower-cost alternatives for optimization purposes. Here as well, the AI-enabled system has the potential to support material-related decision-making.

In the case of material experts, the need for information appears in both the early design stages and the later stages before production. Their work often involves searching through Volvo internal databases, supplier datasheets and catalogs, and previously validated test data. When considering better material options for a specific application or exploring sustainable alternatives, material experts, in particular, need to compare and assess different materials against the current solution and the required performance criteria. The AI-enabled SMDE could provide valuable support to these activities by assisting in information retrieval, comparison, and evaluation, helping material experts to make more informed decisions within their workflow.

6

Evaluation of AI-enabled SMDE

This chapter presents the evaluation of the AI-enabled sustainable material data ecosystem (SMDE) and examines how well the tool addressed the specific needs and requirements identified across the use cases developed in chapter 4. Further, the results of a structured user perception survey collected at the close of the evaluation sessions are presented along with a brief SWOT analysis of the AI-enabled SMDE.

6.1 Use Case Needs Satisfaction

The needs identified during the use case development phase served as the primary basis for assessing the tool's performance. During the evaluation sessions, engineers interacted with the tool using the queries established for each use case and assessed the responses against their actual information requirements. Each need was classified as fully satisfied, partially satisfied, or not satisfied, where partial outcomes indicate that a response was provided but was incomplete, inaccurate, or relied on assumptions that could not be verified. Detailed evaluation use cases are provided in Appendix C. The subsections below summarise the findings for each use case.

6.1.1 Use Case 1 – Side Crash Shield (Chassis)

In this use case, the tool was assessed on its ability to support the identification of a sustainable aluminium alternative to VAW6005A+T6 for a crash-loaded structural component. While the tool was able to suggest alternative grades and return a general comparison of mechanical properties, the responses were largely surface-level and did not consistently provide the depth of information required. Carbon footprint data was returned only partially, with the tool resorting to assumptions rather than verified figures, and the mechanical properties of the reference material itself were returned inconsistently across sessions. More critically, queries around the reliability of the suggestions and simulation accuracy of the proposed alternatives were left unaddressed. The responses were adequate for an initial exploration of alternatives, but fell considerably short of what would be needed to support an informed engineering decision.

6.1.2 Use Case 2 – Chassis Fairing (CAB, Exterior Plastics)

This use case examined the tool's ability to support the selection of a sustainable replacement for PC/ASA in an injection-moulded exterior component. The tool was able to address queries related to processing characteristics, such as injection moulding suitability and warping risk, and provided general information on chemical and thermal resistance. However, the initial material suggestion itself was only partially adequate due to factual inaccuracies, and attempts to filter options by resin type produced irrelevant results. Cost-related queries, which are central to a materials expert engaged in supplier evaluation, were not addressed at all. The responses gave the engineer a starting point for exploration, but the inaccuracies and gaps in the output meant the information could not be used with confidence.

6.1.3 Use Case 3 – Coolant Hose

This was the most extensive use case, involving a material transition for a coolant hose from a two-layer PA 612 configuration to a single-layer solution under defined thermal and chemical resistance requirements. The tool was able to identify candidate materials and address basic processing and mechanical property queries to a reasonable degree. However, the breadth of this use case exposed several notable limitations. Cost comparisons were returned with unverifiable assumptions and no traceable source, and regional pricing differences between supplier locations were not addressed. Retrieval of internal Volvo technical reports and Environmental Product Declaration (EPD) documents was not achieved. Queries referencing specific Volvo material standards were handled only in general terms, without identifying the relevant standard or verifying compliance. A number of responses also contained inaccuracies in the property data returned, which engineers noted reduced their confidence in the output.

6.1.4 Use Case 4 – MUC Side Beam (Chassis, MUC)

This use case focused on re-evaluating the material selection for a crash-critical aluminium side beam with the aim of identifying more sustainable alternatives. The tool showed some capability in returning CO_2 emission data and recyclability comparisons across material grades, and was able to address rheo-casting compatibility. Beyond these, however, the results were limited. The tool was unable to suggest aluminium or steel grades meeting the specific elongation and density requirements, returning irrelevant results instead. Queries that required combining structural performance with sustainability criteria such as ranking materials across crash behaviour, weight, and carbon footprint simultaneously were not addressed. Structural outputs including moment of inertia and torque capacity were limited, and weight-to-strength ratio estimates were accompanied by so many assumptions that they were of limited practical use.

6.1.5 Use Case 5 – B-Pillar Trim (CAB, Interior)

This use case evaluated the tool in identifying sustainable alternatives to a TPO interior trim component, covering material alternatives, mechanical properties, processability, and regulatory compliance. An important factor is that the engineer involved was already aware, through prior experience working with suppliers, that viable sustainable alternatives for this component type are not currently available in the market, and efforts to develop them through supplier collaboration had not yielded a conclusive outcome. The engineer, therefore did not approach this evaluation expecting the tool to produce a deployable solution. While the tool was able to suggest alternative grades and return property comparisons, these outputs represent theoretically available options rather than practically viable ones, given the known supplier constraints. Several responses also lacked the grade-level specificity an experienced engineer would require, and alternatives suitable for Class A surface parts where colorant is moulded at press were not adequately addressed. The higher needs satisfaction rate in this use case should therefore be read with caution it reflects the tool operating within a comparatively well-represented polymer material domain, not a stronger overall capability.

6.1.6 Use Case 6 – Steering and Servo Components (Chassis)

This use case was carried out by the Senior Engineering Task Leader. The evaluation covered two hydraulic components: the high-pressure servo line, currently made from NBR with steel braid, and the oil reservoir. The engineer wanted to find sustainable alternative materials for both components, understand how they could be recycled, and get a cradle-to-grave CO_2 estimate. Both components come with strict constraints around safety, packaging, and PFAS restrictions.

The tool was able to suggest some alternative materials, but the results were too general to be useful for safety critical hydraulic components. It did not provide specific material grades, and the recyclability information it returned was either missing or not detailed enough to act on. The tool also referenced an incorrect standard, which made it difficult to trust the outputs.

On top of the content issues, the engineer found the tool slow to respond, and felt the quality of the answers did not justify the wait. The outputs were visually cluttered, making them hard to read and interpret. The engineer suggested that clearer, more structured answers and the ability to ask follow-up questions would make the tool much more useful. Overall, neither the servo line nor the oil reservoir needs were satisfied. The engineer felt that internal tools like Volvo GPT already provided faster and more relevant results, making it hard to see what this tool added on top of what was already available.

6.2 User Perception Survey

At the end of the evaluation sessions, a structured survey was sent to all seven participants through Microsoft Forms. The survey covered fourteen criteria talked in Table 3.1 across five dimensions usability, output quality, perceived value, data trustworthiness, and efficiency impact rated on a scale of 1 to 7, where 1 is strongly disagree and 7 is strongly agree. The results are visualised as radar charts in Figure 6.1.

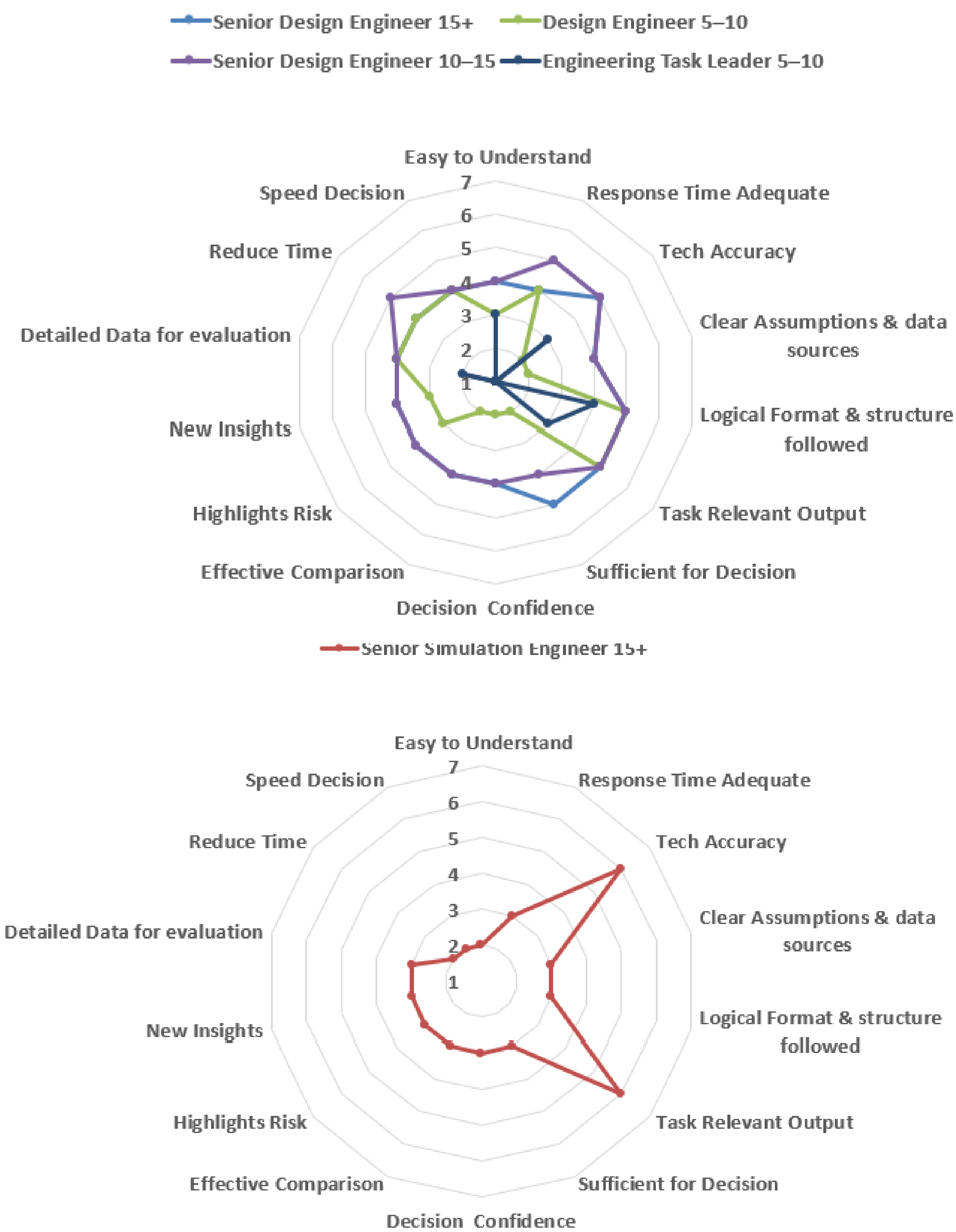

Figure 6.1: Radar charts showing user perception ratings across evaluation dimensions by role group

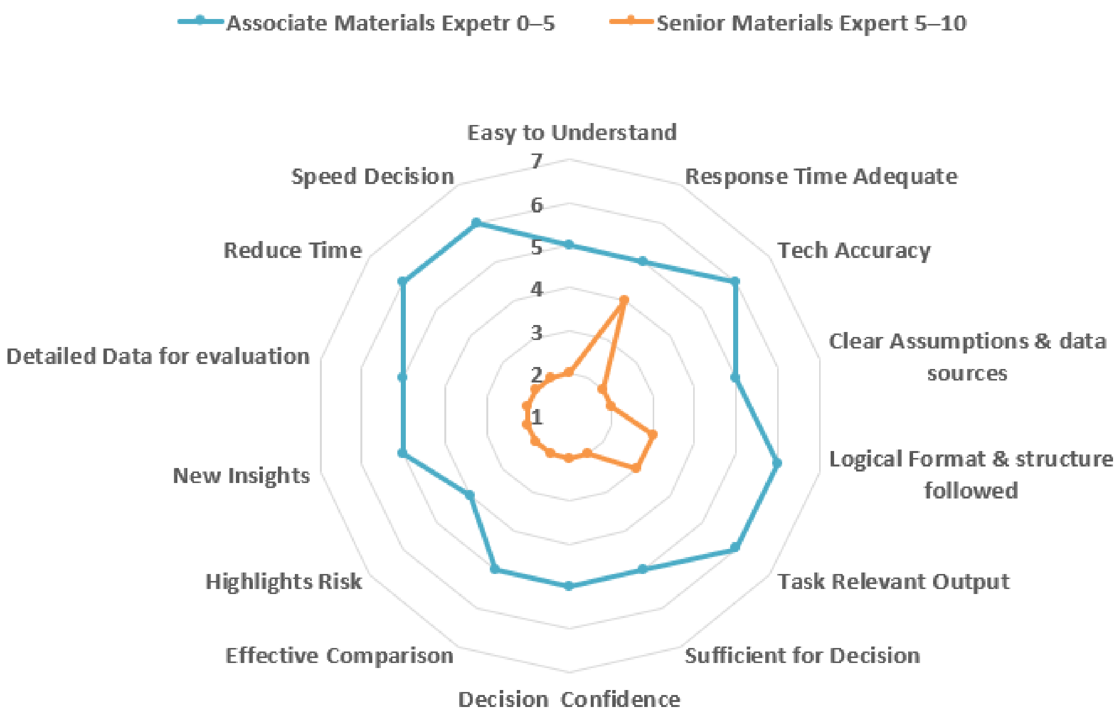

Figure 6.2: Radar chart showing user perception ratings across evaluation dimensions by role group

Looking at the overall picture, most engineers rated the tool around the neutral mark across all dimensions. The output format and task relevance of the responses scored slightly higher, meaning engineers generally felt the tool was presenting information in a reasonable way. However, criteria like decision confidence, transparency of data sources, and efficiency impact scored lower, reflecting that engineers were not yet comfortable relying on the tool for actual decisions.

When looking at individual responses, there is a clear spread of opinions. The junior materials science engineer rated the tool most positively, while the engineering task leader and the senior materials science engineer were the most critical, rating most criteria between 1 and 2. This gap suggests that experience level and role expectations play a significant role in how the tool is perceived. Engineers with more established workflows and higher data expectations found the tool less adequate. The design engineers and senior design engineer remained largely neutral throughout. The senior structural engineer showed an interesting pattern, rating technical accuracy relatively high while rating usability and efficiency low, suggesting the content was seen as reasonable but the overall experience was not.

6.3 Results of Evaluation Criteria

In this section, the detailed assessment of the evaluation of the AI-enabled SMDE through the use case developed and also presented, along with how it satisfied the requirements. This includes the feedback we observed and asked for during the evaluation meetings and from the evaluation survey on different criteria that we considered for evaluating the performance, usability, and value perceived by the users.

6.3.1 Usability

In general, the usability of the AI-enabled SMDE could be classified as moderate, as there were several aspects where it performed rather well and several where it did not. Specifically, one of the brighter sides of this application could be seen in terms of interaction effort, since the tool retains all its chat history from one session to another and thus allows an engineer to build on previous discussions. Learnability was also straightforward, as engineers were generally able to get started without any prior training, which is broadly expected for a conversational AI interface.

Response performance, however, was more mixed. The system handled straightforward queries with reasonable speed but struggled with stability when longer or more complex questions were asked—occasionally getting caught in repetitive loops when it failed to interpret the context correctly. Understandability varied across users as well; while some engineers appreciated detailed responses, others found the outputs excessively long and preferred more concise answers. The system frequently provided unnecessary information unless engineers gave very specific and constrained prompts, and search results occasionally returned out-of-context material—for instance, a query about plastics sometimes surfaced metal-related results.

Output clarity also raised concerns. References and source names provided in the responses were often unclear, making it difficult for engineers to validate the information independently. While the system generally followed logical reasoning and used appropriate terminology, it occasionally made calculation errors—though these were usually recognizable to the engineers themselves. Interpreting technical nomenclature and specific engineering terminology was another area where the system sometimes fell short. These observations are reflected in the evaluation survey responses, as shown in Figure 6.3, where material experts and senior design engineers responded with neutral to slightly agree ratings across the usability criteria, while senior material experts, simulation engineers, and senior task leaders responded with slightly disagree to disagree, suggesting that usability perception correlates with the technical depth and specificity of the engineer's role.

6.3.2 Output Quality of Data and Trust Worthiness

While usability determines how comfortably engineers can interact with the tool, output quality is ultimately what determines whether the tool can be trusted to support real material selection decisions. In this regard, the AI-enabled SMDE showed a mixed performance, with several recurring issues observed across the evaluation sessions.

The accuracy of the results generated by the system remains a key concern. At times when the correct material properties are provided, in some instances, the

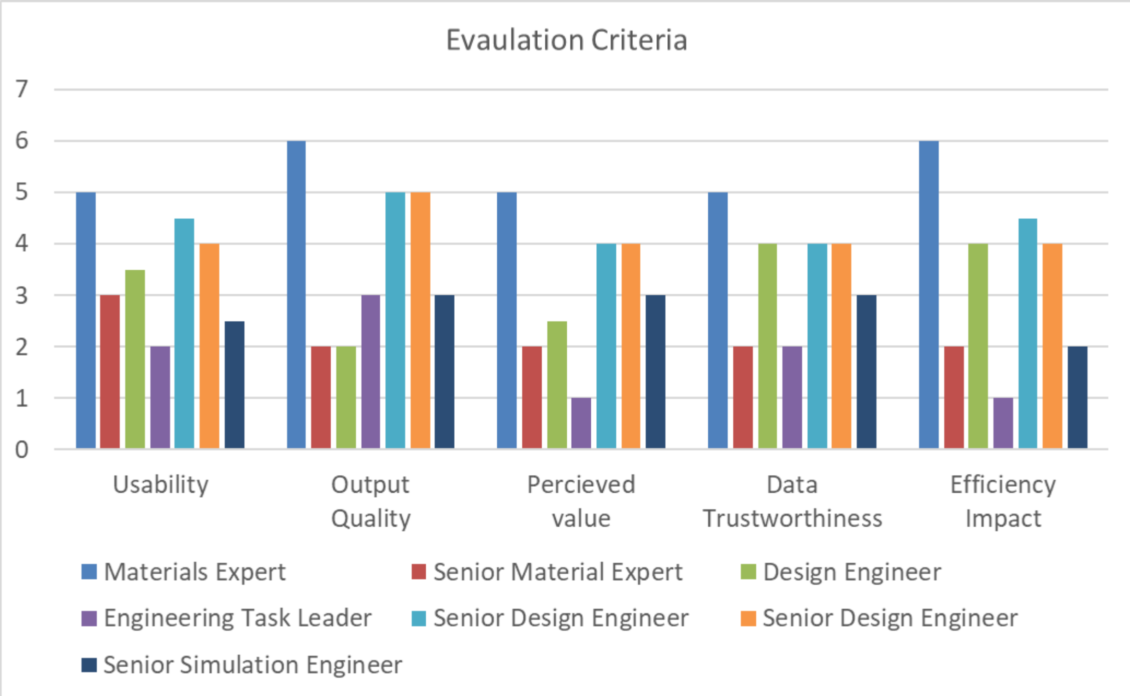

Figure 6.3: Assessment of Criteria

wrong results or even formatting are provided, which can be quickly spotted by the engineer using the system. Material comparisons sometimes show unrealistic or unreliable property values. This may happen due to mistakes in how the data was entered or where it came from. Even if you are referring to known standards or internal sources, there were still wrong values showed up which drastically affects the accuracy of the AI Tool. Reliability is another challenge that needs improvement. Reliability also needs to be improved, since inconsistent information across different sources may lead to different answers to the same query, which causes confusion and decreases trust in the data. This kind of inconsistency, observed occasionally across AI models, raises questions concerning consistency across different runs and scenarios. Also, wrong assumptions in the first response reduce user trust and confidence in the reliability of the system.

Transparency remained a persistent challenge throughout the evaluation. References and source names provided in outputs were frequently unclear or unhelpful for validation purposes, and cost data — while offering a reasonable high-level estimate — lacked proper market context or sourcing, making it difficult for engineers to understand the basis of the figures provided. Sometimes the system correctly identifies when information is not available, but sometimes it still generates wrong or hallucinated information that can directly influence design decisions. Relevance issues were also observed, as discussed in subsection 6.3.1, with search results sometimes returning out-of-context material across different material families.

In addition, the incompleteness of the available ecosystem data further limits the performance of the AI tool, particularly around sustainability data, which was often unavailable or showed large variations without a clear reference baseline, making it difficult for engineers to interpret what the values actually mean or how reliable they are. On a more positive note, the system performed well in retrieving mechanical properties from Volvo's internal standards and produced clean, well-structured comparison tables when specifically requested, which engineers found genuinely useful. These stronger moments are reflected in the survey responses, where senior design engineers and junior material experts rated output quality as slightly agree and agree, respectively. However, the overall output quality still fell short of satisfying the senior material expert, design engineer, and engineering task leader, as illustrated in Figure 6.3, suggesting that the higher the technical expertise and decision-making responsibility of the engineer, the more critically output quality is evaluated.

6.3.3 Value perceived by Users

Perceived value was one of the most subjective dimensions of the evaluation, shaped by each engineer's background, role, and expectations. The tool was generally seen as a useful starting point for exploring new materials and grades, and its reasoning and comparison capabilities were appreciated when the information was reliable. It also helped engineers identify areas worth investigating further, particularly around sustainability, even when the data itself could not be fully trusted.

The Confidence in decisions was a continuing problem. Engineers were able to spot incorrect answers within the options provided, which made it difficult to trust the remaining suggestions. Incorrect assumptions made early in responses further reduced confidence, as these carried through to other subsequent outputs and required manual verification before the information could be used. Access to internal Volvo engineering reports and technical requirements (TR) of certain components was also limited, which undermined the tool's ability to support meaningful material comparisons in a professional context. Material recommendations often provided new grades with little background, making it difficult to independently evaluate them.

Overall, the tool was seen as more accessible and valuable for engineers without a strong materials background, while experienced engineers found it useful mainly as an initial exploration aid, particularly for learning about new sustainable grades, before verifying findings through suppliers or external sources. This is reflected in the survey responses, where most engineers gave neutral to negative feedback on perceived value, with the exception of the material expert, who slightly agreed that the tool provides value when used with well-structured and specific prompts.

Efficiency Impact

The efficiency provided by the tool was minimal, at best. As discussed in the previous sections, engineers frequently needed to filter through irrelevant or out-of-context results to find useful information, and the outputs almost always required manual cross-verification prior to any action being taken, meaning the tool did not meaningfully reduce the effort involved in the material selection process. The speed at which decisions could be made was likewise not improved, because the time spent improving prompts, analyzing responses, and verifying their accuracy compensated whatever gains might have been achieved elsewhere. Response times were also inconsistent. Some queries were answered quickly, others took considerably longer, further undermining the tool's reliability as a time-saving resource. Also, the generic or unclear responses added to this, reducing the practical applicability of the outputs in real engineering decision-making contexts where specific, actionable information is needed.

6.4 SWOT of AI tool

Based on the findings from the use case evaluation and the user perception survey, a SWOT analysis was conducted to summarise the current state of the AI-enabled SMDE. The analysis reflects the strengths and weaknesses observed during the evaluation sessions, as well as the broader opportunities and threats identified in the context of integrating such a tool into an engineering workflow for sustainable material selection.

SWOT Analysis	
Strengths	**Weaknesses**
• Combines material, sustainability, and supplier data. • RAG architecture grounds responses in company documents. • Reduces manual search effort and time. • Supports multi-material comparison across criteria. • Reduces reliance on individual expertise. • Accelerates early-stage sustainable material screening.	• Data quality depends on supplier and external sources. • Risk of hallucinated or fabricated material data. • Assumptions and sources not always disclosed. • Inconsistent accuracy leads to trust issues. • Responses can be generic or out of scope. • Difficult to validate outputs for critical applications. • Limited data for newly developed materials.
Opportunities	**Threats**
• Growing sustainability regulations increase demand. • Enables cost vs. sustainability trade-off analysis. • Preserves knowledge when experienced engineers leave. • Potential for deep integration into PD workflows. • Can expand to LCA, simulation, and crash data. • Supports bio-based and recycled material innovation.	• Competing internal tools with faster, richer outputs. • Regulations change faster than platform updates. • Incorrect data risks poor material decisions. • Organisational resistance may limit adoption. • No standardisation in sustainability metrics across suppliers. • Zero tolerance for inaccuracy in safety-critical parts. • Misalignment with existing workflows reduces uptake.

Table 6.1: SWOT Analysis of the AI-enabled SMDE

7

Recommendations and Discussions

This chapter looks at what the evaluation results from chapter 6 actually mean in practice. The findings from the evaluation sessions are interpreted by looking at how the Sustainable Material Data Ecosystem (SMDE) performed across the different engineering roles and use cases tested. From this, the chapter identifies where the tool needs to improve and what engineers found useful during the sessions. It then moves on to discuss what the results mean for the company and why adoption may not be straightforward. The chapter ends by pointing to areas where future work could extend what was done in this study.

7.1 Areas for Improvement

The evaluation sessions provided valuable insights into how the SMDE can be developed further to better serve the needs of engineers in their daily work. Several clear directions for improvement emerged across the different use cases and roles.

One of the main things that needs to improve is how material comparisons and property values are presented. Having clearer reference materials and more realistic property values would help engineers make more confident decisions. Responses should also include better context and reasoning behind the suggestions, along with proper source references, so engineers can understand where the information is coming from and why a certain material is being recommended.

Output structure is something that engineers felt strongly about. Most preferred getting tables and comparative summaries rather than long blocks of text. Having a structured format as the default would make it much easier and faster to read through the outputs and find what is actually relevant.

The tool should also get better at answering questions more directly. Right now responses sometimes include repeated or out-of-context information that is not useful. Reducing this and focusing on what the engineer actually asked would make the tool more efficient to use. Related to this, having access to more engineering-specific and non-public technical knowledge would also make the responses more relevant and useful compared to what general tools already offer. On the usability side, faster response times, better visual presentation, editing options, and some guidance on how to write good prompts would all make the experience smoother and more practical for everyday use.

Finally, sustainability, cost, and performance data needs better benchmarks and market context so that engineers can properly interpret the values they are given. Supplier sustainability data like carbon equivalent values should also be more consistently included, as this kind of information is important for sustainability comparisons but is not always easy to get.

7.2 Summary of Findings

The evaluation provided a number of important takeaways about where the AI tool currently stands and what role it can realistically play in the material selection process. The tool was found to be useful as a starting point for exploration. It helps engineers quickly get an idea of what materials or grades are worth looking into, and gives useful high-level information on properties, cost, and weight reduction potential. This can save time in the early stages of research by pulling together information from different sources into one place. At the same time, how useful the tool is depends a lot on the quality and completeness of the data behind it. Different datasets were also found to be more useful for different engineering roles, which means the tool does not provide the same value to everyone.

One thing that came up repeatedly was that the quality of the output depends a lot on how the question is asked. When questions were too broad, the responses often contained a lot of irrelevant or excessive information, which made it feel more like a general web search than an engineering tool. Engineers preferred getting fewer but more accurate answers rather than large amounts of information that may or may not be correct. This also raises the question of how this tool is different from other internal AI tools that already exist within the company.

The main takeaway is that the tool works best as a support and exploration tool rather than something engineers can fully rely on for decision-making. Outputs still need to be verified through suppliers, standards, and material experts. For the tool to be more useful beyond exploration, it needs reliable references, clear benchmarks, and structured outputs like comparison tables that engineers can actually work with.

7.3 Adoption and Organisational Implications

One of the main implications that came out of the evaluation is around trust and usability of the tool. Several engineers identified incorrect or inconsistent data in the outputs during the evaluation sessions. In an engineering environment like Volvo Trucks Technology, where components are safety-critical, making decisions based on wrong material data can have serious consequences. This makes it difficult for the company to fully adopt the tool until the data accuracy and reliability reach a level that engineers can genuinely trust. Beyond data accuracy, usability also plays a role here. If engineers find the tool difficult to use or feel that the effort required to get a useful output is too high, they will not use it regularly.

As the literature also points out, tools that are perceived as too complicated or time-consuming tend to get avoided, even when they have real potential value.

The second implication is around the presence of other tools already available within Volvo. During the evaluation, some engineers directly questioned why another tool was being added when tools like Volvo GPT (an internal AI assistant) already exist. This is a genuine challenge for the company. If the role and value of this tool is not clearly communicated and positioned relative to the tools that engineers already use and trust, adoption will be very difficult. Engineers will naturally default to what they are already familiar with. This connects to what the literature describes as the method ecosystem challenge—new tools need to fit into the existing way of working; otherwise, they risk being ignored regardless of their potential.

7.4 Scope for Future Work

The engineers who participated in this study were from the CAB and Chassis departments at Volvo Trucks Technology, and the engineering roles covered were focused on material selection for plastic and metal components. While this provided valuable insights, there are other teams and departments across Volvo where similar work could be carried out to get a broader understanding of how the tool can be useful across the organization.

Extending the persona development and use case evaluation to other engineering areas, such as powertrain and electrical components, would be a natural next step. These areas have their own specific material requirements, data needs, and decision-making workflows that may be quite different from what was studied here. Carrying out the same process of interviewing engineers, developing personas, and building use cases in these contexts could reveal needs and requirements that were not captured in this study.

There is also potential to expand this work to other Volvo business units beyond Volvo Trucks Technology. Different parts of the Volvo Group work with different types of components and may have different sustainability priorities and data challenges. Including these perspectives would give a much more complete picture of how the tool can be developed and positioned across the wider organization.

Sustainable components design engineers are another group worth including in future evaluations. Since sustainability is at the core of what this tool is trying to achieve, including engineers who work directly with sustainable component design in future evaluations would give very relevant feedback on whether the tool actually meets the needs of those who deal with sustainability the most in their work. Expanding the scope of this kind of study to cover more engineering roles, teams, and business units across Volvo would also help identify any gaps in the current tool and would provide a stronger basis for its further development and adoption across the organization.

7.5 Answers to Research Questions

The following overarching research question guided this thesis:

> *How can a sustainable material data ecosystem, supported by next generation AI tools, improve decision-making in the selection of new and More sustainable materials for automotive components?*

To address this, five sub-questions were formulated. Each is answered below based on the findings from the interviews, use case evaluations, and survey responses. The main research question is answered last as a synthesis of the sub-question findings.

Sub-RQ 1: What processes, workflows, and decision criteria are currently used when selecting materials for different categories of automotive components?

Material selection in the case company typically begins early in the design phase, where engineers choose a broad material family based on prior project experience or personal knowledge, provided it satisfies the minimum technical requirements to move the design forward. This initial choice is followed by iterative simulation to confirm that the component performs as required, after which the design is handed to a supplier who proposes a specific material from their existing production lineup, one that already carries the necessary test documentation, is produced at volume, and falls within the project cost boundaries. Sustainability enters the decision at this stage as well, but as a secondary criterion that is only factored in when cost targets are already met. This sequencing means that sustainable alternatives are often raised too late in the process to be realistically implemented, since changing a material after supplier involvement requires re-testing, re-validation, and renegotiation that most projects cannot accommodate within their schedule or budget.

Sub-RQ 2: Which types of sustainability related data and insights are most critical for material selection in early design phases?

Across all engineering roles interviewed, CO_2 emission data was the most consistently requested sustainability indicator and also one of the more reliably available data points in the tool, since suppliers must provide this information for their materials to be included in the ecosystem. Beyond emissions, recyclability and end-of-life data were highlighted as important, particularly for plastic components, and grade-specific sustainability figures were needed rather than high-level estimates at the material family level, since actual decisions require data tied to the specific grade under consideration. For metal components, weight reduction potential was closely linked to sustainability targets, as a lighter component directly lowers lifecycle CO_2. The core problem identified was not a lack of awareness around sustainability among engineers, but rather that the relevant data was scattered across different systems, inconsistent in quality, and typically only became available once suppliers were brought in, by which point many design decisions had already been made.

Sub-RQ 3: At what stages in the engineering and design workflow can a material data ecosystem provide the most valuable decision support?

The early concept and exploration stage offers the clearest opportunity for the tool to add value, since design freedom is still high and sustainable alternatives can realistically be considered. At this point, engineers are still deciding which material family or grade to pursue, and having material suggestions, property comparisons, and sustainability indicators accessible in one place reduces the time spent cross-referencing documents, contacting suppliers, or consulting colleagues. Once a supplier has proposed a material that meets all technical and testing requirements, the window for change narrows sharply, as replacing a material at that stage triggers re-testing, re-validation, and renegotiation that few projects can absorb. The later stages of the workflow, such as supplier selection and final validation, demand highly specific and verified data that the tool in its current form cannot reliably provide, making the early design phase the point where it fits best and where it can have the most meaningful impact.

Sub-RQ 4: How do engineers perceive the usability, relevance, and reliability of AI based decision-support tools during material selection?

Engineer responses to the tool varied considerably depending on role and experience level. On usability, the conversational interface meant engineers could start without any training, and carrying chat history across sessions was well-received as it allowed ongoing material discussions to build on earlier exchanges. Where usability fell short was in response consistency, as complex queries sometimes caused the system to loop or lose context, outputs were often longer than needed unless prompts were very precisely worded, and search results occasionally returned information from unrelated material families. Output quality and trust were evaluated more critically, particularly by engineers in senior or specialist roles. Property values in material comparisons were at times unrealistic, source references were too vague to allow independent verification, and sustainability data was often missing or varied significantly without a reference baseline. Perceived value was similarly limited, as incorrect assumptions early in a response carried through to later outputs, requiring engineers to review everything manually before acting on it. Survey responses reflected this pattern, with senior material experts, simulation engineers, and task leaders rating most criteria in the slightly disagree to disagree range, while junior material experts and senior design engineers were somewhat more positive.

Sub-RQ 5: What recommendations can be proposed to enhance the integration and practical adoption of AI enabled decision-support systems within engineering practices?

The most immediate improvement needed is in output format: structured tables should be the default presentation for material comparisons rather than something engineers have to explicitly request, and source references should be presented as directly accessible links rather than file names embedded in text. Response speed, while acceptable at pilot scale, would need to improve before a wider rollout is realistic, since slow response times actively discourage regular use when faster internal alternatives exist. On the data side, supplier sustainability information needs broader material coverage, and Volvo internal data such as CSD documents and CMD entries should be more consistently and clearly retrievable through the tool. Beyond these functional improvements, the tool's positioning relative to existing internal systems needs to be clearly communicated to engineers. Its specific advantage lies in combining supplier sustainability data with Volvo internal material information in a single interface, which no other current tool offers in this form. Without that clarity, engineers have little reason to incorporate another tool into an already established workflow.

Main Research Question: How can a sustainable material data ecosystem, supported by next generation AI tools, improve decision making in the selection of new and more sustainable materials for automotive components?

The AI-enabled SMDE offers a meaningful but currently partial contribution to sustainable material decision-making. Its strongest case is at the early stages of product development, when engineers are still determining which materials and grades are worth investigating, and the tool reduces the time and effort involved in that initial search by consolidating material properties, CO_2 data, and grade-level comparisons into a single accessible interface. For engineers without a deep materials background, this kind of starting point has clear practical value. That said, the study found consistent boundaries to what the tool currently delivers. Output reliability was uneven, sustainability data coverage was incomplete, and the verification required before acting on outputs offset much of the efficiency gain the tool could otherwise provide. The ecosystem does not need to replace existing workflows to be valuable, but it does need to fit into them at the right moment, early enough that material choices are still open, and reliably enough that engineers trust what it returns. When data completeness, source transparency, and output consistency are improved, the tool has a realistic and well-defined role in making sustainable material selection faster, more systematic, and less dependent on individual experience.

8
Conclusion

The goal of this thesis was to understand how engineers at Volvo Trucks Technology go about selecting materials for automotive components, and to look at whether an AI-enabled Sustainable Material Data Ecosystem(SMDE) could help make that process more sustainable. Engineers from the CAB and Chassis departments were involved throughout the study across three rounds of interviews and evaluation sessions, covering a range of roles in material selection for both plastic and metal components. Through this process, personas were built, use cases were developed, and the existing material selection workflow was mapped out to get a clear picture of where the tool could be most useful.

When the AI-enabled SMDE was tested with the engineers, it showed real promise, especially in the early stages of material selection. Instead of spending time searching through multiple sources manually, engineers could get a quick overview of material options, sustainability data, and cost information in one place. Getting that initial direction on what to look into was where engineers found the most value. That said, issues with data accuracy, how outputs were presented, and the lack of clear source references meant engineers could not always rely on what the tool told them. On top of this, the fact that other tools are already widely used within Volvo, and that trust in AI is still developing in a safety-critical setting, means getting engineers to regularly use the tool will take more than just making it available.

Right now, the tool works best as something engineers use to explore and get a starting point, rather than something they use to make final decisions. If the data quality, output format, and usability are improved, and if the tool finds a clear place alongside the other tools already in the organisation, it has a good chance of becoming something that genuinely helps engineers make faster and more sustainable material decisions at Volvo Trucks Technology.

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A

Persona

Role: Material Expert-CAB
Experience: 2+ years
Location: US

Attributes:
- Problem Solving
- Supportive & Insighful
- Practical & Data-Driven

"Sustainability is only sustainable if it's also sustainable financially"

Responsibilities
- Work with CAB Interior and Exterior Plastics & paint systems.
- Generally, solving material application issues and queries for engineers in R&D
- Understand engineers' requirements and give material suggestions and which tests to take for the application by comparing material properties with proper justification.
- Often give material replacements suggestion using test data from CMD; occasionally support production issues and review new supplier technologies regarding material usage.
- Update CMD with material properties based on test data.
- Involved in later stages of PD
- Use – TRs in KOLA, CSD , CMD referring Standards, certifications, Material properties with fatigue cyclic tests, Test reports like flammability, drop tests etc., previous simulations data and data sheets.

Material Selection:
- Based on cost, the design engineer will design for the minimum set of requirements and purchasing team does the commercial discussions to find the cheapest that meets the standards.
- Based on experience and the data present in the CMD.

Challenges
- Hard to read PDFs and Data Sheets for actual test data.
- Hard to find Green house gas emission, end of recyclability and property comparisons and have to Relly on suppliers' data.
- Lack of reliable performance and sustainability data (e.g., fatigue, LCA) for newer or sustainable materials, forcing engineers to rely on assumptions.
- Supplier data is inconsistent, incomplete, or behind paywalls, making comparison difficult and increasing cost and effort to obtain required data.
- Validation takes more time due to low quality data.
- Test data is stored in a fragmented, person-dependent way, leading to data loss when engineers leave and causing costly re-testing.

Need :
- A single interface that consolidates all material data including simulation results, surrogate testing data, and historical performance for material selection.
- A centralized and reliable data management system where all test data is stored, retained, and easily accessible to ensure continuity and avoid redundant testing.
- Integrating previous material test and simulation data in CMD for future reference
- Shared data between purchasing and material experts to have high level idea on cost comparisons.
- More efficient and structured data management system which is easily accessible.
- To have quick estimates in sustainability data and material properties along with Weight to Strength ratio compensating with thickness initially at high level instead of detailed analysis for later.
- Feedback on materials related to SCEM criteria.

Sustainability Considerations:
- Know about SCEM but not highly prioritized early on in a selection process
- Sustaibable alternatives are not practically possible because of cost.
- CO2 emissions from CEC and End of Life Recyclablity of Materials are often used.

Figure A.1: Associate Material Expert Persona

Role : Design Lead
Team: ESS Installation
Experience: 10 years
Location: Sweden

Attributes:

- Sollution-Driven & Accountable
- Collaborative & Curious

“SCEM is more of a rough calculation”

Responsibilities

- Lead Design engineer for Chassis team, managing and tracking other design engineers and cross-functional teams.
- Extensively involved in concept development in the early stages on completely new solutions for metal components. Not much involvement in detailed design.
- Understanding all the requirements and complexity of the product from the project pre-requisites , number of different solutions needs to be developed is planned.
- Requirements include Variant Type or configuration (4 by 2 or 6 by 2 wheels), Road Conditions such as smooth or rough etc, based on these design and dimension of the components decided followed by simulations.

Material Selection:

- Based on experience, materials used in previous project were used for simulations since there has been many years of validations and simulations behind it. However initially the pitching will be for generic material group like Al, Cast Iron.
- Durability and crush requirements such as frontal, side ,bottom and trailer impact influences the Material selection.

Challenges

- Difficult or time consuming to talk to cost engineer to evaluate cost of different alternatives then simulation engineer for performance and then Sustainability with purchasing and diff supplier to understand CO2 output.- Takes lot of time for each component with each function

Need:

- Early collaboration of purchasing, supplier, and engineering teams in the initial design phase to validate feasibility and explore sustainable alternatives
- Need to understand the level of simulation accuracy and confidence associated with different materials, especially when evaluating new or less-tested options.

Sustainability considerations:

- Sustainability requirements are currently emerging in pre-requisites in a lower level such as SOC
- Source of energy and material is relevant since involved with metals.
- Since the battery technologies are evolving so fast, reuse of components are not considered in near future for few years since there are changes of change in interfaces and component sizes.
- Recycled content - do data in the early phase its up to purchasing and supplier.

Figure A.2: Design Engineer ESS Installations Persona

Role : Senior Engineering Task Leader
Experience: 7 years
Location: Sweden

Attributes:

- Technology-focused
- Agile-minded
- Strategic & Risk-averse
- Non-sustainability-driven

”We have SCEM, but it is not the starting point of the project , We start with technology and if they are components carryforward from previous project, we do not have to change materials most of the time”

Responsibilities

- Lead engineering tasks in Steering and Servo team in Chassis department also Scrum master and agile product owner.
- Currently works in Pumps technologie,electronic power steerings and previous worked with Servo Hydraulic lines (HP & LP).
- Involved in all the stages of DVP and even pre-strudies for technology discussions and concept generations of related components but dont have ownership for any component.
- Resposible for creating and approving TRs for the components in Servo lines which design engineers and suppliers follows whenever new project starts.

Material Selection:

- There are many critical-safety components which are related to powertrain there were no changes in materials for many years since many of the components were carried forwarded from previous projects, however technology gets updated.
- Usually, Material type is decided early at a high level in TRs, based on experience which are referred by design engineers and suppliers but does not mention specific material grade.
- TRs include functional requirements (eg pressure, temp), properties(flexibilty) and testing requirements(CBR) to be fullfilled by the material based on the application and working environments of the components.
- Sometimes material requirements are mentioned in the technical drawings of the components depending on the team.
- Suppliers propose materials based on requirements along with cost, manufacturability, and assembly but also packaging.
- Material selection is an iterative, back-and-forth process with suppliers, where initial choices are often revised based on evolving requirements like lightweighting.
- Usually prefer familiar, proven materials that suppliers can produce at scale, at low cost, and with reliable quality- even when lighter alternatives (like aluminum) are suggested.

Challenges:

- Material requirements are often defined externally by a central materials department, and changes (e.g., restricting steel) may be communicated indirectly via suppliers or SQEs rather than directly to the design team.
- Market readiness is important: A material and design is only useful if the enough supplier are available and can produce it in large quantities on time.
- Material changes take long (about a year) due to testing and validation, making them especially difficult for safety-critical components.
- We are directly connected to Powertrain in Chassis , so SE lines and SAS area have lot of critical components and way of testing is different and requires more lead times.
- Sustainable material suggestions can be made, but final decisions are driven by cost and budget owners.

Need:

- Need to assess supplier availability and production scalability early to ensure the selected material and design are market-ready and feasible for mass production.
- Need for faster testing and validation methods to reduce the time required for material changes, especially for safety-critical components.

Sustainability Consideration:

- SCEM is not used most of the times.
- Sustainability aspects are not taken into consideration, since there are many critical safety parts and material changes can’t be compromised.

Figure A.3: Engineering Task Leader Persona

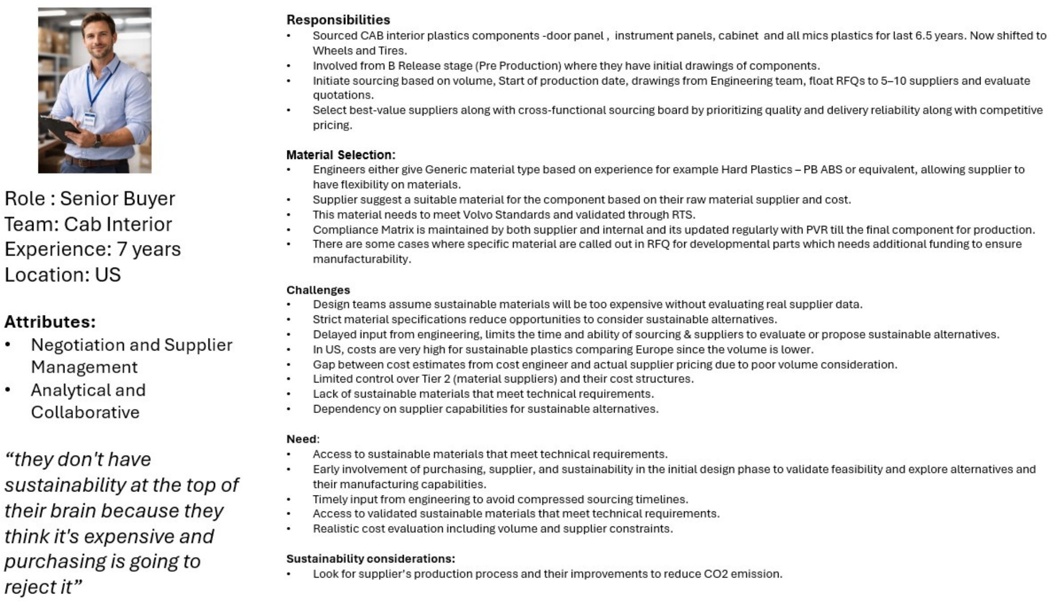
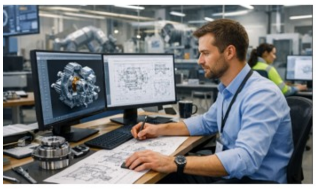


Figure A.4: Senior Buyer Persona

Figure A.5: Senior Design Engineer MUC Persona



Role: Senior Design Engineer
Team: Cab interior
Experience: 14+ Years
Location: US

Attributes:
- Surface quality focused
- Shrinkage & Warpage aware
- Test Data driven

Documents Used
- KOLA
- CSD
- CMD
- Environmental TR
- Testing documents

Tool
- CATIA

"First thing is cost; sustainability is treated as a nice to have."

Responsibilities
- Works on all interior parts in cab living like trims, plastic parts, sun visor, curtain rails, interior lightings, grab panels etc.
- Is involved in all stages of the DVP cycle from the concept phase till the component is produced.
- Responsible for creating the TR for the component that is sent to the supplier.
- Decides on a tentative material for the component after the concept is approved by the stakeholder and it meets all the requirements. At this stage, the B-release of the component is done.
- Use – TRs in KOLA, CSD , CMD, Material spec sheet, material standards and CREO.

Material Selection:
- After the B-release the supplier is involved, they suggest materials that satisfy the requirements set by the component owner.
- Checks for the manufacturability of the material with the supplier, especially scratch resistance.
- The responsibility of the design engineer is to give the core requirement for the components. This generic requirement of the material needs to meet by the supplier and the purchasing department. The best materials that meets the requirements is selected.
- Cyclic loading is used early to screen materials; if fatigue performance is insufficient, a higher-grade material is selected.
- Material selection is determined by properties including moldability, scratch resistance, dimensional stability, shrinkage, and warpage after demolding.

Sustainability Considerations:
- Knows about SCEM but not highly prioritized as it is a relativey new tool.
- Sustainable materials are not easy to get because the suppliers are basically startups and they are not ready for high volume. And also products are not consistent in each batch.
- Replace current materials with alternatives that provide higher recycled content while maintaining required performance.

Challenges
- Getting old test data for the materials.
- Difficulty in Finding the pass criteria for testing a component in TR as that need to be satisfied for the component to clear all requirements.
- Some failure modes are missed because the requirements and testing conditions are not strict enough.
- Comparing materials suggested by the supplier based on the generic requirement given by the design engineer.
- Unclear how much effort or cost Volvo is willing to commit to sustainability improvements.
- Need to identify an effective way to communicate and sell sustainability as customer value.

Need :
- Testing data of the material that has tests like heat cycling, color testing, etc. This helps in choosing a material for the component with confidence.
- Reliable sustainable material supplier that can produce high volume and consistent components.

Figure A.6: Senior Design Engineer US Persona

Role : Senior Materials Expert
Team: Cab Interior
Experience: 3.5 years
Location – US

Attributes:
- Research Driven with PhD
- Sustainability-focused
- Problem Solving & Innovative
- Collaborative & Influential

"the earlier it can be involved or considered, the less we have to try to do retroactively, which is where I run into all my bottlenecks with testing and money"

Responsibilities:
- Lead the material science team in CAB engineering as subject matter expert consultant supporting engineers with material selection, testing, and simulation-related queries rather than owning components directly.
- Focuses on providing reliable material data and insights to assess simulation accuracy and suitability for specific applications.
- Proactively explores new (especially sustainable/recycled) materials and collaborates with engineers to test, validate, and integrate them into products.
- Involved in later stages of PD in C to Prelease or later when issues arise such things don't work as expected and suggests better material options considering the application and manufacturing process or when introducing changes (e.g., recycled materials) into already developed or near-release products retroactively.
- Often work with CAB Interior and Exterior Plastics and Polymer Composites and sometimes metal fasteners along with information support on Al grades and new steel grades.
- Occasionally consult materials early, since material considerations are often secondary to geometry and design in initial phases.

Material Selection:
- Not directly involved in Material Selection of components but gets involved after a material is already chosen, validates better alternatives (e.g., recycled versions), and then helps replace or update materials in existing and future applications once proven.
- Evaluate Sustainable materials based on their ability to meet minimum TRs like strengths, stiffness, thermal resistance , paintable on recycled surface with color matching along with cost.
- Materials are initially selected by product owners that has some minimum requirements as per Volvo Standards which is rolled out to suppliers in RFQ and purshasing evaluate different supplier quotes based on cost , how they are made etc.
- Sometimes specific materials are directly mentioned in RFQs as company's grade based on prior testing, proven technical performance (from engineers), or sustainability interest (from material experts).

Challenges
- **Lack of reliable early-stage tools:** Existing sustainability calculators are too high-level and assumption-based to trust for early material decisions.
- **Dependence on individual expertise:** Decisions rely heavily on personal knowledge, which can vary between experts and is hard to scale.
- Validation takes time like testing, storing data, finding budget, coordinating teams.
- **Limited budget for late-stage validation:** Difficult to secure funding and resources to test, simulate, or revalidate sustainable materials which have high potential and introduced after initial material selection.
- **Limited control over material selection because** Suppliers choose materials based on cost and process compatibility, making it hard to enforce specific sustainable choices and this flexibility in supplier selection leads to differences in materials, making standardization and reuse of past data difficult.

Needs
- **More accurate and trustworthy tools:** A solution that provides reliable, low-assumption sustainability insights early in the selection process.
- **Clear comparison metrics:** Easy way to compare materials (e.g., CO_2, recycled content, impact) in a standardized format.
- **Better alignment with suppliers:** A way to guide or influence supplier choices towards sustainability and performance goals without removing their flexibility.
- Need allocated funding in order to get good material data for simulation and validation of materials.
- **Early involvement in material selection:** To include sustainable options in RFQs, enable parallel testing within budget, and have validated alternatives ready if issues arise later.

Sustainability Considerations:
- One of the early and key users of SCEM and uses quite retroactively in material selection.
- More focused on Design for Circularity and recyclability.
- End of recyclability of materials is highly considered because it is difficult for plastics components which needs to be fixed together.
- Recycled content, density of material or light weighting component are related to overall CO2 emissions.
- SOC in materials is mandatory.

Figure A.7: Senior Material Expert Persona

Role : Simulations Engineer
Team: ESS Installation
Experience: 25 Years+
Location :Sweden

Attributes:
- Consultant
- Structural analysis

Tools & Documents Used
- ANSA
- Abaqus
- CMD data
- CSD data

"we have material libraries to find those value of yield and ductility, etcetera. That can be a little bit difficult sometimes to find the material details."

Responsibilities
- Set up and perform structural analyses, ensuring correct boundary conditions, assumptions, and evaluation against defined requirements.
- Define analysis criteria based on application (e.g., durability below yield, crash in plastic region) and validate results accordingly.
- Identify, verify, and apply accurate material properties (e.g., yield strength, ductility) using material libraries and data sources.
- Interpret simulation results to assess performance limits and ensure compliance with strength and durability targets.
- Recommend alternative materials or adjustments to optimize strength, ductility, and weight based on analysis outcomes.
- Collaborate with design engineers to support material selection and ensure design feasibility from an analysis perspective.

Material Selection:
- Design engineers choose the initial material based on experience, standards, or past projects.
- Validates selected materials through simulations (durability, crash) and if stresses are below yield (durability) then the material is acceptable or may even be optimized (lighter/cheaper). But if the stresses are above allowable limits recommend a stronger or more suitable material based on material libraries.
- Iterative process where a material is selected ,analyzed and refined.

Challenges
- Hard to find accurate and complete material data from material libraries in their department comparing other teams.
- Getting data for above yield materials are difficult. Plastic behavior requires detailed experimental data and complex models, which makes simulations above yield much harder to set up accurately, often requiring assumptions or tweaking data for similar materials (e.g., different aluminum types).

Need :
- Access to detailed material data for plastic behavior (beyond yield), especially for different material variants.
- Reliable and standardized material data to avoid manual adjustments or assumptions during analysis.
- A common, integrated material database across teams and locations (e.g., Bangalore, Gothenburg) for easy data sharing and consistency.

Sustainability Considerations:
- Reduce the weight of the component by selecting lighter material which helps in reduced CO2 emissions production.
- Recyclability of Aluminum is more environmental positive for their components

Figure A.8: Simulation Engineer Persona

Role : Sustainability Leader
Experience: 4 years
Location: Sweden

Attributes:
- Influential & Collaborative
- Data Driven & System level thinker.

"Always have to balance between the different features in sustainability. There will never be like one solution fits all"

Responsibilities
- Advice & support sustainable decisions without final authority over selection of materials for Chassis Team Gothenburg
- Influence more at Early stage of PD and involved till C release
- Review SCEM and propose sustainable material alternative for potential components by connecting engineers with material experts.
- Review meeting with Chassis internal, Platform sustainability for sustainable pre-studies Eg: End of life Vehicle directive and follow-up EPICs and sync meetings with global sustainability team.
- Use SCEM rollup sheet, LCA guidelines

Material Selection:
- Does not select any material since there is no part ownership.
- Engineers discuss with buyers for sustainable material options usually.
- Has no direct contact with purchasing team but some indirect collaborations through platform sustainability team and connect engineers with fossil free material purchasing team if there is a need and usual buyer does not have any options.

Challenges
- Hard to know which sustainable materials exist in the market.
- Even if alternatives exist, it is unclear whether they work for a specific application.
- Some sustainable options (like zero-steel) are available only for certain material grades.
- Lack of reliable and early-stage cost visibility for sustainable solutions, creating uncertainty in evaluating their overall cost impact.
- Lack of detailed and precise sustainability data, as existing tools provide only high-level emission estimates, limiting accurate environmental impact assessment.
- Difficulty in obtaining consistent and reliable CO_2 data from suppliers, as it depends on their varying capabilities and mismatches in LCA tools and databases.
- Lack of direct collaboration between sustainability team and purchasing.

Need:
- Dedicated budget to implement sustainable solutions since it affects total cost.
- Detailed and precise sustainability data with applicability for a particular component or manufacturing process.
- Better collaboration between engineering, purchasing and suppliers to get awareness about possible options during design decisions.
- Standardized and reliable supplier data for requesting sustainable options in RFQs.

Sustainability considerations:
- LCA guidelines for suppliers on CO2 emission , which is currently not mandatory because "currently anything we get is better that nothing"
- Material and Environmental impact in the SCEM which has five criteria. Additionally, there are other features driven by engineers such is load capacity, weight reduction, energy efficiency, maintainability etc. which are indirectly connected to sustainability.
- Reducing diversity which is connected to circularity.
- "No criteria is important than others since we have different requirements and it is difficult to fulfill all of them. So, we always find balance depending on case to case". Eg: In plastic components we can reduce weight and reduce CO2 emissions. But plastics can't be recycled or it's difficult to find recycled plastic.
- SOC is legal requirement so it's mandatory to do it.
- CO2 is quantifiable and main focus currently. But circularity is difficult to calculate, and we must argue whether its achieved or not but to fulfill Volvo sustainability goals it is considered.

Figure A.9: Sustainability Leader Persona

B

Requirements List

Table B.1: Detailed User Needs Identified from Interviews

Engineer / Persona	**Need Description**	**Need Type**
Design Engineer	Reliable test data from the raw material (heat cycling, color testing).	Data
	Need for recycled content of materials.	Data
	Need for heat treatment data and its impact on material properties.	Data
	Need for data on supplier energy sources used during material production.	Data
	Need for estimation of mechanical properties such as stiffness, ductility, tensile strength, yield strength, and formability of sustainable materials.	Data
	Need for up-to-date sustainability material data.	Data
	Need for reliable crash analysis data for material evaluation.	Data
	Need for data on trade-off between cost, performance, and sustainability criteria of materials.	Data
Material Engineer	Need material testing data in a centralized database.	Data
	Need previous simulation data of materials in a centralized database.	Data
	Rapid high-level estimation of sustainability data.	Output
	Need for data on greenhouse gas emissions, recyclability, and property comparisons.	Data
	Need for reliable performance and sustainability data for new sustainable materials.	Data
	Need for reliable validation data from raw material suppliers.	Data
	Early involvement in material selection for testing and validation of sustainable materials.	Organizational
	Need for efficient representation of technical documents regarding testing.	Latent
	Need for cost-effective sustainable material alternatives.	Data
Simulation Engineer	Need for detailed material behavior data beyond yield properties, especially for different plastic material variants.	Data

Engineer / Persona	**Need Description**	**Need Type**
Buyer	Timely input from engineering to avoid compressed sourcing timelines.	Organizational
	Realistic cost evaluation including volume and supplier constraints.	Organizational
Sustainability Leader	Need for quantifiable circularity data for materials.	Data
	Need for reliable recycled plastic data.	Data
	Need for grade-specific sustainability data.	Data
Design & Material Engineer	Need for manufacturability data for sustainable materials.	Data
	Need for clear and robust testing requirements, conditions, and pass criteria to capture all relevant failure modes.	Testing Related
	Need for reliable suppliers capable of consistent high-volume material production.	Supplier Related
	Need for standardized material selection and early supplier scalability assessment to ensure feasible mass production.	Organizational
	Need for standardized material comparison and ranking based on properties and supplier data.	Output Related
	Need for feedback and reasoning on sustainability criteria of materials.	Output Related
	Need for weight optimization data, including strength-to-weight estimation with thickness adjustments.	Data
Design, Simulation, Material Engineer	Need for validated and trustworthy simulation data to ensure accurate evaluation of new or less-tested materials.	Data
	Need for shared data between purchasing and material experts to have a high-level idea on cost comparisons.	Centralized Material Database
	Need for an integrated and accessible material data management system across teams and locations.	Centralized Material Database
	Need for validated location-specific CO_2 data that reflects supplier and production differences.	Data
Common	Need for consistent and comparable supplier material data.	Data Quality Related
	Need for reliable sustainability assessment tools.	Data Quality Related
	Need for detailed sustainability data aligned with manufacturing processes.	Data Quality Related
	Need for standardized, accessible, and high-quality material data to reduce manual assumptions.	Data Quality Related
	Need for clear information on available budget and dedicated funding for validating sustainable materials.	Budget and Testing Time Related
	Need for faster and cost-effective validation methods for material change.	Budget and Testing Time Related
	Need for early collaboration of purchasing, supplier, and engineering teams to explore feasible sustainable alternatives in early design iterations.	Collaboration Related

C

Evaluation of AI Tool with Use Cases

Persona	Information Needs	Tools Response	Comments
Use Case 1 -- Side Crash Shield (Chassis, ESS)			
Simulations Engineer (P6) and Design Lead (P7)	Find Sustainable Alternative for VAW6005A+T6 Aluminum alloy	Yes	
	Filter the Aluminum alloys from them which can be formable	No	
	Carbon Foot print materials for the given Weight	Partial	Gives incomplete information and assumptions
	Show some materials with similar ductility or 20% lower	Partial	Not sure if the provided data is correct
	Compare the yield strength, tensile strength also fracture elongation properties with reference material	Yes	
	Requirement on Heat Treatment for the material	Partial	But some incorrect information as well
	Reasoning on reliability	No	
	Simulation accuracy of this alternative material compare to reference material	No	
	Additional Needs During the Evaluation Meeting		
	Explanation for Sustainability Critieria such as GWD, ODP,AP, EP	Yes	
	Fracture Elongation of Sugested material	Yes	
	Mechanical properties of VAW6005A+T6	No	Sometimes it gives and sometimes it doesnt
	Material suitable for Extrusion Process	Yes	General Information
Use Case 2 -- Chassis Fairing (CAB, Exterior Plastics)			
Senior Material Expert (P2), CAB	Sustainable alternative for PC ASA with similar impact strength, UV resistance with lower weight	Partial	Incorrect informations
	Suitability for injection molding and formability and chances of wrapping	Yes	
	Shrinkage Charecteristics of sugested materials	Yes	
	Chemical resistance, Moisure resistance, Thermal Stability of the materials	Yes	
	Additional Needs During the Evaluation Meeting		
	Filtering the options with High level Resin types	Partial	Irrelevant informations
	Compare chorpy notch impact strength or Izod and Cost and Stifness	No	Incorrect and irrelevant informations
	Source of Cost details	No	
	Need for material selection guidance based on functional(Stiffness), aesthetic, and aerodynamic requirements.	Yes	
	Sustainability Rating or Carbon footprint	Yes	
	Previous Test results on scratch resistance, Uv stability and mechanical properties of the materials	Yes	But General information
Use Case 3 -- Coolant Hose			
Material Expert (P1), CAB	Situable material meeting required Operating temperature and pressure	Yes	
	Compactibility of material with Ethylene Glycol Coolant	Partial	
	Tensile strength, flexibility of materials	Yes	
	CO2 or Green House Gas emissions, LCA, Recyclabilty of the materials	Partial	Incomplete informations
	Reasoning on compactablity of material from double later to single layer hose	Yes	
	Additional Needs During the Evaluation Meeting		
	Compactibility of material with Extrusion process	Yes	
	Glass fiber content needed to balance increased strength and stifness will allowing flexibility - Reasoning	Yes	
	Compare Carbon emissions during production, difference in weights and cost	Partial	Incorrect cost data and sustainability data - assumptions
	Comparing Tensile strength, ductility, youngs modulus , impact strengths	Yes	
	Summarize a Volvo Standard	Partial	No details
	Suggesting a Volvo standard for UV stability of exterior plastics	Partial	Very general information
	Validation of material compliance with exterior UV durability requirements and standards - Reasoning	Yes	
	Recommendation of material for exterior placstic that can withstand UV for 2000 hours	Yes	
	Compare Cost of different plastic grades including glass filler versions	Partial	Assumptions
	Compare UTS, Flexural Strength, Tensile Modulus, Flexural Modulus, Ductility of the plastic materials	Yes	But incorrect information
	Looking for information on TR and engineering reports from EPDs	No	
	Comparing cost of materials from Europe and North America	No	
Use Case 4 -- MUC Side Beam (Chassis, MUC)			
Senior Design Engineer (P5), Chassis MUC	Suggest some Al or Steel grades which offers better elongation and lower density.	No	Irrelevant information
	Compare the max yield strength and moment of inertia of these material grades	No	
	CO2 emission	Yes	
	Compare the CO2 data the material grades from supplier in different locations and based on how they are produced	Yes	
	Compare other recyclable aluminum grade materials with Aluminum VAW6082+T6	Yes	
	Material Compactability with rheo-casting manufacturing method	Yes	
	Compare and rank these materials based on crash performance, weight and sustainability	No	
	Comparing energy absorption and failure behavior under crash conditions	Yes	
	Al material best for crash impact comparing properties	Yes	
	Additional Needs During the Evaluation Meeting		
	Compare Torque which can take without failure for beam in different Al	No	
	Which thickness best for square beam comparing Crash performance, cost, carbon foot print	Partial	Many assumptions
	Weight reduction and weight to strength ratio estimation	Partial	Many assumptions
Use Case 5 -- B-Pillar Trim (CAB, Interior)			
Senior Design Engineer (P3) & Senior Buyer (P4), CAB Interior	Sustainable Options for Thermylene XPT R020 TPO resin	Yes	
	Recyclabilty of the materials	Yes	
	List of talc-filled TPO (~20%) grades offer comparable mechanical performance	Yes	
	Comparing Tensile strength, Flex modulus, Charpy notch strength	Yes	
	Shrink rate and Flex modulus of the suggested material	Yes	
	Additional Needs During the Evaluation Meeting		
	Sustainable Alternative Resin for PP+20% EPDM	Partial	Some irrelevant information
	Suitability for injection molding	Yes	
	Alternatives that can be used for class A parts, where the colorant is molded at the press	No	Incorrect and some incomplete responses
	Resins ability to be colored specifically with masterbacth or colorant added at press	Yes	Provides information whether can be done or not
	Material with injection mold grade resin that can replace PP + mineral or talc filler	Yes	Some data not avalaible
	Specific grades that use natural materials such as hemp fiber, cellulose, or others as filler in a PP resin	Yes	
	Compare Material Properties of Thermylene XPT 444a R020 to Jute, Hemp and bioplastics	Yes	
	Burnrate of resins comparing Volvo's maximum requirement or FMVSS201	Yes	

D

Questions and Prompts for AI Tool Evaluation

This appendix provides the complete list of questions and prompts used during the evaluation of the AI-enabled material data ecosystem. The prompts are organized by use case and consist of a primary query followed by structured Guiding Questions, as used during the third round of evaluation sessions with engineers.

Use Case 1 – Side Crash Shield (Chassis, ESS)

Primary Query: Suggest some alternative sustainable material choices for VAW6005A+T6 with similar properties.

Guiding Questions:

1. Filter the aluminium alloys from them that are formable.
2. Among them, show materials with similar ductility or up to 20% lower.
3. Compare the yield strength, tensile strength, fracture, and elongation properties of these materials with VAW6005A+T6.
4. Does the alternative material require heat treatment?
5. What is the carbon footprint of these materials?
6. How reliable are the suggestions, and how are they validated?
7. What level of confidence can we expect in the real-world performance of these alternatives?
8. Suggest some aluminium or steel grades that offer better elongation and lower density.
9. Compare the maximum yield strength and moment of inertia of Stena AL 44300, VSSC44+N, and VSSC44+U.
10. Compare how much torque a 50×150 square beam made from different aluminium or steel grades can withstand without failure, varying thickness and material grades based on yield strength, elongation, and tensile strength.
11. Compare the CO_2 emissions and energy consumption of the previously mentioned materials.

Use Case 2 – Chassis Fairing (CAB, Exterior Plastics)

Primary Query: Suggest some recyclable, sustainable alternatives for PC/ASA with specific grades for the chassis fairing, that are strong enough to withstand road debris, have good UV stability, are not heavier than the current material, and are suitable for injection moulding.

Guiding Questions:

1. What is the CO_2 footprint of the suggested alternatives, and are they recyclable?
2. How does the carbon footprint change if this material is sourced from the US versus Europe, and what is the impact of transportation if sourced from Asia versus locally?
3. How reliable are these sustainability estimates, and what assumptions are being made?
4. Rank the suggested alternatives using sustainability as one of the key metrics, providing specific rather than generalised information.
5. What are the shrinkage characteristics of the suggested material compared to the current PC/ASA? Does it contain glass fibre?
6. Is the suggested material compatible with the existing injection moulding tooling? What are the chances of warping after demoulding, and would tooling modifications be required?
7. What is the estimated confidence level that the new sustainable grade could be used directly in the existing tooling without modification?
8. Compare the key material properties — including chemical resistance, moisture resistance, and thermal stability — between the suggested alternatives and the current material.
9. Which tests are most critical for this material and application, and which properties must be validated before production?
10. Are there any previous test results or similar application data available for the suggested material?
11. What are the key risks associated with using this material compared to the current material?
12. Which tests could potentially be avoided for this application to save time and cost, and what is the likelihood of success if proceeding without full testing?

Use Case 3 – Coolant Hose (CAB)

Primary Query: The current material used for the coolant hose is PA 612, designed as a two-layer component. I want to redesign it into a single-layer solution. What alternative materials could achieve this while meeting an operating temperature of 150°C and a burst pressure of P480, in compliance with the relevant standards?

Guiding Questions:

1. The hose comes into contact with ethylene glycol coolant. Is the suggested material compatible and resistant to degradation in this environment?
2. Can it provide the required mechanical strength, flexibility, and barrier properties in a single-layer configuration?
3. What is the density of the suggested material, and is weight reduction possible compared to the current PA 612?
4. What are the key mechanical properties of the material, such as stiffness, strength, and fatigue performance, and how does its weight-to-strength ratio compare to the current material?
5. Can it be processed using the same manufacturing method as the current material, or are process changes required?
6. Among the suggested options, which materials have lower greenhouse gas emissions, and what is the carbon footprint associated with their production?
7. Is reliable life cycle assessment data available for these materials, and how recyclable are they at end of life?
8. How reliable is the provided data, and what assumptions are being made?
9. Which tests are most critical for this material and application before proceeding to production?
10. Compare the suggested materials based on cost index, weight, and CO_2 emissions to identify the best overall trade-off.

Use Case 4 – MUC Side Beam (Chassis, MUC)

Primary Query: Which aluminium material grades offer higher elongation while keeping adequate yield strength for the defined crash performance requirements?

Guiding Questions:

1. Which of these aluminium grades provide the lowest CO_2 (kg CO_2/kg) while meeting the elongation and yield requirements?
2. How do the candidate materials rank across SCEM sustainability dimensions — CO_2 cradle to gate, recycled content, recyclability, and design for circularity?
3. Compare the CO_2 data for these material grades from suppliers in different locations and based on their production methods.
4. Compare the maximum yield strength and moment of inertia of the candidate material grades.
5. Are these material grades compatible with the rheo-casting manufacturing process?

6. Compare other recyclable aluminium grades with VAW6082+T6 in terms of elongation, yield strength, and density.
7. Suggest aluminium or steel grades that offer better elongation and lower density than the current material.
8. Compare and rank the candidate materials based on crash performance, weight, and sustainability.
9. How do the identified sustainable alternatives compare to the current material in terms of energy absorption and failure behaviour under crash conditions?
10. What material or design changes can reduce component weight without compromising crash performance?

Use Case 5 – B-Pillar Trim (CAB, Interior)

Primary Query: Give a list of talc-filled TPO (∼20%) grades that offer comparable mechanical performance — tensile strength, flexural modulus, and Charpy notch strength — with a lower CO_2 footprint and recycled content.

Guiding Questions:

1. How do the performance specifications — including tensile strength, flexural modulus, Charpy notch strength, and shrinkage rate — of the suggested alternatives compare against the benchmark TPO material?
2. The benchmark material has a flexural modulus of 2100 MPa. What alternative solutions exist that are fundamentally different in material composition from the current TPO?
3. What is the verified CO_2 footprint (kg CO_2/kg) for each suggested grade?
4. Which of the suggested alternatives best meets the overall sustainability requirements when considering recycled content, recyclability, and carbon footprint?
5. Is retooling the existing injection moulding tooling necessary for the suggested material, and what changes would be required?

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