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Optimizing the Requirements Engineering Process for the Luggage Compartment Load Floor

Master's thesis in Production Engineering

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Abstract

This thesis focuses on the luggage compartment load floor, a component that is often overlooked in vehicle development despite its influence on customer experience and product cost. Conducted at Volvo Cars, the study aimed to optimize the requirements engineering process for the load floor by identifying outdated and excessive requirements and developing a structured prioritization framework to reduce unnecessary complexity and cost while maintaining customer value.

The study employed a mixed-methods approach, combining semi-structured interviews, internal and external surveys, benchmarking, production observations, and analysis of internal quality data. The findings indicate that several requirements no longer reflect actual customer needs and have been carried over from previous vehicle programs without sufficient validation. To address this, a structured Requirements Engineering framework was developed to support the development, specification, and management of requirements. The framework was validated through the P113 case study, demonstrating that requirements can be systematically challenged when decisions are supported by empirical data. The results indicate that cost reductions can be achieved by removing outdated requirements without negatively affecting customer satisfaction.

Keywords: Requirements Engineering, Product Development, Requirements Management, Requirements Prioritization, Customer Value, Traceability, Over-specification, Automotive Industry.

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William Lindström, Nathan Tekle, Gothenburg, June 2026

List of Acronyms

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

CNL	Controlled Natural Language
DFA	Design For Assembly
EV	Electric Vehicle
MBSE	Model-Based Systems Engineering
NL	Natural Language
PQ	Perceived Quality
PQS	Product Quality Survey
RD	Requirements Development
RE	Requirements Engineering
RESPECT	REquirement SPECification using Templates
RM	Requirements Management
RS	Requirements Specification
SBO	Strategic Business Owner
SPO	Strategic Product Owner
WOW	Way Of Working

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1
Introduction

This chapter introduces the project, along with the subject and scope of the master's thesis. The purpose of this chapter is to provide a solid background and overview of the project, its intended contribution, and its scope.

To ensure a comprehensive understanding of the research environment and technical scope, this chapter defines the organizational and operational context of the study. Furthermore, it provides an overview of Volvo Cars and the specific engineering department in which the research was conducted, highlighting the internal processes relevant to product development.

1.1 Background

The global automotive industry is currently navigating a period of unprecedented transformation, primarily driven by the transition toward electrification, digitalization, and the circular economy [1]. As vehicle manufacturers commit to all-electric lineups, the focus on resource efficiency and weight optimization has intensified. For an electric vehicle (EV), every kilogram of mass directly impacts energy consumption and driving range, necessitating a more rigorous and data-driven approach to component design and material selection. Furthermore, the shift toward sustainable manufacturing requires a departure from traditional "linear" development models toward circular strategies that prioritize durability and recyclability without compromising the premium brand experience.

This thesis is conducted in collaboration with Volvo Cars, a company at the forefront of this transition with a stated ambition to become a fully electric car company, and also aims to reach net zero greenhouse gas emissions by 2040 [2]. The research is hosted within the Vehicle Engineering department, which plays a pivotal role in the mechanical architecture and integration of interior components. At Volvo, the development of complex systems relies on a legacy of high-quality engineering standards; however, the rapid pace of market innovation demands a constant evaluation of these internal norms. To maintain competitiveness, the department utilizes advanced digital benchmarking tools, which provide high-fidelity teardown data and technical insights into "best-in-class" competitor solutions.

The focal point of this study is the luggage compartment load floor, a component that must balance diverse and often conflicting requirements, including structural integrity, acoustic performance, weight efficiency, and aesthetic quality. Historically, there has been a risk of requirements becoming over-specified, as Requirements Specifications (RS) are often carried over from previous vehicle generations without sufficient validation against current market demands. This can lead to over-engineering, a phenomenon where internal perceptions of quality result in increased costs and weight that do not necessarily translate to added customer value. Ultimately, this drives a bigger challenge connected to the environment, where resources are being exploited worldwide and not utilized in a sustainable manner.

The disruption in automotive consumption and technology necessitates a corresponding disruption in Requirements Engineering (RE) decision-making. As the industry moves toward more efficient and sustainable architectures, the challenge for engineers is to optimize the RS to ensure it is lean, correct, and based on empirical data. By utilizing competitive benchmarking as an elicitation and validation tool, this thesis aims to bridge the gap between legacy internal standards and modern market realities, ensuring that the next generation of load floor specifications is optimized for the demands of the future automotive landscape.

1.2 Aim

This thesis aims to review the current requirements and propose improvements to the RE process for the luggage compartment load floor at Volvo Cars. This is achieved by identifying redundant or excessive requirements and developing a structured Requirements Engineering framework to reduce unnecessary complexity and cost while maintaining customer value.

1.3 Scope and Limitations

The scope of this thesis is limited to the luggage compartment load floor and its associated requirements. Although requirements from surrounding systems and connected components are taken into account, the scope is intentionally kept focused on the load floor itself rather than the broader system. The project is conducted at a conceptual level and does not include detailed design proposals or physical prototyping; instead, it provides recommendations and a framework intended to support future development decisions.

The work is further limited by the project time frame of 30 credits, which restricts the depth of analysis that could be conducted within the project.

1.4 Research Questions

Three research questions were developed to guide the work:

- RQ1: What are the current challenges in the requirements engineering process for luggage compartment load floors at Volvo Cars?

- RQ2: How can a structured prioritization framework be integrated into the existing RE process to address these challenges?

- RQ3: What are the effects and lessons learned from applying the proposed Requirements Engineering framework to a real-world load floor project?

RQ1: The first research question aims to establish a clear understanding of the current state of the RE process at Volvo Cars, specifically for the luggage compartment load floor. Before any improvements can be made, it is necessary to identify potential challenges within the current system and how the current requirements are defined, managed, and traced back to actual customer needs.

RQ2: Building on the findings from RQ1, the second research question explores how a structured Requirements Engineering framework can be developed and integrated into the existing process. The goal is to introduce a systematic approach that supports the development, specification, and management of requirements while helping engineers evaluate which requirements genuinely add customer value and where resources should be allocated.

RQ3: The third research question evaluates the practical impact of applying such a framework in a real development project. By examining a real-world case from Volvo Cars, the aim is to gain an understanding of what works, where challenges arise, and what value can be gained from challenging and removing requirements that no longer serve a clear purpose. This provides a validation of the framework developed in RQ2.

2
Theory

This chapter aims to establish a theoretical framework. The purpose is to motivate the choice of analytical areas and explain how the theory is used to identify challenges and guide improvement work in RE.

Furthermore, the chapter outlines the key concepts and models that explain why each analytical step in this study is necessary to understand and optimize the RE process for the luggage compartment load floor. Since optimization and product development play an important role in enabling both reliable and flexible production, this understanding is particularly important in manufacturing environments characterized by high product variety.

2.1 Requirements Engineering

RE is defined as a systematic and disciplined approach to the identification, analysis, and management of the goals and constraints of a system. Within the engineering lifecycle, RE serves as the critical bridge between the high-level expectations of stakeholders and the technical implementation of the product. The primary objective of RE is to ensure that the developed system effectively fulfills its intended purpose while mitigating the risks associated with miscommunication or misunderstanding of needs [3].

As a core activity within the RE phase, RS involves the formalization and documentation of analyzed requirements into structured artifacts. Theoretical frameworks in RE distinguish between the process of eliciting needs and the act of specifying them. The resulting specification serves as the primary reference for all downstream development activities, including design, manufacturing, and verification [4].

2.1.1 Requirements Development

RE consists mainly of three pillars: the first, Requirements Development, the second, Requirement Specification, and the third, Requirements Management. RE is seen as the umbrella term for the field, and the development phase consists of four important steps: Elicitation, Analysis, Documentation, and Validation.

Elicitation
Unlike the passive term of “gathering,” elicitation implies an active, iterative discovery process. According to Pohl, elicitation involves the systematic identification and acquisition of requirements from various stakeholders and sources to define the system’s goals and boundaries [4]. In the context of complex automotive systems, such as a luggage compartment load floor, elicitation serves to bridge the gap between abstract customer desires and concrete technical constraints.

Analysis
The analysis phase serves as the analytical bridge between the initial elicitation of needs and the final formalization of specifications. According to Pohl, the primary objective of requirements analysis is to detect and resolve conflicts between stakeholders’ goals, evaluate the technical and economic feasibility of proposed requirements, and prioritize them based on their value-to-cost ratio [4].

Furthermore, the analysis phase incorporates the requirement negotiation, where trade-offs between conflicting attributes are evaluated. By utilizing a structured analysis framework, requirements are categorized and prioritized to ensure that the final specification is not only correct but also feasible and minimalist. This ensures that the resulting system architecture is optimized for both competitive performance and cost-efficiency, by grounding technical decisions on empirical data [5].

Documentation
The documentation phase of the requirements development involves the action of capturing, organizing, and recording information into a structured, persistent format. The primary objective of this documentation is to provide a clear, unambiguous, and verifiable basis for all subsequent engineering activities, including system design, procurement, and quality assurance [4].

Validation
The validation phase constitutes the final evaluative stage of the requirements development process. Its primary purpose is to ensure that the documented requirements accurately represent the stakeholders´ needs and provide a “fit-for-purpose” foundation for system development., According to Pohl, validation answers the fundamental question “Are we building the right system?” This is distinct from verification, which focuses on technical compliance with the specification [4].

2.1.2 Requirements Specification

The RS phase is the process of formalizing the elicited and analyzed needs into a structured, persistent, and verifiable documentation format [6]. The primary objective of this phase is to produce a “single source of truth” that serves as the basis for design, manufacturing, and quality assurance. Rather than merely documenting existing norms, this phase focuses on the precise articulation of requirements to ensure they meet rigorous quality criteria of completeness, consistency, correctness, and non-ambiguity.

Effective documentation in this phase is critical to mitigating the risk of misinterpretation during the later stages of the vehicle development cycle. By formalizing a data-driven specification for the load floor, the project ensures that each requirement is verifiable, meaning that its fulfillment can be objectively verified through testing or simulation. This formalization is not only a technical necessity for Volvo's internal Engineering-to-Order processes but also an academic prerequisite for establishing traceability, allowing each engineering constraint to be mapped directly back to its empirical source, thereby eliminating the requirements that have been passed on from previous generations, often found in legacy documentation, which is also known as "zombie requirements".

Unambiguity
Unambiguity is the requirement quality ensuring that a statement can be interpreted in only one way by any reader, regardless of their technical background. In complex engineering projects, ambiguity often arises from the use of subjective terminology, such as "premium feel," "lightweight," or "easy to use," which lacks a measurable threshold [7]. To achieve unambiguity, requirements must be articulated using precise, quantitative constraints and objective criteria. Eliminating ambiguity is a prerequisite for verifiability; if a requirement is open to multiple interpretations, it becomes impossible to design an objective test to prove its fulfillment, leading to significant risk during the quality assurance phase [8].

Completeness
Completeness refers to the degree to which a specification contains all the necessary information, constraints, and environmental conditions required for the design and implementation of the system. A complete requirement does not leave "To Be Defined" (TBD) gaps or omit critical performance requirements [3]. In the context of a vehicle load floor, completeness implies that every technical aspect, including load-bearing capacity, material tolerances, and interface geometries, is fully accounted for [9]. Within the broader RS, completeness also ensures that the document addresses all stakeholder needs elicited during the discovery phase, providing the development team with a holistic and finalized specification [5].

Consistency
Furthermore, consistency dictates that no individual requirement within a specification contradicts another, nor should a requirement conflict with higher-level system goals or standards. Internal consistency is vital to avoid "technical deadlock," where fulfilling one requirement (e.g., minimizing weight for sustainability) makes it physically or economically impossible to fulfill another (e.g., meeting maximum point-load durability targets). Achieving consistency requires a rigorous cross-examination of requirements during the analysis phase. In large-scale automotive manufacturing, maintaining consistency is a primary driver of system integrity, ensuring that the load floor functions harmoniously as a sub-component within the vehicle's wider architecture [5].

Correctness
Correctness is the attribute that confirms that a requirement accurately represents a validated stakeholder need or a physical reality. While a requirement might be perfectly documented and consistent, it is only "correct" if it reflects the true intent of the user or the technical necessity of the system. In this thesis, correctness is evaluated by comparing legacy specifications against empirical data from competitive benchmarking. Identifying a "zombie requirement" is essentially an exercise in identifying a lack of correctness, where a requirement persists in the documentation despite no longer serving a valid functional or business purpose. Ensuring correctness is the desired goal of the Validation phase, confirming that the specification is building the "right product" for the intended market [5].

Furthermore, a key theoretical tension exists between academic proposals for formal, model-based specifications and the industrial reality of practice. Research indicates that while formal methods offer precision, Natural Language (NL), which consists of subjective, non-technical terms, remains the predominant medium for specification in industry due to its accessibility to diverse, non-technical stakeholders [3].

To address the deep-rooted weaknesses of Natural Language, such as ambiguity, inconsistency, and lack of structure, theoretical approaches emphasize the use of templates and guidelines. The templates act as a structural framework that constrains the flexibility of NL, ensuring that specific attributes (e.g., functionality, ergonomics, or perceived quality) are documented consistently across the project [3].

In practice, these templates often result in a hybrid specification where text-based requirements are supplemented by other instruments, such as sketches, diagrams, or models. The effectiveness of a specification is therefore determined by how well these templates facilitate the organization and interrelation of the requirements set [3].

The theoretical foundation for optimizing requirements must account for the persistent challenges identified in industrial settings. These include [3]:

- Organizational Complexity: Managing the high volume of requirements and the diverse tools used to store them.
- Artifact Quality: Ensuring that requirements are not only documented but are also actionable, unambiguous, and traceable throughout the system's lifecycle.
- Practice-Research Gap: The ongoing difficulty in aligning academic methodologies with the practical constraints and needs of large-scale engineering organizations.

2.1.3 Requirements Management

Requirements Management (RM) constitutes the systematic governance and maintenance of a specification throughout the entire product lifecycle [10]. While Requirements Development focuses on the discovery and formalization of a baseline, RM ensures the integrity and alignment of the baseline as project conditions, stakeholder needs, or technical constraints evolve.

The core objective of RM is to facilitate controlled change, maintain version consistency, and provide end-to-end traceability. In an automotive context, effective management is critical for handling the high degree of complexity and correlations inherent in vehicle architecture. It acts as a safeguard against ambiguity and ensures that every design modification is impact-analyzed, verified, and mapped back to its source. By establishing robust management protocols, the organization guarantees that the finalized physical product remains in strict compliance with the validated requirements, even within highly iterative or long-term development cycles [10].

2.1.4 Requirements Engineering Economics

The economic justification for robust RE is largely defined by the concept of Error Cost Calculation, which was famously quantified by Barry Boehm in his seminal work, Software Engineering Economics [11]. Boehm's research demonstrates that the cost of correcting a requirement-related error increases exponentially as a project progresses through its development lifecycle. This is often summarized by the "1:10:100 rule", which suggests that a defect identified during the initial requirements phase costs a fraction of what it would cost to adjust during system testing or, most catastrophically, after the product has entered production.

In the context of large-scale automotive manufacturing, these economic stakes are further amplified by physical constraints; a requirement error discovered after the introduction of industrialization involves not only software rework but also the potential sacrifice of expensive physical tooling and significant supply chain disruptions. By advocating for "front-loading", the strategic allocation of resources to early-stage elicitation and validation, Boehm argues that organizations can significantly mitigate the "hidden tax" of rework, which often accounts for 40% - 50% of total project costs. Furthermore, RE should not solely be viewed as a documentation exercise, but as a critical cost-avoidance discipline that ensures resources are invested in validated value-adding features rather than late-stage error [11].

In the automotive industry, production improvement is often hindered by "product proliferation", the tendency to create too many product variants, which increases manufacturing complexity and inventory costs [12]. Theoretical frameworks for benchmarking suggest that companies must identify the "appropriate level of variety" during the concept phase.

By using benchmarking as a strategic tool, engineers can determine which features (e.g., specific load floor configurations) truly add customer value and which contribute to "over-engineering". Streamlining these choices during concept generation allows for production improvements by simplifying the supply chain and reducing the number of unique parts required on the assembly line.

Cost reduction is also achieved through the "verification-ready" nature of early specifications, by utilizing Controlled Natural Language (CNL) and model-driven templates such as the REquirement SPECification using Templates (RESPECT) approach, which allows for the early identification of logical inconsistencies or ambiguous requirements [13].

When requirements are unambiguous and traceable, the risk of "scope creep" or the development of unnecessary features is minimized. Furthermore, structured specifications facilitate better communication between the concept team and production engineers, ensuring that the proposed designs are optimized for assembly (Design for Assembly) before significant capital is committed to production infrastructure.

Early-phase cost reduction requires a strict prioritization of requirements based on strategic business goals. Theoretical models emphasize that not all requirements carry equal weight; by distinguishing between "must-have" functional requirements and "nice-to-have" aesthetic attributes early in the concept generation, managers can allocate resources more efficiently [14]. This alignment ensures that the final concept is economically viable and production-ready from the outset. By investing in accurate RS early on, organizations can achieve substantial cost reductions by preventing "rework”, the costly process of redesigning components like the luggage compartment load floor after production tools have already been created, for example.

2.2 Benchmarking

Benchmarking is an effective approach in innovation and product development. The approach involves analyzing competitors, products, processes, or solutions to learn from them and potentially identify improvements. According to Goncharuk, benchmarking can be explained as “a constant process of learning and evaluation of the products, services, and practices of the most serious competitors or companies that are leaders in their fields” [15]. This highlights the importance of not seeing benchmarking as a one-time thing, but a constant, continuous process aimed at improving performance by learning from leading organizations.

The main benefit and motivation behind benchmarking is that companies learn from solutions that have already proven successful instead of developing everything by themselves. The literature emphasizes that there is limited value in reinventing existing solutions, which is the background to why benchmarking is used [16]. The goal is to study competitors and industry leaders to identify effective solutions that can be adapted to improve internal products and processes. Another important purpose of benchmarking is to help companies move beyond traditions. This means that companies need to evolve and improve continuously in order to remain relevant and competitive in their industry [16].

Benchmarking is therefore a tool for improvement where companies identify and analyze “best practices” [16]. Bhutta and Huq define benchmarking as “The process of identifying the highest standards of excellence for products, services, or processes, and then making the improvements necessary to reach those standards” [16]. This shows that benchmarking is more than just identifying the best practices; it also includes adapting and implementing improvements internally [16].

Benchmarking can involve detailed technical analysis of competitor products. It is common for companies to purchase competitor products in order to analyze their design and performance. In the automotive industry, it’s a common practice to purchase competitors’ cars and disassemble them in order to do a detailed engineering analysis [17].

2.3 Kano Model

The Kano Model was originally developed in 1984 by Noriaki Kano. Its purpose is to understand how different product attributes influence customer satisfaction. The model categorizes and prioritizes customer needs to clarify customer requirements and support product development decisions [18]. An important aspect of the model is that it presents an asymmetrical and non-linear view of the relationship between product performance and customer satisfaction, which highlights that higher performance does not always lead to higher customer satisfaction. The Kano Model classifies requirements in three different main categories [19], see figure 2.1

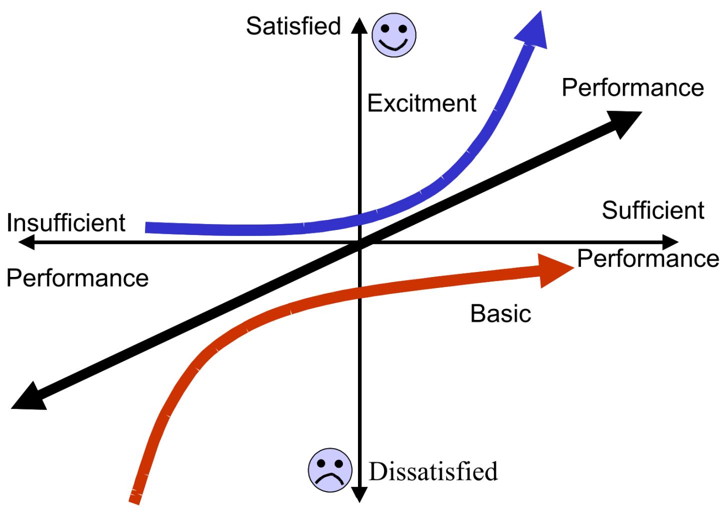


Figure 2.1: Kano Model

- Basic requirements: This is a requirement that the customer doesn't specifically ask for, which means that if this type of requirement is fulfilled, it won't lead to any increase in satisfaction for the customer [18]. But on the other hand, if the requirements aren't fulfilled or if the performance of the requirement is insufficient, it will lead to a large dissatisfaction for the customers; this requirement category is to represent basic expectations [19].

- Performance requirements: This is a requirement that can be asked for before even using a product [18], it's a linear requirement category where the performance level of the requirement affects whether it will lead to a satisfied or an unsatisfied customer [19].

- Excitement requirements: This is the type of requirement that increases the satisfaction for the customer; if the requirement is not fulfilled, it won't affect the satisfaction negatively [18]. But if they are fulfilled, they can significantly increase customer satisfaction [19].

Two other requirements can be used in a Kano Model [18]:

- Indifferent requirements: This is a requirement that neither provides any satisfaction nor dissatisfaction for the customers, whether available or unavailable. This means that these types of requirements need to be reduced since they do not help the product become better [18].

- Reverse requirements: A requirement that the customer does not ask for and they do not want. If this requirement is present, customer satisfaction will be reduced [18].

2.3.1 Operations Strategy and Market Requirements

To evaluate how low-level component specifications align with overarching corporate objectives, product development processes must be evaluated through the lens of operations strategy. Slack and Lewis define operations strategy as the total pattern of decisions that shape the long-term capabilities of any type of operation and their contribution to overall strategy [14]. A central challenge in large-scale manufacturing is ensuring "Strategic Fit", the agreement of a company's internal operational resources with the competitive requirements of its external market.

To systematically analyze this alignment, Slack and Lewis introduced the Operations Strategy Matrix. This universal conceptual framework intersects two primary dimensions: market requirements and operational resources. The market requirements dimension is defined by standard performance objectives, typically categorized as quality, speed, dependability, flexibility, and cost, which reflect what the customer values. Intersecting these are the operational resource decision areas, which govern structural and infrastructural capacities, including process technology, supply networks, and development organization. In an optimized system, the intersections within the matrix are aligned, indicating that engineering resources are configured to satisfy verified customer needs. Conversely, deviations or "misfits" within the matrix expose operational waste, where excessive resources are expended on performance attributes that do not contribute to realized customer value or strategic differentiation as seen in figure 2.2 [14].

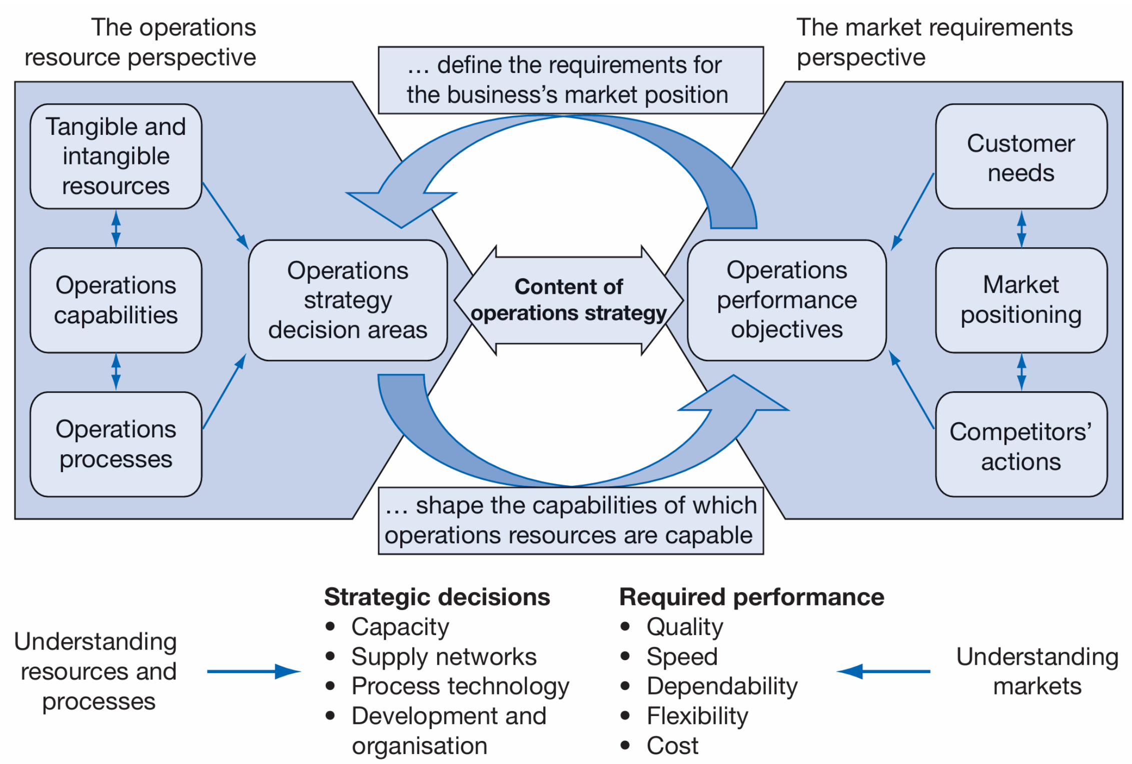


Figure 2.2: Operations Strategy Matrix

2.4 Qualitative Research

Qualitative research is a multifaceted approach to inquiry that seeks to understand the social world from the perspectives of those living within it. Unlike quantitative research, which focuses on the measurement of variables and the testing of hypotheses through numerical data, qualitative research is concerned with the meanings, interpretations, and experiences that individuals connect to their environment.

The core of a qualitative study lies in its ability to explore the "why" and "how" of human behavior and organizational processes. It is inherently inductive, which means that theories and patterns emerge from the data rather than being imposed upon them from the beginning. This makes it a critical tool for researchers exploring areas where existing knowledge is insufficient or where the context of the study can be highly complex.

In an academic context, a qualitative study allows for the deconstruction of complex systems by examining the shared language, culture, and values of the participants.

It recognizes the researcher as a central instrument in the research process, acknowledging that subjectivity is not a bias to be eliminated, but a lens through which deeper insights can be gained.

Qualitative methods, such as semi-structured interviews and thematic analysis, are employed to provide a rich, detailed "thick description" of a phenomenon. This level of detail is essential for identifying the variables and themes that may later be tested or validated through quantitative means. By engaging in a qualitative study, the researcher can map the underlying motive behind professional practices and decision-making processes that are often left undocumented in formal records.

A qualitative study serves as a bridge between the existing literature and the empirical world, while a literature study establishes what is known globally; the qualitative study investigates how those global theories are shown within a specific context. It provides the "contextual intelligence" necessary to understand the nuances of a problem, ensuring that the conclusions of a thesis are not only theoretically sound but also practically relevant and grounded in real-world data.

To maintain academic accuracy, qualitative research relies on the concept of trustworthiness, which encompasses credibility, transferability, dependability, and confirmability. Rather than seeking statistical generalization, qualitative studies aim for analytical generalization, where the insights gained from one context can be applied to understand a similar phenomenon elsewhere. This rigor is achieved through systematic data collection, transparent analysis, and the triangulation of multiple data sources, which ensures that the findings are robust and defensible.

In the field of RE, the specification process is increasingly viewed not only as a technical documentation task but as a complex socio-technical activity that requires a deep understanding of organizational contexts and human interaction. To optimize an RS for a specialized component, such as a luggage compartment load floor, a qualitative approach is required to deconstruct the underlying structures and semantic meanings embedded within existing engineering processes.

Theoretical frameworks in RE emphasize that requirements are rarely static or self-evident; rather, they emerge through an iterative process of dialogue and interpretation among diverse stakeholders. Dick et al. argue that elicitation requires qualitative methods, such as semi-structured interviews, to uncover the actual needs of an organization [5]. A qualitative study allows the researcher to navigate the expert knowledge distributed across various departments and identify the logical justifications that underpin the product's definition.

Despite the advancement of formal modeling techniques, NL remains the predominant medium for RS in industrial settings. A central theoretical challenge with NL is its inherent awareness of ambiguity and varying interpretations based on the reader's area of expertise.

Franch et al. highlight that the optimization of a specification often involves the implementation of "instruments," such as templates or guidelines, designed to constrain the flexibility of language without sacrificing its accessibility [3]. In this context, a qualitative study is essential to analyze how these linguistic artifacts are utilized in practice and to understand why certain requirements are formulated in ways that may lead to inconsistencies throughout the development chain.

While Requirements Traceability is often defined as the ability to follow the lifecycle of a requirement, a critical component of this traceability is the qualitative rationale, the understanding of why a particular decision was made. Wang et al. observe that one of the primary challenges in industrial RE is maintaining the quality of traceability links as project complexity increases [10].

Through qualitative inquiry, the researcher can map dependencies that are not always explicitly documented in digital systems. This is vital for optimizing a specification to ensure it is resilient to late-stage changes and technical trade-offs.

Finally, a qualitative approach is motivated by the need to bridge the gap between academic models, such as the RESPECT method for template-based specification, and industrial reality. For the optimization of the load floor specification to be successful, a qualitative analysis of prevailing workflows is required. This provides the necessary context to determine which theoretical frameworks are applicable and how they can best be integrated to enhance requirement quality and mitigate complexity costs in the early phases of development.

2.5 Quantitative Research

Quantitative research focuses on collecting and analyzing numerical data to identify patterns and relationships. The method is used to answer questions such as how many, how long, or to what extent something occurs [20]. The research process is structured and planned, where hypotheses and research phases are defined before data collection begins. Quantitative research commonly uses standardized methods to ensure reliable results. Another important characteristic is the emphasis on reliability and objective analysis, often using larger sample sizes to strengthen the credibility of the results [20].

To ensure high research quality, quantitative studies commonly evaluate the validity and reliability of the research methods and instruments [21]. Validity refers to how accurately a research method or instrument measures what it is intended to measure. An example from Heale et al., "a survey designed to explore depression but which actually measures anxiety would not be considered valid", illustrating the importance of validity in quantitative research [21]. One type of validity is content validity, which refers to whether an instrument covers all relevant aspects of the studied concept. Another type is construct validity, which evaluates whether an instrument truly measures the intended concept [21].

Reliability refers to the consistency of a research instrument and whether similar results would be obtained if the measurement is repeated under the same conditions [21]. A reliable instrument should therefore produce stable and consistent results over time. Reliability is especially important in quantitative research because standardized methods depend on consistent measurements to produce trustworthy findings [21].

2.6 Toyota Production System

While the Toyota Production System (TPS), pioneered by Taiichi Ohno, originally targeted physical inefficiencies and material overproduction on the manufacturing shop floor, modern operations management theory explicitly extends these paradigms to product development, information environments, and systems engineering [22]. In non-physical engineering processes, waste (Muda) manifests as the generation, processing, and maintenance of data, specifications, or targets that do not directly map to a recognized customer value driver or an active regulatory constraint [23].

- Overproduction
- Waiting
- Transportation
- Over-processing
- Inventory
- Motion
- Defects

2.6.1 Resistance to Change

The optimization of a requirements specification is fundamentally constrained by organizational psychology and the sociotechnical culture embedded within large-scale automotive ecosystems. According to change management theory, organizational resistance to process optimization is rarely a blind rejection of institutional progress; rather, it represents an active defense mechanism protecting an established workflow or mitigating individual accountability risks [24].

To prevent and mitigate this resistance within the context of systems engineering, organizations must implement systemic mechanisms that decouple risk from individual engineer accountability. Within the domain of the Toyota Production System (TPS), this is achieved by shifting the operational focus from individual blame to process-driven quality gates, commonly operationalized as information Poka-Yoke (mistake-proofing) mechanisms [22]. By utilizing constrained natural language templates and standardized architectural matrices, such as the Slack and Lewis Operations Strategy Matrix, the requirements engineering framework itself serves as an automated quality filter [14]. This structural alignment stops information waste (Muda) and unvalidated heritage targets at the source before they pollute the active development loop [23]. Furthermore, establishing robust, bidirectional traceability links from high-level corporate and customer needs down to low-level component specifications fosters an environment of psychological safety [9]. When the rationale behind a requirement is explicitly and transparently mapped within the system's infrastructure, the cognitive load and perceived personal risk of decommissioning a 'zombie requirement' are removed, transforming data cleanup from an individual technical gamble into a standardized, data-driven operational victory.

3
Methods

This chapter describes the methodology used in the study. The methods include interviews, surveys, production site observations, benchmarking, collection of internal quality data, and requirements engineering analysis, providing a comprehensive foundation for investigating the current requirements engineering process and the load floor system

3.1 Pre-study

A pre-study was conducted during the initial phase of the project to establish a baseline understanding of the load floor and its associated RS. The purpose was to build the necessary knowledge about the product and its requirements, identify relevant stakeholders, and establish a solid foundation for the rest of the study.

3.2 Data collection

Data for this study were collected using a mixed-methods approach to achieve a comprehensive understanding of the research project. Different data collection approaches were used to capture both the internal perspective within the organization and the external perspective of customers' expectations. A wide use of data sources enables methodological triangulation, which reduces the risk of drawing conclusions based on limited or one-sided information, strengthening the validity and robustness of the findings.

3.3 Primary data

Primary data was collected to capture both internal stakeholder perspectives and external user needs. The data collection included interviews, surveys, and production site observations.

3.3.1 Interviews

Semi-structured interviews were conducted with key stakeholders at Volvo Cars, primarily attribute owners responsible for the requirements related to the load floors in the vehicle luggage compartment. The interviews were carried out in two phases to progressively deepen the understanding of the current RE process.

The participants were selected based on recommendations from the project supervisor at Volvo Cars to ensure a holistic view of the function areas. The different function areas consisted of seven attribute owners from the sections: Perceived Quality (PQ), Design, Strategic Business Owner (SBO), Strategic Product Owner (SPO), Ergonomics, Durability, and Service. In total, 14 interviews were conducted across two interview rounds. This approach enabled the study to capture multiple perspectives and identify the complexity of the system. The stakeholders represented different functional areas, enabling the study to capture a broader system and understand how these areas interact.

An interview guide was developed to ensure that relevant information was collected throughout the interviews. The guide consisted of predefined themes, which included requirement origin, purpose, traceability, and prioritization while still allowing flexibility for participants to elaborate on their experiences and perspectives. Each interview had a duration of approximately one hour and was conducted at Volvo Cars meeting rooms or online via Microsoft Teams. Notes were taken during each interview, and key insights were documented during and right after each session to ensure accuracy.

The first round of interviews aimed to establish a foundational understanding of both the load floor as a product and the associated requirements. The goal was to ask open-ended questions to encourage respondents to freely describe their perspectives.

Following the initial analysis of the first round of interviews, and after gaining a deeper understanding of the product and its processes, a second round of interviews was conducted. At this stage, a deeper understanding of the system had been developed, enabling more focused and specific questioning. The purpose of the second round of interviews was to validate preliminary findings, try to clarify ambiguities, and further investigate specific patterns identified in the first phase. Particular emphasis was placed on requirement traceability, interpretation differences, and the decision-making processes.

Both the first and second rounds of interviews allowed for a more nuanced understanding of the RE process and increased the reliability of the findings by enabling cross-verification of insights across different stakeholders.

3.3.2 Survey

A survey was conducted to capture customer perspectives on the load floor. The survey consisted of both structured questions, such as multiple-choice questions, and open-ended questions that allowed respondents to elaborate on their preferences. All survey questions can be found in Appendix A.

To ensure clarity and minimize misinterpretation, the survey was designed with a strong emphasis on simplicity and questions that are easy to interpret. Before publishing, structured interviews were conducted to test whether potential respondents interpreted the questions as intended. The purpose of the structured interviews was to identify unclear or ambiguous questions and improve them before broader distribution.

3.3.3 Production Site Observation

An observational study was conducted at the production site early in the project. The purpose was to gain an understanding of the assembly process, specifically the mounting sequence of the load floor in the luggage compartment.

The observation was complemented by informal discussions with production operators to gather practical insights into challenges encountered during assembly. This data collection activity aimed to identify potential challenges in the production process and evaluate whether improvements to the requirements could be made.

3.4 Secondary Data Collection

Secondary data was gathered to complement the primary data and provide additional context for the study. Sources included academic literature on RE, market reports, and benchmarking data from competing automotive manufacturers.

Internal company data was also used as an important source of secondary information. This included Product Quality Survey (PQS) data, which reflects customer feedback after 90 days of vehicle usage, as well as warranty service data that provided insights into product performance. Together, these data sources enabled a more objective evaluation of product quality and customer satisfaction.

3.5 Benchmarking as a Method

To establish a comprehensive understanding of the current industry standards, a benchmarking study was conducted during the initial weeks of the project. The study included over 50 vehicle models across 26 different car brands. To achieve a comprehensive perspective, the benchmarking included not only direct competitors but also brands from both higher and lower market segments. This provided a holistic view of Volvo's performance and enabled a clear comparison of how design solutions and technical execution vary across different price points.

The vehicles were categorized into segments based on market positioning and price. The mass-market segment focused on affordable, high-volume vehicles, while the premium segment consisted of brands competing directly with Volvo. The luxury segment included high-end manufacturers with price points significantly above the Volvo range. The research was carried out at car dealerships in the Gothenburg area, enabling a firsthand inspection of the different load floor solutions.

To ensure the reliability of the findings, a standardized observation protocol was developed, ensuring that each vehicle model was evaluated against the same set of predefined criteria. Some of these criteria included material quality, fit and finish, durability, folding mechanisms, handles, and other relevant attributes. For example, the structural integrity was assessed by applying manual pressure to the floors to observe deflection. All observations were documented through notes and photographs to ensure a consistent analysis. This approach provided the necessary data to identify industry trends and served as a foundation for the evaluation of Volvo's performance compared to competitors.

3.6 Requirements Engineering Analysis

To evaluate the internal RE landscape, a qualitative analysis was conducted focusing on three core pillars: development, specification quality, and lifecycle management. The method used was to gather primary data from several key stakeholders responsible for the RE lifecycle. To ensure a holistic view of the process, the participants were selected based on their experience in RE and platform administration. These included stakeholders who provided knowledge about the platform that is used internally. To investigate the traceability within the utilized MBSE platform, discussions were conducted with a key MBSE stakeholder as well as a senior technical leader.

Furthermore, in order to validate the theoretical insights gained from interviews, an empirical audit was performed on a representative sample of RS related to the luggage compartment load floor. The objective was to assess backward traceability, the ability of cross-functional stakeholders to successfully navigate their way from a technical requirement back to its source or "parent".

The audit aimed to identify which of the RS are lacking a clear source and to evaluate the transparency of the MBSE environment. By examining the RS through the lens of an inexperienced user, the study aimed to determine if the current documentation provided sufficient context to prevent misinterpretation.

Furthermore, arbitrary samples of RS connected to the luggage compartment load floor were taken and examined. The aim was to examine whether there was a clear traceability between the RS and the source. This was done by analyzing each RS individually.

3.6.1 SMART-criteria

In this study, the SMART-criteria served a dual purpose, first as an audit tool to evaluate the current state, and second as a design template for the proposed optimized RE process [25]. The criteria were applied as follows:

- **Specific**: Requirements were evaluated for clarity and precision. A requirement failed this criterion if it contained "weak" or subjective words like pre-

mium, sufficient, or robust without further definition.
- **Measurable**: This was used to check for verification criteria. If a requirement did not have a clear test method or a numerical value (e.g., "must withstand X kg"), it was flagged as non-measurable.
- **Achievable**: This assessed technical feasibility and whether the requirement was accessible to stakeholders within the Model-Based Systems Engineering (MBSE) platform.
- **Relevant**: This was used to identify "zombie requirements." If a requirement could not be traced back to a current customer need or a benchmarking "Opportunity," its relevance was questioned.
- **Time-bound:** Requirements were audited to ensure they were linked to a source (backward traceability), and also to ensure that they are up to date.

4
Results

In this chapter, the results of the study are presented. The chapter is divided into a current state analysis and the different phases of the requirements engineering process, supported by findings from interviews, surveys, benchmarking, and structural and cost analyses.

4.1 Current State Analysis

The objective of this chapter is to present the empirical findings from the data collection regarding Volvo Cars current Requirements Engineering process for the luggage compartment load floor. The chapter establishes the baseline against which the proposed improvements are evaluated.

When analyzing the current situation at Volvo Cars, it was observed that the structure and traceability of requirements are not always fully comprehensible to all the different stakeholders. Many of the RS were developed in previous vehicle programs based on historical decisions and technical constraints. Due to limited resources and time constraints during projects, many stakeholders have limited opportunities to further investigate the link between the RS and specific customer value, and therefore have to accept them as they are.

When proceeding, the presence of a strong engineering culture with high standards was identified. While this contributes to robust products, it may also result in requirements being defined at a higher level than what is necessary from a customer perspective. A common perception among stakeholders was that requirements are often associated with larger safety margins than necessary, increasing product cost. Stakeholders also highlighted that it can be difficult to identify which specific requirements do not provide customer value, since many stakeholders work with RS, but not many are involved in the RM.

Another key observation is that the load floor is often considered relatively late in the development process, which creates challenges as its requirements and responsibilities tend to expand significantly. In current vehicle models, the load floor is also expected to protect sensitive components located beneath it. However, stakeholders do not always share a common understanding of whether this responsibility falls within the scope of the load floor system or outside it. This ambiguity creates difficulties when adopting a holistic perspective of the luggage compartment system.

Due to this reason, the interviews served as a foundation for understanding the current state of the RE process at Volvo Cars. In chapter 4.1.1, a summary of the results from the interviews with the different departments is presented. It contains brief comments that answer what is necessary to consider when understanding the RE process for the load floor of the luggage compartment.

4.1.1 Results from interviews

This section presents the empirical findings derived from semi-structured interviews with key stakeholders at Volvo Cars. The data were processed using thematic analysis to identify recurring patterns regarding the current requirements landscape. To ensure academic integrity and confidentiality, respondents are categorized by their professional roles, and their insights are integrated to highlight the gap between internal engineering perceptions and external market data.

Identifying and defining user needs and preferences
The findings suggest that the customer expects the load floor to have a “flush” level with the trunk threshold to ensure ergonomic accessibility. A primary requirement that was highlighted was the presence of an integrated lifting mechanism for the user to be able to lift the load floor and access the storage underneath. Furthermore, many stakeholders highlighted a shift in customer usage patterns, where the focus has moved from maximizing load weight towards improving organization and utilizing luggage compartment volume more efficiently compared with previous usage patterns.

Internal perspectives and organizational culture
A recurring theme during the interviews was a strong adherence to brand identity, often summarized by the statement, “A Volvo is a Volvo.” While this reflects pride in the brand’s heritage of safety and quality, from a RE perspective, it can signal a risk of "internal perception bias." This mindset may lead to the preservation of legacy requirements simply because they are perceived as part of the brand’s DNA, even if they no longer align with current market data.

This is further exemplified by the view highlighted by a Senior Engineer, stating that “there are no outdated requirements, we should only improve them.” This perspective highlights a core challenge in the "cleaning" of specifications: an additive logic where requirements are modified or enhanced, but rarely deleted. This contributes to Requirement negligence, where "zombie requirements" persist because the organization prefers additional improvement over fundamental re-validation.

Strategic alignment
During discussions with representatives from the PQ department, one respondent noted, “We want to be at the same level as the competitors, not better.” This quote is significant as it challenges the traditional tendency toward over-engineering. It suggests a strategic move toward market parity, ensuring that Volvo meets the "premium threshold" defined by the market without incurring the unnecessary costs

or weight penalties associated with exceeding it.

The complexity of trade-offs in requirements engineering
Finally, the operational reality of the department was captured in the observation that “balancing requirements is the biggest challenge”. This underscores the analysis phase as a process of constant negotiation between conflicting attributes. For the vehicle load floor, this involves the difficult trade-off between the ability to handle load, sustainability (recycled materials), weight targets for electrification, and maintaining the “premium feel” expected by the customer.

In the second round of the interviews, building on greater knowledge and a better understanding of the topic itself, allowed for the opportunity to ask deeper questions and also to straighten out any unclear patterns that were noticed and highlighted by other departments.

During the analysis, it became clear that often, it was very difficult to track down the person responsible for a certain RS, and also that interpretations varied regarding whether a requirement was interpreted as a requirement, a must-have, or just a guideline. Concerning traceability and correctness, this is quite important to distinguish.

Another finding presented is that decisions are often based on experience rather than a structured framework. While experience is valuable, this can lead to inconsistencies in how requirements are defined and prioritized.

4.1.2 Current state analysis of the requirements lifecycle

Requirements development
The analysis of the development phase reveals significant inconsistencies in how requirements are initially defined and structured. The observations made indicate a lack of a standardized process, as there is no clear distinction between a rigid “must-have” constraint and simple "guidelines." This ambiguity in the "weight" of a requirement complicates the negotiation phase, as different teams may prioritize the same technical goal differently. As a result, the decision-making process becomes less efficient as stated by respondents from different departments, often relying on internal team consensus rather than a standardized organizational protocol. Furthermore, the level of detail varies greatly depending on the author, suggesting that the development process lacks a unified template or framework.

Requirements specification
Regarding the quality of the actual documentation, the audit highlighted recurring deficiencies in Completeness and Unambiguity. While some specifications are robust, a significant number of RS lacks the necessary context that is required for external stakeholders to understand the underlying purpose or the background of a requirement.

One major issue is that many requirements do not tell the user how to prove that they have fulfilled the requirement, nor do they provide a measure that should be taken by the user if they simply cannot be met. Many specifications do not state what mandatory measures should be taken if a requirement is not met. Without these predefined consequences, requirements often lose their underlying value, which tends to lead to subjective interpretations by different stakeholders and the risk of potential technical misalignment during the later stages of the vehicle development cycle.

Requirements management

Requirements at Volvo Cars are managed by a system on a platform for MBSE. The system provides a centralized archive that facilitates traceability and maintains a trail of historical updates and contributors. However, the platform presents a high degree of navigation complexity, which can hinder efficiency for inexperienced users.

A primary concern in the current management process is the "awareness gap" that could occur regarding live updates. This is due to the reason that the tool requires users to manually select and monitor specific requirement sets. As highlighted by different stakeholders, this manual process means critical modifications made during the active development cycle can easily go unnoticed. This lack of a clear automated change-notification protocol introduces a risk where engineers continue to work against outdated baselines, which can potentially lead to significant integration errors.

Furthermore, a significant number of requirements specifications tend to lack completeness. Some may be difficult to interpret, missing context, or not clearly linked to a specific purpose. Some of the RS were missing measures that should be taken if the requirements were not met. This eventually results in ambiguity and increases the risk of different interpretations across teams.

An observation was also made on inconsistencies in how requirements are used, as in some cases they are treated as strict “must-haves,” while in others, they function more as guidelines. This lack of standardization makes it difficult to ensure alignment across the organization and can lead to inefficiencies in both development and decision-making.

4.1.3 Traceability to real customer needs

One of the key findings is that traceability between requirements and actual customer needs is often unclear. While many requirements are assumed to be based on customer expectations, the direct connection is not always documented or validated.

This creates a gap where it becomes difficult to assess whether a requirement truly adds customer value or if it is maintained due to tradition or internal standards.

Furthermore, this can be connected to the internal MBSE process, where the platform's traceability features are not optimized to maintain clear connections among key stakeholders, such as the end customer, different engineering departments, and executives.

Some requirements may have evolved without being critically assessed, which creates uncertainty around their relevance and actual contribution to customer value, with the risk of increased costs.

At the same time, this highlights a broader challenge of ensuring that technical requirements are aligned with real customer needs. If this alignment is unclear, there is a risk of over-specification, where requirements exceed what customers actually perceive or benefit from. This can lead to unnecessary cost and complexity without improving the overall customer experience.

4.1.4 Identification of Waste in the RE process

To gain a deeper understanding of the current Requirements Engineering (RE) process, the empirical findings were analyzed through the lens of the Toyota Production System (TPS) and its concept of the seven wastes, as well as organizational resistance to change. The findings indicate that several forms of non-value-adding activities (Muda) are present within the RE process, particularly in the handling and evolution of requirement specifications.

A recurring observation from both interviews and document analysis is that requirements are frequently retained and expanded rather than removed, even when their connection to customer value is unclear. This results in an accumulation of "zombie requirements", where specifications are inherited from previous vehicle generations without validation. From a TPS perspective, this reflects overproduction of information, where requirements are created or maintained beyond what is necessary.

The analysis of the RS revealed that many requirements are over-detailed without a clear purpose, difficult to interpret due to the inclusion of many ambiguous terms, and lacking measurable validation criteria. This leads to unnecessary processing in downstream activities such as design, testing, and communication, where engineers must interpret or rework unclear requirements. This aligns with over-processing waste, where more work is performed than required to deliver value.

Furthermore, the presence of large numbers of legacy requirements within the MBSE system indicates information inventory waste. Requirements are stored, maintained, and reused without systematic validation of their relevance. This creates defects that are shown in, for example, misinterpretations or rework.

While the presence of waste can be identified through TPS, the empirical findings suggest that the root cause is largely organizational rather than purely technical. This is highlighted by interview data showcasing a culture where requirements are rarely removed, existing specifications that are perceived as "safe choices," and where challenging requirements are associated with risk. For example, the mindset that “requirements should be improved, not removed” reflects a strong resistance to change. This behavior aligns with the concept of organizational resistance, where existing processes are preserved to avoid accountability risks, maintain stability in complex systems, and reduce perceived uncertainty.

4.2 Data from Quality Systems

To complement the interviews and surveys, data from Volvo Cars internal quality systems were analyzed to provide a data-driven perspective of how the load floor actually performs in the field.

4.2.1 Product Quality Survey

Data from the PQS indicates a low level of dissatisfaction regarding the load floors. There are very few, if any, reported issues across all models. This lack of negative feedback suggests that the current and previous load floors are meeting customer expectations, although the available data does not allow firm conclusions regarding whether those expectations are being exceeded.

4.2.2 Current State Quality and Warranty Trends

Warranty and service data further support the PQS findings. Analysis of service records during the three-year warranty period shows a minimal number of defects or technical deviations related to load floor components. The only recurring issue identified was a failure in the opening mechanism of a handle on an older premium model. This defect has been addressed and resolved in newer iterations of that specific model segment. Aside from this recurring issue, there are no clear weaknesses or technical flaws associated with the load floors.

4.2.3 Internal Data Validation

To verify these findings, the data were reviewed by experts from both the service and the current state quality department. These experts confirmed that the incident rates and associated quality costs for the load floors are significantly lower than those for many other parts of the car.

4.3 Survey Results

The structured interviews helped validate and clarify the survey questions. They ensured that the questions were interpreted consistently and provided deeper insight into the respondents’ reasoning behind their responses.

The results from both the internal and external surveys indicated that there was a wide range of user behavior and preferences depending on different variables. 104 respondents took part in the external survey, developed for individuals outside Volvo Cars and not involved in vehicle development or design. Internally, 341 respondents from Volvo Cars, primarily within the Vehicle engineering department, participated in the survey, consisting of 22 questions. A sample of the questions and results will be presented in this chapter.

The questions were randomized to maintain focus and reduce survey fatigue, preventing repetitive or careless answers. Two of the 22 questions covered age and demographics. Regarding geography, the majority of both internal and external respondents were located in Europe. However, the external group was slightly more diverse, including a few respondents from North America and Asia, as shown in Figure 4.1. In terms of age, the external survey consisted of a younger population compared to the internal one, as illustrated in Figure 4.2.

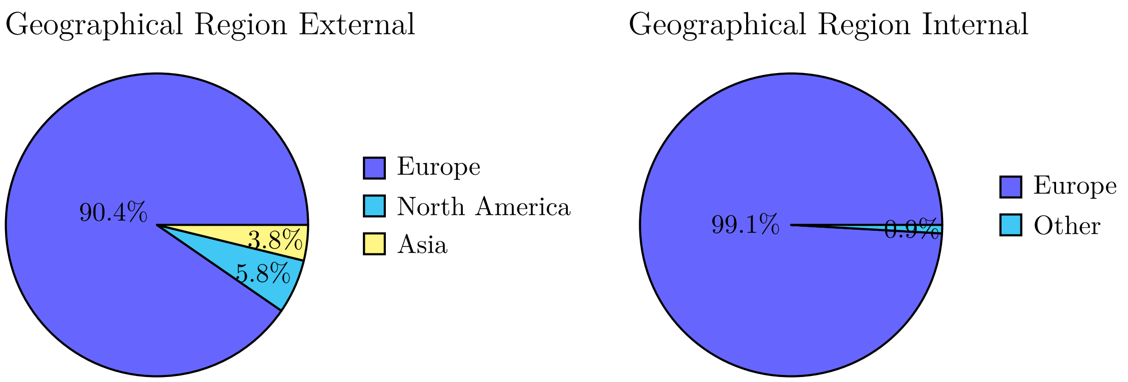


Figure 4.1: Demographic distribution of survey respondents

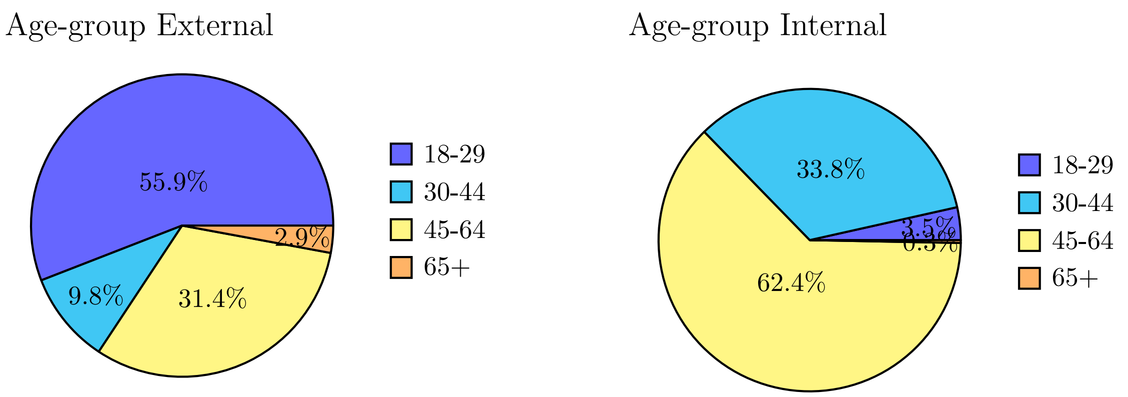


Figure 4.2: Age distribution of survey respondents

One of the strongest findings from both the internal and external surveys was the strong emphasis on functionality rather than premium feel. This was particularly evident in a question asking respondents which single attribute they would prioritize in the luggage compartment. In Figure 4.3, there is a vast majority choosing "functional" as a primary attribute that would be prioritized, and secondary, that it should be robust. This pattern was seen in both the external and internal surveys.

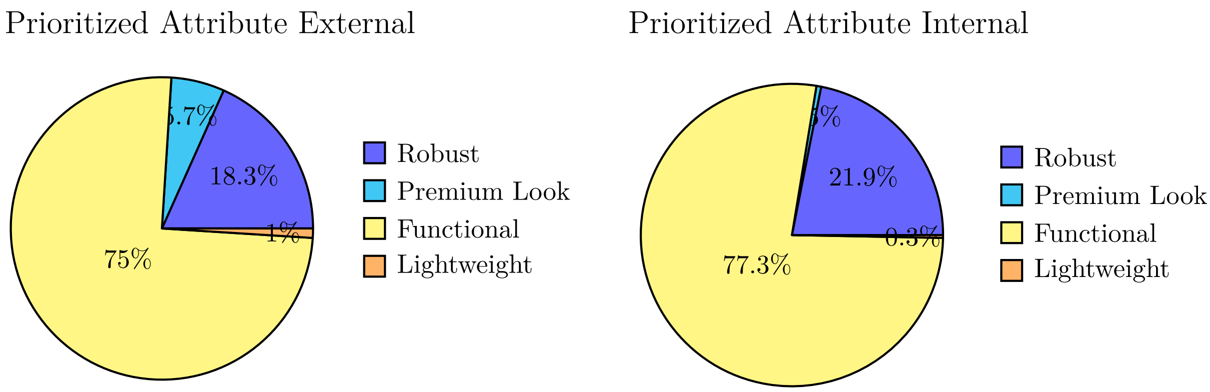


Figure 4.3: Most important load floor attribute according to survey respondents

4.3.1 Analysis of Qualitative Survey

To analyze the qualitative data from the survey, a thematic analysis was conducted on the open-ended responses. This allowed for the identification of recurring "pain points" and value drivers that standardized multiple-choice questions might overlook.

A wide range of topics was brought up in the open-ended questions; however, the four major and most frequent topics are presented in this section, which includes comments from both the internal and external surveys conducted. While the quantitative data provided a baseline for usage frequency and demographics, the open-ended comment sections offered deeper insights into the specific attributes that define a "high-quality" load floor from a user perspective.

The most frequent topic, mentioned by 48 respondents, was the necessity of a flush or flat floor. Users expressed a strong preference for a load floor that sits level with the trunk sill and the folded rear seats. The qualitative feedback indicates that this is not merely an aesthetic preference but an ergonomic requirement; a flush floor allows heavy objects to be slid without the need for vertical lifting over a threshold.

Thirty respondents highlighted the importance of a sturdy and solid load floor. The comments often linked the "feel" of the floor to the overall premium image of the vehicle. Interestingly, many users expressed concerns about the floor "sagging" or "feeling flimsy" when loading heavy items, even if they rarely carry maximum-weight loads. This suggests that "sturdiness" is a key driver of perceived quality, a subjective value that must be translated into objective technical requirements during the specification phase.

The third most frequent theme (28 mentions) concerned the handle and general ease of use when accessing the storage space beneath the floor. Respondents emphasized the need for an intuitive, ergonomic handle that can be operated with one hand. Several comments pointed out that current solutions can be difficult to grip, especially when carrying items in the other hand. This feedback provides a clear mandate for the Requirements Development phase to prioritize tactile interaction and accessibility.

Finally, 19 respondents explicitly mentioned cleanability as a critical factor. The comments focused on the difficulty of removing sand, dirt, or spills from carpeted surfaces. This highlights a potential gap in the current legacy requirements, which may prioritize durability or acoustics over the ease of maintenance.

4.4 Benchmarking Results

The benchmarking study revealed variation in load floor solutions across different brands, models, and vehicle segments. Differences were found not only between luxury, premium, and mass-produced vehicles but also within the same brand across different price points and model types. This clearly indicates that the load floor is not a component with a clear industry standard, but rather one that is shaped by trade-offs related to cost constraints and design priorities. A common challenge identified during the study is the balance between functionality and aesthetics. While smart and functional features were common for mass-produced vehicles, they could sometimes result in a less sleek, "premium" appearance, which is expected in higher-end models.

Several recurring solutions were identified, such as multi-level load floors and foldable structures. While these solutions were identified across all segments, the execution differs significantly. The main differences were found in material quality, structural robustness, precision, and user interaction.

Mass-produced vehicles showed the greatest variation, particularly when it came to materials, fit, and precision. Their load floors were generally simpler, less robust, and of lower perceived quality. For example, handle solutions were often very simple, where cut-out holes and textile loops were pretty common, which contributed to a lower perceived quality and limited ergonomics. In several cases, the load floor showcased poor fitment, which resulted in visible gaps where dirt and smaller objects could fall through. The structural strength of the mass-produced vehicle's load floor showed noticeable deflection when manual pressure was applied. Overall, the mass-produced vehicles appeared to prioritize cost efficiency and basic functionality for their load floors, ensuring that the basic and performance requirements described by the Kano model were met.

Premium and luxury vehicles, on the other hand, demonstrated a higher level of execution, particularly in material quality, precision to detail, and features. However, it was found during the benchmarking phase that there isn't any clear "high-end" load floor identified; instead, different manufacturers emphasized different attributes, such as flexibility, finish, and features. An additional observation was the inconsistency within premium and luxury brands, where lower-priced models showed significantly lower quality compared to their more expensive models.

Volvo's solutions were generally found to perform well compared to competitors across all segments. Rather than excelling in a single aspect, Volvo demonstrates a balanced performance in terms of functionality, robustness, and usability. The benchmarking indicates that Volvo places a significant focus on the load floor compared to many competing brands. This positions Volvo strongly across all three segments. In addition, Volvo shows a high level of consistency across all different models. Even lower-priced models maintain a strong level of precision, fit, and perceived quality.

4.5 Case: P113

For confidentiality reasons, the actual vehicle model name cannot be disclosed. Therefore, the vehicle is referred to as P113.

During interviews with the durability department, a design decision made during the development of the P113 load floor was identified. The decision involved removing a structural support element located beneath the load floor. This component was originally intended to contribute to the structural performance of the load floor and support compliance with a durability-related requirement.

As a result of this design change, the load floor no longer fulfilled the predefined durability requirement specified for the component. Despite this deviation, the modified design was implemented in the final product. To investigate the outcome of this decision, a follow-up analysis was conducted using available service and warranty data. This included reviewing reported issues, customer complaints, and warranty claims related to the load floor to determine whether the design change resulted in reduced product quality or customer dissatisfaction.

The analysis did not identify any increase in reported durability-related issues associated with the load floor. Furthermore, no recurring failure patterns, customer complaints, or warranty cases could be linked to the removal of the structural support element. The absence of reported issues was consistent across all reviewed data sources. The P113 case therefore represents an example where a deviation from an established durability requirement did not result in identifiable quality issues, customer complaints, or warranty claims in the available data.

4.6 Sensitive Components Under the Load Floors

As described in section 4.1, a key observation identified during the interview phase was the placement of sensitive components under the load floor. For Volvo's EVs, it was observed that multiple sensitive components are frequently located beneath the load floor. These components include electrical units that require protection from external loads. As a result, the load floor must fulfill additional functional requirements related to durability and protective capability, requiring the load floor to exhibit minimal deflection under load. This new setup also minimizes the chance of getting support from the car structure, as the current structure does not support it enough, leading to a thicker and more expensive load floor.

This configuration introduces specific constraints on the load floor design. The presence of underlying components requires the load floor to withstand higher loads and ensure sufficient stiffness to prevent deformation that could affect the components below.

In contrast, observations from the benchmarking study indicate that several competitor vehicles utilize alternative design layouts. In these cases, sensitive components are more frequently positioned outside the area of the load floor. This difference in component placement reduces the direct dependency between the load floor and the protection of sensitive systems. As a result, the functional demands placed on the load floor in these vehicles appear to be less influenced by the need to protect underlying components. This was reflected in thinner and less complex load floor designs compared to those observed in Volvo vehicles.

4.7 Production Site Findings

Observations from the production site indicated that the assembly process for the load floor is stable and well-functioning. The lack of negative feedback or reported problems suggested that the current requirements regarding production are at a sufficient level. The mounting sequence was observed to be performed with ease, which suggests a high level of Design For Assembly (DFA).

The discussions with the production operators further validated these findings, as there were no significant installation difficulties in the current assembly sequence. However, they noted one issue regarding the interface with surrounding components. The issue noted was that the plastic cover around the rear seats can occasionally obstruct the load floor during integration into the luggage compartment. This observation indicates that opportunities for improvement may exist in the interface between the load floor and surrounding components.

4.8 Cost Analysis

The historical analysis of Volvo's latest load floor solutions revealed a significant variation in design complexity and cost across different vehicle models. Due to the sensitive nature of the cost data, price differences are presented using a cost index ranging from 1 to 5.

One of the key findings was that Load Floor 1 (see Appendix B) has a cost index of 4. The elevated cost is associated with its increased flexibility and design complexity, including integrated hinges, baggage holders, and a three-section modular design. In contrast, Load Floor 2 (see Appendix C), implemented within the same vehicle architecture, has a cost index of 1. This demonstrates the substantial cost variation that can exist between load floor concepts designed for the same vehicle.

Several of Volvo's premium vehicle models, including both electric and combustion-engine vehicles in higher price segments, utilize load floors with a cost index of 2. These solutions, referred to as Load Floors 3, 4, 5, and 6 (see Appendices D, E, F, and G), maintain a premium appearance and material quality while relying on comparatively simple designs with fewer mechanical components.

The analysis also identified the most expensive solution in the dataset, Load Floor 7 (see Appendix H), with a cost index of 5. The higher cost is associated with the integration of a pop-up divider that enables compartmentalization of the luggage area. Notably, this solution is implemented on the same vehicle platform as Load Floor 6, which has a cost index of 2. A summary of all investigated load floor variants and their corresponding cost indices is presented in Table 4.1.

Table 4.1: Summary of load floor variants and their cost index

Load Floor	**Cost Index (1-5)**
Load Floor 1	4
Load Floor 2	1
Load Floor 3	2
Load Floor 4	2
Load Floor 5	2
Load Floor 6	2
Load Floor 7	5

Since the analysis only considers the load floor component itself, no conclusions can be drawn regarding the total cost of the complete luggage compartment system. Different vehicle models may require different supporting structures beneath the load floor, which are not included in the present analysis. Therefore, the most relevant comparisons are those made between load floor concepts implemented within the same vehicle architecture and under the same structural conditions.

Within such comparable conditions, a clear increase in cost was observed when additional flexibility and features were introduced. Load Floor 1 and Load Floor 7, which incorporate more advanced and adjustable solutions than their corresponding alternatives, Load Floor 2 and Load Floor 6, exhibited approximately twice the component cost. The analysis showed that increased flexibility and design complexity were associated with higher component costs.

4.9 Result from V436 simulation

For confidentiality reasons, the actual vehicle model name cannot be disclosed. Therefore, the vehicle is referred to as V436.

Based on discussions with Volvo Cars durability department, simulation analyses were performed on Load Floor 3 (see Appendix D). The purpose was to evaluate the structural response of the load floor under both the specified requirement load and an excessive load exceeding three times the specified requirement. The objective was to investigate how the load floor behaved under extreme loading conditions and to determine the extent of additional deformation at substantially higher loads.

The simulations were conducted by applying a uniformly distributed load across the load floor surface. The results showed nearly identical deflection behavior for both the requirement load case and the excessive load case, with no significant increase in deformation observed despite the substantially higher applied load.

Further analysis of the simulation results showed that a significant portion of the applied load was transferred to the supporting structures beneath the load floor. In particular, the protective metal casing surrounding the sensitive battery components absorbed a large share of the load, thereby limiting the deformation of the load floor itself. As a result, the load floor was able to withstand loads exceeding three times the specified requirement without reaching or damaging the protected components located beneath it.

4.10 Upper limit strength test

The upper limit strength test was conducted on load floors 1 and 2 described in the cost analysis (see appendix B and C). The objective was to determine if the performance varies between the two solutions, where one is a highly minimalist and cost-effective option, while the other offers extensive flexibility and functionality at a significantly higher cost.

The test was conducted at a Volvo Cars test facility using a cut-out rear section, including the rear seats and the complete trunk chassis structure. After ordering and mounting all necessary support structures for both load floors, the two variants were evaluated. To measure the distance variance, a steel beam was mounted across the center of the load floor, with a reference beam positioned above the entire setup, see figure 4.4 for a picture of the setup.

Figure 4.4: Upper limit load test setup for load floor 2

The test protocol specified that the final load measurement would be taken after a duration of 16 hours. The load floors were loaded with a distributed load consisting of equally sized sandbags, see figure 4.5. The goal was to evaluate the performance of the load floors at extreme levels and identify the differences between them. To achieve this, both load floors were tested with a load significantly exceeding the established requirement, in this case, approximately 55% above the set limit.

Figure 4.5: Upper limit load test setup with uniformly distributed load on the load floor

The results from the tests on the two different load floors were extremely similar, showing almost no difference in performance. As presented in Table 4.2, load floor 1 had a deflection of 18 mm after 16 hours under load, while load floor 2 had a deflection of 17 mm. Furthermore, once the sandbags were removed, both floors showed the same permanent deformation of only 2 mm.

Load Floor	**Deflection (16 h) [mm]**	**Permanent Deformation [mm]**
Floor 1	18	2
Floor 2	17	2

Table 4.2: Measured deflection and permanent deformation of load floors 1 and 2

Overall, the test results showed only minor differences between the two load floor variants. Despite the substantial difference in component cost between load floor 1 and load floor 2, both solutions demonstrated similar deflection characteristics during the 16-hour loading period and identical permanent deformation after unloading.

5
Discussion

This chapter discusses the findings of the study. It analyzes the main results, explains the proposed framework, and evaluates the limitations of the methods used. Finally, suggestions for future work are presented.

5.1 Key findings

This section discusses the main findings of the study and the insights gained from the results.

5.1.1 Current Challenges in the Requirement Engineering Process

The findings highlight that the load floor is a highly complex component integrated within a larger system, requiring many aspects to be considered during development. The results indicate that the RE process is heavily influenced by stakeholder interpretation and judgment. As Volvo Cars operates in a highly dynamic automotive industry, the RE process needs to be up to date with development, specifications, and management.

As for today, there is no single individual or dedicated task force responsible for the complete RE process related to the luggage compartment and consequently the load floor. This can encourage a “better safe than sorry” approach, where existing requirements and practices are retained rather than critically re-evaluated. This tendency becomes particularly evident in a fast-changing environment such as the automotive industry. However, Volvo Cars is also a large organization with a lot of information transferred through long and complex communication chains. Therefore, some of the identified challenges may be connected to the communication between different stakeholders, rather than the RE process itself.

The interview data further suggest that there is no clearly standardized approach for RD, RS, and the RM within the Vehicle Engineering department. Instead, the organization tends to rely on the competence and experience of engineers, managers, and other stakeholders. This often results in effective decision-making, as experienced employees have developed a strong understanding of what works well in practice. However, this approach can also create challenges when knowledge and decision-making are heavily dependent on individual experience. Differences in skill levels and experience may make it more difficult for less experienced employees to navigate complex requirements and decision-making processes, increasing the importance of clear methods, documentation, and standardized ways of working.

5.1.2 Challenges of Defining Customer Value

One major challenge identified during the study was the difficulty with subjective qualities when discussing the luggage compartment. For example, respondents highlighting the desire of having a "sturdy floor" can be hard to measure. In terms of RE and, and more specifically, RS, this can be challenging for engineers to quantify and verify. Optimally, a study defining how a sturdy load floor is perceived should be conducted to make it measurable and determine a corresponding target value, for example measuring deflection in mm. However, this introduces a trade-off, as the resources required to define and validate such requirements must be balanced against the value generated by achieving a more accurate specification of customer needs.

5.1.3 Customer Value versus Complexity and Cost

The benchmarking data reveal that the current Volvo load floor is significantly heavier and more complex than many competitor solutions. From a broader perspective, this is not just a design choice; it is a strategic trade-off. In the era of electrification, weight efficiency has become increasingly important. By maintaining "Requirement Inertia" (zombie requirements) that prioritize extreme and infrequent load cases over weight efficiency, Volvo is essentially "paying" in battery range for a product feature that, according to the survey data, the majority of customers never experience. This means that Volvo is securing almost every customer behavior, rather than securing the majority of customer behavior related to the luggage compartment load floor.

Moreover, according to the benchmarking and survey data collected, the majority of vehicle users perceive "premiumness" in the luggage compartment as primarily functionality rather than aesthetics, as compared to the cockpit, for example. Looking back at the Kano model, this implies that the majority of users look for the "must-haves" in the luggage compartment, while a small minority look for the "delights" in the luggage compartment area. Regarding the cost of the component, as seen in Appendix B and C. Load floor 1 costs approximately twice as much as load floor 2, meaning that it shall generate higher customer satisfaction, since, when discussing with developers, the focus on this vehicle was to present a premium luggage compartment. However, when analyzing the survey results, this tends not to be the case, meaning that they increase cost without improving customer satisfaction proportionally.

Another interesting finding is that there was no clear difference in performance between load floor 1 and load floor 2. Even though load floor 1 costs more than twice as much as load floor 2, it performed similarly and even slightly worse. A likely explanation for this is that load floor 1 features hinges between its different sections to provide flexibility. However, these hinges reduce the floor's inherent structural strength, meaning that an extra support structure is required on the load floor to maintain sufficient robustness. This design can be seen in the right image in Appendix B. As a result, additional cost is needed to achieve a highly flexible and adjustable load floor perform as well as a very minimalistic and less expensive design.

When relating these findings to the survey results, it is clear that customers primarily value functionality and robustness in the luggage compartment. Since load floors 1 and 2 perform similarly in these aspects, the significantly higher cost of load floor 1 is difficult to justify from a customer value perspective. While load floor 1 offers greater flexibility, the survey indicates that this feature is of limited importance to most users. As a result, Volvo may be incurring significantly higher costs to satisfy a relatively small customer demand. Over time, investments in features that generate limited customer value may reduce the overall cost-effectiveness of the product.

5.1.4 Evidence of Over-Specification and Excessive Safety Margins

One interesting finding from the simulations is the large safety margin of the load floor system. Even when the load exceeded three times the specified requirement, only a small increase in deformation was observed. This indicates that the system can withstand significantly higher loads than those it is designed for.

While safety margins are important to ensure robustness and durability, the results suggest that the current solution may be more robust than necessary. Since higher load capacity often requires additional material and supporting structures, there may be opportunities to reduce the cost of the load floor system while still meeting the specified requirements and maintaining a sufficient safety margin.

The P113 case provides a concrete example of how requirements can be challenged and re-evaluated using real-world performance data. In this case, a structural element beneath the load floor was removed despite concerns regarding compliance with the original durability requirement. The findings suggest that reassessing requirements based on empirical evidence can reveal opportunities to reduce costs without adversely affecting product performance or customer satisfaction. This highlights the importance of validating requirements against actual field data rather than relying solely on assumed risks or extreme-use scenarios.

A key implication is that Volvo's load floor solutions often exceed customer expectations, as evidenced by minimal product quality surveys and warranty data. This can be interpreted in two ways; the positive interpretation is that Volvo delivers robust, high-quality products aligned with brand identity. The critical interpretation is that there is a systematic over-engineering, where additional cost and weight do not translate into increased customer value, over-engineering components have a significant environmental impact, and do not align with the company's and global sustainability vision. The P113 case is particularly important as it demonstrates that failing a requirement did not result in negative customer outcomes. This suggests that some RS are not "correct" in the RE sense, as they do not reflect actual customer need.

5.1.5 Need for a Structured Prioritization Framework

Furthermore, the findings also highlight that a structured framework, focusing on the three pillars of RE, is desired at different levels within the development of the luggage compartment load floor. A framework could work as a checklist for stakeholders to verify and validate that the process is accurate to maintain and meet the desired customer requirements, implementing a standardized Way of Working (WOW).

5.2 Framework for Requirements Engineering

A common challenge identified throughout the study is the communication between stakeholders. Many stakeholders with relation to the luggage compartment load floor highlight that a standard or a clear procedure would be preferable when working with the RE processes. Ultimately, a framework for each of the three pillars, development, specification, and management in the RE process, would potentially provide a solution to this challenge. Furthermore, providing a standardized framework for each of the pillars would imply that an objective reference can always be expected by stakeholders, meaning that engineers, designers, managers, etc. can hold each other accountable for not having sufficient requirements. Implementing this would generate a higher quality in the overall RE process, leading to a lean process and essentially, less waste than previously over time. By integrating these pillars into a cohesive framework, the process becomes more transparent, consistent, and aligned with real customer value. The framework serves as a decision-support tool and checklist, ensuring that each requirement is justified, clearly defined, and continuously validated throughout the product lifecycle.

The key elements of the framework should consist of clear, concise, and comprehensible language for all stakeholders. This implies that there is a common language used among stakeholders, and that the different needs are specified in a sense that is understandable on different levels, which would minimize ambiguity.

5.2.1 Overall Structure of the Framework

The framework is structured as a three-stage process, where each stage corresponds to one of the core RE pillars:

- Requirements Development (RD) – What should be built?
- Requirements Specification (RS) – How should it be described?
- Requirements Management (RM) – How should it be controlled over time?

These stages are interconnected and iterative, which ensures continuous validation and improvement of requirements rather than a linear “define once” process. This is particularly important in a dynamic industry such as automotive development, where requirements evolve.

5.2.2 Framework for Requirements Development (RD)

The findings show that requirements have been developed with high variability, whereas some lack structure, and some are very clear. This led to often being dependent on relying on individual experience rather than data-driven methods. To address this, the framework introduces a structured RD process consisting of four key steps:
Elicitation - The elicitation process must ensure that all requirements originate from validated and traceable sources, rather than legacy assumptions. Each requirement must be checked off with stakeholders and referenced to a need, whether it is a legal need or just a customer desire. Preferably, the elicitation should consist of data from either customer insights, benchmarking observations, legal or safety constraints, or internal stakeholder needs.

Analysis - During the analysis phase, requirements are evaluated and prioritized based on their value contribution and system impact. An example of this could be to use the Kano model to estimate different features and attributes, based on quantitative and qualitative data. Requirements that are not necessities and do not contribute to measurable customer value should be challenged or removed, or simply redefined to guidelines.

Specification (within RD) - Before formal documentation, requirements must be pre-structured and clarified to ensure they are ready for specification. This step includes:

- Clear definition of requirement intent
- Identification of measurable parameters
- Initial alignment across stakeholders

This stage acts as a bridge between analysis and formal specification, ensuring that ambiguous or poorly defined requirements are not carried forward into the documentation phase.

Validation - The validation stage ensures that requirements are both relevant and correct before being implemented. An example of questions stakeholders could ask in the validation phase could be "Does this reflect a real customer need?" "Is it supported by data?" and "Can it be challenged without negative impact?"

5.2.3 Framework for Requirements Specification (RS)

The analysis of current requirements specifications revealed significant issues related to ambiguity, lack of completeness, and inconsistent structure. To address this, the framework defines four key quality criteria for all requirements:

Unambiguity - Requirements must be formulated in a way that allows only one interpretation, regardless of stakeholder background. Subjective terms such as “premium,” “robust,” or “sturdy” must be translated into measurable parameters. For example: “Sturdy” should be changed to a maximum allowable deflection under

load. This directly addresses the identified issue of subjective interpretation and reduces the risk of misalignment in later development stages.

Completeness - Each requirement must contain all necessary information for implementation and verification. This includes:

- Context and purpose
- Measurement method
- Acceptance criteria
- Actions if the requirement is not fulfilled

The findings showed that many current requirements lack verification criteria and fallback actions, which reduces their practical usability and increases interpretation differences.
Consistency - All requirements must be aligned internally and with system-level objectives. Conflicts between requirements must be identified and resolved during the development phase. For example:

High strength vs. low weight trade-offs
This is particularly important given the complexity of balancing durability, sustainability, and cost, which was identified as a major challenge in the study.

Correctness - Each requirement must accurately represent a validated need or constraint. Correctness is ensured by linking requirements to:

- Customer data
- Benchmarking insights
- Technical necessity

5.2.4 Framework for Requirements Management (RM)

The results showed that while requirements are stored within an MBSE system, challenges exist in terms of usability, update awareness, and lifecycle management. This creates risks such as “requirement drift” and outdated specifications being used in development. To address these issues, the framework defines three core elements of Requirements Management:

Traceability - All requirements must maintain bidirectional traceability, meaning that there should be a backwards traceability to the customer need or a source. It should also consist of a forward traceability to design, verification, and validation activities. This ensures that the relevance of each requirement can be continuously evaluated, supporting the conclusion that lack of traceability is a key driver for over-specification.

Change management - Requirements must be actively managed throughout the development lifecycle. This includes:

- Structured change processes
- Clear documentation of updates
- Impact analysis for each change

Improved change management reduces the risk of unnoticed updates, which was identified as a major issue in the current system.
Version Control - To ensure consistency and alignment, all requirements must be version-controlled. This includes:

- Clear version history
- Visibility of changes
- Controlled release of requirement sets

This addresses the issue where stakeholders work with outdated requirements due to poor update visibility.

Essentially, the framework would support more consistent decision-making, reduce reliance on individual experience, and help ensure that resources are focused on areas that create real customer value.

Such a framework should ensure that all requirements are clearly linked to customer needs, include proper justification, and are evaluated based on their value contribution.

Key elements of the framework could include traceability, prioritization criteria, and a standardized way of distinguishing between must-haves and optional features.

5.3 Methodology Discussion, Challenges and Limitations

While the chosen methodology approach resulted in answered Research Questions, several challenges and concerns occurred during the data collection and data analysis stage. These factors must be considered when analyzing and interpreting our final result.

From a wider operations management perspective, the proposed Three-Pillar Optimization Framework functions as more than an administrative or systems engineering checklist; it operates as an informational Poka-Yoke (mistake-proofing) mechanism designed to eliminate waste at the early stages of the product lifecycle. In traditional manufacturing, quality is ensured by stopping the line when a defect is detected to prevent it from running down the assembly line. By enforcing the SMART criteria and integrating Slack and Lewis's Strategic Fit matrix as active quality gates, the proposed framework executes an informational "line clearance" within the requirements database.

The framework systematically intercepts and blocks Overproduction Waste by demanding that every proposed requirement explicitly prove either an empirical customer-centric motivation or a modern regulatory derivation. By filtering out unquantifiable attributes and subjective text strings early in the concept phase, the framework directly decreases downstream Over-processing. This ensures that engineering resources are strictly allocated to features that return verified customer value or strategic compliance, which streamlines the physical product architecture before significant capital is committed to physical tooling and assembly infrastructure.

The empirical insights gathered from the technical leader interviews highlight that optimizing a requirements specification is an inherently sociotechnical challenge that cannot be solved solely by modifying user permissions or database interfaces in an MBSE system. Overcoming the deep-rooted challenges, such as "requirement inertia," requires an organizational culture shift that addresses the psychological safety of the engineering staff.

As long as the internal governance structures at Volvo Cars do not encourage stakeholders to challenge non-compliance with legacy baselines while ignoring the systemic costs of over-engineering, engineers will continue to protect outdated RS as a form of risk mitigation. To break this loop and successfully deploy the proposed framework, management must realign the operational culture to reward lean optimization. Decommissioning an obsolete, unlinked, or redundant technical requirement must be reframed and celebrated as an operational victory, specifically, the targeted elimination of data inventory waste, rather than being perceived as an introduction of technical risk.

5.3.1 Benchmarking Limitations

One key concern found during the benchmarking stage at the beginning of our thesis work was the variances in our documentation quality. During the analysis phase, the settings and habits were different, where the light, amount of dirt, scratches, and angles of the pictures influenced how the potential viewers interpreted the data. This was something that limited the trustworthiness of the survey results, for example, when it came to pictures from the benchmarking. The lack of visual standardization may have introduced a degree of subjectivity into the participants' evaluation when it comes to assessing which load floor is most preferred. However, the analysis of the load floors and the observations made during the in-person evaluations were not significantly influenced. A major limitation of the benchmarking study was that the survey could not be fully standardized. This was largely due to the inability to control the conditions under which the vehicles were assessed at different car dealerships.

5.3.2 Interviews Limitations

The data collection from the interviews with different departments was complicated by limited transparency and a lack of information sharing among attribute owners. Throughout the interview process, it became evident that stakeholders sometimes approached questions from the perspective of their own functional responsibilities and priorities. In some cases, this limited the transparency of available information and made it more challenging to obtain a complete overview of the system. Another thing we encountered was "knowledge gaps" between the different attribute owners, where one department believed that another held certain information, but upon following up, that second department was unaware of the data. This lack of clarity between different parts of the organization made it harder to get a complete picture.

5.3.3 Survey Limitations

Several challenges were encountered during the survey process. One of the primary challenges encountered was ensuring that the questions were interpreted as intended. It became clear early on that questions could be interpreted differently between respondents and us. To address this, structured interviews were utilized as a validation method. This allowed the questions to be tested and refined, ensuring that they were consistently understood as intended.

Another challenge was the technical limitation of Google Forms, which presented a significant challenge to the quality of the data. The software lacked the flexibility to capture more nuanced information effectively from the respondents. For example, the software didn't allow for ranking the answering alternatives from best to worst, which resulted in only choosing the best or worst alternative based on the question. Another technical limitation was that the software didn't offer the possibility to answer "yes" or "no" and write the reasoning afterwards; the only possible way of doing it was to add "other" as an option, but this presented some confusion for the respondents when we did our structured interviews.

Another limitation was the low response rate compared to the total number of people who saw the survey. Although many people viewed the link, only a small percentage actually completed it. This meant the final data relied heavily on friends, family, and personal networks. This limited our reach outside of Europe, which is a drawback because a more global response would have made our results more reliable and representative of the real world.

5.4 Future work

Based on our findings, three areas for future research have been identified. The first area focuses on investigating the luggage compartment as a complete system rather than focusing solely on the load floor. Due to time constraints, this thesis was limited to the load floor itself. However, as the project progressed, the understanding of how the different components interact and influence one another increased significantly. Analyzing all surrounding components was beyond the scope of this thesis, but it became evident that all parts within the luggage compartment contribute to the overall performance and attributes of the final product. Future research should therefore adopt a system-level perspective, including the development of a framework for the entire luggage compartment and an analysis of all connected components.

Building on this, a second area with significant potential for future research is the expansion of the benchmarking study. Instead of focusing solely on competing automotive manufacturers, future work could investigate other industries, such as the aerospace or marine industries. This could provide a new perspective on how other industries work with RE. Expanding the analysis beyond the automotive industry may introduce alternative approaches and contribute to a broader understanding of different methods and practices.

Finally, the knowledge and findings from this study could be used to implement changes at a higher level within the company. Now that a clearer understanding of the current system and the gaps in the existing structure has been established, the next step would be to present the proposed framework to higher management. Sharing these findings and gathering their input could help drive organizational change and support improvements to the current WOW. This would allow the company to better meet customer needs while reducing unnecessary costs, ultimately leading to higher customer satisfaction.

6
Conclusion

This chapter summarizes the key findings of the thesis, which aimed at optimizing the RE process for the luggage compartment load floor at Volvo Cars. Including investigating how RS are defined, used, and aligned with actual customer value. The study combined qualitative and quantitative methods, including interviews, benchmarking, surveys, and internal quality data. Three research questions guided the work, and the conclusions below directly address each of them.

6.1 RQ1: What are the current challenges in the requirements engineering process for luggage compartment load floors at Volvo Cars?

The empirical analysis reveals a clear gap between what engineers specify and what customers actually value. The current process is shaped by a conservative culture where requirements are regularly added but rarely removed, causing outdated specifications, so-called "zombie requirements", to accumulate up over time. As a result, designs continue to account for extreme historical use-cases such as loading heavy appliances, even though surveys indicate that customers today place greater value on functionality and ease of cleaning.

In EV platforms, this challenge is further complicated by poor early coordination between teams, where requirements for the load floor are not aligned with surrounding system decisions. This forces the load floor to protect sensitive electrical components placed underneath it, making the design unnecessarily thick and requiring additional support structures beneath it, both of which add cost and weight that could have been avoided with better requirement alignment early on. Adding to this, tool layout limitations in the requirements software mean that changes are not easily noticed by users, causing specifications to drift out of date.

6.2 RQ2: How can a structured prioritization framework be integrated into the existing RE process to address these challenges?

To address the challenges identified in RQ1, a structured Requirements Engineering framework can be integrated into the existing RE process as a decision-support tool. The framework supports the development, specification, and management of requirements by providing a structured approach for validating their relevance, quality, and traceability throughout the product lifecycle. It functions as a checklist where each requirement must be justified by answering questions such as: Does it reflect a real customer need? Can it be traced to a stakeholder or source? Is it still relevant based on current usage patterns and available data?

The framework also ensures that requirements are clearly formulated, unambiguous, and supported by appropriate verification methods. By linking requirements to customer value, benchmarking insights, and technical needs, the framework reduces reliance on historical assumptions and individual experience. Furthermore, it supports continuous review of existing requirements to identify and remove outdated requirements, helping maintain lean, relevant, and value-driven specifications over time.

6.3 RQ3: What are the effects and lessons learned from applying this prioritization framework to a real-world load floor project?

The framework was tested in a real development project, where the P113 case study demonstrated its practical value. During the development of the P113 model, a structural support element was removed, meaning the load floor technically failed to meet its internal strength requirements. Despite this, analysis of 90-day survey data and three-year warranty data showed no customer complaints or defects related to the change. Current state experts further confirmed that the load floor already has significantly lower failure rates and associated costs compared to most other vehicle components. This demonstrates that requirements can be safely questioned and removed when decisions are supported by real-world data rather than assumed worst-case scenarios. The broader takeaway is that Volvo Cars can achieve meaningful cost and weight reductions by actively removing outdated legacy requirements, and that resistance to change within risk-averse engineering cultures can be overcome when the evidence is clear.

6.4 Final Conclusion

This thesis shows that the greatest opportunity for improving the luggage compartment load floor is not in redesigning the physical product, but in improving the RE process itself. The current approach contributes to over-specification and unnecessary complexity that drives up cost and weight without actually improving the customer experience. By moving toward a structured, data-driven RE process, Volvo Cars can remove outdated requirements, reduce cost and weight, and improve development efficiency, all while maintaining perceived quality. Decisions made early in development have a significant impact on the final product, and treating RE as a strategic priority is key to getting those decisions right.

Bibliography

[1] H. M. Valladares Montemayor and R. H. Chanda, “Automotive industry’s circularity applications and industry 4.0,” *Environmental Challenges*, vol. 12, p. 100725, 2023, doi: 10.1016/j.envc.2023.100725.

[2] Volvo Cars, “Volvo Cars adjusts electrification ambitions, remains committed to fully electric future,” *Volvo Cars Media Relations*, Sep. 4, 2024. [Online]. Available: https://www.media.volvocars.com/global/en-gb/media/pressreleases/333118/volvo-cars-adjusts-electrification-ambitions-remains-committed-to-fully-electric-future.

[3] X. Franch, C. Palomares, C. Quer, P. Chatzipetrou, and T. Gorschek, “The state-of-practice in requirements specification: an extended interview study at 12 companies,” *Requirements Engineering*, vol. 28, pp. 377-409, 2023, doi: 10.1007/s00766-023-00399-7.

[4] K. Pohl, *Requirements Engineering: Fundamentals, Principles, and Techniques*. Berlin, Heidelberg: Springer, 2010.

[5] J. Dick, E. Hull, and K. Jackson, *Requirements Engineering*, 4th ed. Cham, Switzerland: Springer International Publishing, 2017, doi: 10.1007/978-3-319-61073-3.

[6] *Systems and software engineering — Life cycle processes — Requirements engineering*, ISO/IEC/IEEE Standard 29148:2018, 2018.

[7] D. M. Berry and E. Kamsties, “Ambiguity in Requirements Specification,” in *Perspectives on Software Requirements*, J. C. S. do Prado Leite and J. H. Doorn, Eds. Boston, MA: Springer, 2004, pp. 7-44, doi: 10.1007/978-1-4615-0465-8_2.

[8] K. Stylidis, R. Söderberg, and C. Wickman, “Defining Perceived Quality in the Automotive Industry: An Engineering Approach,” *Procedia CIRP*, vol. 36, pp. 165-170, 2015, doi: 10.1016/j.procir.2015.01.076.

[9] K. Wiegers and J. Beatty, *Software Requirements*, 3rd ed. Pearson Education, 2013.

[10] B. Wang, R. Peng, Y. Li, H. Lai, and Z. Wang, “Requirements traceability technologies and technology transfer decision support: A systematic review,” *Journal of Systems and Software*, vol. 146, pp. 59-79, 2018, doi: 10.1016/j.jss.2018.09.001.

[11] B. W. Boehm, “Software Engineering Economics,” *IEEE Transactions on Software Engineering*, vol. SE-10, no. 1, pp. 4-21, Jan. 1984, doi: 10.1109/TSE.1984.5010193.

[12] A. Gunasekaran, D. White, L. F. Scavarda, J. Schaffer, A. J. Scavarda, A. da Cunha Reis, and H. Schleich, “Product variety: an auto industry analysis and

a benchmarking study," *Benchmarking: An International Journal*, vol. 16, no. 3, pp. 387-400, 2009, doi: 10.1108/14635770910961399.

[13] I. Darif, G. El Boussaidi, and S. Kpodjedo, "Requirements specification using templates: a model-driven approach," *Software and Systems Modeling*, vol. 24, pp. 1897-1934, 2025, doi: 10.1007/s10270-025-01265-6.

[14] N. Slack and M. Lewis, *Operations Strategy*, 6th ed. Harlow, England: Pearson Education Limited, 2020.

[15] A. G. Goncharuk, N. O. Lazareva, and I. A. M. Alsharf, "Benchmarking as a performance management method," *Polish Journal of Management Studies*, vol. 11, no. 2, pp. 27-34, 2015.

[16] K. S. Bhutta and F. Huq, "Benchmarking – best practices: an integrated approach," *Benchmarking: An International Journal*, vol. 6, no. 3, pp. 254-268, 1999, doi: 10.1108/14635779910289261.

[17] F. Khamidova, N. Abdurashidova, J. Khojiev, S. Makhmudov, Z. Mamadiyorov, and J. Tukhtabaev, "Analyzing the Auto Industry: Benchmarking for Competitive Market Assessment," in *Proc. 7th International Conference on Future Networks and Distributed Systems (ICFNDS '23)*, pp. 432-437, 2024, doi: 10.1145/3644713.3644775.

[18] A. Ishak, R. Ginting, B. Suwandira, and A. F. Malik, "Integration of Kano Model and Quality Function Deployment (QFD) to Improve Product Quality: A Literature Review," *IOP Conference Series: Materials Science and Engineering*, vol. 1003, no. 1, p. 012025, 2020, doi: 10.1088/1757-899X/1003/1/012025.

[19] G. Tontini, "Integrating the Kano Model and QFD for Designing New Products," *Total Quality Management & Business Excellence*, pp. 599-612, 2007, doi: 10.1080/14783360701349351.

[20] A. Ghanad, "An Overview of Quantitative Research Methods," *International Journal of Multidisciplinary Research and Analysis*, vol. 6, no. 8, 2023, doi: 10.47191/ijmra/v6-i8-52.

[21] R. Heale and A. Twycross, "Validity and reliability in quantitative research," *Evidence-Based Nursing*, vol. 18, pp. 66-67, 2015, doi: 10.1136/eb-2015-102129.

[22] J. K. Liker, *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, 1st ed. New York, NY: McGraw-Hill, 2004.

[23] M. Poppendieck and T. Poppendieck, *Lean Software Development: An Agile Toolkit*, 1st ed. Boston, MA: Addison-Wesley, 2003.

[24] E. B. Dent and S. G. Goldberg, "Challenging 'resistance to change'," *The Journal of Applied Behavioral Science*, vol. 35, no. 1, pp. 25–41, 1999, doi: 10.1177/0021886399351003.

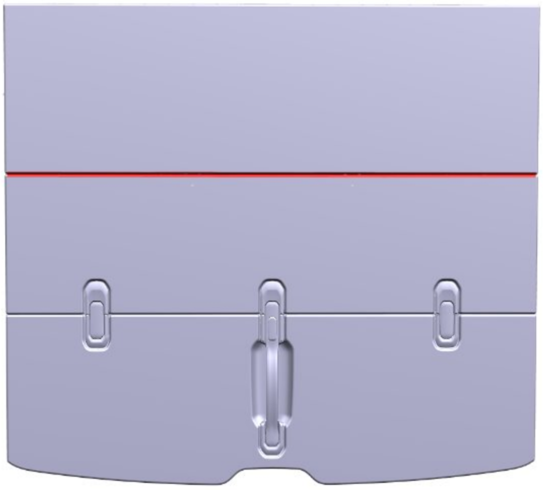
[25] G. T. Doran, "There's a S.M.A.R.T. way to write management's goals and objectives," *Management Review*, vol. 70, no. 11, pp. 35–36, 1981.

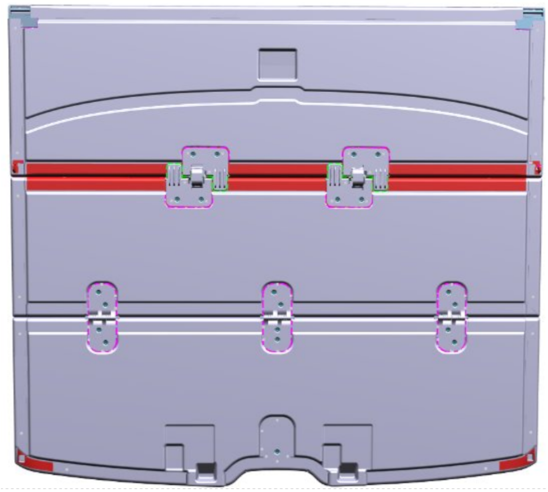
A
Survey Questions

1. Which geographical region best describes where you live?
2. What is your age group?
3. How often do you use the bag holders in the luggage compartment?
4. If you could allocate additional budget to certain areas of the car, where would you prioritize spending it?
5. What is the heaviest load you have put in your trunk?
6. What is the heaviest load you expect your load floor to handle?
7. On a scale of 1-10, how important is it that the load floor can stay in an upright/open position when accessing the storage underneath?
8. How often do you actively use the load floor's features (e.g., folding, lifting, or changing levels)?
9. Which attribute do you prioritize most in a load floor?
10. Which load floor feels the most premium to you?
11. On a scale of 1-10, how important is a premium look in the luggage compartment to you (e.g., no visible screws or hinges)?
12. How important is the first impression of the luggage compartment compared to the cockpit/front seat?
13. Which handle feels the most premium to you?
14. Do you use an additional plastic/textile mat on the load floor for protection?
15. Have you ever reacted negatively to your cargo floor?
16. What signals high quality the most in a load floor? (Select a maximum of 2)
17. Would you pay extra for a more premium cargo floor?
18. How important is it for you to be able to store the cargo cover under the load floor?
19. If you had to choose, what would you prioritize in the cargo area?
20. Imagine you are picking up a new car. The cargo floor functions perfectly but has a slightly simpler finish than the rest of the interior. How would you react?
21. Would it be ok to have a very minimalistic load compartment (clean load floor without many features)?
22. Is there anything that you would like to change in your luggage compartment area?

B

Load Floor 1





C

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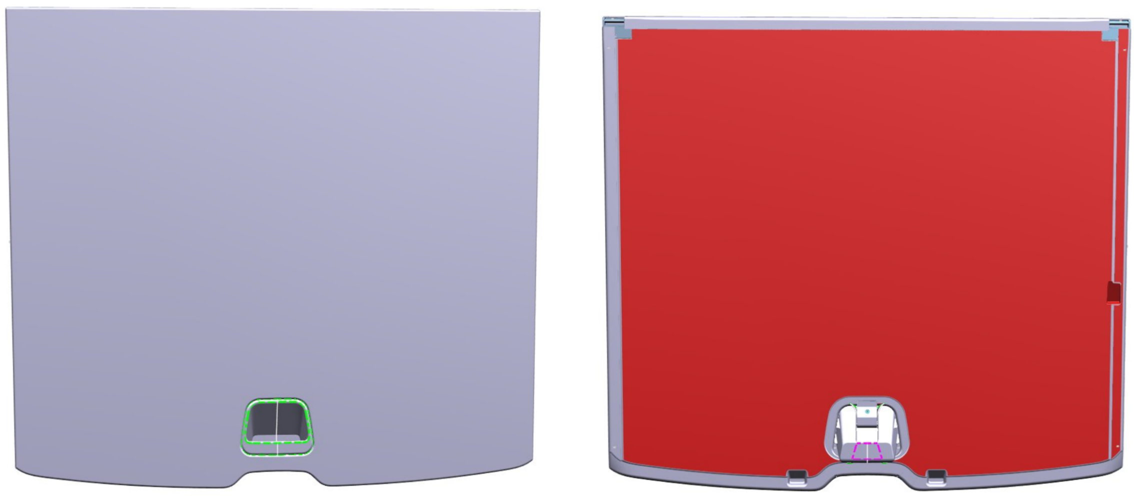
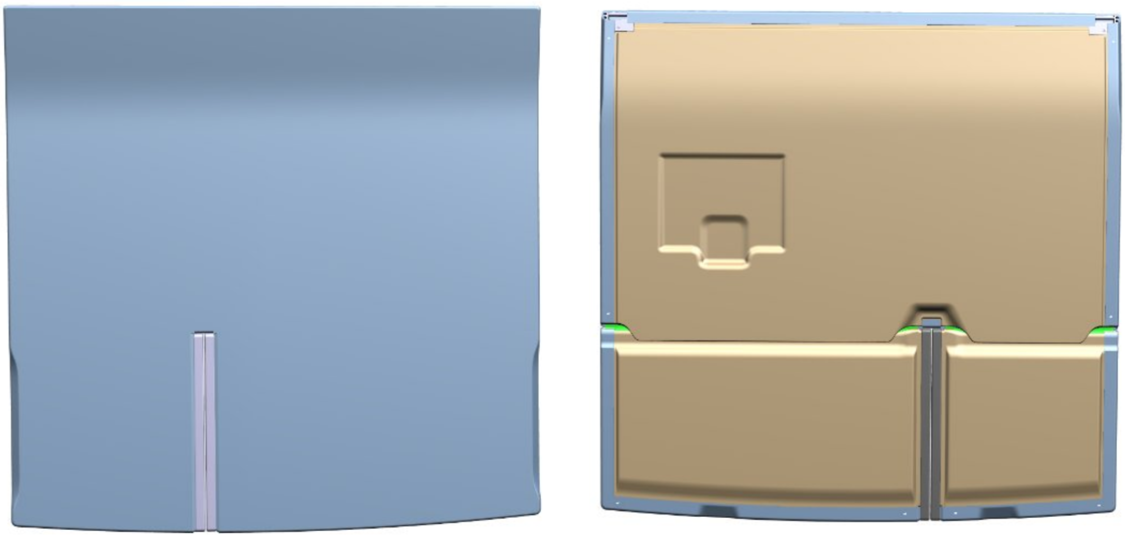


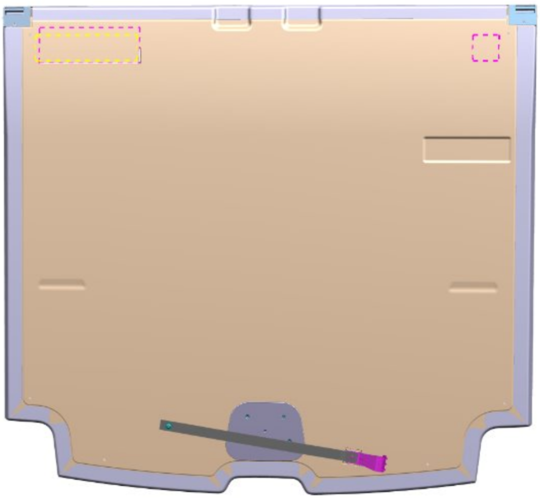
D

Load Floor 3



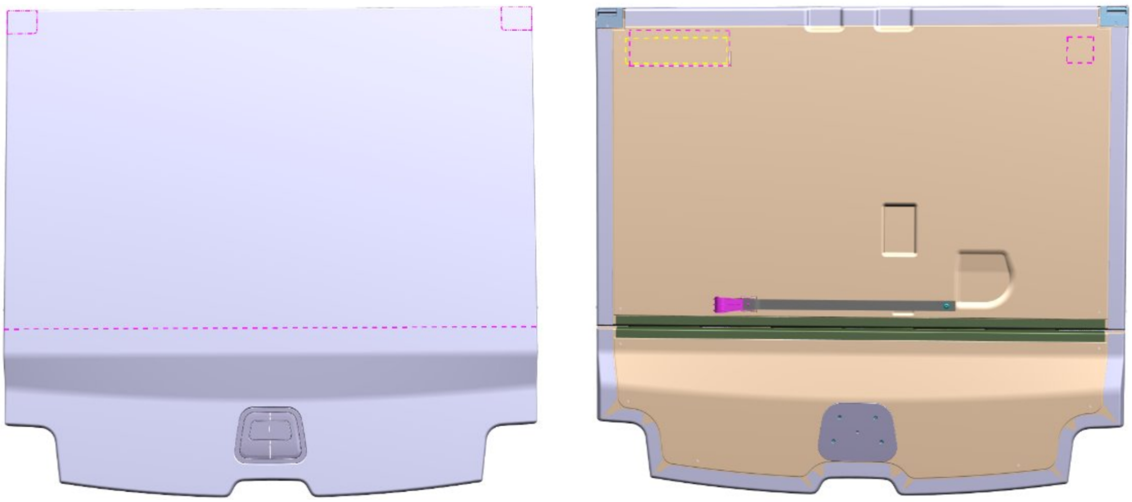
E

Load Floor 4



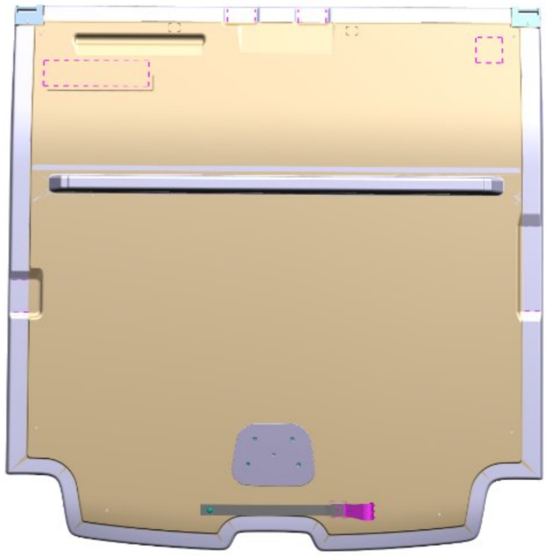
F

Load Floor 5



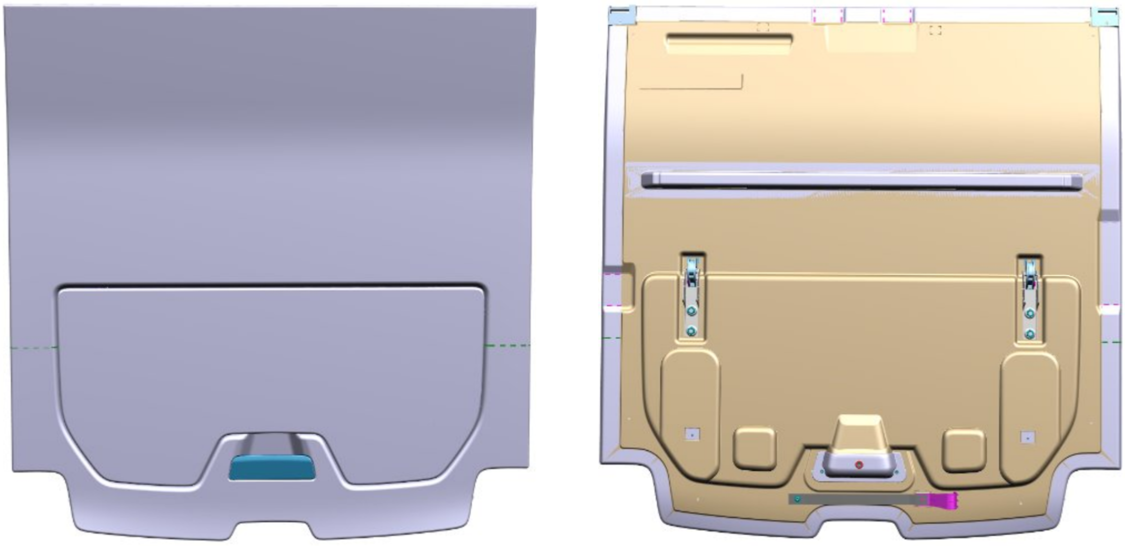
G

Load Floor 6



H

Load Floor 7



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