MASTER

Defining Sustainability Indicators with 3PL Service Providers
Design Principles for a Digitally Empowered Method

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Award date:
2023

Master Thesis Project (1ZM96)

Defining Sustainability Indicators with 3PL Service Providers: Design Principles for a Digitally Empowered Method

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Liechtenstein, July 7, 2023

Preface

This is my master's thesis titled *"Defining Sustainability Indicators with 3PL service providers: Design Principles for a Digitally Empowered Method"*. I completed this thesis as part of the requirements for my Master's program in Innovation Management at Eindhoven University of Technology. The research was conducted at Hilti's Global Logistics department, and I dedicated my time to it from October 2022 to June 2023.

My interest in sustainability and logistics was sparked during my time in Jakarta, where I did an internship at DHL Supply Chain to pursue my Bachelor's degree in Industrial Engineering and Management. Observing the high traffic congestion and poor air quality in Jakarta motivated me to seek solutions for the environmental challenges associated with global supply chains. I am grateful to Hilti AG for providing me with an opportunity to delve deeper into this subject again.

Following the pandemic, I felt compelled to embark on a new research endeavour beyond the borders of the Netherlands. Not only geographically, but also during the study, I delved into uncharted territory, acquainting myself with unfamiliar operating systems, and interactive data visualization software. Moreover, I honed my research acumen by undertaking theoretical analysis and conducting semi-structured interviews, thereby enhancing my proficiency in advanced research methodologies. This immersive experience taught me that grappling with challenges is a fundamental aspect of personal and professional growth. It further solidified my belief that I flourish in an international professional setting. This inclination stems primarily from the diverse individuals and cultures I have had the privilege of collaborating with.

In particular, I would like to express my gratitude to my university supervisors, Joost Wouters, and Layla Martin, for their guidance and support. You challenged me to maintain an academic perspective in a solution-oriented organizational environment. As I sit here, with the weight of countless deleted words behind me, I realize that your incessant requests for brevity were not merely academic nitpicking, but a lesson in the profound wisdom of *"less is more"*. I would also like to thank my company supervisor, Oliver Weich, for his knowledge and expertise. You were not only an exceptional supervisor but also a personable and approachable individual. I express my heartfelt appreciation to the rest of my dedicated team at Hilti, who warmly embraced me and provided unwavering support throughout my journey. Their collective efforts and camaraderie have made my experience all the more enriching and fulfilling. I cannot forget the other interns at Hilti, who made my stay memorable by enjoying long walks in the mountains, snowboarding, and socializing together. Lastly, I thank my friends and family who visited me in Liechtenstein and made my time there unforgettable. I feel rejuvenated and ready for the next step as a young professional.

Sincerely,

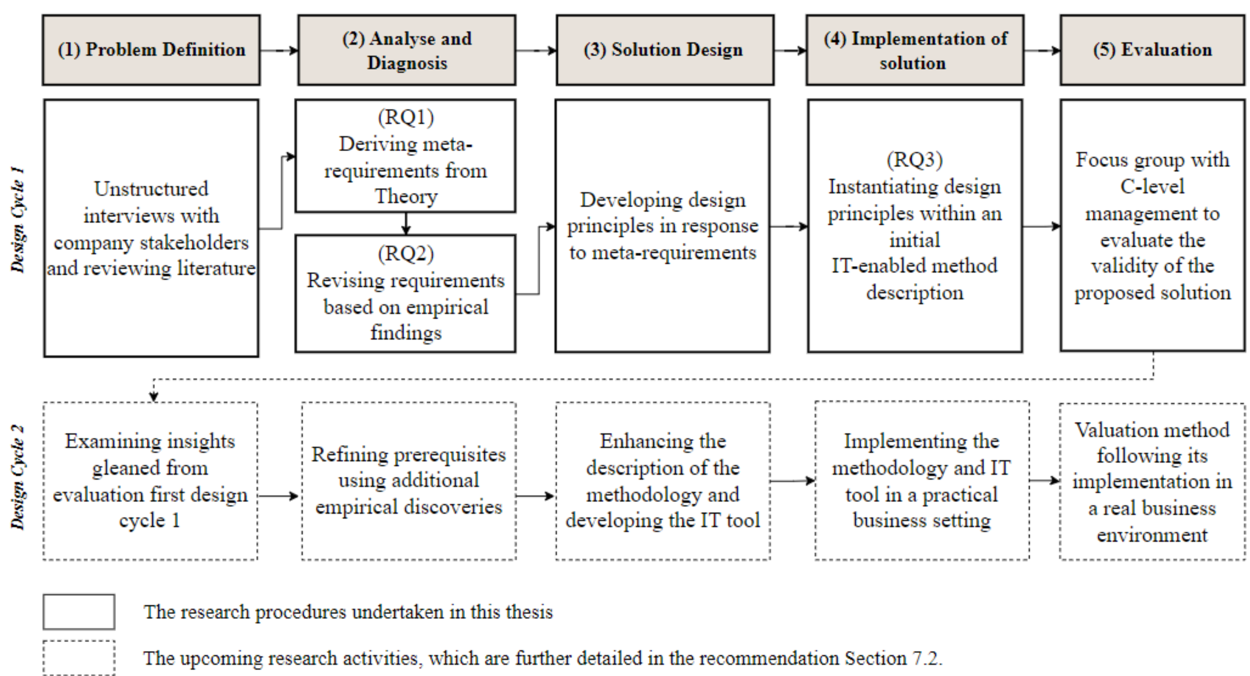
Thijs J. Joosten

Management Summary

Problem: The lack of a shared and comprehensive set of sustainability Key Performance Indicators (KPIs) between Hilti and Third-Party Logistics (3PL) service providers in Hilti's last-mile transport operations hinders the ability to prioritize greenhouse gas (GHG) reduction efforts and set joint sustainability targets. This leaves the company vulnerable and non-responsive to GHG-related risks and opportunities.

Objective: The objective of this thesis is to develop a digitally empowered method that guides the shared definition of a comprehensive set of sustainability KPIs for both Hilti and 3PL service providers, allowing for the prioritization of GHG reduction efforts and the establishment of joint sustainability targets.

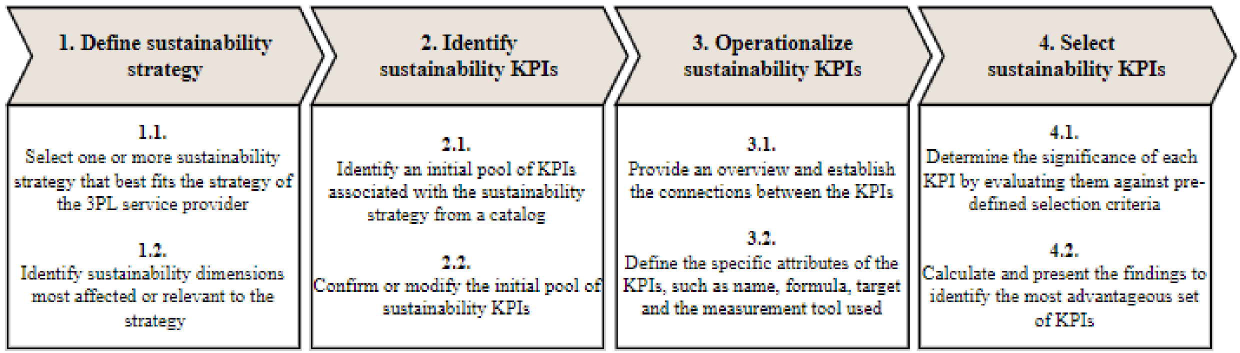
Research Design: The research design follows Problem-solving Cycle of Van Aken et al., 2012, and is in line with a Design Science Research (DSR) paradigm. It involves defining the business problem, analyzing and diagnosing the meta-requirements for a solution, designing and developing design principles, instantiating the principles in an initial solution, and demonstrating its validity. Unstructured interviews with stakeholders and a preliminary literature review are conducted to identify and define the problem. Meta-requirements are derived from theoretical analysis and refined based on empirical findings from semi-structured interviews with 3PL service providers. Design principles are formulated to address the meta-requirements, and an IT-enabled method and prototype are developed. A focus group with C-level managers evaluates the proposed solution design. The thesis presents an initial design cycle and offers recommendations for a second design cycle to further enhance the proposed solution design.



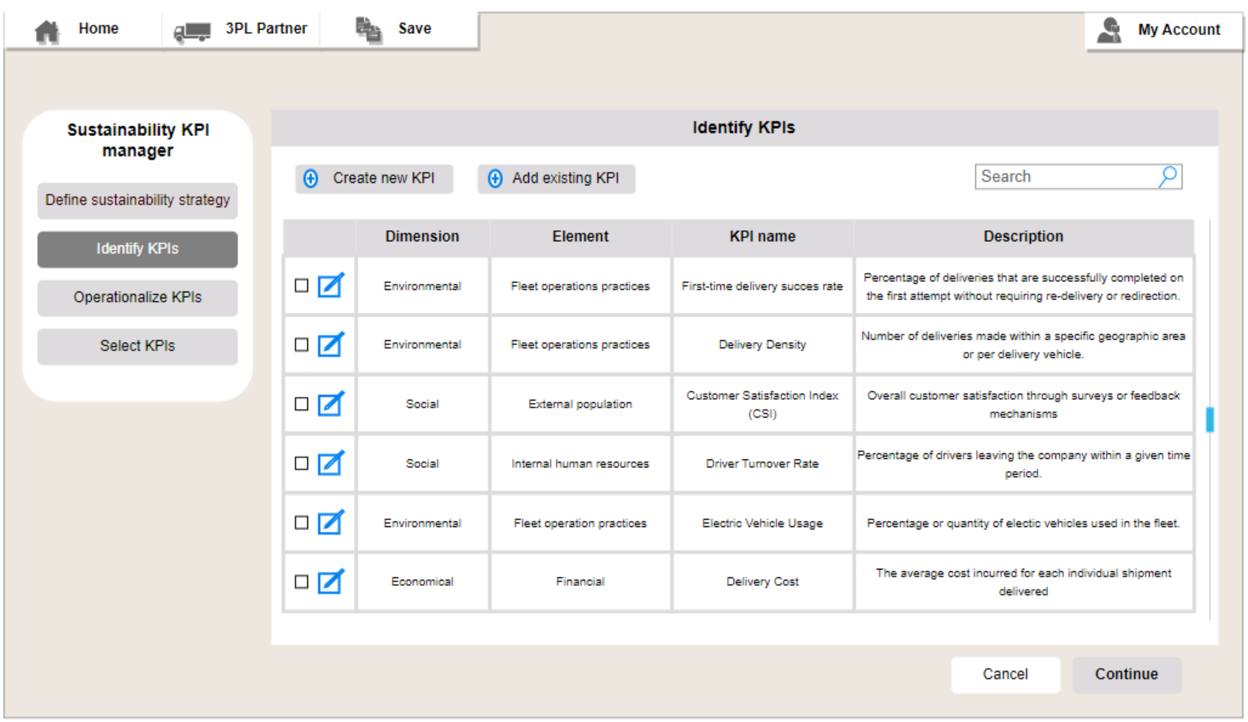
Findings: The theoretical analysis resulted in six Theory-Derived Meta-Requirements (TD-MRs) for establishing sustainability KPIs in shipper-3PL relationships, emphasizing collaborative decision-making on variables, metrics and targets. Furthermore, ensuring alignment on performance feedback, and continuous improvement. Through empirical findings, these TD-MRs were refined into four Empirically-Revised Meta-Requirements (ER-MRs). Design Principles (DPs) were introduced, targeting the ER-MRs and guiding the development of the digitally empowered method that guides the shared definition of a comprehensive set of sustainability KPIs for both Hilti and 3PL service providers.

Contribution: This research contributes to the development of design knowledge in the form of DPs. These principles provide guidelines for researchers and designers to create methods that facilitate the integration of sustainability KPIs with 3PL service providers. The proposed DPs bridge the gap between sustainability goals and operational practices, foster shipper-3PL collaboration, improve performance measurement, and enable informed decision-making. The proposed method consists of four primary steps, namely: (1) *sustainability strategy definition*, (2) *sustainability indicator identification*, (3) *operationalization of the sustainability indicators*, and (4) *selection of the the sustainability indicators*. Each of these steps is facilitated by an digitally-empowered method and aligns with the DPs. To demonstrate the functionalities of the digitally empowered method, an initial prototype has been developed.

The proposed method description is illustrated in the Figure below:



As an example, the Figure below illustrates a screenshot of the user interface of the digitally-empowered method, which supports the second step of the proposed method:



Recommendation: To enhance the proposed method and IT tool, it is recommended to embark on a second design cycle, refining the method description and prototype based on lessons learned. The prototype should be advanced into a fully functional IT tool, and the method should be implemented in a real-life business environment. Detailed recommendations for implementation include planning, clear communication channels, training, pilot testing, and the full-scale rollout. Through the implementation of the discoveries and suggestions put forth in this thesis, organizations can effectively bridge the divide between sustainability objectives and operational practices. This will lead to enhanced collaboration between shippers and 3PL service providers, improved performance measurement, informed decision-making capabilities, and ultimately, a competitive edge achieved through sustainable practices.

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Acronyms

3PL Third-Party Logistics. 9–13, 15, 16, 18–22, 24, 27, 28, 34, 36, 37

DP Design Principles. 3, 5, 16, 28, 29

DSR Design Science Research. 13–15, 34, 35, 37, 38

ER-MR Empirical-revised Meta-requirements. 5, 16, 22–27

ERP Enterprise Resource Planning. 20

ESLPM Environmental Sustainability Logistics Performance Management. 17

FWCI Field-Weighted Citation Impact. 18

GHG Greenhouse Gas. 9–12, 19, 34

GLD Global Logistics Distribution. 10

KPI Key Performance Indicators. 10–13, 15, 18, 20–22, 24–31, 34–37

LCA Life Cycle Assessment. 19

LSP Logistics Service Provider. 17

RFI Request For Information. 10

RFQ Request For Quotation. 10

RQ Research Question. 13, 34

SOP Standard Operating Procedure. 10

TD-MR Theory-derived Meta-requirements. 5, 16–22, 27

1 Fundament

1.1 Context

The climate crisis poses the risk of irreversible damage to humans and ecosystems, demanding mitigation and adaptation efforts across all levels of society. The prospect of global warming exceeding the 2°C trajectory proposed as the maximum in the Paris Agreement (2015), renders climate-resilient development virtually impossible in certain regions of the world (IPCC, 2022). At the same time, demand for last-mile transportation is rapidly increasing – the World Economic Forum (2020) projects it to grow by 78% in 2030 – and because of that, its environmental impact is also expected to grow significantly in the next few years. Numerous interpretations of last-mile transportation are available, but a widely accepted perspective is that it pertains to the final segment of the supply chain, encompassing the journey from the ultimate distribution center to the recipient's desired destination (Lim et al., 2018; Harrington et al., 2016). Frequently characterized as one of the costliest, least efficient, and environmentally impactful aspects of the supply chain, the last-mile segment bears such descriptions (Gevaers et al., 2014). The efficiency of operations relies on various factors, including consumer density and designated time windows (Boyer et al., 2009), congestion (Muñuzuri et al., 2012), fragmentation of deliveries (Leung et al., 2018), and shipment size and homogeneity (Xing et al., 2011). Last-mile transportation causes various externalities, especially air pollution (Ranieri et al., 2018), noise (Aljohani and Thompson, 2018), congestion (Allen et al., 2017) and an increase in Greenhouse Gas (GHG) emissions in the Earth's atmosphere (Edwards et al., 2010; Van Loon et al., 2015; Ranieri et al., 2018). GHG emissions get their name since changes in the concentration of these gases, from human activity (such as burning fossil fuels), increase the risk of global warming (Mohajan, 2017; IPCC, 2022). These issues are only growing worse, and lawmakers and the public are pressuring multinational companies to play their part in securing a regenerative future. Heeding this call to action, commitments initially focused on reducing Scope 1 and Scope 2 GHG emissions, which are produced directly by companies or indirectly through the purchase of energy. While this development has been promising, accounting for one's direct carbon emissions may not be enough anymore as the remaining global carbon budget is being rapidly depleted (Friedlingstein et al., 2022). Today, more organizations are also pledging to reduce their Scope 3 indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions. Generally, Scope 3 emissions are the largest source of emissions at companies, often several times the impact of Scope 1 and 2 emissions (Huang et al., 2009). In this scenario, sustainability management of the company's own logistics operations is not enough anymore for achieving a sustainable last-mile, and companies are also required to adopt measures to reduce negative externalities of transportation services purchased from Third-Party Logistics (3PL) service providers.

1.2 Company Introduction

One company that recognizes the growing need for improving sustainability in its third-party last-mile transport operation is Hilti AG (hereafter referred to as Hilti). The Liechtenstein multinational specializes in the development, manufacturing, and marketing of products for various industries including construction, building maintenance, energy, and manufacturing. Their products cater primarily to professional end-users. Hilti's product line focuses on anchoring systems, fire protection systems, installation systems, measuring and detection tools such as laser levels, range meters, and line lasers, as well as power tools like hammer drills, demolition hammers, diamond drills, cordless electric drills, heavy angle drills, and power saws, along with associated software and services. Established in 1941 by two brothers named Martin and Eugen Hilti, the company now employs approximately 31,000 people worldwide and is dedicated to making work on construction sites easier, faster, and safer. The mission statement *"We passionately create enthusiastic customers and build a better future"* highlights the importance of achieving long-term success through the delivery of exceptional products and services that exceed customer expectations and contribute to a sustainable future. In view of the environmental challenges the world faces today, Hilti lives up to this mission statement more than ever before. In 2020, the company laid important foundations by developing a holistic sustainability strategy, anchoring the topic of sustainability throughout the entire organization, and committing to net-zero latest by 2050 (including Scope 3 emissions). In 2021, the company started focusing efforts on improving business processes and integrating sustainability aspects into decision-making and one important focus area for reducing Scope 3 emissions became transportation within the global supply chain. This includes emissions from the transportation and distribution of products (excluding fuel and energy products) purchased or acquired in the reporting year in vehicles and facilities not owned or operated by the company, as well as other transportation and distribution services purchased from 3PL service providers.

This research project is conducted by the Global Logistics department of Hilti, which is responsible for enhancing logistic processes on a global and regional level. Specifically, the project has been assigned to the Global Logistics Distribution (GLD) team, which focuses on managing warehouse and transport operations. The GLD team is responsible for managing worldwide inbound and outbound replenishment, as well as last-mile transport to customers. Hilti completely outsources its last-mile transport operation, making 3PL service providers crucial players in meeting changing market conditions and achieving sustainability goals. It is estimated that 3PL service providers generate 93% of Hilti's total transport and warehouse GHG emissions, with 28% of that stemming from the last-mile transport operation. It is essential to highlight that when referring to Hilti's last-mile transport operation, we encompass the entirety of the operation starting from the products leaving the last Hilti distribution centre until they reach the recipient's desired destination point. This includes the entire network design of the 3PL service providers, which sets it apart from the conventional last-mile definition commonly used in literature, focusing solely on the final segment of the supply chain (Lim et al., 2018; Harrington et al., 2016). To align with Hilti's corporate strategy and commitments to reduce Scope 3 GHG emissions, the GLD team is tasked with improving sustainability in the last-mile transport operation. Worldwide the company works with around 3,000 different 3PL service providers. Carriers act on different geographical scales with Hilti, some partnerships are global, others regional or local. Good 3PL partnership management is crucial, as the company can expect higher flexibility, service level and leveraging from carriers.

1.2.1 3PL Partnership Management at Hilti

3PL partnership management at Hilti involves the collaborative effort between Hilti and selected 3PL service providers to ensure smooth and streamlined logistics operations. The primary goal of this management approach is to enhance the overall efficiency, effectiveness, and customer satisfaction of the supply chain.

3PL partnerships management at Hilti consists of three functional elements:

1. *Tender management:* Refers to the process of managing the bidding process for transportation services. This process is used to find the most efficient and cost-effective transportation provider. Two types of documents used in the tender management process are Request For Information (RFI) and Request For Quotation (RFQ). RFI is a preliminary document used to gather information from potential service providers about their capabilities, experience, and pricing structure. RFQ is a document used to solicit price quotes from potential suppliers for transportation-related goods or services. An RFQ typically includes a detailed description of the transportation needs of the organization, the expected delivery or service schedule, and the evaluation criteria that will be used to assess the quality of the quotes received.

2. *Contract management:* If the tender response is successful, negotiations will take place between the carrier and Hilti to finalize the contract terms and conditions. This part of 3PL partnership management is called contract management. The contract management process includes a global framework agreement with logistics partners, a standardized legal framework, clear liabilities for both parties and the flexibility to customize individual attachments such as service descriptions or pricing.

3. *Operations management:* After the contract is awarded, Hilti must manage the contract, in other words, making sure that carriers deliver the transport services as per the agreed terms, and ensure that all contractual obligations are met. In the context of 3PL partnership management, operations management includes establishing best practices for setting up and steering 3PL partnerships, creating clear Standard Operating Procedure (SOP)s, defining performance management standards and Key Performance Indicators (KPI), and establishing decision criteria for technology interface decisions. This ensures that all parties involved in the partnership are aligned and can work together effectively to meet Hilti's operational goals, such as reducing costs and improving customer satisfaction.

1.3 Theoretical Background

3PL service providers are companies that offer outsourced logistics and supply chain management services, including transportation, warehousing, and distribution, to help shippers optimize their operations and focus on their core activities (Evangelista et al., 2018). Literature suggests that sustainability has become an important consideration for shippers, with a demand for green 3PL services (Lieb and Lieb, 2010; Lee and Wu, 2014; Martinsen and Huge-Brodin, 2014). To meet this demand, 3PL service providers should consider adopting eco-efficient transport logistics, and integrating sustainability KPI into their operations, which may even lead to financial benefits in the long run (Bask et al., 2018; Laari et al., 2018). From the shipper's perspective, measuring the sustainability KPIs of 3PL service providers, can incentivize them to improve their sustainability practices (Coşkun et al., 2022).

A logistics purchasing process culminates in the execution phase, following the tender, negotiations, and contracting phases (Jazairy, 2020). This phase signifies the initiation of operational execution, where the agreed-upon rules and commitments between the contracting parties are put into action (Marasco, 2008). During this phase, the 3PL service providers carry out physical and transactional activities while the shipper monitors the process, with both parties striving for successful operations through individual and cooperative efforts (Bagchi and Virum, 1996; Monczka et al., 2015). Effective monitoring relies on measurable and achievable outcomes, necessitating regular meetings to identify any discrepancies between planned and actual performance metrics (Bagchi and Virum, 1996). Overall, the improvement of shipper-3PL relationships hinges on a well-executed operational kick-off, which necessitates effective and transparent communication while sensibly adapting working standards to ensure alignment throughout the duration of the relationship (Jazairy et al., 2017).

In the execution phase, shippers frequently overlook sustainability KPIs, even if they were explicitly mentioned in the contracts. Additionally, shippers tend to display greater commitment to environmental sustainability before the contract is signed rather than after its implementation (Jazairy, 2020). This is because of a lack of alignment between shippers' internal departments (e.g. procurement and operations) on environmental and operational objectives and the predominant focus is on traditional measures compared to sustainability ones in the execution. Shippers place higher importance on following up with traditional performance indicators (e.g. lead time) in comparison to sustainability KPIs (e.g. GHG emissions) (Jazairy, 2020). Another reason is shippers' trust in 3PL service providers to comply with the sustainability demands that were specified pre-contractually (Jazairy, 2020).

However, the literature suggests that collaborative efforts between shippers and 3PL service providers are essential in the execution phase (Bask et al., 2018; Lun et al., 2015; Persdotter Isaksson et al., 2019). Integrating sustainability KPIs between organizations is emphasized by more researchers (Ganesan et al., 2009; Morali and Searcy, 2013; Maestrini et al., 2017). When shippers embrace sustainability and integrate it into their business operations, it becomes imperative for 3PL suppliers to do the same (Yang et al., 2013). This integration aligns with the principles advocated in supply chain management literature, which promote the integration of diverse business processes with supply chain partners to enhance performance (Gopal and Thakkar, 2012; Alfaro et al., 2009). Nevertheless, researchers have identified a lack of process-based approaches to integrate sustainability KPIs between shippers and 3PL service providers (Ahi and Searcy, 2015; Colicchia et al., 2013; Persdotter Isaksson et al., 2019).

1.4 Problem Definition

A field problem refers to an empirical situation in an organization that needs improvement according to several important stakeholders within the firm (Van Aken et al., 2012). Stakeholders from multiple departments at Hilti were interviewed to define the problem statement of this research project. Appendix A provides a summary of the individuals who were interviewed. It's important to note that these interviews were conducted in a highly informal manner and were not formally recorded or documented. The aim of the interviews was to get a first understanding of how Hilti could improve sustainability in the last-mile transport operation. The process of defining a problem is often characterized as a complex and messy endeavor (Ackoff, 1981). It involves a combination of individual perceptions of reality, subjective value judgments derived from those perceptions, and the influence of various individuals, both influential and less influential, who make these judgments. The Cause-and-Effect diagram that resulted from the interviews is shown in Appendix B. Notice that, by the definition of the problem mess, an important demarcation is made: external triggers, root causes, intermediate causes and the symptom with respect to the business problem are taken into account. Furthermore, the causes identified are grouped into the different functional elements of 3PL partnership management at Hilti.

In addition to the opportunity to preserve the remaining global carbon budget, three external factors have prompted Hilti to enhance sustainability in the last-mile transport operation. Firstly, segments of the value chain that have high GHG emissions are inherently more exposed to risks arising from resource price fluctuations and evolving regulatory landscapes. This includes stricter efficiency standards for logistics services and potential carbon emission taxation (Bhatia, Ranganathan, et al., 2004; Barbose et al., 2008). Secondly, existing markets are being disrupted while new markets are emerging, to remain competitive in companies must provide solutions that align with a low-carbon future (Bhatia, Ranganathan, et al., 2004; Hargadon, 2011). Lastly, there is mounting pressure on Hilti from investors, customers, peers, suppliers, and civil society to comprehensively measure, manage, and reduce their climate impact. Market research indicates that sustainability in last-mile transport is a demand expressed by customers in the professional construction products industry (Hilti Market Development Report, 2021). Moreover, reporting and reducing Scope 3 emissions have become integral aspects of reporting frameworks such as the CDP climate change questionnaire, the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD), and initiatives like the Science Based Targets initiative, which aim to drive ambitious corporate action (Bhatia, Ranganathan, et al., 2004; Jazairy and von Haartman, 2020).

Three fundamental root causes have been identified pertaining to the existing practices in managing 3PL partnerships. Firstly, the absence of sustainability as a prominent criterion during the selection of 3PL suppliers indicates a deficiency in the supplier selection protocol with regard to its emphasis on environmental and social considerations. Secondly, the omission of sustainability clauses within the contractual agreements between Hilti and 3PL suppliers reflects a gap in policy formulation and implementation, thereby neglecting the integration of sustainable practices into the partnership framework. Lastly, the lack of a shared and comprehensive set of sustainability KPIs with current 3PL service providers to constantly monitor the last-mile transport operations indicates a deficiency in the design of the current performance measurement system.

The identified root causes have led to three intermediate causes. The first intermediate cause is that tenders for logistics services are still being awarded to high-emitting 3PL suppliers, which is a result of the first root cause - sustainability not being a key criterion in the supplier selection process. The second intermediate cause is the lack of guarantee for adherence to GHG reduction plans, which is a result of the second root cause - sustainability not being included in the contracting documents. The third intermediate cause is the absence of a tool for prioritizing GHG reduction efforts and setting sustainability targets with 3PL service providers, which is a result of the third root cause - the absence of a shared and comprehensive set of sustainability KPIs. These intermediate causes can lead to the continued release of harmful emissions into the environment, and hindering progress towards other sustainability goals.

These root causes, together with their intermediate causes, are making it impossible for Hilti to respond effectively to business opportunities, increasing resource prices, a changing regulatory landscape, and social pressure on climate action. More specifically, these causes are leaving the company vulnerable and non-responsive. Overall, this is hindering Hilti's ability to adapt to a changing business environment and effectively respond to GHG-related risks and opportunities. This puts the company at risk of falling behind its competitors and failing to meet the expectations of its stakeholders, including customers, investors, and regulators.

The problem definition for a field problem project involves choosing a specific issue or set of issues to address (Van Aken et al., 2012). When selecting a business problem, it requires a process of naming and framing the problem (Schwartz, 1987). By utilizing established concepts to define and understand the problem and its causes, the problem can be categorized as a particular type. Naming the problem is closely linked to framing, as it involves connecting the problem to an existing frame of reference. This frame of reference determines the project's focus, scope, and establishes the theoretical and empirical boundaries of the problem that needs to be tackled. In this research project, the primary focus is on incorporating sustainability KPIs into operational management of 3PL suppliers. This is the most crucial challenge faced by Hilti. Without a clear and shared understanding of the current sustainability performance, the company and its 3PL service providers will be unable to measure progress towards sustainability goals effectively. Additionally, since most partnerships are already established, the potential for improvement lies primarily within the existing 3PL service providers. To provide context and clarify the scope of the research problem, the problem statement is presented explicitly below:

"The lack of a shared and comprehensive set of sustainability KPIs for Hilti and 3PL service providers in the last-mile transport operation, hinders the ability to prioritize GHG reduction efforts and set joint sustainability targets, leaving the company vulnerable and non-responsive to GHG-related risks and opportunities"

1.5 Research Objective and Questions

Based on the problem statement in Section 1.4, the objective of this research project is to design a solution that recommends how to establish a joint and comprehensive set of sustainability KPIs for Hilti and 3PL service providers in last-mile. This study constructs design criteria based on theoretical and empirical research. The ultimate goal is to enhance Hilti's performance measurement practices, ensuring a stronger alignment with the company's current sustainability strategy. Based on the problem statement and to establish the scope and depth of the research project, the following research objective is formulated:

"To develop an digitally empowered method that guides the shared definition of a comprehensive set of sustainability KPIs with 3PL service providers, allowing to prioritize GHG reduction efforts and set joint sustainability targets"

A subset of Research Question (RQ) is defined to retrieve design requirements from theory (RQ1) and practice (RQ2). Answering RQ1 and RQ2 are prerequisites to answering RQ3, which acts as the overall research question.

- *RQ1 (theory-oriented):* What are the design requirements suggested in the literature that should be considered for designing of a methodology guiding the shared definition of a comprehensive set of sustainability KPI within shipper-3PL relationships?
- *RQ2 (practice-oriented):* What are the needs and preferences of 3PL service providers for an method that guides the shared definition of sustainability KPIs and how do they inform the revision and refinement of the design requirements identified in the literature?
- *RQ3 (solution-oriented):* How can a digitally empowered method be developed to facilitate the shared definition of a comprehensive set of sustainability KPIs for Hilti and 3PL service providers, enabling effective prioritization of GHG reduction efforts and the establishment of joint sustainability targets in the last-mile transport operation?

1.6 Thesis Outline

This thesis adopts a Design Science Research (DSR) approach to address the research questions at hand. Within this context, the proposed artefact is an digitally empowered method that facilitates the collaborative definition of a comprehensive set of sustainability KPIs with 3PL service providers. The primary objective of this research paper is to present the results obtained from an initial design cycle of the DSR project. The emphasis of this cycle was primarily placed on formulating design principles that facilitate the development of the methodology. The thesis is structured as follows, Chapter 2 introduces the research design, explaining the approach taken to propose the ultimate solution design. In Chapter 3, a theoretical analysis addresses the first research question (RQ1) and derives theory-based requirements for the artefact. Moving to Chapter 4, the second research question (RQ2) is answered through a revision of the theory-derived requirements, incorporating empirical findings from semi-structured interviews. Chapter 5 showcases the answer to RQ3, presenting design principles and a comprehensive description of the proposed solution design. Chapter 6 presents the results from a focus group, aimed at validating the design principles and proposed IT-enabled method, Finally, Chapter 7 concludes the thesis by offering practical recommendations to advance the proposed solution design, outlining subsequent steps in the DSR project. It also provides practical suggestions for implementing the solution within the business context and discusses the overall contributions and limitations of the thesis.

2 Research Design

To define an digitally empowered method that guides the shared definition of a comprehensive set of sustainability KPIs with 3PL service providers, this research follows the Design Science Research (DSR) paradigm, which aims to create and evaluate an artefact that addresses the identified business problem (Hevner et al., 2004). In many cases, DSR involves multiple iterative design cycles to contribute to existing knowledge (Hevner, 2007; Sonnenberg and Vom Brocke, 2012). Within this paradigm, the epistemological emphasis lies not in the pursuit of a universal truth, but rather in the creation of practical tools tailored to specific contexts (Romme, 2016). These tools, referred to as design principles, act as a vital link between theory and practice. While grounded in theory, these design principles are testable in real-world applications (Berglund et al., 2018). Strict adherence to the DSR paradigm results in a context-specific, solution-oriented theory rather than a generic explanatory theory. As highlighted by van Van Aken et al., 2012, the development of a solution-oriented theory is based on systematic, controlled, and triangulated observations, along with methodical case analyses, peer-reviewed examinations, and tested conclusions. In the end, design principles play a crucial role in encapsulating design knowledge, enabling its reuse (Chandra Kruse et al., 2016). They serve as a valuable resource for designers, assisting them in generating specific instances of artifacts that can be used for comparable problems (Möller et al., 2020).

The research design is structured according to the DSR methodology and followed the Problem-solving Cycle, a process proposed by Van Aken et al., 2012. Accordingly, the research process involves defining the business problem, analysis and diagnosis to define the design requirements of a solution artefact, designing and developing design principles of the solution artefact, instantiating the design principles in an initial solution artefact, and showcasing it in an appropriate setting to evaluate its validity. The research design is presented in Figure 1. The Figure illustrates the initial design cycle of the DSR project, in other words, the research procedures undertaken in this thesis. Also, in the Figure recommendations for a second design cycle are provided, which are elaborated on in the recommendations in Section 7.2.

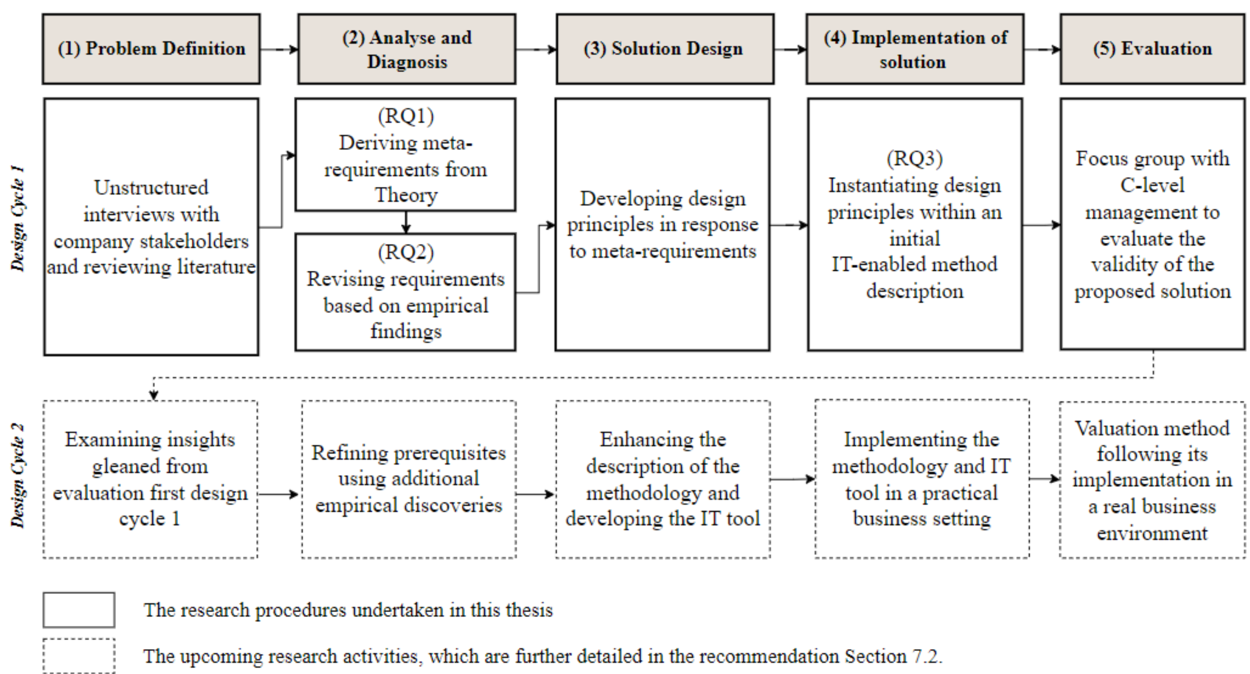

Figure 1: Research design (based on Van Aken et al., 2012)

The Problem-solving Cycle starts with the problem definition. To identify and define the problem, unstructured interviews with company stakeholders are held and existing academic literature on sustainability performance measurement in a 3PL context is reviewed. Based on this analysis, the theoretical background and problem definition was explicated in Section 1.3 and Section 1.4 respectively. In the second step, the problem is addressed. Guidelines are followed to derive meta-requirements for guiding the development of design principles (Peffers et al., 2007; Möller et al., 2020). Meta-requirements establish the overarching goals and constraints of a system, while design principles offer specific guidelines for achieving those goals during the design phase (Walls et al., 1992). To define the Theory-derived Meta-requirements (TD-MR), existing knowledge is obtained through a literature review. This step addresses the first research question (RQ1), a detailed methodology of the theoretical analysis is provided in Section 3.1. Subsequently, the meta-requirements derived from the literature are revised based on empirical findings from semi-structured interviews with 3PL service providers. This resulted in the development of Empirical-revised Meta-requirements (ER-MR). In Section 4.1, a comprehensive methodology for the empirical analysis is presented, specifically addressing the second research question (RQ2). In the third step of the Problem-solving Cycle, design principles were formulated in response to the derived ER-MRs. These DPs act as prescriptive guidelines, offering valuable direction for the design and development of the artefact and are structured following the framework introduced by Chandra et al., 2015. Subsequently, in the fourth step of the Problem-solving Cycle, to demonstrate the design principles, an initial method description and supporting IT tool prototype were instantiated to address the final research question (RQ3). In the final stage, a focus group comprising three C-level managers from Hilti was conducted, with the main objective centered around assessing the validity of the proposed solution design.

3 Meta-requirements based on Theoretical Analysis

In the following chapter, a comprehensive exploration of Theory-derived Meta-requirements (TD-MR) is reported, crucial for the successful development of the artefact at hand. Building upon the foundation of existing theories and research, this chapter serves as a roadmap for understanding and addressing the essential elements necessary to create the digitally empowered method. The methodology of the theoretical analysis is explained in Section 3.1, while Section 3.2 presents the results of the analysis and defines the TD-MRs. Section 3.3 marks the conclusion of the chapter.

3.1 Methodology

3.1.1 Search Process

The theoretical analysis builds on the Environmental Sustainability Logistics Performance Management (ESLPM) process integration framework which consists of six activities: (1) selecting sustainability variables, (2) defining sustainability metrics, (3) setting sustainability targets, (4) measuring sustainability metrics, (5) providing performance feedback, and (6) analysis and improvement of sustainability metrics (Persdotter Isaksson et al., 2019). In turn, the ESLPM process integration framework builds further on the performance management process framework (Forslund and Jonsson, 2007). This ESLPM process integration framework is used because it explains each process activity needed for establishing integrated performance measurement systems in shipper-3PL relationships. The six process activities served as a starting point for the search process, in order to obtain more relevant information pertaining to these six process activities.

Given the vast amount of literature available, various search criteria are employed to extract the most relevant sources. Section 2.1.2 explains the search strings utilized, while additional search criteria are outlined in Section 2.1.3. A fundamental aspect of the search process was the snowballing method applied to acquiring additional pertinent literature. This method was applied both forwards and backwards; backwards snowballing entails tracking references utilized in a particular study, while forward snowballing involves searching for articles that cite a specific article (Van Aken et al., 2012).

3.1.2 Search String

When conducting a literature review, an important aspect is to formulate appropriate search terms and strings. According to Siddaway et al., 2019, there are various best practices that should be followed when performing this task. One key consideration is to account for synonyms. For example, Ali et al., 2020, suggest that *"contract logistics"*, *"Logistics Service Provider (LSP)"*, *"logistics outsourcing"*, and *"logistics alliances"* can all refer to 3PL. To prevent missing articles on synonyms, several *"OR"* Booleans are used. Additionally, Siddaway et al., 2019, recommend including different forms or spellings of terms, such as *"sustainability"* or *"sustainable"*, and *"analyse"* or *"analyze"*, to ensure comprehensive search results. During the search process, different synonyms, forms, and spellings are considered. For instance, to prevent missing articles on forms an *"*"* is used. Hereby, when searching articles that include *"sustainable"* or *"sustainability"*, *"sustainab*"* is used in the search string.

3.1.3 Selection Criteria

Then the literature available under the above-mentioned areas was searched and gathered using selection criteria. The articles which deal with sustainability performance evaluation and measurement were reviewed, especially when considered in a shipper-3PL relationship. To guarantee a certain quality of the literature, several criteria are used when selecting relevant literature. These criteria are provided in Table 1. First of all, a search string and search terms are defined that are used during the selection of relevant literature. This search string is based on the methodology explained in the previous subsection. Next, the literature must be peer-reviewed and available in full-text to guarantee that the literature could be checked by the researcher self and that it is checked by other researchers. Therefore, it is also important that the literature is written in English or Dutch. At least two electronic databases should be used during the systematic literature review (Siddaway et al., 2019). The databases that are used during this research are Scopus and ProQuest. To ensure the literature used in the study met high-quality standards, the Field-Weighted Citation Impact (FWCI) from Scopus was employed as a criterion. All literature sources selected with the ProQuest database were also selected with Scopus, which made this decision possible. The FWCI is a metric that measures how well a document is cited in comparison to similar documents. A value above 1.00 indicates that the document is more cited than the average expectation. The FWCI takes into account various factors, such as the publication year, document type, and associated disciplines. It calculates the ratio of a document's citations to the average number of citations received by similar documents over a three-year period. This metric gives equal weight to each discipline, eliminating discrepancies in researcher citation behaviour. However, according to Van Aken et al., 2012, design-oriented studies should not overlook lower-ranked journals. Lower-ranked journals may contain more practically relevant studies than top-ranked journals, which tend to be more theory-oriented. Therefore, while journal ranking is considered, it is not a strict criterion.

Table 1: Selection criteria for literature review

Criteria	*Rationale*
Search strings / keywords	TITLE-ABS-KEY (((”3PL” OR ”logistics service provider” OR ”contract logistics” OR ”logistics outsourcing” OR ”logistics alliances”) AND (”performance” AND ”measurement” OR ”assessment” OR ”evaluation” OR ”indicator” OR ”analy*”) AND (”sustainab*” OR ”green”)
Requirements literature	Full-text available, peer-reviewed
Language	English or Dutch
Literature databases	Scopus and ProQuest
Journal ranking (FWCI)	A value greater than 1.00

3.1.4 Search Sources

The theoretical analysis includes a total of 31 studies, which were selected based on specific search criteria and a thorough assessment of their content and usability. The inclusion process involved exploring the titles, abstracts, and conclusions of each article. Once the most relevant articles were identified, their relevant information was compiled to create the TD-MRs.

3.2 Results

A total of six TD-MR have been identified from the literature. This section is divided into six subsections, with each subsection focusing on the explanation and rationale behind every TD-MR.

3.2.1 Jointly Select Variables (TD-MR-1)

Shipper-3PL relationships are characterized by outsourcing logistics functions to specialized service providers. These relationships have evolved beyond cost-centric considerations to encompass environmental and social dimensions (Björklund and Forslund, 2013; Jung, 2017; Kumar and Anbanandam, 2022). Collaborative partnerships between shippers and 3PL service providers are crucial for achieving sustainability goals and optimizing supply chain performance (Morali and Searcy, 2013). Various studies have proposed and identified sustainability KPIs for measuring and evaluating supply chain sustainability performance (e.g., Colicchia et al., 2013; Chardine-Baumann and Botta-Genoulaz, 2014; Qorri et al., 2018). However, the literature lacks consensus on the selection and implementation of sustainability KPIs, particularly in the context of shipper-3PL relationships (Evangelista et al., 2018; Björklund and Forslund, 2019). The relevance of different logistics variables depends on the unique characteristics of both 3PL suppliers and shippers (Forslund and Jonsson, 2007; Martinsen and Huge-Brodin, 2014). Collaboration and joint decision-making have been recognized as essential components of successful partnerships (Persdotter Isaksson et al., 2019). Jointly selecting sustainability variables enables shippers and 3PL service providers to align their objectives and focus on common sustainability goals. This collaborative approach enhances communication, trust, and cooperation, leading to improved sustainability performance (Carrim et al., 2020). In the context of defining sustainability KPIs in shipper-3PL relationships, the first meta-requirement (TD-MR-1) emphasizes the need for the artefact to allow shippers and 3PL service providers to jointly select variables. This requirement ensures a collaborative and aligned approach to measuring and managing sustainability in the supply chain. Following the first meta-requirement:

TD-MR-1: The artefact should allow shippers and 3PL service providers to jointly select variables that determine which sustainability KPIs should be adopted by both organizations.

3.2.2 Jointly Define Metrics (TD-MR-2)

Effectively measuring and operationalizing the selected sustainability variables requires the use of clear and well-defined metrics or calculation procedures. Analysis of the sustainability metrics used by companies shows a large discrepancy in what and how the companies measure and report concerning their sustainability performance (Székely and Knirsch, 2005). However, when it comes to shipper-3PL relationships, it becomes essential to establish a shared understanding of these metrics to ensure alignment and data consistency between the organizations (Jin and High, 2004; Hervani et al., 2005; Forslund and Jonsson, 2007; Medne and Lapina, 2019 Persdotter Isaksson et al., 2019). In order to support companies in defining their sustainability metrics, a wide array of methodologies and standards have been developed, including Life Cycle Assessment (LCA) (e.g., Facanha and Horvath, 2005; Guo and Ma, 2017), carbon footprint calculators (e.g., EcoTransIT, 2014), social impact assessment tools (e.g., Gilbert and Rasche, 2007; Jung, 2017), and sustainability reporting guidelines (e.g., GHG Protocol, 2013; EN16258, 2012; ISO, 2021). According to Wild, 2021, there are currently twelve different approaches employed for estimating GHG emissions associated with road freight transportation. These methodologies possess diverse legal frameworks, originating from research institutions, commercial enterprises, and governmental initiatives, and are either globally applied or restricted to specific geographical regions (Wild, 2021). But most importantly, they use different methodologies for defining the metrics. As an example, the calculation of GHG emissions in road freight transportation can be done using either the formula *"fuel used multiplied by emission factor"* or *"distance travelled multiplied by an emission factor"* (GHG Protocol, 2013). However, employing these different approaches results in distinct outcomes. Collaborative efforts allow for the consideration of contextual factors, specific industry requirements, and the integration of both parties' expertise in developing meaningful and applicable metrics (Schwarz et al., 2002; Székely and Knirsch, 2005). The second theory-derived meta-requirement (TD-MR-2) emphasizes the need for the artefact to allow shippers and 3PL service providers to jointly define metrics that support the operationalization of the identified sustainability KPIs. This meta-requirement ensures that both parties actively participate in developing the metrics. Hence, the second meta-requirement is proposed:

TD-MR-2: The artefact should allow shippers and 3PL service providers to jointly define metrics to support the operationalization of the identified sustainability KPIs.

3.2.3 Setting Joint Target (TD-MR-3)

Setting sustainability targets is crucial for driving meaningful change and improvement in sustainable supply chain practices. These include industry-specific benchmarks, regulatory requirements, stakeholder expectations, and the ability to measure and track progress over time (Zhang et al., 2008; McKinnon and Piecyk, 2012). In the context of shipper-3PL relationships, joint target setting enhances the overall accuracy and effectiveness of performance management (Jørsfeldt et al., 2016; Persdotter Isaksson et al., 2019). However, few shippers are setting joint targets with their 3PL service providers (Forslund, 2012). The literature presents various categories of sustainability logistics targets. For instance, there are (i) quantitative versus qualitative targets, such as achieving a 30% reduction in absolute energy consumption from non-renewable sources by 2030 or obtaining ISO certification for sustainable logistics practices; (ii) absolute versus intensity targets, involving reducing GHG emissions in a specific quantity over time or decreasing emissions per kilometre driven; and (iii) top-down versus bottom-up targets, where top-down targets are uniformly applied at the organizational level across all functions, while bottom-up targets involve internally assessing different aspects within an organization to identify opportunities for emissions reduction on an organizational level (Forslund and Jonsson, 2007; McKinnon and Piecyk, 2012; Persdotter Isaksson et al., 2019). The third theory-derived meta-requirement (TD-MR-3) emphasizes the need for the artefact to allow shippers and 3PL service providers to jointly set sustainability targets that support the operationalization of the identified sustainability variables and metrics. This meta-requirement ensures that both parties actively participate in defining targets, fostering collaboration, and shared commitment towards sustainable practices. The third meta-requirements is formulated as follows:

TD-MR-3: The artefact should allow shippers and 3PL service providers to jointly set sustainability targets to support the operationalization of the identified sustainability KPIs.

3.2.4 Jointly Define how to Measure the Metrics (TD-MR-4)

Selecting the appropriate measurement approach is crucial for generating reliable and meaningful insights into sustainability performance. The literature presents three issues related to the integration of this activity: (i) different measurement frequencies, such as yearly, monthly or weekly; (ii) average versus specific measurement, average for all buyers and 3PL service providers or individual measuring for each partner; and (iii) direct versus indirect measurement report generation, directly from internal systems like Enterprise Resource Planning (ERP) and external calculators or indirectly by using spreadsheets for reports creation (Forslund and Jonsson, 2007; Persdotter Isaksson et al., 2019). The utilization of tools for measuring sustainability metrics plays a crucial role in establishing consistent routines and ensuring the reliability of measurements (Gunasekaran and Kobu, 2007). As mentioned in Section 3.2.2, carbon calculators have been developed to support companies in defining their sustainability metrics, but they also assist in the actual measuring of the metrics (e.g., EcoTransIT, 2014). Collaborative decision-making for these issues within shipper-3PL relationships is crucial for data consistency and comparability (Hartmann et al., 2013; Busch et al., 2022). 3PL service providers were found to possess effective real-time data collection capabilities, although their abilities to generate reports varied (Forslund, 2012). The fourth theory-derived meta-requirement (TD-MR-4) emphasizes the need for the artefact to allow shippers and 3PL service providers to jointly define and select tools that support the measurement of the identified sustainability KPIs. This meta-requirement ensures that both parties actively participate in determining the measurement approach and tools to be utilized, enhancing collaboration and alignment in sustainability performance measurement. Next, the fourth meta-requirements is presented:

TD-MR-4: The artefact should allow shippers and 3PL service providers to jointly define how to measure the metrics to support the operationalization of the identified sustainability KPIs.

3.2.5 Jointly Define the Performance Feedback Process (TD-MR-5)

Performance feedback plays a critical role in evaluating and enhancing the sustainability performance of 3PL service providers. In shipper-3PL relationships, both parties should have the opportunity to comment on provided feedback and suggest adjustments if necessary. It allows for the consideration of different perspectives and encourages joint decision-making regarding necessary adjustments to improve sustainability performance. Subsequently, acceptance of performance feedback by both organizations is crucial and involves acknowledging strengths and weaknesses, taking ownership of identified areas for improvement, and actively working towards implementing changes (Forslund and Jonsson, 2007; Sanders et al., 2011; Persdotter Isaksson et al., 2019). Moreover, research on supplier development highlights the direct correlation between penalties, rewards, and supplier performance (Krause et al., 2000; Selviaridis and Norrman, 2015). Specific penalties (e.g., contract termination, reduced business, fines) and incentives (e.g., increased business, preferred supplier status, price premiums, public recognition) are positively linked to reduced sustainability violations and operating costs (Patil et al., 2022). Therefore, companies could consider implementing a bonus-malus system into their performance feedback system. The fifth theory-derived meta-requirement (TD-MR-5) emphasizes the need for the artefact to assist shippers and 3PL service providers in deciding how feedback should be provided, commented on, adjusted, and finally accepted. This meta-requirement ensures that both parties agree on how the feedback process should be organized. The fifth meta-requirements is formulated as follows:

TD-MR-5: The artefact should allow shippers and 3PL service providers to jointly define the performance feedback process to support the operationalization of the identified sustainability KPIs.

3.2.6 Jointly Define the Analysis and Improvement Process (TD-MR-6)

Finally, collaborative review, analysis and improvement processes enable shippers and 3PL service providers to share insights, leverage collective expertise, and develop targeted strategies to enhance sustainability performance (Forslund and Jonsson, 2007; Persdotter Isaksson et al., 2019). Shippers and 3PL service providers can jointly apply analytical techniques, such as benchmarking, trend analysis, and root cause analysis, to gain insights into the factors influencing sustainability performance. The collaborative review and analysis of sustainability KPIs provide the foundation for improvement planning. Joint improvement planning encourages shared responsibility, commitment, and alignment towards sustainable practices (Jazairy, 2020). The sixth theory-derived meta-requirement (TD-MR-6) emphasizes the need for the artefact to enable shippers and 3PL service providers to jointly decide how to review, analyze, and improve selected sustainability KPIs. This meta-requirement ensures active participation from both parties in the review and analysis processes, fostering collaboration, and continuous improvement in the sustainability performance. What follows is the last meta-requirement derived from theory:

TD-MR-6: The artefact should allow shippers and 3PL service providers to jointly define the analysis and improvement process to support the operationalization of the identified sustainability KPIs.

3.3 Conclusion

In conclusion, six meta-requirements are derived from the literature. The TD-MRs establish the overarching goals and constraints of the digitally empowered method design. The review highlighted the importance of collaborative decision-making in selecting sustainability variables, defining metrics, setting targets, and choosing measurement tools. Additionally, it emphasized the significance of jointly defining how the performance feedback processes should be organised and how collaborative review, analysis, and improvement of selected KPIs should take place. These meta-requirements underscore the need for active participation and collaboration between shippers and 3PL service providers to drive continuous improvement in sustainable practices. Further research is required to revise these meta-requirements with empirical evidence. This revision process is done and described in the next chapter of the thesis.

In summary, the following TD-MRs were derived from this theoretical analysis:

- *TD-MR-1*: The artefact should allow shippers and 3PL service providers to jointly select variables that determine which sustainability KPIs should be adopted by both organizations.
- *TD-MR-2*: The artefact should allow shippers and 3PL service providers to jointly define metrics to support the operationalization of the identified sustainability KPIs.
- *TD-MR-3*: The artefact should allow shippers and 3PL service providers to jointly set sustainability targets to support the operationalization of the identified sustainability KPIs.
- *TD-MR-4*: The artefact should allow shippers and 3PL service providers to jointly define how to measure the metrics to support the operationalization of the identified sustainability KPIs.
- *TD-MR-5*: The artefact should allow shippers and 3PL service providers to jointly define the performance feedback process to support the operationalization of the identified sustainability KPIs.
- *TD-MR-6*: The artefact should allow shippers and 3PL service providers to jointly define the analysis and improvement process to support the operationalization of the identified sustainability KPIs.

4 Revised Meta-Requirements based on Empirical Findings

In this chapter, the Theory-derived Meta-requirements (TD-MR) are revised based on empirical findings from semi-structured interviews with Hilti's eight biggest 3PL service providers. TD-MRs are typically built upon certain assumptions about user needs, preferences, and behaviours, empirical findings allow us to test these assumptions and validate whether they hold true in practice (Möller et al., 2020). Section 4.1 provides detailed information about the interview methodology. The analysis of the interviews yields four new Empirical-revised Meta-requirements (ER-MR), which are presented in Section 4.2. Section 4.3 concludes by discussing the implications of these findings in relation to the thesis.

4.1 Methodology

4.1.1 Data Collection

The objective of the interview is to gather empirical findings from Hilti's eight biggest 3PL service providers to understand their needs and preferences related to the digitally empowered method that guides the shared definition of sustainability indicators in the last-mile transport operation. The interview questions are deliberately formulated in a manner that does not explicitly reveal the insights derived from theory, since the focus of the interviews is solely on understanding the preferences and needs of the 3PL service providers for the method. However, efforts were made to establish face and content validity of the interview guide and questions. Face validity was achieved by discussing the interview questions with a small group of colleagues at Hilti and incorporating their feedback to improve clarity and relevance (George, 2022). Content validity was ensured by aligning the interview questions with the research objective and incorporating established knowledge from theory (Adeoye-Olatunde and Olenik, 2021), but again without giving away too much about the meta-requirements recommended in the literature. Regarding reliability, several measures were taken to enhance consistency and replicability. First, a standardized interview protocol was developed and followed for each participant to ensure uniformity across interviews, a comprehensive reference for the interview process and questions can be found in Appendix D. Additionally, the use of recorded Microsoft Teams calls allowed for reliable and accurate capture of the interview data, minimizing the risk of information loss or misinterpretation (George, 2022). Furthermore, the transcriptions of the audio recordings were checked for accuracy against the original recordings to maintain data integrity (Oltmann et al., 2016). By addressing validity through piloting and content alignment and reliability through standardized protocols and accurate transcriptions, the semi-structured interviews in this study aimed to provide robust and trustworthy data for analysis and interpretation

The sample selection for the semi-structured interview involved reaching out to the top ten 3PL partners in Hilti's last-mile operations, chosen based on the cost incurred by Hilti in 2021. In order to be eligible for participation, the partners were required to fulfil specific criteria. Firstly, they needed to have a sustainability strategy in place and maintain a dedicated sustainability assessment department. Additionally, they were required to serve as global partners of Hilti, meaning their involvement extended beyond local or regional operations. Lastly, the partners needed to express willingness to take part in the study. This selection process resulted in eight participating 3PL partners. The interviewees consisted of individuals holding positions such as Supply Chain Managers and Sustainability Managers. These individuals were chosen because of their expertise or involvement in the development of sustainability KPIs within shipper-3PL relationships. The interviews took place between February and March 2023. Prior to the interviews, participants were provided with the necessary information and were notified about the scheduled interview dates. Details about the interviews can be found in Table 2.

4.1.2 Data Reporting and Analysis

Since the aim of the thesis is to define a method for guiding the shared development of sustainability KPIs in shipper-3PL relationships, process coding was applied. Process coding in qualitative data analysis involves identifying and categorizing the various processes, actions, or activities that are evident in the data. In process coding, identified codes often have verbs in their code name, such as *"identify"* or *"select"*. It

Table 2: List of interviewees and interview duration of the semi-structured interviews

ID	*Job Description Interviewee(s)*	*Duration*
3PL1	Senior Engineer Planning & Engineering Sustainability Manager Planning & Engineering Sustainability	56 min
3PL2	Senior Manager Corporate Environment & Climate Strategy Sustainability Compliance Specialist	104 min
3PL3	Head of Corporate Administrative Support Sustainability Coordinator	37 min
3PL4	Head of Environment Southeast Europe	48 min
3PL5	Head of Sustainability Supply Chain Logistics Specialist	42 min
3PL6	Senior Analyst Sustainability Reporting	112 min
3PL7	Head of Sustainability Supply Chain	63 min
3PL8	Sustainability Coordinator	59 min

focuses on understanding and analyzing the actions, sequences, or steps that occur within the data and their significance within the research context (Hedlund-de Witt, 2013). The study employed a thematic analysis, combining both inductive and deductive reasoning. The deductive coding began by using the TD-MRs as initial codes. The interview transcripts were then thoroughly examined to identify relevant excerpts that fit within these predefined codes. In addition, an inductive coding process was undertaken, starting with the raw data itself. The data were carefully grouped into emerging themes, allowing for the development of two additional codes. In Figure 2, all codes after deductive and inductive reasoning are presented.

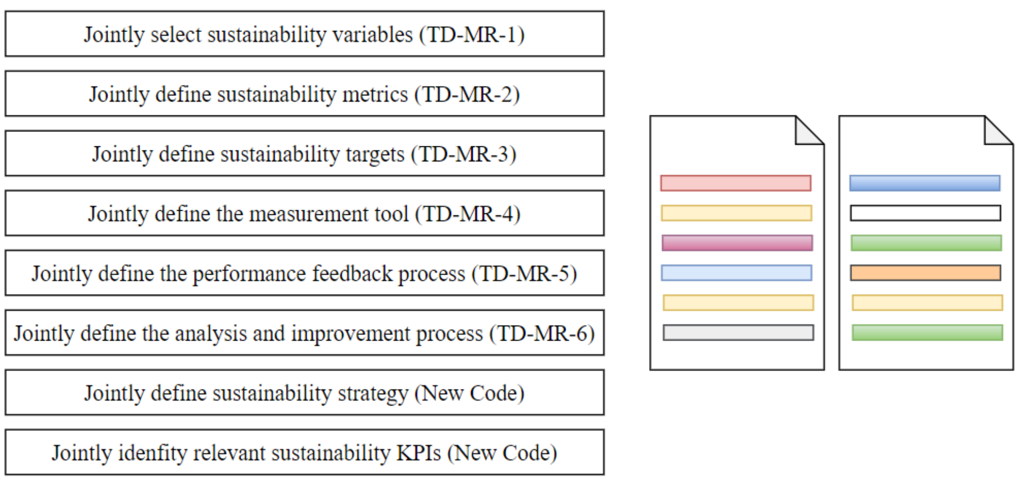

Figure 2: Initial codes after deductive and inductive reasoning

Subsequently, the codes are collated with excerpts and the codes were grouped into new themes (ER-MRs). For a detailed breakdown of the coding scheme employed in the analysis, please refer to Figure 3. The findings provided valuable insights into the process needs and preferences of the interview participants. By analyzing and interpreting the interview data, the study was able to refine and revise the existing TD-MR based on the empirical evidence gathered. The most coded need or preference for the digitally empowered method was to guide the operationalization of sustainability KPIs (ER-MR-3), with a total of 47 coded responses. In Section 4.2 the narrative is written, explaining each ER-MR using quotes from the interviews.

4.2 Results

In this section, the results of the qualitative analysis conducted are presented. The narrative of each ER-MR is explained in its own dedicated subsection using illustrative quotes from the interviews.

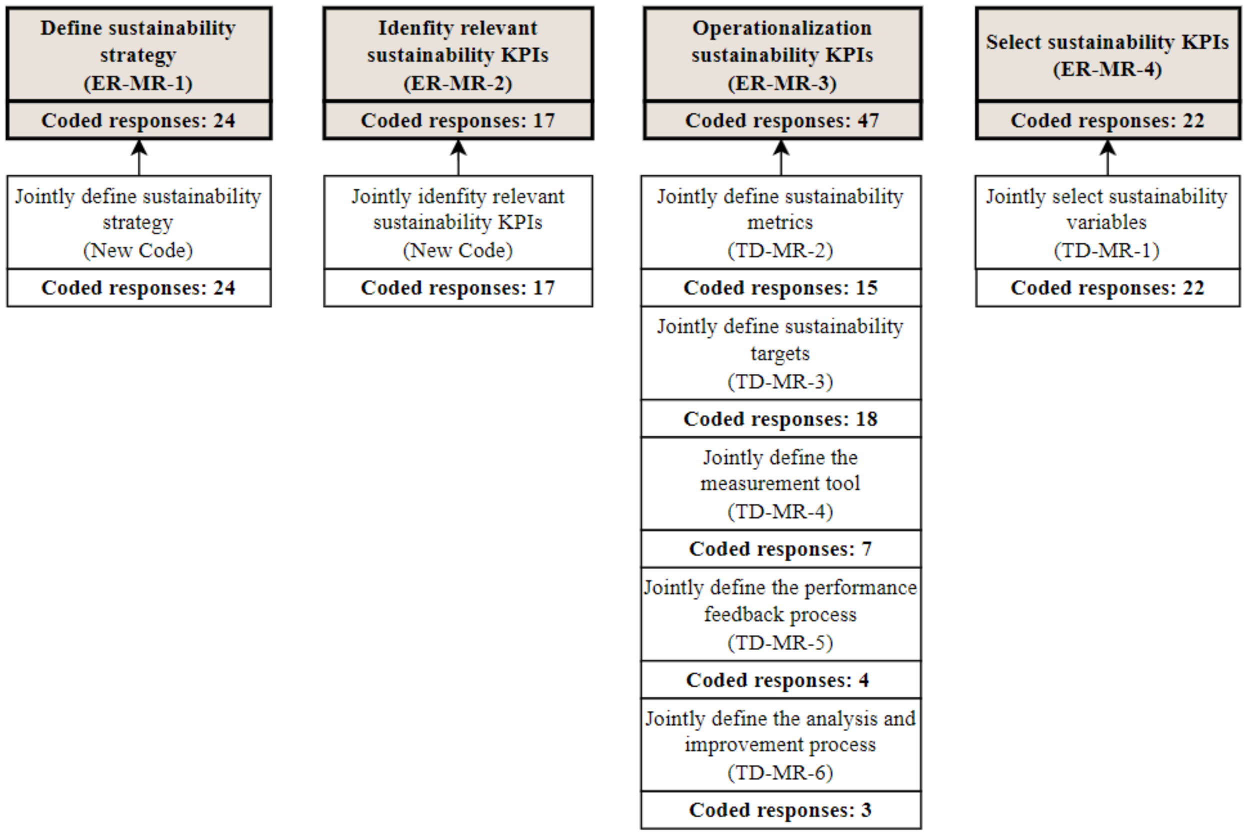

Figure 3: Outcomes derived from the process of coding the qualitative interview data

4.2.1 Sustainability Strategy as the Basis for KPI Selection (ER-MR-1)

In this subsection, the narrative focuses on emphasizing that the sustainability strategy employed by 3PL service providers should serve as the initial foundation for selecting sustainability KPIs within the shipper-3PL relationship. Presented below are five illustrative quotes that provide evidence supporting this primary requirement.

- *"Our sustainability strategy focuses on reducing carbon emissions and promoting renewable energy sources. Any KPIs we define should align with these goals."* (3PL1 - Senior Engineer Planning & Engineering Sustainability)
- *"As a company, we prioritize waste reduction and recycling, we think it is important that the KPIs we establish reflect these objectives."* (3PL3 - Head of Corporate Administrative Support)
- *"Our focus is on improving fuel efficiency and optimizing routes, which guides the definition of our KPIs."* (3PL5 - Logistics Specialist)
- *"It's important that the KPIs align with these goals to minimise the environmental impact of the transport operations."* (3PL6 - Senior Analyst Sustainability Reporting)
- *"As a part of our sustainability strategy, we emphasize the use of electric vehicles and alternative fuels in the transport for Hilti, we are willing to set up metrics that allow Hilti to track progress towards these goals."* (3PL2 - Sustainability Compliance Specialist)

Based on the statements provided, it is evident that the sustainability strategy of each 3PL service provider plays a crucial role in guiding their operations and shaping their approach to the partnership with Hilti. By considering the individual sustainability strategies of the 3PL service providers, the shared definition of sustainability KPIs can be customized to address their specific goals and priorities. The quotes obtained during the interviews emphasize the need for the artefact to consider the specific sustainability strategy of each logistics partner when defining the relevant KPIs. The importance of considering the sustainability strategies of 3PL service providers becomes even more evident when exploring the variations that exist among these strategies. The interview process revealed that different service providers have distinct approaches and priorities when it comes to sustainability. Some may focus on reducing carbon emissions and promoting clean energy sources, while others prioritize waste reduction and recycling initiatives. Additionally, there are those who focus is on improving fuel efficiency and optimizing routes. In other interview quotes, it also became clear that organizations are working on social responsibility as well, by supporting local communities and providing fair working conditions for their employees for example. These statements underscore the importance of tailoring the KPIs to align with the individual sustainability strategies of the service providers, rather than imposing a standardized set of metrics. Based on these findings, it is concluded that considering the sustainability strategy of 3PL service providers should be the starting point of the digitally empowered method. Through inductive reasoning, this led to the formulation of the following meta-requirement:

ER-MR-1: The artefact should take the sustainability strategy of the 3PL service providers as the basis for the definition of sustainability indicators.

4.2.2 Joint Identification of KPIs Relevant to the Sustainability Strategy (ER-MR-2)

This subsection explores the narrative of the second ER-MR. With the sustainability strategy as the starting point, interviewees indicated that the artefact should facilitate the identification of KPIs that align with the sustainability strategy being considered. In other words, an IT-enabled method that helps users to identify relevant KPIs, is considered another important requirement for the design. Provided below are five illustrative quotes that provide support for the second ER-MR-2:

- *"The method should provide a systematic approach to identify KPIs that directly contribute to our sustainability objectives."* (3PL1 - Manager Planning & Engineering Sustainability)
- *"It would be helpful if the method includes a list of potential KPIs, categorized based on their relevance to our sustainability strategy."* (3PL5 - Head of Sustainability Supply Chain)
- *"The method should facilitate a collaborative process where we can identify and prioritize the most relevant KPIs for our sustainability goals."* (3PL4 - Head of Environment Southeast Europe)
- *"We would benefit from a tool that assists us in identifying KPIs that are meaningful for our organization and resonate with our sustainability priorities."* (3PL8 - Sustainability Coordinator)
- *"Having a clear understanding of which KPIs are most relevant to our sustainability strategy will enable us to track our progress more effectively."* (3PL4 - Head of Environment Southeast Europe)

The interviewees highlighted the need for a systematic approach to identify performance indicators that directly contribute to their sustainability objectives. They expressed the desire for a tool that provides a comprehensive list of potential KPIs categorized based on their relevance to their sustainability strategies. This would allow them to easily identify and evaluate indicators that align with their specific strategy. The interviewees also mentioned the importance of flexibility and customization options. This indicates that the method should allow for tailoring the selection of KPIs to the unique focus areas and priorities of each 3PL service provider. In inductive reasoning, a subsequent ER-MR is proposed:

ER-MR-2: The artifact should help identify sustainability indicators relevant to the considered sustainability strategy.

4.2.3 Joint Operationalization of Identified Sustainability KPIs (ER-MR-3)

This subsection explores the narrative that the solution design should facilitate sustainability indicator operationalization. In the theoretical analysis it became clear that many steps are important for the integration of the performance measurement process in shipper-3PL relationships, such as jointly defining the metrics, setting joint targets and jointly selecting the measurement tool (Persdotter Isaksson et al., 2019). After collating codes with excerpts and organizing them into new emerging themes through evaluation and revision, the numerous thematic domains related to the operationalization of the KPIs were collectively grouped under the new ER-MR-3, representing all operationalization activities in one step. Below, you will find five illustrative quotes that back up the narrative:

- *"The method should provide a structured framework for us to define how the indicators should be integrated in our day-to-day operations."* (3PL2 - Sustainability Compliance Specialist)
- *"We need a tool that helps us translate our sustainability goals into actionable KPIs that can be measured and monitored."* (3PL3 - Head of Corporate Administrative Support)
- *"The method should guide us in establishing clear targets and milestones for each sustainability KPI, so that we can track progress and drive improvements together."* (3PL7 - Head of Sustainability Supply Chain)
- *"I think that we need to align how we define the metrics and caluclation methods for each KPI, and agree on how frequently we are reporting results."* (3PL8 - Sustainability Coordinator)
- *"Collaboration is key in operationalizing sustainability KPIs. The method should allow us to jointly set the targets, define the formulas and data sources for example"* (3PL1 - Manager Planning & Engineering Sustainability)

The interviewees stressed the need to translate the identified KPIs into practical actions and guidelines that can be seamlessly integrated into their existing operational processes. They emphasized the importance of having a tool that can offer guidance on implementing the KPIs, including target setting, defining the metrics, and laying out how the performance feedback and improvement process should run. Furthermore, the interviewees highlighted the significance of collaboration and communication between Hilti and the 3PL service providers. It is crucial for both parties to work together in a cooperative manner to ensure the smooth implementation of the identified KPIs. An effective approach should facilitate this cooperative process, allowing Hilti and the 3PL partners to jointly define how they will put the KPIs into practice. By utilizing deductive reasoning, the aforementioned process led to the development of the subsequent meta-requirement:

ER-MR-3: The artefact should support the operationalization of the identified sustainability indicators.

4.2.4 Selection and Adoption of Sustainability KPIs by Both Organizations (ER-MR-4)

This subsection elucidates the narrative emphasizing that the artifact's role needs to be in selecting the to-be-adopted sustainability indicators for both the organizations. Presented below are five illustrative quotes that back up the fourth ER-MR-4:

- *"Selecting sustainability KPIs that are adopted by both organizations allows us to collaborate and have mutual understanding of the performance."* (3PL1 - Manager Planning & Engineering Sustainability)
- *"The method should provide a mechanism for evaluating the feasibility and relevance of sustainability KPIs from both Hilti's and our perspective."* (3PL3 - Head of Corporate Administrative Support)
- *"We need a method that allows us to identify common ground in terms of sustainability KPIs, so we can align our efforts and measure the same things."* (3PL2 - Senior Manager Corporate Environment & Climate Strategy)
- *"A platform for collaborative discussions and negotiations between Hilti and us to agree on the final set of shared KPIs."* (3PL6 - Senior Analyst Sustainability Reporting)
- *"We need a tool that helps us evaluate the impact and resource requirements of each potential KPI to make informed decisions before we both adopt the metrics."* (3PL4 - Head of Environment Southeast Europe)

The interviewees highlighted the need for a structured process to assess the relevance and feasibility of potential KPIs and make informed decisions about their adoption. They mentioned the importance of evaluating the impact, resource requirements, scalability, and practicality of each KPI. Transparent and inclusive decision-making processes, and data-driven evaluations. This indicates that the method should facilitate a collaborative environment where both parties can discuss and evaluate the potential KPIs, considering factors such as the measurement cost, data availability and quality before making the final decision for selection. By supporting the selection process, the method can assist in identifying the most appropriate and impactful KPIs that can drive sustainability improvements in the last-mile transport operation for both Hilti and the 3PL service providers. Through mostly deductive reasoning, this led to the formulation of the following meta-requirement:

ER-MR-4: The artefact needs to help selecting sustainability indicators to determine the ones to-be-adopted by both organizations.

4.3 Conclusion

In conclusion, through empirical findings from semi-structured interviews with Hilti's largest 3PL service providers, the six TD-MRs were revised and refined, resulting in the formulation of four ER-MRs. These ER-MR derived from real-world data and insights, provide more accurate and applicable guidelines for the design of the artefact. By incorporating the sustainability strategies of 3PL service providers, suggesting the relevant KPIs based on this strategy, supporting the operationalization of relevant KPIs, and facilitating collaborative selection processes, the artefact can effectively assist in aligning sustainability goals and driving sustainable practices in 3PL operations. The next chapter will focus on the design and development of the artefact based on the four new ER-MRs, taking into consideration the specific needs and preferences identified through the empirical confrontation.

In summary, the following ER-MRs were derived from this empirical analysis:

- *ER-MR-1*: The artefact should take the sustainability strategy of the 3PL service providers as the basis for the definition of sustainability indicators.
- *ER-MR-2*: The artifact should help identify sustainability indicators relevant to the considered sustainability strategy.
- *ER-MR-3*: The artefact should support the operationalization of the identified sustainability indicators.
- *ER-MR-4*: The artefact needs to help selecting sustainability indicators to determine the ones to-be-adopted by both organizations.

5 Design Principles and Solution Design

In this chapter, the focus is on presenting Design Principles (DP) that specifically addresses the meta-requirements. These DPs are introduced in Section 5.1. Subsequently, in Section 5.2, the DPs take on a crucial role in guiding the design and development of the artefact, which is a digitally empowered method that guides the shared definition of a comprehensive set of sustainability KPIs with 3PL service providers.

5.1 Design Principles

In this section, a set of DPs is introduced that specifically targets the design requirements. These principles act as instructions, offering valuable direction on how the solution should be designed and developed. The design principles are structured following the framework introduced by Chandra et al., 2015:

"Provide the system with [material property-in terms of form and function] in order for users to [activity of user/group of users in terms of action], given that [boundary conditions - user group's characteristics or implementation settings]" (Chandra et al., 2015)

5.1.1 Boundary Conditions

Determining boundary conditions for the solution design involves defining the limits and constraints within which the solution must operate. These conditions help establish the context and scope of the problem and should be acknowledged in the design process (Chandra et al., 2015). The boundary conditions are provided by the project supervisor at Hilti. Here's a brief explanation of the boundary conditions of the implementation setting: (i) *compatibility with network infrastructure*, the digitally empowered method must be compatible with the organization's existing network infrastructure and server configurations; (ii) *open-source technology adoption*, the digitally empowered method should be developed using open-source technologies to align with Hilti's policy of avoiding proprietary software; (iii) *meeting project deadline*, the implementation of the digitally empowered method should be completed within six months to meet the organization's project deadline; (iv) *multiple user roles and permissions*, the digitally empowered method should support multiple user roles with different levels of access and permissions, from both Hilti and 3PL service providers; and (v) *secure handling of partner data*, the digitally empowered method should be capable of handling and processing sensitive partner data while adhering to strict data protection regulations.

For each principle, those responsible for implementation include software developers who seek to create the methodology and IT infrastructure to define sustainability indicators in shipper-3PL relationships. Potential users of the digitally empowered method are employees responsible for developing Hilti's and 3PL service providers sustainability KPIs. Potential users include: (i) *sustainability managers*, who are responsible for developing and implementing sustainability strategies within their organizations; (ii) *transport managers*, who oversee the transport operations of both Hilti and the 3PL service providers; (iii) *logistics coordinators*, who play a critical role in coordinating and executing the logistics operations; and (iv) *account managers*, who are responsible for managing the business relationship between Hilti and the 3PL service providers. They would benefit from the solution by having access to agreed-upon KPIs.

By considering the boundary conditions, designers can gain insights into the unique requirements and constraints imposed by the user group and the implementation settings (Chandra et al., 2015). This understanding enables DPs to be developed that are better aligned with the users' needs and the specific context in which the system will operate. The explanation for each design principle is elaborated on in the following subsection.

5.1.2 DP-1: Features for Selecting the Sustainability Strategy

Identifying suitable performance indicators can pose a challenge when aiming to align them with a comprehensive sustainability strategy. Hence, there is a need for a structured and adaptable approach that allows users to select from established sustainability strategies (e.g., Bosona, 2020; Colicchia et al., 2013). This aids in describing their intended sustainability strategy, with each strategy impacting one or more dimensions of sustainability, such as economic, environmental, and social aspects. Consequently:

DP1 (Considers ER-MR-1): To assist users in describing the considered sustainability strategy of 3PL service *providers for which KPIs need to be defined, it is crucial to provide features that allow for the selection of a sustainability strategy.*

5.1.3 DP-2: Features for identifying sustainability KPIs from existing catalog

Identifying the most pertinent sustainability indicators for the specific sustainability strategy is crucial. By leveraging an established sustainability indicator catalog, users can select sustainability indicators from a validated and recognized group of examples. The sustainability indicators found in these catalogs have undergone application and evaluation in various contexts, offering the flexibility to adapt or substitute them to align with the specific sustainability strategy at hand. There is an existing collection of dedicated sustainability indicators available for different aspects of the strategy. Accordingly:

DP2 (Considers ER-MR-2): To facilitate the identification of relevant sustainability KPIs for the considered sustainability strategy, it is important to provide features that allow users to easily identify KPIs from an existing catalog.

5.1.4 DP-3: Features for sustainability KPI operationalization

The artifact is to facilitate the operationalization of KPIs by allowing users to define specific attributes for each identified sustainability indicator. These attributes should include variables name, metrics, calculation formula or qualitative question, data source, target details, and measurement tool. Additionally, features that allow both organizations to define the performance feedback, analysis and improvement process. Through the shared operationalization, the digitally-empowered method establishes a shared understanding among stakeholders (Persdotter Isaksson et al., 2019). The following principle is highly recommended:

DP3 (Considers ER-MR-3): To enable users to effectively operationalize sustainability KPIs, it is essential to provide features that allow them to specify the characteristics of each KPI.

5.1.5 DP-4: Features for sustainability KPI selection criteria

To choose the appropriate sustainability indicators for an organization's sustainability goals, users must have the necessary information to make informed decisions from a variety of potential KPIs. The relevance of different logistics variables depends on the unique characteristics of both 3PL suppliers and shippers (Forslund and Jonsson, 2007; Martinsen and Huge-Brodin, 2014). By jointly selecting sustainability variables, shippers and 3PL service providers can align their objectives and focus on common sustainability goals (Persdotter Isaksson et al., 2019). In this process, users need to determine the significance of each KPI by utilizing predefined selection criteria. Assigning weights to these criteria allows for the computation of a prioritized list of KPIs, identifying the most suitable set for the organization. Incorporating quantitative criteria into this process reduces subjective judgments when evaluating their relative importance, which differs from the traditional method of manual KPI selection. One effective approach is to convert the criteria to a standardized scale. This conversion enables the calculation of the importance of each KPI within the context of the organization's sustainability strategy. Therefore, the fourth principle can be summarized as follows:

DP4 (Considers ER-MR-4): To assist users in selecting the sustainability KPIs that the organizations should adopt, it is important to offer features that ascertain the importance of every sustainability indicator built upon predefined selection criteria.

5.2 Solution Design: Method Description and Tool Prototype

This section presents a description of the proposed method that guides the shared definition of sustainability KIPs with 3PL service providers. Additionally, it introduces the initial prototype of the accompanying IT tool. The method, illustrated in Figure 4, consists of four key steps along with their respective substeps. These steps are: (1) *sustainability strategy definition*, (2) *sustainability indicator identification*, (3) *operationalization of the sustainability indicators*, and (4) *selection of the the sustainability indicators*. Every step is facilitated by an digitally-empowered system that aligns with the DPs established in the previous Section 5.1.

To demonstrate the functionalities of the IT-enabled method, an initial prototype has been developed. The user interfaces of the prototype can be found in Appendix D. The subsequent paragraphs will describe in detail The primary phases of the methodology and the manner in which the digital system facilitates their execution.

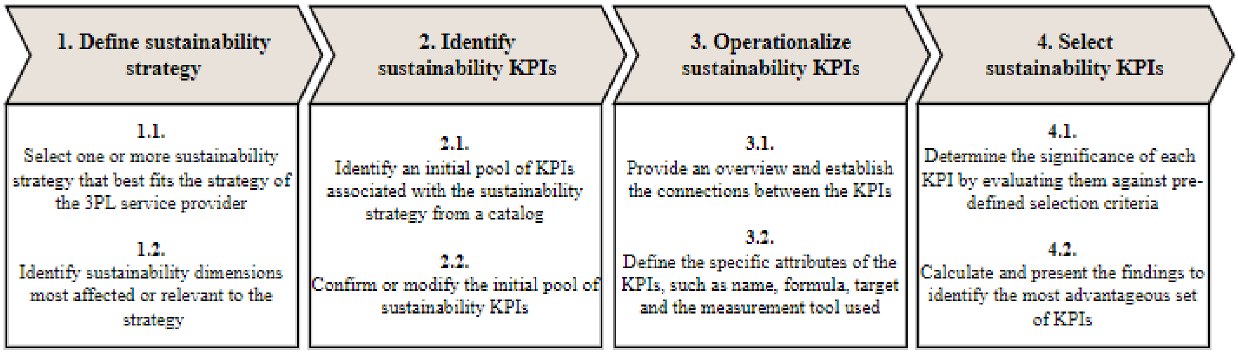

Figure 4: Proposed method steps and corresponding sub-steps

The initial stage involves defining the sustainability strategy for which organizations seek to identify sustainability indicators. To assist users in formulating their intended sustainability strategy, it is advisable for the digitally empowered tool to integrate established sustainability strategies that have been adopted from Bosona, 2020. The list encompasses descriptions and relevant examples of real-world sustainability strategies employed in last-mile logistics. The IT tool should automatically indicates the specific sustainability dimensions (environmental, economic, or social) that are influenced or relevant to each sustainability strategy. For a comprehensive compilation of sustainability strategies, including their descriptions and the corresponding affected sustainability dimensions, please refer to Appendix E. In Appendix D, Figure 6, the user interface of the tool facilitating this step is shown.

As the process enters its second stage, incorporating the selected strategies and relevant sustainability dimensions, the method assembles and presents a compilation of potential sustainability indicators. These indicators are gathered from an extensive catalog created by synthesizing information from various literature references. (e.g., Bajec and Tuljak-Suban, 2019; Oršič et al., 2019; Nitisaroj and Liangrokapart, 2020; Colicchia et al., 2013; Jung, 2017). The user has the option to validate or customize the initial KPI selection by incorporating new or existing KPIs as necessary. Please consult Appendix F for the proposed catalog of sustainability KPIs. In Appendix D, Figure 7, the user interface of the tool facilitating this step is shown.

Moving to the third step, the process of operationalizing sustainability KPIs begins. The IT tool is utilized to organize all the identified KPIs under each sustainability dimension (see Appendix D, Figure 8). During this step, users have the ability to define the relationships between the indicators, such as whether they have a positive or negative impact on each other (illustrated in Appendix D, Figure 9). To enhance the operationalization of the KPIs, the tool offers an editing option (refer to Appendix D, Figure 10). Users can modify the variable's name, metrics (either through a formula or a qualitative question), the target value (e.g., quantitative and intensity-based), and the type of measurement (whether it is specific or average). The tool also provides the option to select an appropriate measuring tool, such as EcoTransIT, to effectively measure the indicators. Additionally, users can determine the frequency of performance feedback (e.g., weekly, monthly). Furthermore, the tool allows users to specify if a fine and bonus system is applied based on the KPIs' performance.

In the fourth step, a collection of sustainability KPIs is selected utilizing performance indicator selection criteria (Mourtzis et al., 2018). As displayed in Appendix D, Figure 12, users have the capability to specify and adjust the weights assigned to each criterion. Based on these weighted values, the digital tool calculates and presents a favourable set of sustainability indicators for both organizations to adopt (refer to Appendix D, Figure 11). The five criteria encompass: (i) data quality; (ii) interdependency; (iii) frequency; (iv) accessibility; and (v) cost. First, the data quality criterion evaluates the quality of data associated with a sustainability KPI. During the operationalization step, the IT tool automatically assigns a Likert scale rating, ranging from *"very low"* to *"very high"*, based on the source type. Second, the interdependency criterion quantifies the relationships between sustainability KPIs. Since the methodology assumes the absence of historical data, statistical analyses and correlation calculations are not applicable. Instead, the estimation of interdependency is automatically conducted using predefined formulas established during the operationalization. By decomposing the formula, the IT tool identifies the fundamental KPIs (representing raw data) upon which a specific KPI is based, providing an objective measurement of its relationships with other KPIs. Third, the value of the frequency criterion is automatically derived from the *"measuring frequency"* attribute specified in the previous step (e.g., daily, monthly) and is converted into Likert scale values. Fourth, the accessibility criterion represents the level of difficulty in obtaining data for a particular sustainability KPI. It is assessed on a Likert scale ranging from *"very low"* to *"very high"*. Last, the cost criterion assesses the cost associated with acquiring access to data for a given sustainability KPI and is evaluated on a Likert scale ranging from *"very low"* to *"very high"*.

6 Focus Group Validation

A focus group is conducted with three managers from Hilti Global Logistics to evaluate the proposed method description and tool prototype. The methodology of the focus group is discussed in Section 6.1, while Section 6.2 describes the results. A conclusion is provided in Section 6.3.

6.1 Methodology

A focus group involving three managers from Hilti Global Logistics is conducted to assess the proposed method description and tool prototype. At the beginning of the session, the requirements and principles were presented, along with a description of digital tool and screenshots of the user interface. Every participants have extensive experience ranging from 5 to 20 years at Hilti and are actively involved in implementing the company's (sustainability) strategy on a global scale. They hold different positions, including the Head of Global Logistics, the Head of Global Transport and Warehousing, and the project's company supervisor, the Global Process Manager Distribution. As the moderator, I facilitated the discussion. The focus group took place at the Hilti Headquarters in Liechtenstein and lasted for one hour. To evaluate the validity of the solution design, the participants were asked to provide their judgment on how correct, feasible, unambiguous, and complete the proposed method is (Wiegers and Beatty, 2013). At the end of the group discussion, the managers were asked to collectively fill in the assessment form (refer to Appendix H), to conclude the session. The focus group guideline and more comprehensive methodology description for the focus group session can be found in Appendix G.

6.2 Results

6.2.1 Correctness

The correctness of a design typically refers to the degree to which a design accurately represents the intended functionality and meets the requirements of the system (Wiegers and Beatty, 2013). The experts acknowledged the correctness of the solution design to be *high*. As one manager stated: *"I appreciated the attention to detail in the design. I think the tool will help us to align our measurement system with the carriers"*. Another manager added: *"It captured the essence of what we wanted to achieve. I think it is a practical solution for meeting our requirements and ensuring the intended functionality"*.

6.2.2 Feasibility

Feasibility in design involves evaluating the extent to which a design is practical and achievable within the given constraints and limitations (Wiegers and Beatty, 2013). During the session, we sought valuable insights regarding the feasibility of implementing the solution design proposed. The consensus among all the managers was clear: this method and tool are indeed technically feasible and reasonable to implement (feasibility is *high*). As one manager put it, *"From a technical standpoint, there are no major obstacles in implementing this method and tool"*. However, it is worth noting that they highlighted the importance of tailoring the tool to cater to the specific needs of the carrier. As one expert explained, *"While the requirements and principles serve as a comprehensive framework, we might consider adapting and implementing the tool iteratively to address the unique context of the carrier"*. This iterative approach allows them to gradually incorporate the method into their existing workflows and gradually refine it over time. Taking these expert recommendations into account, it is explicitly stated in the recommendations that the method should be refined and made iteratively, and both Hilti and the carriers have the flexibility to begin at different method steps based on their specific circumstances in Section 7.2. This recommendation acknowledges the diverse needs and varying starting points of organizations, ensuring that the proposed method remains adaptable and practical in real-world scenarios.

6.2.3 Unambiguousness

Unambiguousness refers to the ability of the design to convey its intended meaning and functionality in a clear and easily understandable manner. A design that is unambiguous leaves no room for misinterpretation or confusion regarding its purpose, features, or user interactions (Wiegers and Beatty, 2013). During the focus group, the issue of unambiguousness in the requirements and principles was addressed, and the experts unanimously acknowledged it to be *medium*. One expert confidently stated, *"It is crucial that IT can derive a consistent and clear understanding from the requirements and principles, otherwise this leads to misinterpretations and misunderstandings, causing delays and errors in the implementation process"*. They also emphasized the need for a shared understanding. One of them stated, *"The people using the tool must have a solid grasp of the organization's data requirements. Without a clear understanding, they may struggle to effectively define the metrics"*. Another expert added, *"Involving stakeholders from different departments during the application of the method can significantly contribute to unambiguousness. Their diverse perspectives can help identify potential pitfalls and ensure a comprehensive approach"*. Consequently, the recommendation to let the tool be used by a diverse group of stakeholders was added in Section 7.2.

6.2.4 Completeness

Completeness in design refers to the degree to which a design includes all the necessary and relevant components, features, and functionalities to meet the intended goals and requirements. It involves ensuring that no essential elements or functionalities are missing or overlooked (Wiegers and Beatty, 2013). The experts emphasized the completeness to be *high*, emphasizing that the design eliminates ambiguity and allows for seamless implementation. As one expert explained, *"By including all the required information, we minimize the risk of misinterpretation or misunderstanding. Designers can refer to these documents and find clarity, knowing exactly what is expected of them"*. Another expert concurred, stating, *"I think the requirements and principles of the method and tool are clear, ensuring that IT encompasses the necessary information to implement it"*.

6.3 Conclusion

To conclude, the experts approved the meta-requirements and principles, as well as the proposed solution design. They also verified the technical feasibility of both the method description and the supporting IT tool. However, they advised adopting an iterative approach, therefore the recommendation in Section 7.2 stating the methodology could be used in an integrative way was included, allowing users to begin at all steps. Regarding clarity, the experts agreed that designers could achieve a consistent understanding of the requirements and principles. They emphasized the importance of understanding the organization's data availability when using the tool and suggested involving stakeholders from different departments. Consequently, recommendations for potential users were added in Section 7.2. Lastly, it was confirmed that the outlined method and DPs are comprehensive, covering all essential information to ensure effective implementation.

7 Conclusion, Recommendations, Discussion

This chapter presents the findings of the research. In Section 7.1, the problem statement and research objective are concluded by addressing the three RQs initially raised in Section 1.5. Section 7.2 provides a practical recommendation for advancing the proposed solution design, outlining the subsequent steps in the DSR project, as well as offering practical suggestions on implementing the solution within the business context. The research culminates in Section 7.3, which includes a discussion of its overall contributions and limitations.

7.1 Conclusion

In conclusion, this thesis has addressed the research problem of the lack of a shared and comprehensive set of sustainability KPIs for Hilti and 3PL service providers in the last-mile transport operation. This gap hinders the ability to prioritize GHG reduction efforts and set joint sustainability targets, leaving the company vulnerable and non-responsive to GHG-related risks and opportunities. The research objective was to develop a method that guides the shared definition of a comprehensive set of sustainability KPIs with 3PL service providers, enabling effective prioritization of GHG reduction efforts and the establishment of joint sustainability targets. Following the DSR paradigm, this thesis employed a structured research design. The research process involved defining the business problem, analyzing and diagnosing the meta-requirements for a solution from both theory (RQ1) and practice (RQ2), designing and developing the design principles, instantiating the design principles in an initial method description and tool prototype, and demonstrating its validity in a suitable context (RQ3). The conclusions of these three RQs are presented below.

- *RQ1 (theory-oriented):* What are the design requirements suggested in the literature that should be considered for designing of a methodology guiding the shared definition of a comprehensive set of sustainability KPI within shipper-3PL relationships?

The literature review aimed to extract valuable insights from existing theory regarding the design considerations for an digitally empowered method. Collaborative decision-making emerged as a key finding, emphasizing the importance of active participation and joint involvement between shippers and 3PL service providers throughout the process. This collaborative approach is crucial in stages such as selecting sustainability variables, defining metrics, setting targets, and measuring KPIs, defining the performance feedback and improvement process, ensuring a shared understanding and ownership of sustainability objectives. Based on the analysis, six meta-requirements (TD-MRs) were derived from theory, serving as initial overarching goals and constraints for the method's design. TD-MR-1 highlights the need for joint selection of variables determining the adopted sustainability KPIs. TD-MR-2 emphasizes jointly defining metrics for operationalizing the identified KPIs. TD-MR-3 focuses on jointly setting sustainability targets, aligning efforts towards achieving sustainable outcomes. TD-MR-4 underscores jointly defining the measurement of sustainability metrics, ensuring feasibility and accuracy. TD-MR-5 addresses joint definition of the performance feedback process, facilitating monitoring and assessment of progress. TD-MR-6 highlights joint definition of the analysis and improvement process. The findings underscore the critical role of collaboration and active participation between shippers and 3PL service providers in the shared definition of sustainability KPIs. The derived TD-MRs provide comprehensive design considerations for the method's development, ensuring effective implementation and alignment with sustainability goals.

- *RQ2 (practice-oriented):* What are the needs and preferences of 3PL service providers for an method that guides the shared definition of sustainability KPIs and how do they inform the revision and refinement of the design requirements identified in the literature?

The practice-oriented research question (RQ2) aimed to understand the needs and preferences of 3PL service providers regarding the method. Empirical data was collected through interviews with Hilti's largest 3PL service providers to revise and refine the design requirements identified in the literature. Based on the empirical findings, the theoretical design requirements (TD-MRs) were revisited and refined, resulting in four new empirical requirements (ER-MRs). ER-MR-1 emphasizes considering the sustainability strategy of a 3PL provider as the basis for defining KPIs, ensuring alignment with their objectives. ER-MR-2 highlights the need to identify relevant KPIs based on the sustainability strategy of the 3PL provider, tailoring them to address specific challenges and priorities. ER-MR-3 emphasizes supporting the joint operationalization of identified sustainability KPIs, providing practical guidance and tools for implementation and measurement. ER-MR-4 focuses on facilitating the selection of shared sustainability KPIs, ensuring mutual agreement and alignment with the objectives of both the shipper and the 3PL provider. Overall, these empirical insights refine and enhance the design requirements identified in the literature, making the method more relevant and applicable.

- *RQ3 (solution-oriented):* How can a digitally empowered method be developed to facilitate the shared definition of a comprehensive set of sustainability KPIs for Hilti and 3PL service providers, enabling effective prioritization of GHG reduction efforts and the establishment of joint sustainability targets in the last-mile transport operation?

Based on the empirical requirements (ER-MRs), four design principles were constructed for the digitally empowered method: (DP1, Considers ER-MR-1) to assist users in describing the considered sustainability strategy of 3PL service providers for which KPIs need to be defined, it is crucial to provide features that allow for the selection of a sustainability strategy; (DP2, considers ER-MR-2) to facilitate the identification of relevant sustainability KPIs for the considered sustainability strategy, it is important to provide features that allow users to easily identify KPIs from an existing catalog; (DP3, considers ER-MR-3) to enable users to effectively operationalize sustainability KPIs, it is essential to provide features that allow them to specify the characteristics of each KPI; and (DP4, considers ER-MR-4) to assist users in selecting the sustainability KPIs that the organizations should adopt, it is important to offer features that ascertain the importance of every performance indicator according to pre-established selection criteria. These design principles served as guiding principles for the development of the method, ensuring that it effectively addresses the specific needs and preferences identified through the research. Additionally, a mock-up of the IT tool was created, incorporating the identified features and detailing how they would be implemented in practice. To evaluate the proposed solution, a focus group consisting of c-level management experts was assembled. The focus group reviewed the design principles, assessed the validity of the proposed solution design. The experts provided positive evaluations, confirming the suitability and effectiveness of the design principles and the proposed solution. Refinement suggestions were provided, including two key aspects: (i) incorporating an iterative approach into the tool's development to support flexibility; and (ii) enabling user access from different departments such as sales, finance, and IT. These suggestions were emphasized to underscore the significance of ensuring widespread understanding of the organization's data availability when defining sustainability KPIs. In conclusion, the findings from RQ3 indicate that the development of an digitally empowered method, incorporating the identified design principles and features, holds promise for facilitating the shared definition of sustainability KPIs between Hilti and its 3PL service providers. This method can enable effective prioritization of GHG reduction efforts and the establishment of joint sustainability targets in the last-mile transport operation.

7.2 Recommendations

Regarding the future progression of the DSR project, the objective is to enhance the proposed method and the accompanying IT tool. Therefore, it is advisable to embark on a second design cycle (Van Aken and Romme, 2012). This subsequent design cycle should encompass the following steps:

1. Refine the method description and IT tool prototype based on the lessons learned from the validation step in this first design cycle. Again, suggestions for refinement included: (i) making the tool iteratively; and (ii) allowing user access from more business units (e.g., sales or finance), emphasized because of the importance of widespread understanding of the organization's data availability when defining sustainability KPIs.

2. Refining prerequisites using additional empirical discoveries. For example with a second round of semi-structured interviews, this time with smaller 3PL partners that are maybe less advanced in sustainability performance measurement. This allows the method to be tailored to a broader audience.

3. Advance the prototype into a fully functional IT tool.

4. Implement the digitally empowered methodology in an actual business setting, with a specific focus on implementing the method within the operational 3PL supplier management processes at Hilti.
5. Set up other focus groups and conduct interviews with users of the method at Hilti and the carrier side, about their experiences using the digitally-empowered methodology. Evaluating interactions between employees will help to improve the practicality of the solution design (Nunamaker Jr et al., 2015).

methodology and accompanying IT tool will be utilized. Engaging with professionals will enhance the practical significance of the artifact.

Note that recommendations for potential users of the tool are already explained in the method description in Section 5.2.1. However, regarding the fourth recommendation, more detailed recommendations for implementing the IT-infused method into Hilti's operational 3PL supplier management processes are outlined:

(a) *Plan the implementation process*: Develop a detailed implementation plan that outlines the steps, timelines, and responsibilities for deploying the digitally empowered method. Identify the key stakeholders involved, including Hilti's internal team, 3PL service providers, IT department, and any external consultants or vendors if needed.

(b) *Establish clear communication channels*: Set up effective communication channels to engage with the 3PL service providers and ensure their understanding and buy-in for the implementation process. Regularly communicate the purpose, benefits, and expected outcomes of the method to all relevant stakeholders.

(c) *Provide training and support*: Conduct training sessions or workshops for both Hilti's internal team and the 3PL service providers on how to effectively use the tool. Provide comprehensive documentation, user manuals, and ongoing support to address any questions or issues that arise during the implementation phase.

(d) *Pilot test the method*: Before fully implementing the digitally empowered method across all 3PL service providers, consider conducting a pilot test with a select group of providers. This allows you to identify and address any potential challenges, refine the processes, and gather feedback to improve the overall implementation approach.

(e) *Roll out the method*: Once the pilot test is successful, roll out the method to all 3PL service providers. Communicate the implementation plan, provide the necessary support, and establish a timeline for each provider to start using the method and reporting sustainability KPIs through the IT tool.

(f) *Monitor and evaluate progress*: Regularly monitor and evaluate the progress of the implementation. Analyze the sustainability KPI data, review performance against the established goals, and identify areas for improvement or corrective actions. Conduct periodic review meetings with the 3PL service providers to discuss the results, address any challenges, and jointly identify opportunities for optimization.

(g) *Continuous improvement*: Foster a culture of continuous improvement by actively seeking feedback from all stakeholders involved in the implementation. Encourage open dialogue, share best practices, and adapt the digitally empowered method and processes based on the lessons learned and evolving sustainability requirements.

7.3 Discussion

This Section delves into the various implications and limitations associated with the study. In 7.3.1, the theoretical implications are thoroughly examined, shedding light on how the findings contribute to existing theories. Moving on to 7.3.2, the focus shifts towards the managerial implications, discussing how the results can be practically applied in real-world settings to inform decision-making and strategy development. Finally, in 7.3.3, the research limitations are addressed, acknowledging the boundaries and constraints of the study, and providing valuable insights into potential avenues for future research and areas that require further investigation.

7.3.1 Theoretical Implications

The primary theoretical contribution of this research lies in the development of design knowledge manifested as DPs. (Gregor and Hevner, 2013). These design principles serve as guidelines for researchers, enabling them to create methods that facilitate the definition and integration of sustainability KPIs with 3PL service providers. These design principles serve to encapsulate design knowledge, facilitating reuseability (Chandra Kruse et al., 2016) and aiding researchers in generating specific solutions for analogous challenges (Sein et al., 2011; Möller et al., 2020). By providing these design principles, the research addresses existing gaps in the literature and responds to the calls for process-based approaches to integrate sustainability KPIs between buyers and 3PL service providers (Ahi and Searcy, 2015; Colicchia et al., 2013; Persdotter Isaksson et al., 2019). The importance of integrating sustainability performance management between organizations is emphasized by numerous researchers (Ganesan et al., 2009; Morali and Searcy, 2013; Maestrini et al., 2017). This integration aligns with the principles advocated in the supply chain management literature, which promote the integration of diverse business processes with supply chain partners to enhance performance (Gopal and Thakkar, 2012; Alfaro et al., 2009). Overall, the research provides design principles for digitally empowered method that contribute to the development of sustainable practices and the effective integration of sustainability KPIs in buyer-3PL relationships. These contributions align with the current research needs and call for process-based approaches.

7.3.2 Managerial Implications

From a pragmatic standpoint, the proposed design principles can assist IT professionals in designing digitally empowered method that helps workers in establising sustainability indicators with 3PL service providers. By providing systematic guidance for sustainability KPI definition, the research contributes to bridging the gap between sustainability strategy and operational practices in supply chain management, as shippers often overlook sustainability KPIs during the execution phase (Jazairy, 2020). The solution design encourages collaboration and communication between buyers and 3PL suppliers by providing a structured framework for discussing and aligning their sustainability objectives, fostering a sense of shared responsibility for sustainability outcomes and closing the sustainability performance management *"process integration gap"* that many organizations face (Persdotter Isaksson et al., 2019). This enables businesses to track their sustainability performance accurately, identify areas for improvement, and make informed decisions to drive progress towards their sustainability goals. Moreover, it provides a basis for benchmarking and comparison across different buyer-3PL relationships, fostering healthy competition and continuous improvement in sustainability practices. In summary, the thesis provides valuable insights and recommendations for designing IT-infused method that support the definition of sustainability KPIs. By applying these findings, businesses can bridge the gap between sustainability goals and operational practices, foster collaboration and communication, improve performance measurement and evaluation, and leverage sustainability for strategic decision-making and competitive advantage.

7.3.3 Research Limitations

This section delves into the discussion of pertinent limitations that should be acknowledged and addressed in order to ensure a comprehensive understanding of the study. Information system DSR is a distinct research paradigm embedded in specific contexts, creating artefacts with social and technical impacts (De Leoz and Petter, 2018). Specific guidelines are necessary to help DSR researchers in reporting limitations because *"It is difficult to over-emphasize the significance of design work and design knowledge in information systems for both research and practice"* (Gregor, Jones, et al., 2007). Hence, to report the limitations of the thesis, the guidelines for self-reported limitations in DSR by Barata et al., 2023, are followed. Limitations are classified into four categories: (i) input knowledge, (ii) research process, (iii) resulting artefact, and (iv) design knowledge (Barata et al., 2023).

Input Knowledge: First, the sample size of unstructured interviews to define the business problem was limited, and information was collected from particular experts and a reduced number of interviewees to prepare the process. This limitation implies that the insights and perspectives gathered from the interviews may not fully represent the diversity of opinions and experiences within the relevant field or industry. The findings and conclusions drawn from this limited sample size may lack generalizability and may not capture the full range of potential issues or challenges related to the business problem (Barata et al., 2023). Second, the problem definition for a field project is a result of selecting one or more issues to work on from a broader problem context (Van Aken et al., 2012). The process of selecting a business problem involves naming and framing the problem, which relies on existing concepts and theories (Schwartz, 1987). In this research project, the frame of reference was focused on making sustainability part of operational 3PL supplier management. This framing decision influences the design of the research and shapes the theoretical and empirical boundaries of the problem under investigation. However, by narrowing the research focus to a specific aspect, such as sustainability in 3PL supplier management, there is a risk of excluding other important dimensions or perspectives that could contribute to a more comprehensive understanding of the overall problem (Barata et al., 2023). The research may not capture the full complexity of the business problem or consider alternative interpretations and solutions that could arise from a broader framing or inclusion of different perspectives.

Research Process: First, DSR heavily relies on the judgments and perspectives of the researchers involved. The subjective nature of design choices and decisions introduces the potential for biases in the research process. The researchers' personal beliefs, experiences, and preferences can influence the design decisions and, consequently, impact the outcomes of the study (Barata et al., 2023). Second, the study's findings may be influenced by the selection of participants for the semi-structured interviews. In this case, only the eight largest 3PL service providers were invited to participate. These companies are major multinational corporations with a specific focus on sustainability. Their practices and perspectives may differ from those of smaller 3PL partners who may have different priorities, resources, and capabilities. Therefore, the research results may not fully capture the diversity of viewpoints and experiences within the broader 3PL industry.

Resulting Artifact: First, the validation of the artefact was solely reliant on the feedback and judgments of the participants involved in the focus group. This approach introduces subjectivity into the evaluation process, as participants' perceptions and perspectives may vary. The lack of independent or external validation limits the objectivity and reliability of the validation results. The findings might be influenced by participants' biases, preferences, or limited perspectives, which can affect the validity and generalizability of the results (Barata et al., 2023). Second, the developed artefact has not been implemented or tested in a real-world situation. It means that the practical application and real-world effectiveness of the artefact remain uncertain. Without real-world usage and validation, it is challenging to assess how the artefact performs in a dynamic and complex environment, and whether it effectively addresses the identified problem. Additionally, if the artefact representation is still under development, it implies that it may lack refinement and may not fully capture the intricacies and nuances of the problem or the desired solution (Barata et al., 2023).

Design Knowledge: First, while the developed outcome or solution in the research project may have improved the problematic situation, it is limited by the absence of a comparison with alternative solutions that address the same problem. Without comparing the developed outcome with alternative approaches or interventions, it becomes challenging to assess the relative effectiveness, efficiency, or suitability of the proposed solution. The absence of such comparisons restricts the ability to make informed decisions regarding the best course of action or the optimal design choice (Barata et al., 2023). Second, the thesis is specifically focused on addressing a particular business problem at Hilti, indicating a context-specific approach. The findings, insights, and solutions generated through this research may be heavily influenced by the unique characteristics, constraints, and requirements of the Hilti organization. Consequently, the generalizability or transferability of the design knowledge to other contexts or organizations may be limited (Barata et al., 2023). The specific context of Hilti might have specific nuances, resources, and organizational factors that may not be present or applicable in other contexts, thereby limiting the broader applicability of the design knowledge.

Appendices

A List of Interviewees for Problem Definition

Table 3: List interviewees of unstructured interviews for problem definition

Interviewee	*Position*
Oliver Weich	Global Process Manager Distribution
Thomas Krohn	Head of Transport Hilti Central Europe
Judy Huany	Head of Transport Hilti China
Martin Schäfer	Sustainability Program Manager
Richard Gibbs	Controller Global Logistics

B Cause-and-effect Diagram

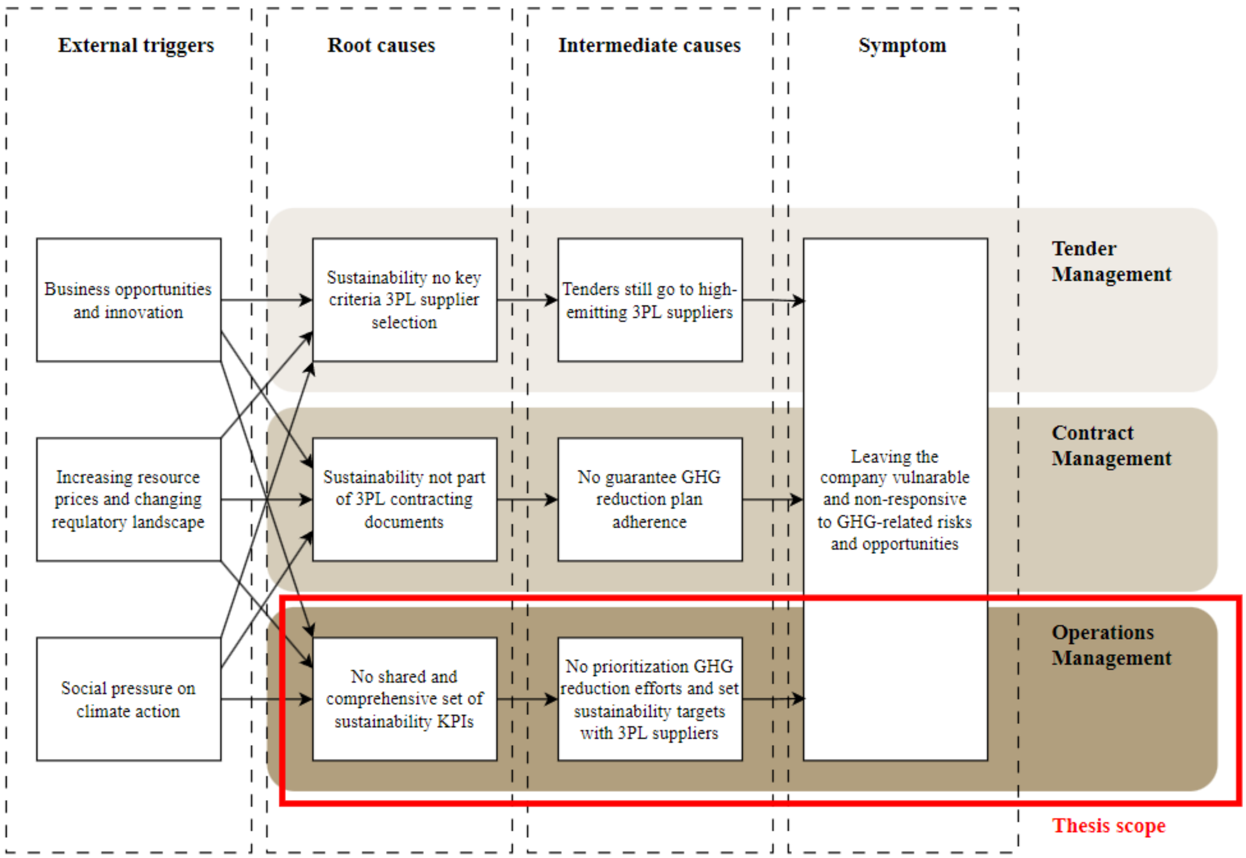

Figure 5: Cause-and-effect diagram

C Semi-structured Interview Guideline

Table 4: Semi-structured interview details

Objective	The objective of the interview is to gather empirical findings from Hilti's eight biggest 3PL service providers to understand their needs and preferences related to the design of an digital system guiding the shared definition of sustainability indicators for the last-mile transport operation.
Interviewees	Representatives from Hilti's eight biggest 3PL service providers, individuals who are knowledgeable about sustainability practices, performance measurement, and decision-making processes within their respective organizations.
Interviewers	Thijs J. Joosten (researcher) Oliver Weich (company supervisor)
Location	Conducted remotely via video conference
Duration	Approximately 60-90 minutes per interview
Recording	Seek permission from participants to record the interviews for accurate note-taking and analysis purposes
Confidentiality	Assure participants of the confidentiality of their responses and that their inputs will be anonymized in the research findings
Consent	Obtain informed consent from participants to participate in the interview and use their responses for research purposes

Semi-structured interview Questions:

1. Can you briefly describe your organization and the services you provide to Hilti as a 3PL service provider?
2. How long have you been working with Hilti as a 3PL service provider? Can you tell me about your experience working with them?
3. In your opinion, what are the key sustainability challenges and opportunities in the last-mile transport operation for Hilti?
4. How do you currently measure and assess sustainability in your last-mile transport operation for Hilti? Do you have any specific sustainability KPIs in place?
5. What are your preferences and needs when it comes to defining sustainability KPIs for Hilti's last-mile transport operation? What factors or criteria should be considered in designing these KPIs?
6. How do you believe the shared definition of sustainability KPIs between Hilti and 3PL service providers can contribute to improving sustainability performance in the last-mile transport operation?
7. What criteria or principles do you think should be considered when defining sustainability KPIs for the last-mile transport operation with Hilti? Are there any specific areas or aspects that should be prioritized?
8. Are there any industry standards or frameworks that you currently follow or reference when it comes to sustainability measurement and reporting in the last-mile transport operation? If so, which ones and how do they influence your approach?
9. How would you prefer to collaborate with Hilti in jointly defining and establishing sustainability KPIs? What level of involvement and communication would you consider ideal for this process?
10. What strategies or actions do you believe Hilti could take to incentivize and motivate your company to actively engage in sustainability improvements in the last-mile transport operation?
11. Are there any additional suggestions, ideas, or insights you would like to share regarding the development and implementation of the digitally-empowered methodology that guides the process of jointly defining sustainability indicators in the partnership between your company and Hilti?

D Tool Prototype

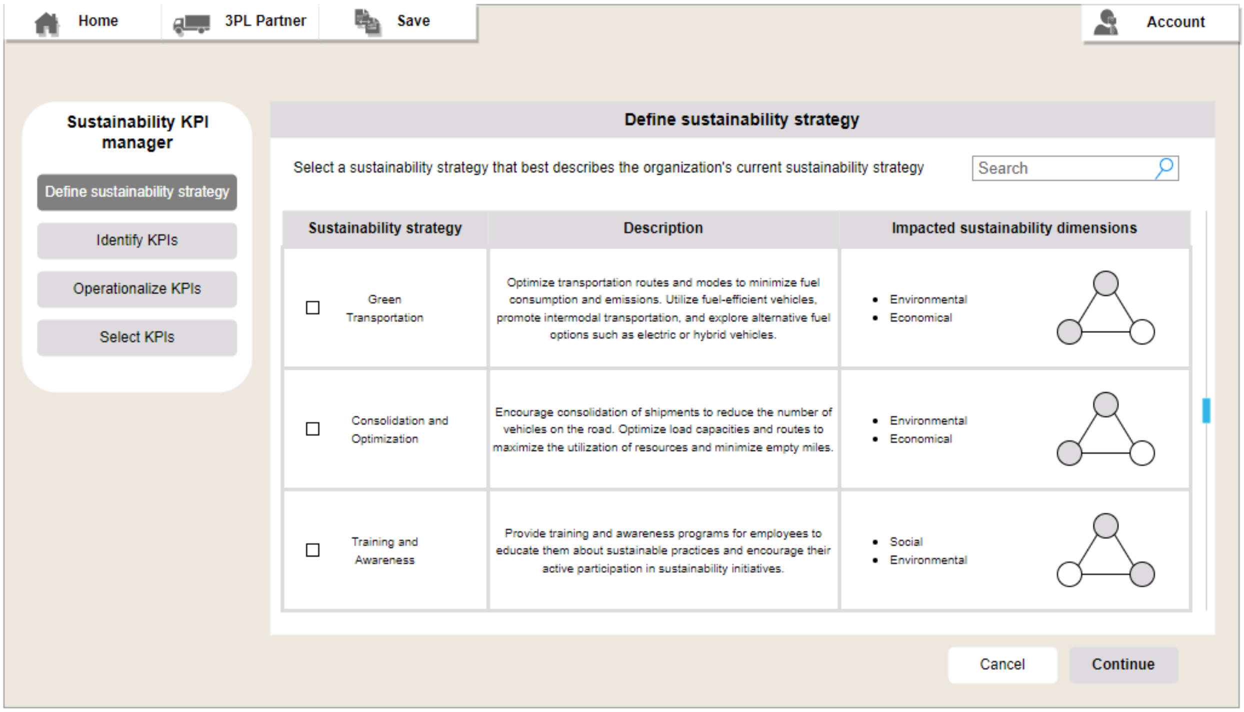

Figure 6: User interface of the IT tool that facilitates the execution of step 1. in the method

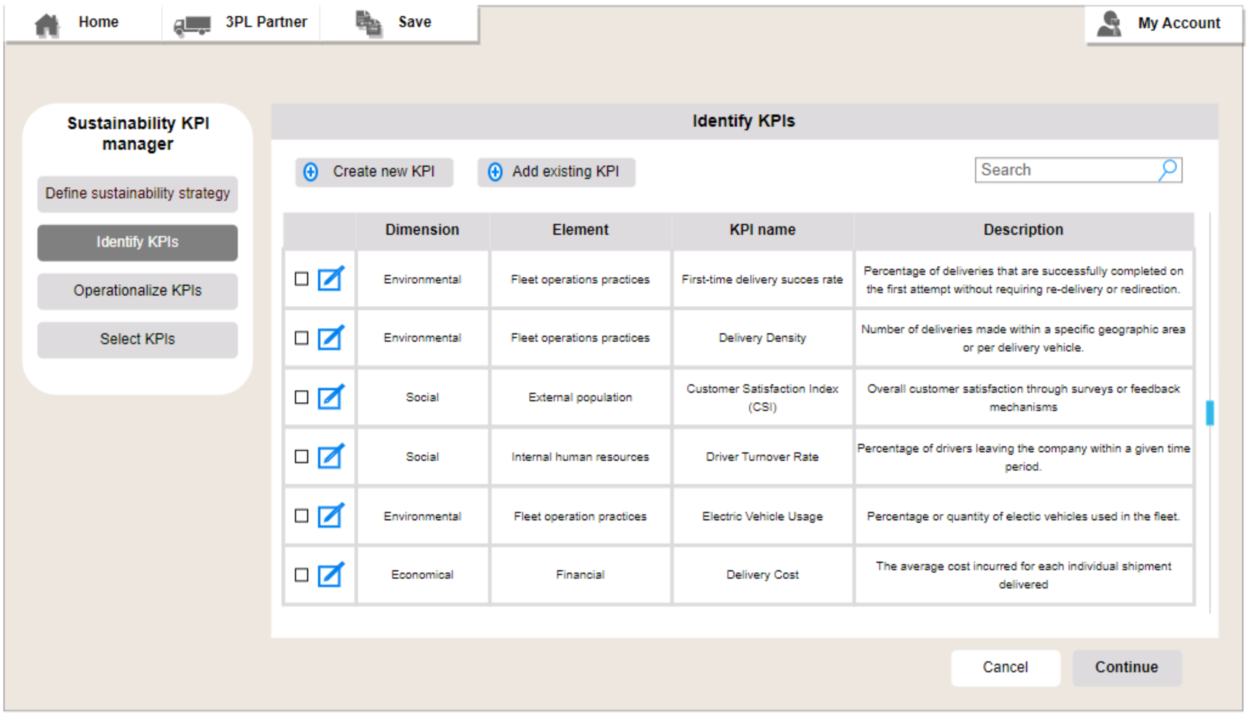

Figure 7: User interface of the IT tool that facilitates the execution of step 2. in the method

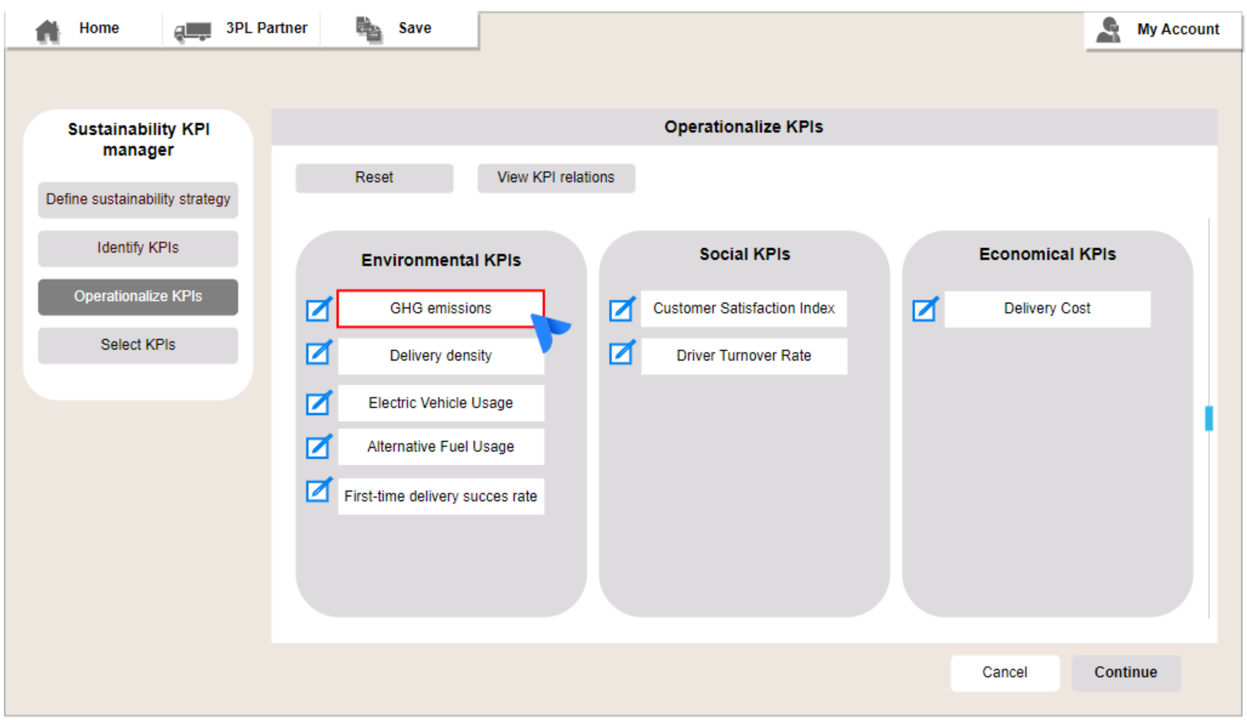

Figure 8: User interface of the IT tool that facilitates the execution of the 3. step in the method

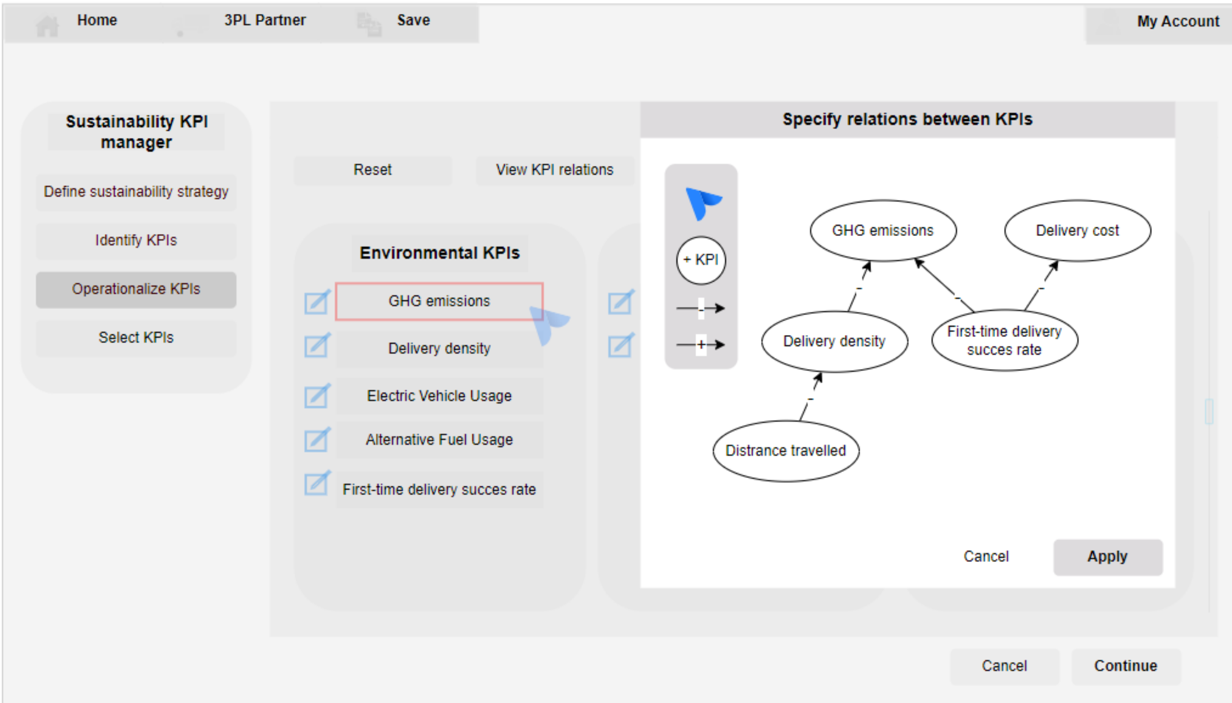

Figure 9: User interface of the IT tool that facilitates the execution of the 3.1 step in the method

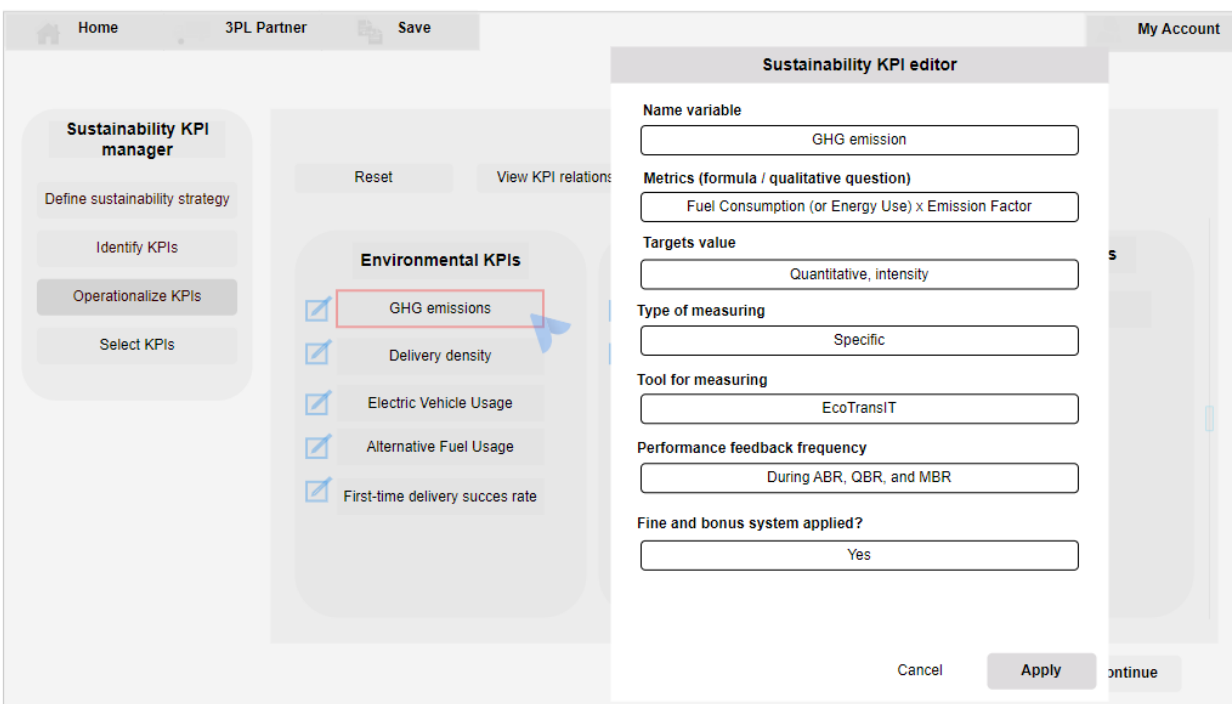

Figure 10: User interface of the IT tool that facilitates the execution of the 3.2 step in the method

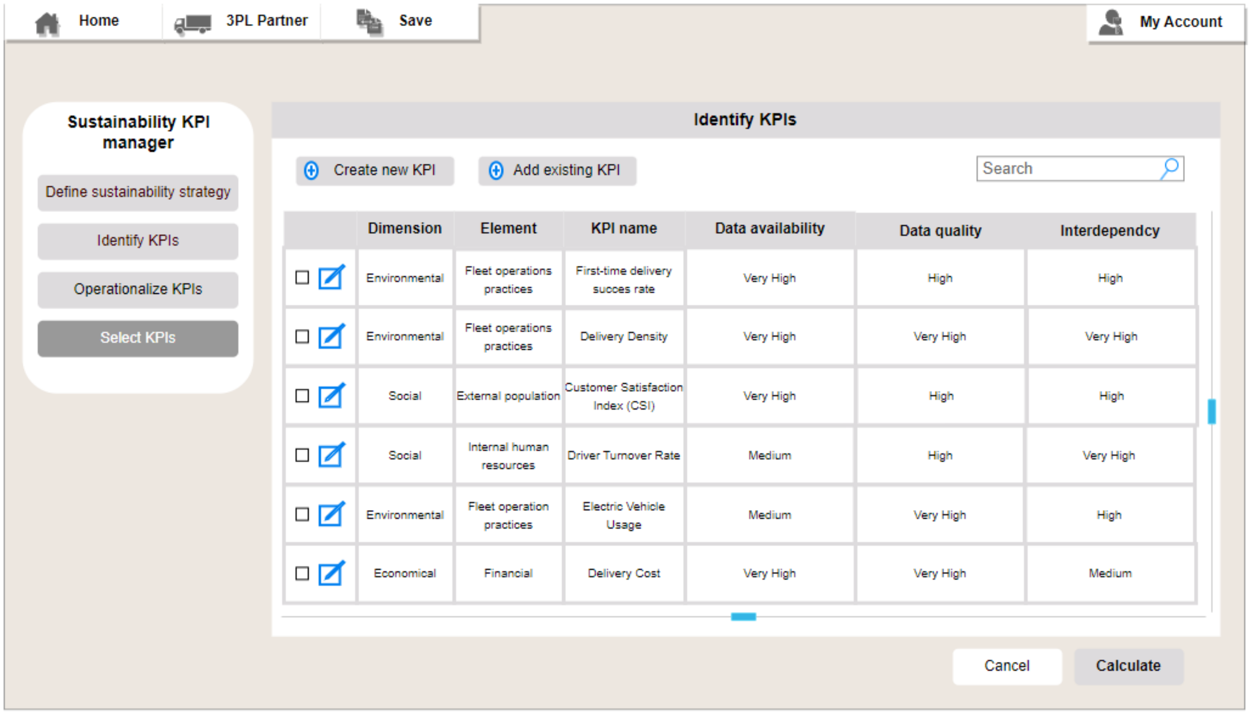

Figure 11: User interface of the IT tool that facilitates the execution of the 4. step in the method

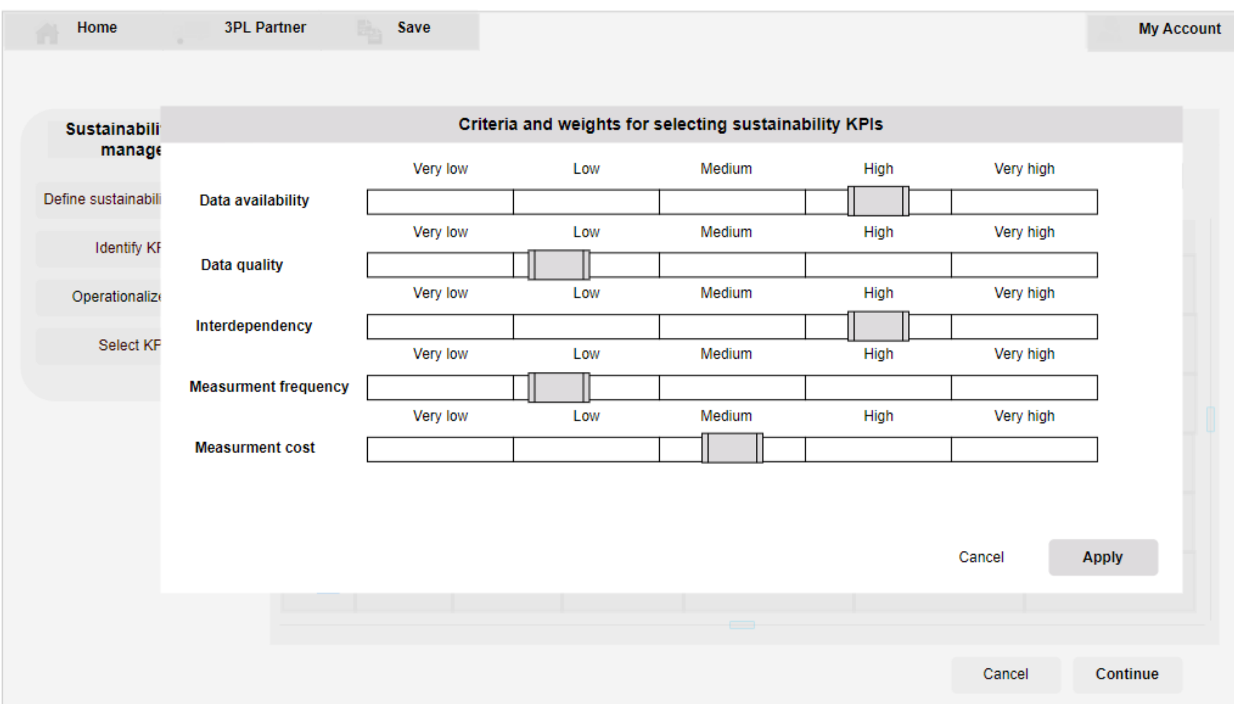

Figure 12: User interface of the IT tool that facilitates the execution of the 4.1 step in the method

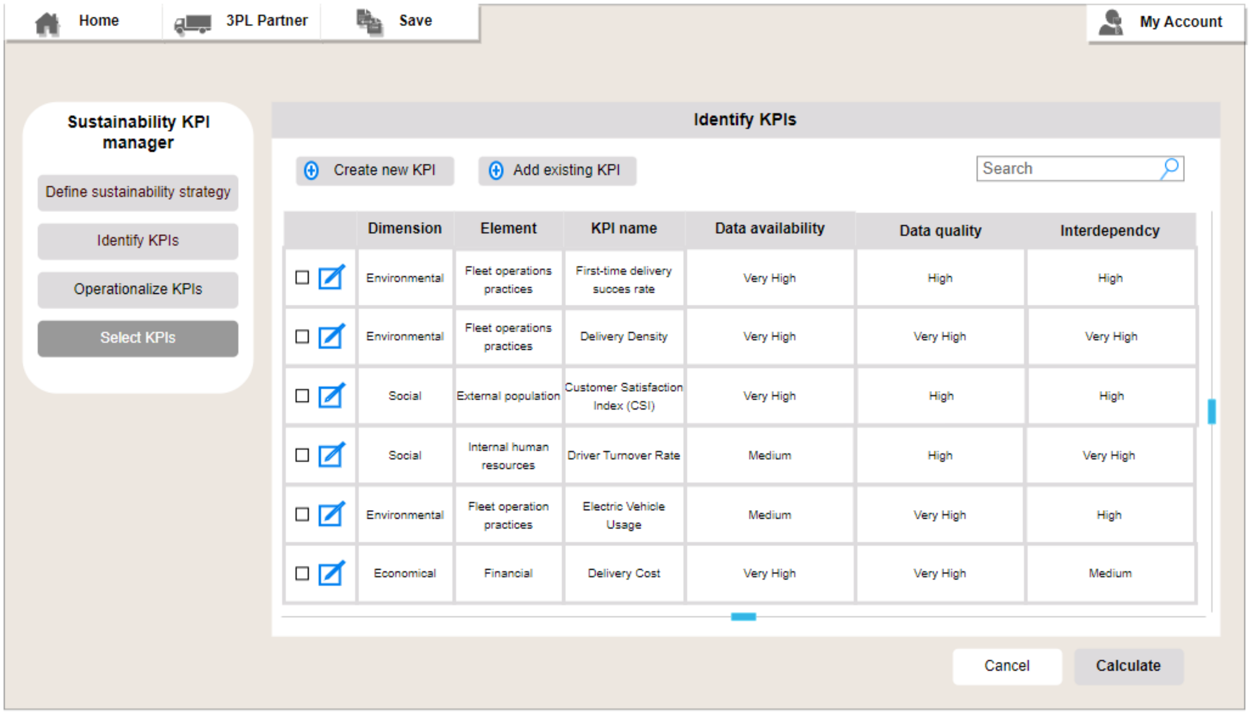

Figure 13: User interface of the IT tool that facilitates the execution of the 4.2 step in the method

E Sustainability Strategy Catalog

Table 5: Sustainability strategy catalog (based on Bosona, 2020)

Sustainability Strategy	*Description*	*Dimensions*
Green transportation	Adopting environmentally friendly vehicles, such as electric, hybrid, or vehicles powered by alternative fuels, to reduce emissions	Environmental
Route optimization	Utilizing advanced technology and algorithms to optimize delivery routes, minimizing distances traveled and fuel consumption	Environmental, Economic
Consolidation and optimization	Combining multiple shipments into a single delivery, reducing the number of vehicles on the road and optimizing resource utilization	Environmental, Economic
Microhubs and urban warehouses	Establishing smaller distribution centers closer to delivery areas, minimizing distances travelled and reducing emissions	Environmental, Economic
Cargo bikes and electric scooters	Using environmentally friendly modes of transport for last-mile deliveries in urban areas, such as cargo bikes or electric scooters, to eliminate emissions	Environmental, Social
Crowdshipping and peer-to-peer networks	Partnering with crowdshipping platforms or creating peer-to-peer delivery networks to utilize spare capacity in vehicles, optimizing resource utilization	Environmental, Social, Economic
Packaging optimization	Encouraging efficient packaging practices to minimize waste, reduce the need for excess materials, and optimize cargo space	Environmental, Economic
Parcel lockers and pickup points	Establishing designated pickup points where customers can collect their packages, reducing the need for individual home deliveries	Environmental, Social, Economic
Data analytics and real-time tracking	Utilizing data analytics and real-time tracking systems to optimize routes, minimize fuel consumption, and improve operational efficiency	Environmental, Economic
Reverse logistics and recycling programs	Implementing efficient processes for product returns and recycling programs for packaging materials to minimize waste	Environmental, Social, Economic
Renewable energy adoption	Utilizing renewable energy sources, such as solar panels or wind turbines, to power distribution centers or charging stations for electric vehicles	Environmental, Economic
Workforce engagement	Engaging employees and drivers in sustainability initiatives, providing training on eco-friendly practices, and fostering a culture of sustainability	Environmental, Social, Economic
Community engagement	Collaborating with local communities to address their specific needs and concerns related to last-mile transport operations	Social
Noise pollution reduction	Implementing measures to minimize noise pollution associated with last-mile deliveries, such as using electric vehicles or enforcing specific delivery hours	Environmental, Social

F Sustainability KPI Catalog

Table 6: Sustainability KPI catalog

Dimension	*KPI name*	*Description*	*Author(s)*
Environmental	Distance travelled	Tracks the average distance travelled for each package delivered	Bajec and Tuljak-Suban, 2019
Environmental	GHG emissions	Measures the amount of GHG emissions produced per mile travelled	Oršič et al., 2019
Environmental	Fuel consumption rate	Tracks the amount of fuel consumed for each delivery made	Nitisaroj and Liangrokapart, 2020
Environmental	Energy efficiency rate	Measures the energy efficiency of vehicles used	Oršič et al., 2019
Environmental	Alternative fuel adoption rate	Tracks the percentage of alternative fuels used in the fleet	Colicchia et al., 2013
Environmental	Electric vehicle adoption rate	Tracks the percentage of electric vehicles used in the fleet	Colicchia et al., 2013
Environmental	Waste reduction	Measures the reduction in waste generated during the delivery process	Oršič et al., 2019
Environmental	Noise pollution level	Tracks the impact of noise pollution in urban areas	Colicchia et al., 2013
Environmental	Cargo space utilization	measures the efficiency of utilizing the available cargo space within delivery vehicles.	Bajec and Tuljak-Suban, 2019
Social	Customer satisfaction	Measures the satisfaction level of customers	Jung, 2017
Social	Employee turnover rate	Measures the percentage of employees who leave a company over a specific period of time	Jung, 2017
Social	On-time delivery rate	Tracks the percentage of deliveries made within the scheduled timeframe	Bajec and Tuljak-Suban, 2019
Social	Transport accidents rate	Measures the number of transport accidents	Bajec and Tuljak-Suban, 2019
Social	Philanthropy spending	Total financial resources allocated for charitable purposes and initiatives that benefit society	Jung, 2017
Social	Employee well-being index	Tracks the well-being and work-life balance of employees	Jung, 2017
Social	Training hours per employee	Measures the average number of training hours provided to employees	Oršič et al., 2019
Social	Diversity and inclusion index	Tracks the diversity and inclusivity of the workforce	Jung, 2017
Economic	Delivery cost	Measures the average cost of delivering goods per mile traveled	Oršič et al., 2019
Economic	Revenue per delivery	Tracks the revenue generated from each delivery made	Bajec and Tuljak-Suban, 2019
Economic	Return of investment	Measures the financial return on investment	Nitisaroj and Liangrokapart, 2020
Economic	Vehicle utilization rate	Measures the percentage of time a vehicle is actively used for deliveries	Nitisaroj and Liangrokapart, 2020
Economic	First-time delivery rate	Measures the percentage of deliveries that are successfully completed on the first attempt	Nitisaroj and Liangrokapart, 2020

Table 6 continued from previous page

Economic	Delivery completion rate	Measures the percentage of scheduled deliveries that are successfully completed	Bajec and Tuljak-Suban, 2019)
Economic	Delivery accuracy rate	Measures the percentage of deliveries made without errors or discrepancies	Bajec and Tuljak-Suban, 2019

G Focus group Guideline

Table 7: Focus group details

Objective	The aim of this focus group is to assess the proposed method and tool prototype of the research project. The focus group will gather feedback from three experienced managers to evaluate the correctness, feasibility, unambiguousness, and completeness of the design.
Participants	Head of Global Logistics Head of Global Transport and Warehousing Global Process Manager Distribution (project supervisor)
Moderator	Thijs Joosten (researcher)
Location	Hilti Headquarters in Liechtenstein
Duration	1 hour
Materials	Presentation of the requirements and design principles Description of the initial method Screenshots of the prototype

Focus group Guideline:

1. Introduction (5 minutes)
   (a) Welcome and introduce yourself as the moderator.
   (b) Thank the participants for their attendance.
   (c) Provide a brief overview of the focus group's objective and agenda.
   (d) Clarify that the purpose is to gather feedback on the proposed method description and prototype tool.
2. Presentation of Requirements and Design (15 minutes)
   (a) Present the requirements and design principles to the participants.
   (b) Clearly explain each requirement and principle, ensuring they have a comprehensive understanding.
   (c) Share the description of the initial method and showcase relevant screenshots from the prototype.
   (d) Encourage participants to ask questions for clarification during or after the presentation.
3. Open Discussion (30 minutes)
   (a) Facilitate an open discussion among the participants.
   (b) Encourage participants to share their thoughts, concerns, and suggestions regarding the solution design.
   (c) Prompt participants to evaluate the validity of the design by focusing on the following aspects:
      i. Correctness: Assess whether the proposed solutions align with the intended goals and objectives.
      ii. Feasibility: Determine the practicality and implementation potential of the solutions within Hilti's Global Logistics.
      iii. Unambiguousness: Identify any areas where the design may be unclear or open to interpretation.

    iv. Completeness: Evaluate whether the proposed solutions adequately address all relevant aspects of the problem.

  (d) Record key points and quotes brought up during the discussion.

4. Assessment Form (5 minutes)

   (a) At the conclusion of the group discussion, distribute the assessment form (refer to Appendix H) to the participants.

   (b) Instruct participants to fill in the assessment form collectively, discussing their viewpoints and reaching a consensus where possible.

5. Conclusion (5 minutes)

   (a) Express appreciation for the participants' valuable contributions and insights.

   (b) Provide information on the next steps and how their feedback will be utilized.

   (c) Offer an opportunity for participants to ask final questions or raise any remaining concerns.

Appendices

H Focus group Assessment Form

Please assess the *Correctness* of the Solution Design

- [x] The proposed design is accurate and aligns with the goals and objectives (High)
- [ ] The proposed design has some minor inaccuracies or deviations from the intended goals (Medium)
- [ ] The proposed design significantly deviates from the intended goals and objectives (Low)

Note: ____________________

Please assess the *Feasibility* of the Solution Design

- [x] The proposed design is highly practical and can be implemented effectively (High)
- [ ] The proposed design has some practical challenges, but overall, it can be implemented (Medium)
- [ ] The proposed design is not feasible to implement due to significant limitations (Low)

Note: Make the tool iteratively

Please assess the *Unambiguousness* of the Solution Design

- [ ] The proposed design is clear and leaves no room for misinterpretation or ambiguity (High)
- [x] The proposed design has some areas that may be unclear or open to interpretation (Medium)
- [ ] The proposed design lacks clarity and is highly ambiguous (Low)

Note: Involving the stakeholders from different departments during the application

Please assess the *Completeness* of the Solution Design

- [x] The proposed design covers all relevant aspects and fully addresses the problem at hand (High)
- [ ] The proposed design addresses most of the relevant aspects but may have some minor gaps (Medium)
- [ ] The proposed design is incomplete and fails to adequately address several important aspects (Low)

Note: ____________________

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