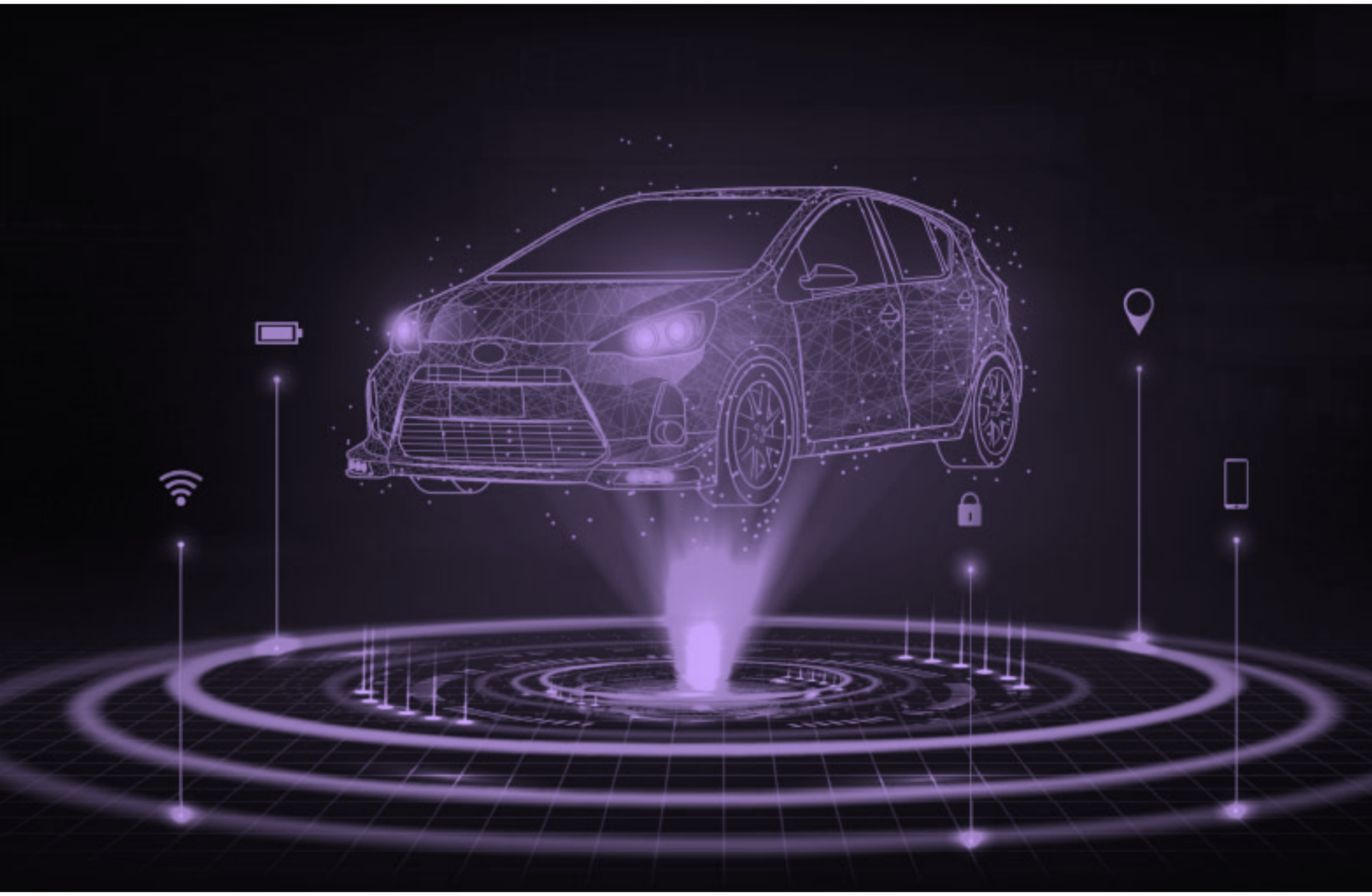

Advancing WEEE Management in the Automotive Industry

The Application of the International Data Space for Improved Information Sharing

Angel Aardse - 2023

TU Delft

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The Application of the International Data Space for Improved Information Sharing

Master thesis submitted to Delft University of Technology in partial fulfilment of the requirements for the degree of

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by

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Preface

Dear Reader,

I'm thrilled to share with you my thesis on improving WEEE Information sharing in the automotive industry through data spaces. This marks not only a significant milestone in my academic journey at TU Delft, within the MSc in Complex Systems Engineering and Management, but also an end to an enriching chapter of my life.

Writing this thesis has been an incredible experience, filled with learning, challenges, and personal growth.

I would like to express my deepest gratitude to my First Supervisor, Dr. Jolien Ubacht, for her incredible guidance and patience throughout this process. Her support, especially during the tough times, was crucial in helping me stay focused and motivated. I am truly grateful for her mentorship.

I also extend my thanks to Prof.dr.ir Nitesh Bharosa (Chair) and Dr. Linda Kamp (Second Supervisor) for their helpful feedback and guidance during this process.

Next, a special thank you goes out to my family, boyfriend, friends, and colleagues for their constant support and encouragement. Your belief in me played a crucial role in my graduation journey.

I hope this thesis provides useful insights and encourages further exploration into the role of data spaces for information sharing in the automotive industry.

Angel Aardse
Rotterdam, 2023

Summary

This thesis studies the environmental challenge posed by the generation of Waste Electrical and Electronic Equipment (WEEE) in the rapidly growing electronics industry, focusing on the automotive industry. Annually, over 50 million tons of electronic waste are produced globally, but only a fraction is recycled, leading to significant environmental and health hazards. The automotive industry, increasingly integrating electronics into vehicles, has contributed to the WEEE stream.

Despite European Commission directives like the End-of-Life Vehicle (ELV) and WEEE Directives aiming to foster a circular economy, there remains a gap in addressing WEEE in ELVs. Current ELV dismantling processes often result in the loss of valuable Critical Raw Materials (CRMs). The complexity of the automotive industry, compounded by a fragmented Information Technology (IT) landscape, presents further challenges in managing the lifecycle of vehicles and recovering useful materials from ELVs during the dismantling stage. Therefore, this thesis explores the potential of the International Data Spaces (IDS), a data space initiative, in enhancing WEEE data sharing between dismantlers and stakeholders. It focuses on how IDS can meet the specific needs of vehicle dismantlers and improve WEEE management and CRM recovery in ELV dismantling. Addressing these challenges is crucial for transitioning to a more sustainable and circular automotive industry, which is the core objective of this research.

The main research question is: *How can the International Data Space (IDS) initiative facilitate WEEE information sharing between manufacturers and dismantlers within the automotive industry*?

This thesis adopts a structured approach to investigate the role of the IDS in enhancing WEEE information sharing within the automotive industry. The research is divided into five distinct phases:

1. **Exploratory Phase:** This phase addresses the question of current barriers to information sharing regarding WEEE in the automotive industry. It utilizes the Circular Economy (CE) monitoring framework by Rukanova et al. (2023) to analyze these barriers, using desk research to gather secondary data.
2. **Requirements Elicitation Phase:** Focusing on identifying essential requirements for facilitating WEEE information sharing, this phase is subdivided into three sub-questions, each exploring different viewpoints: barriers identified in the previous phase, legislative landscape, and dismantlers' perspective. This involves desk research, analysis of regulations and directives, and interviews with dismantlers.
3. **Application Phase**: Here, the feasibility of meeting the identified requirements using IDS is explored. Academic articles and documentation from the IDSA are employed to assess IDS's potential in addressing information-sharing challenges.
4. **Concluding Phase**: This phase integrates the findings from previous stages to answer the main research question about the role of IDS in facilitating WEEE information sharing between manufacturers and dismantlers.
5. **Discussion Phase:** The final phase discusses the research approach, conclusions, limitations, and ideas for future research.

Each phase builds upon the previous one, ensuring a comprehensive and systematic exploration of the topic.

First, we delved into the barriers to WEEE information sharing within the automotive industry, addressing the SQ1: *What are the current barriers to information sharing regarding WEEE within the automotive industry?*

The analysis is structured around four dimensions: the specific CE context, public values, actors, and digital infrastructures, as suggested by Rukanova et al. (2023). This multifaceted approach facilitates a comprehensive understanding of the complexities and hurdles in WEEE information sharing during the ELV stage.

- **Specific Circular Economy Context:** The focus is on managing ELVs, particularly the de-pollution and dismantling stages. It's revealed that while certain materials like iron, aluminum, and copper are recycled, valuable elements in electronic components are often discarded due to insufficient recycling capabilities related to information sharing.
- **Public Values**: Driven by European policies, especially the new ELV Regulation, the transition to a CE prioritizes specific public values. These include designing for circularity, improving treatment processes, enhancing the collection, and expanding the regulatory scope to cover more vehicles.
- **Actors**: The actors in the ecosystem, including government bodies, executive actors, and business entities, each hold critical data and influence policy developments. However, there are notable gaps and conflicts in information sharing among these actors, particularly between manufacturers and dismantlers.
- **Digital Infrastructures:** Current systems like the International Material Data System (IMDS) and the International Dismantling Information System (IDIS) are inadequate for efficient data sharing, plagued by inconsistent data entry and restricted accessibility. The lack of a unified database for all relevant information is a significant barrier.

The identified barriers encompass incomplete documentation, lack of harmonization, significant information gaps between manufacturers and dismantlers, inconsistent data entry, perception of data sharing as a competitive threat, conflicts over supply chain transparency, administrative burdens, lack of standardization, and restricted data accessibility. These findings provide a foundation for developing requirements in the following research phase.

The next phase is the requirements elicitation. Here, SQ2 is answered: *"What requirements are necessary to enable effective information sharing for dismantlers regarding EEE within the automotive industry?"*.

The elicitation of requirements is approached through a combination of desk research, legislative analysis, and stakeholder interviews. This process aims to integrate multiple perspectives, including barriers identified in the previous phase, legislative mandates, and insights from dismantlers, to formulate a comprehensive set of requirements.

Key findings from the elicitation are as follows:

- **From Barrier Analysis**: Requirements are formulated based on identified barriers, such as incomplete documentation and limited electronics recovery in ELVs. This includes the need for detailed component data, location data of components, standardized data entry, and digital data sovereignty to enhance dismantlers' efficiency and compliance with regulations.
- **From Institutional Analysis**: Requirements derived from analyzing the ELV Regulation, WEEE Directive, and CRM Act highlight the need for accessible dismantling information, interoperability between information systems, and facilitating a circular vehicle passport. This reflects the evolving legislative landscape impacting the automotive dismantling sector.
- **From Stakeholder Interviews**: Interviews with professionals in the field reveal practical requirements, emphasizing the importance of detailed dismantling information, including safety data for electric vehicles, data interchangeability, and user-friendly interfaces. These requirements are critical for meeting the day-to-day operational needs of dismantlers.

Next the IDS is evaluated based on the requirements identified in the previous chapter for adequate WEEE information sharing regarding ELVs within the automotive industry. SQ3 is answered: *How can IDS facilitate meeting the identified requirements?* The key findings are elaborated on below.

Access to fundamental dismantling information

Dismantlers and manufacturers need to join the IDS and for dismantlers to gain access to fundamental dismantling information. The onboarding process is detailed, noting the requirement for dismantlers to possess technical capabilities and possibly external IT support due to their limited IT expertise. The potential for IDS to facilitate more comprehensive data sharing is contingent upon manufacturers' willingness to participate and share data within the IDS.

Ease of use for dismantlers
IDS is expected to simplify the data access process for dismantlers by providing a single interface, which contrasts with the current practice of navigating multiple databases. The IDS architecture can reduce administrative burdens and ensure user-friendliness, although its ease of use could not be empirically tested within the thesis.

Facilitating digital data sovereignty
IDS provides robust access and usage control mechanisms, supporting data sovereignty. This feature is essential for manufacturers to share more information, balancing the need for transparency with intellectual property rights. Access control is managed through models like RBAC and ABAC, ensuring that only authorized entities can access specific data sets. Usage control mechanisms further enforce data usage restrictions, maintaining the integrity and security of data exchanges.

Interoperability between information systems
IDS's emphasis on semantic interoperability and its common vocabulary ensure effective communication and data exchange within the network. The IDS Connector and Information Model are key in enabling interoperability between various systems, including the potential for integration with national vehicle registries.

Facilitating Circularity Vehicle Passport
IDS can potentially support the circularity vehicle passport concept introduced in the new ELV Regulation. The IDS framework, adhering to open standards, can facilitate secure and standardized data exchange, which is crucial for the passport's functionality.

This thesis explores the facilitation of WEEE information sharing between manufacturers and dismantlers within the automotive industry, using the IDS initiative. The thesis concludes that IDS can provide a secure, standardized platform for data exchange, addressing many identified barriers. However, its effectiveness depends on stakeholder participation, regulatory incentives, and further research into implementation challenges and the development of specific ontologies for the automotive industry. The thesis contributes to societal goals of sustainable development and circular economy by proposing a pathway to optimize resource use and compliance with environmental standards. It also advances scientific understanding by bridging knowledge gaps in WEEE information sharing in the automotive industry and proposing a practical solution.

List of Acronyms

CE	Circular Economy
CoSEM	Complex Systems Engineering and Management
CRM	Critical Raw Material
CRMA	Critical Raw Materials Act
DPP	Digital Product Passport
EC	European Commission
ECU	Electronic Control Unit
EESC	European Economic and Social Committee
ELV	End-of-Life Vehicle
ELVD	End-of-Life Vehicle Directive
EoL	End-of-Live
EPA	Environmental Protection Agency
EU	European Union
IDS	International Data Space
IDIS	International Dismantling Information System
IDS	International Data Space
IDSA	International Data Space Association
IDS-RAM	International Data Space Reference Architecture Model
IMDS	International Material Data System
IP	Intellectual Property
IS	Information System
IT	Information Technology
MRQ	Main Research Question
NGO	Non-Governmental Organization
OEM	Original Equipment Manufacturer
ParIS	Participant Information Service
PCB	Printed Circuit Board
ProSUM	Prospecting Secondary raw materials in the Urban mine and Mining wastes
SDG	Sustainable Development Goal
SLF	Shredded Light Fraction
SQ	Sub Research Question
RDF	Resource Description Framework
WEEE	Waste Electrical and Electronic Equipment
WEEED	Waste Electrical and Electronic Equipment Directive
WFD	Waste Framework Directive
WSR	Waste Shipment Directive

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1 Introduction

The electronics industry is among the world's fastest-growing sectors, but with its growth comes the environmental issue of massive Waste Electrical and Electronic Equipment (WEEE) generation (Sureshkumar et al., 2023). The Environmental Protection Agency (EPA) has highlighted WEEE's environmental and health hazards. According to Sureshkumar et al. (2023), electronics generate more than 50 million tons of waste annually, and only 15-20% gets recycled globally, with the remainder ending up in landfills in low- and middle-income nations. Over the years, the automotive industry has emerged as a substantial contributor to the WEEE stream, driven by the growing integration of electronic components in modern vehicles (Bulach et al., 2018; Cozza et al., 2023; Sureshkumar et al., 2023) Car electronics are among cars' most valuable sources of Critical Raw Materials (CRMs) (Andersson et al., 2019; Cozza et al., 2023). An average medium-sized car contains around 15 electronic elements; luxury models can have up to 50 (Cozza et al., 2023; Cucchiella et al., 2015; Rosa & Terzi, 2023).

Despite the European Commission's directives, such as the ELV and WEEE Directives aimed at fostering a circular economy in the automotive sector and beyond (European Commission, 2000, 2012), a specific focus on the handling of WEEE in End-of-Life Vehicles (ELV) remains largely unaddressed. Current ELV dismantling processes often lead to the loss of valuable materials and CRMs, as these are not efficiently separated but instead form part of the shredded light fraction (SLF) that is eventually incinerated, as reported by Tazi et al. (2023).

The automotive industry is known for its complexity due to the vast number of components it uses, which many different suppliers supply. This makes managing the entire lifecycle of vehicles challenging. Adding to this complexity is the issue of the fragmented IT landscape. Essential data, mainly information about CRMs, is spread across various databases with restricted access. This fragmented data management makes it difficult to effectively handle End-of-Life Vehicles (ELV) and recover valuable materials, a concern noted by Cozza et al. (2023)

With the automotive industry shifting to zero-emission mobility and vehicles increasingly integrating electronics, there will be an increase in demand for copper and other CRMs. They include the rare earth materials used in permanent magnets, e-drive motors, of which the automotive sector is one of the most significant users, and other electronic devices (European Commission, 2023a). According to Articles 11 and 13 of the proposed ELV Regulation, vehicle passports should contain information on parts and components containing CRMs within vehicles, which should be in digital format (European Commission, 2023a). Vehicle passports can be seen as similar to digital product passports (DPPs), which are part of the recent legislative agenda of the EC. At their core, DPPs aim to relay product-related information to stakeholders inside and outside the product value chain (Ducuing & Reich, 2023). One of the first examples to be realized is the battery passport, drafted in the EU battery regulation. The proposed EU battery regulations also mention that "Battery passport and interlinked data spaces will be key for safe data sharing, increasing transparency of the battery market and traceability of large batteries throughout their life cycle" (Walden et al., 2021). The question is if this insight could also be used for electronics in automotive vehicles.

"Data Spaces" refers to ecosystems encompassing data models, datasets, ontologies, data sharing agreements, and specialized management services, along with associated soft skills in areas such as governance, social interactions, and business processes (Scerri et al., 2022). In 2023, several data space initiatives often focus on a specific sector or domain. These initiatives facilitate the sharing of data for their participants, both for data consumers (car dismantlers) and data producers (suppliers and manufacturers) in a particular application domain or from a specific sector perspective (Grothe, 2023). In addition to sector- or domain-specific data space initiatives, some cross-domain initiatives develop and agree on cross-domain principles, standards, or functionalities for data sharing. New or existing data space initiatives can adopt these cross-domain initiatives' principles, concepts, functions, and building blocks.

This thesis explores the potential of the Data Space initiative, specifically the International Data Spaces (IDS), in enhancing WEEE data sharing within the automotive industry. The focus is on evaluating how IDS aligns with the industry's specific needs, particularly from the perspective of vehicle dismantlers. Data Spaces represent ecosystems encompassing data models, datasets, ontologies, and specialized services, as Scerri et al. (2022). defined. This research aims to identify opportunities for improving WEEE management and CRM recovery in ELV dismantling by analyzing the interplay between these data spaces and the automotive sector's requirements.

1.1 Knowledge gaps

In this section, the knowledge gaps are identified based on a literature review to examine the scientific relevance of the thesis. These identified gaps serve as the foundation for the Main Research Question (MRQ) (see section 1.4). A systemic literature review offers a comprehensive perspective on CE research, WEEE information sharing in the automotive industry, and data spaces. Articles were found using specific keyword searches, as shown in Figure 1 Prisma flow diagram

The PRISMA flow diagram was used to ensure a structured reporting of the systematic review, which has four stages: identification, screening, eligibility, and inclusion. During the identification phase, two search queries were input into the Scopus database to retrieve articles. In the screening phase, articles were evaluated based on their abstracts and keywords to ensure relevance to the topic. The eligibility phase involved assessing articles against specific inclusion and exclusion criteria. Finally, four additional articles were selected in the inclusion phase. Rukanova et al. (2021) and Ubacht et al. (2023) as they provide a more insightful perspective on CE governance monitoring, Walden et al. (2021) as it provides insights into DPPs, and Scerri et al. (2022) to gain more insights on the challenges and opportunities of Data Spaces.

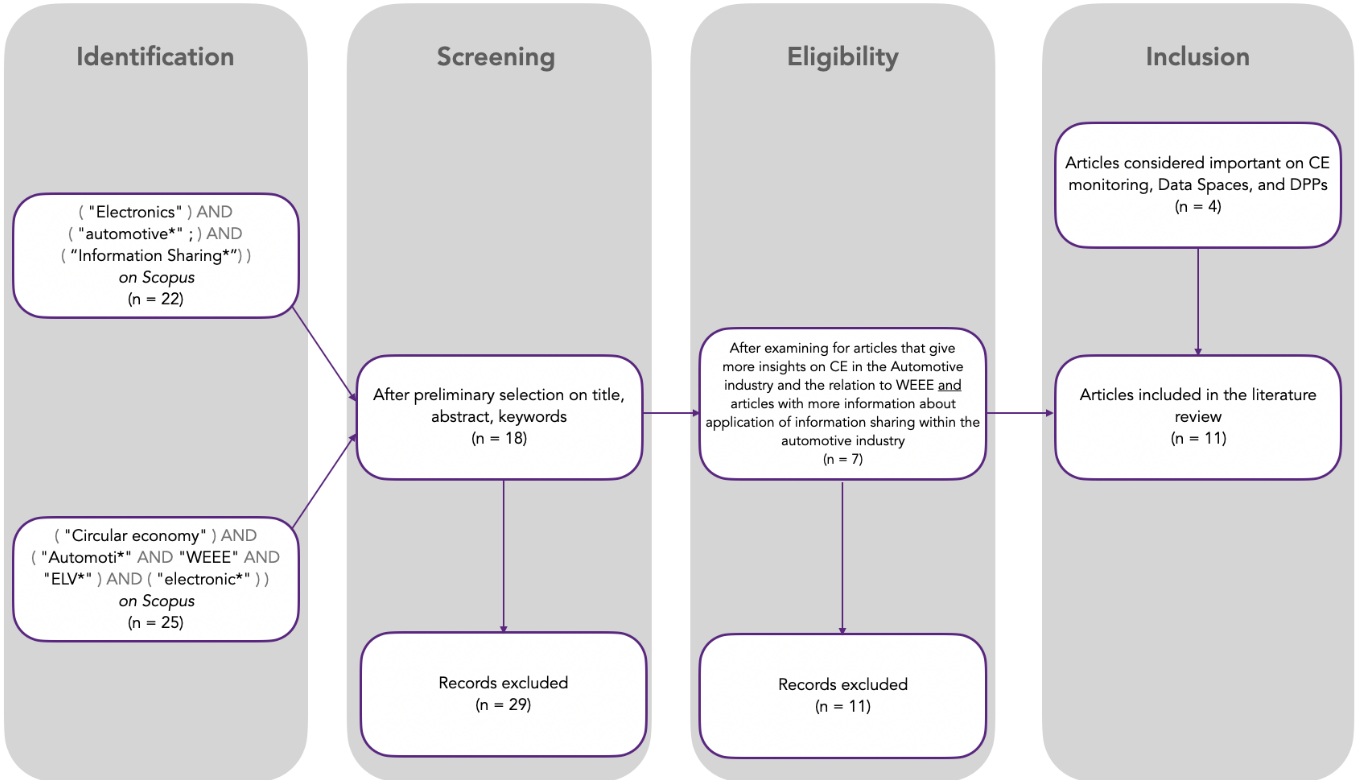

Figure 1 Prisma flow diagram (own work)

This review reviews 11 scientific articles involving data sharing and WEEE in the automotive industry. An overview of these articles can be found in Table 1. Of these articles, four were published in 2023, three in 2022, three in 2021, and one in 2015. This suggests that data sharing and WEEE in the automotive industry are just being explored.

Table 1 Overview of literature

AUTHOR(S)	YEAR	TITLE
Mügge et al.	2023	Empowering End-of-Life Vehicle Decision Making with Cross-Company Data Exchange and Data Sovereignty via Catena-X
Cozza et al.	2023	Circular manufacturing ecosystems: Automotive printed circuit boards recycling as an enabler of the economic development
Rosa & Terzi	2023	Supporting the Development of Circular Value Chains in the Automotive Sector Through an Information Sharing System: The TREASURE Project
Ubacht et al.	2023	Data Sharing Arrangements for Monitoring in the EU Circular Economy: The Case of CBAM and Steel Import for the EU Auto-motive Sector
Scerri et al.	2022	Common European Data Spaces: Challenges and Opportunities
Jäger-Roschko & Petersen	2022	Advancing the circular economy through information sharing: A systematic literature review
Jang et al.	2022	Recycling and Material-Flow Analysis of End-of-Life Vehicles towards Resource Circulation in South Korea
Rukanova et al.	2021	Digital Infrastructures for Governance of Circular Economy: A Research Agenda
Walden et al.	2021	Digital Product Passports as Enabler of the Circular Economy
Soldatos et al.	2021	A digital platform for cross-sector collaborative value networks in the circular economy
Cucchiella et al.	2015	Automotive printed circuit boards recycling: an economic analysis

The automotive industry is witnessing an extensive integration of electronics. However, Cozza et al. (2023) and Rosa & Terzi (2023) highlight a significant discrepancy between the integration of electronics and the recovery efforts of CRMs, aggravated by recycling costs and the lack of information sharing transparency. This underscores the industry's challenge in aligning technological and digital advancements with the goals of a circular economy. Walden et al. (2021) and Rukanova et al. (2021) emphasize the critical role of digitalization in facilitating the CE within the automotive industry. They argue that digital technologies are pivotal in overcoming transparency, standardization, and data sharing challenges. Despite the recognized potential, the IS community has yet to fully engage with CE research, suggesting a gap in research leveraging digital technologies to support CE practices.

A fundamental problem highlighted in the literature is the difficulty in sharing information about managing WEEE in ELVs. Cucchiella et al. (2015) emphasize the lack of research on information sharing about electronic components, which is essential for successful WEEE recycling and dismantling. Furthermore, Scerri et al. (2022) & Soldatos et al. (2021) highlight the lack of adherence to best practices and standards in data sharing, indicating a lack of adequate, interoperable, ethical, and scalable data-sharing solutions.

Furthermore, the literature indicates a pressing need for improved information sharing on the management of electronics in ELVs. Jäger-Roschko & Petersen (2022) argue for enhanced inter-organizational information sharing to foster circularity. Yet, the absence of specific examples and infrastructures for information sharing in these discussions points to a gap in understanding how such improvements can be realized.

The perspective of dismantlers is notably underrepresented in the literature. While the importance of information sharing for sustainable resource management is acknowledged, the direct flow of information between manufacturers and dismantlers is rarely addressed (Jang et al., 2022; Mügge et al., 2023). This oversight indicates a gap in understanding the specific needs and challenges faced by dismantlers in the information-sharing ecosystem. DPP are identified as a promising solution to overcome data transparency, standardization, and sharing challenges. However, Walden et al. (2021) note the specific challenges in DPP implementation, particularly from the dismantlers' viewpoint, are not thoroughly addressed. This oversight highlights an incomplete understanding of the specific information needs faced by dismantlers.

The exploration of knowledge gaps in WEEE information sharing within the automotive industry highlights significant challenges in data availability, manufacturer-dismantler information sharing, and the implementation of digital solutions like DPPs. These gaps underscore the need for a comprehensive approach to facilitate effective information sharing, potentially through initiatives like the International Data Space (IDS), which will be further elaborated upon in section 2.3.1.1.

1.2 Research Scope

This research will examine how information about WEEE can be shared between manufacturers and dismantlers in the automotive industry, with a particular emphasis on supporting the transition towards a CE. The thesis will investigate the potential contributions of the IDS data space initiative in enhancing this information exchange, aligning with the objectives of the anticipated ELV regulation.

The core of the research will involve an in-depth exploration of the role of IDS in promoting effective data sharing. This will be especially relevant for circular economy (CE) strategies and the expected implementation of vehicle passports. A vital aspect of the study will be the viewpoint of car dismantlers in the Netherlands. Their role is vital in recovering CRMs from ELVs, and understanding their perspective is crucial for the success of circular economy initiatives.

The research will primarily include interviews with participants involved in the Dutch dismantling industry to understand the Dutch situation comprehensively. This approach will provide valuable insights into the local challenges and practices. By focusing on the Dutch context, the study aims to offer practical, relevant, and actionable findings that can aid decision-makers in the automotive recycling industry, particularly in devising secure and efficient data-sharing strategies. This research will contribute to the academic understanding of data sharing in the automotive recycling industry and offer tangible benefits to industry stakeholders.

1.3 Relevance

This research is relevant for both science and society. Science because it contributes to resolving the knowledge gaps identified in section 1.1. The research is also relevant to society, as the outcome of this thesis can contribute to the implementation of a CE and inform policymakers, regulators, and industry stakeholders about on new data sharing initiatives, which could be used for, for instance the implementation of vehicle passports. The implementation of these insights can lead to improved WEEE management practices, reduced environmental impact, and enhanced resource efficiency, fostering a more sustainable and resilient automotive industry (Cozza et al., 2023).

1.4 Main Research Question

Given the above-mentioned findings, the identified knowledge gap and the scope, the following main research question (MRQ) is formulated:

How can the International Data Space (IDS) initiative facilitate WEEE information sharing between manufactures and dismantlers within the automotive industry?

2 Theoretical background

This chapter provides a theoretical foundation for the following chapters in this thesis and is divided into four different sections. First, the circular economy is explained. Next, the concept of DPPs is explained. The third and final section elaborates on the IDS and its core concepts.

2.1 The Circular Economy

The CE has emerged as a transformative framework that aims to replace the traditional "make, use, dispose" model with a sustainable approach that minimizes waste and pollution. It is supported by initiatives like the UN's Sustainable Development Goals, particularly SDG 12, which focuses on responsible consumption (Jäger-Roschko & Petersen, 2022; MahmoumGonbadi et al., 2021; Rukanova, Ubacht, et al., 2023). The CE framework, strongly promoted by the European Commission through the Green Deal and CE Plan, encourages industries to maximize the use of resources and reduce environmental impact (Mügge et al., 2023).

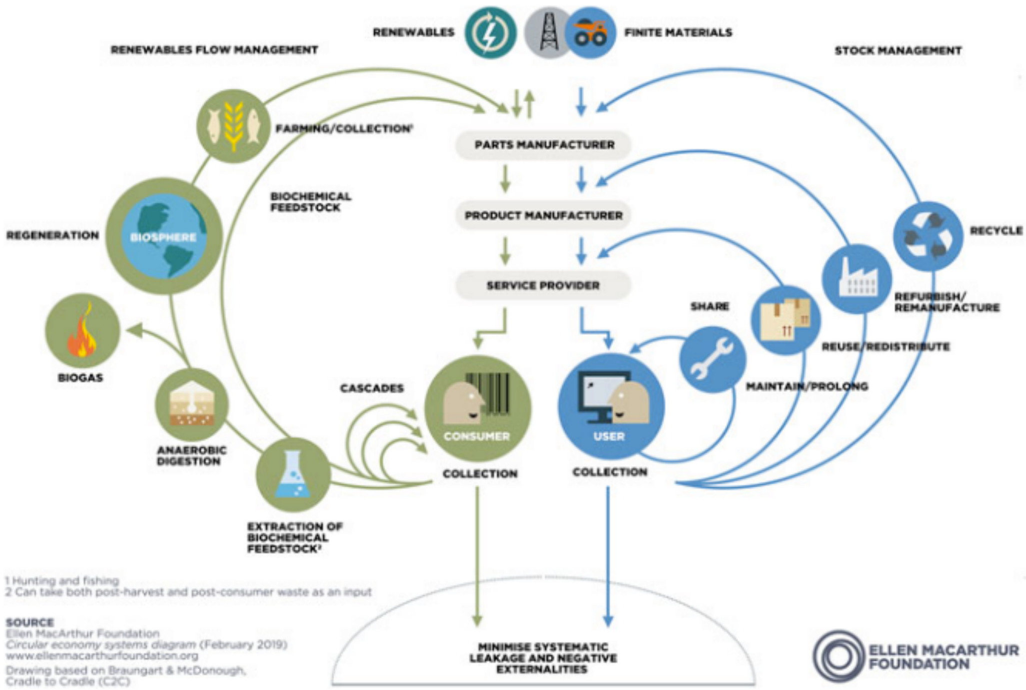

Figure 2 Outline of the circular economy (Ellen MacArthur Foundation, 2021, p.399)

In essence, CE aims to decouple economic growth from resource depletion by optimizing the use of materials. This is achieved through three key principles: eliminating waste and pollution, keeping products and materials in use, and restoring natural systems (Ellen MacArthur Foundation, 2021). CE differentiates between biological cycles, which involve natural materials like food and wood that can be reintegrated into the environment, and technical cycles, which focus on extending the life of products and components through strategies like repair, remanufacture, and recycling, see Figure 2.

Digital technologies are integral to this shift forwards the CE, providing critical support through virtualization, dematerialization, and data analytics. Overall, CE represents a progressive economic model prioritizing sustainable practices and innovative business models, underpinned by digital technology, to achieve a balance between economic growth and environmental stewardship (Ellen MacArthur Foundation, 2021; Mügge et al., 2023).

2.1.1 CE Monitoring

As mentioned, the EC has proactively introduced initiatives, directives, and regulations to catalyze the transition to a CE. This shift is particularly crucial within the automotive industry, where the principles of CE are essential for sustainable growth and operation. For the practical realization of these principles, monitoring systems that rely on data are essential (Rukanova, Ubacht, et al., 2023; Ubacht et al., 2023). CE monitoring is crucial for ensuring the achievement of CE goals. Digitalization is key in this monitoring, offering visibility and traceability. However, implementing this effectively is challenging due to the scattered nature of the necessary data across various information systems and global supply chains (Rukanova, Ubacht, et al., 2023). These supply chains span different countries, legal jurisdictions, and economic zones, making transparency and traceability complex from technical, institutional, and organizational perspectives. Additionally, the quick rollout of EU policies requires national governments to rapidly develop mechanisms to monitor and promote circularity and sustainability.

Based on recent studies Rukanova, Ubacht, et al. (2023), identified several dimensions that appeared to be relevant to CE monitoring, which they combined into a high-level framework shown in Figure 3 that can be used as a conceptual lens to demonstrate the complexity of CE monitoring in a specific field. The dimensions are:

- **Public value drivers for CE monitoring (1) in the CE context (2):** Medaglia et al. (2022) present a framework that positions the government at the heart of the CE transition, leveraging the NATO model to identify governments' roles as Nodality, Authority, Treasure, and Organization in CE (Rukanova, Ubacht, et al., 2023). They highlight the prominent roles of Authority through policymaking and regulation and Treasure by offering subsidies to encourage CE-aligned initiatives . This approach is particularly evident in the EU's regulatory push for CE, imposing new requirements on public organizations and businesses to uphold public values. Rukanova, van Engelenburg, et al. (2023) extend this discussion to international trade, noting the evolving information needs for monitoring these values and the implications for digital infrastructure. They stress the importance of considering these needs within the broader spectrum of public values governments aim to monitor and protect, emphasizing the complexity of managing multiple values and the strategic use of IT and stakeholder engagement in this context (Rukanova, Ubacht, et al., 2023).

- **Actors and their own systems (3):** Governments play a crucial role in CE monitoring, but it is essential to consider the broader ecosystem of actors involved (Rukanova, Ubacht, et al., 2023). Medaglia et al. (2022) emphasize the need to understand the interplay between various stakeholders, including businesses, NGOs, IT providers, and research institutes, and their roles in CE processes. Rukanova et al. (2021) expand this view by including auditors, banks, and insurance companies, highlighting the diversity of data sources and the digital infrastructures required for adequate data access and CE monitoring. By focusing on specific actors within the supply chain, these studies shed light on the valuable data held by different entities and the importance of digital infrastructures in facilitating CE monitoring (Rukanova, Ubacht, et al., 2023).

- **Digital infrastructures (4):** CE monitoring requires the development of complex infrastructures to link data across different actors within the ecosystem (Rukanova, Ubacht, et al., 2023). Therefore, this dimension aims to identify how to allow access to data that resides in multiple platforms for CE monitoring, which digital infrastructure can support the necessary data-sharing solution, or where the gap in required data is.

Despite the promising potential of innovations regarding digital infrastructures , such as voluntary data pipelines for sharing business data with governments, the unique requirements posed by a CE introduce a new set of monitoring challenges. Mügge et al. (2023) highlight the intricate nature of the automotive supply chain, with its vast network of suppliers, as a significant hurdle in monitoring CE. The chain's complexity hinders the execution of optimal End-of-Life (EoL) strategies. Although digital solutions promise better transparency, they come with their issues. Acquiring the necessary data for CE monitoring often means navigating a maze of global supply chains and separate systems, which can be a barrier to achieving full transparency (Rukanova, van Engelenburg, et al., 2023).

Moreover, Mügge et al. (2023) highlight that despite the crucial role of transparent data exchange in advancing the circular economy, the lack of comprehensive vehicle information poses a barrier. Although digital technologies offer possible solutions, they also bring about barriers related to data sovereignty and compliance issues. Suppliers, who are worried of potential risks associated with data sharing, become even more cautious because of the high competition in the automotive industry. This often leads to a reluctance to share sensitive information. Consequently, for CE monitoring to be truly effective, data providers must retain control over their data, ensuring it is used securely and purposefully (Mügge et al., 2023).

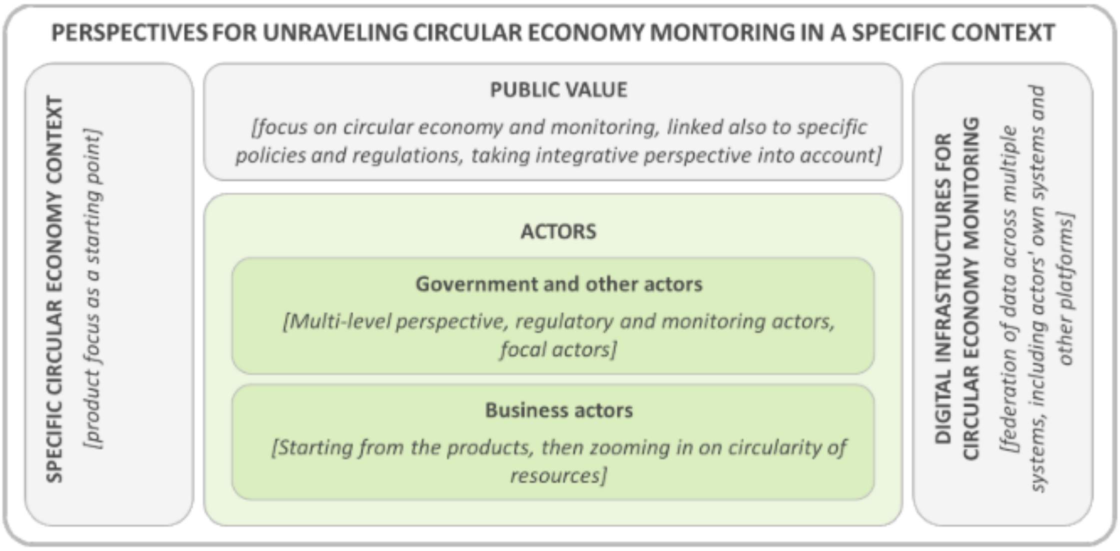

Figure 3 Conceptual framework for circular economy monitoring (Rukanova et al., 2023, p. 547)

2.2 Digital Product Passports

A DPP is a product-unique dataset that registers and processes information related to the product. DPPs are introduced by the EC as a means of facilitating the collection, sharing, and retrieval of product-related data (Nowacki et al., 2023). A DPP is a digital document accompanying an individual product item carrying information about its lifecycle, material, origin of materials used in its production, distribution information, history of use, carbon footprint, involved actors, and others (Nowacki et al., 2023). The aim is for DPPs to facilitate the discovery and collection of product data by critical stakeholders, such as regulatory agencies, businesses that need data for compliance monitoring, and consumers. The concept has been recently introduced, and details regarding the types of data involved, the implementation of DPP infrastructure, and DPP governance are yet to be defined and standardized. Figure 4 shows an overview of the DPP ecosystem, including the value chain participants, the DPP system, and the other stakeholders.

2.2.1 Circularity Vehicle Passport

Under the latest ELV Regulation, there is a requirement to create a circular vehicle passport, serving as a data repository for precise, comprehensive, and accurate information about the safe removal and replacement of vehicle parts and components (European Commission, 2023a). This initiative must align with existing and emerging digital tools, current regulations (see Appendix E – Overview of legislation analysis), and platforms in the automotive sector that track vehicles' environmental performance.

New concepts like Data Spaces as developed in engineering sciences, are often presented as a data sharing solution with built-in governance models through algorithms and/or decentralization (Ducing & Reich, 2023). Data Space initiatives can play a role in facilitating the needed data for the CE, and the automotive industry. Therefore, the following section will elaborate on Data Spaces, with a focus on the IDS.

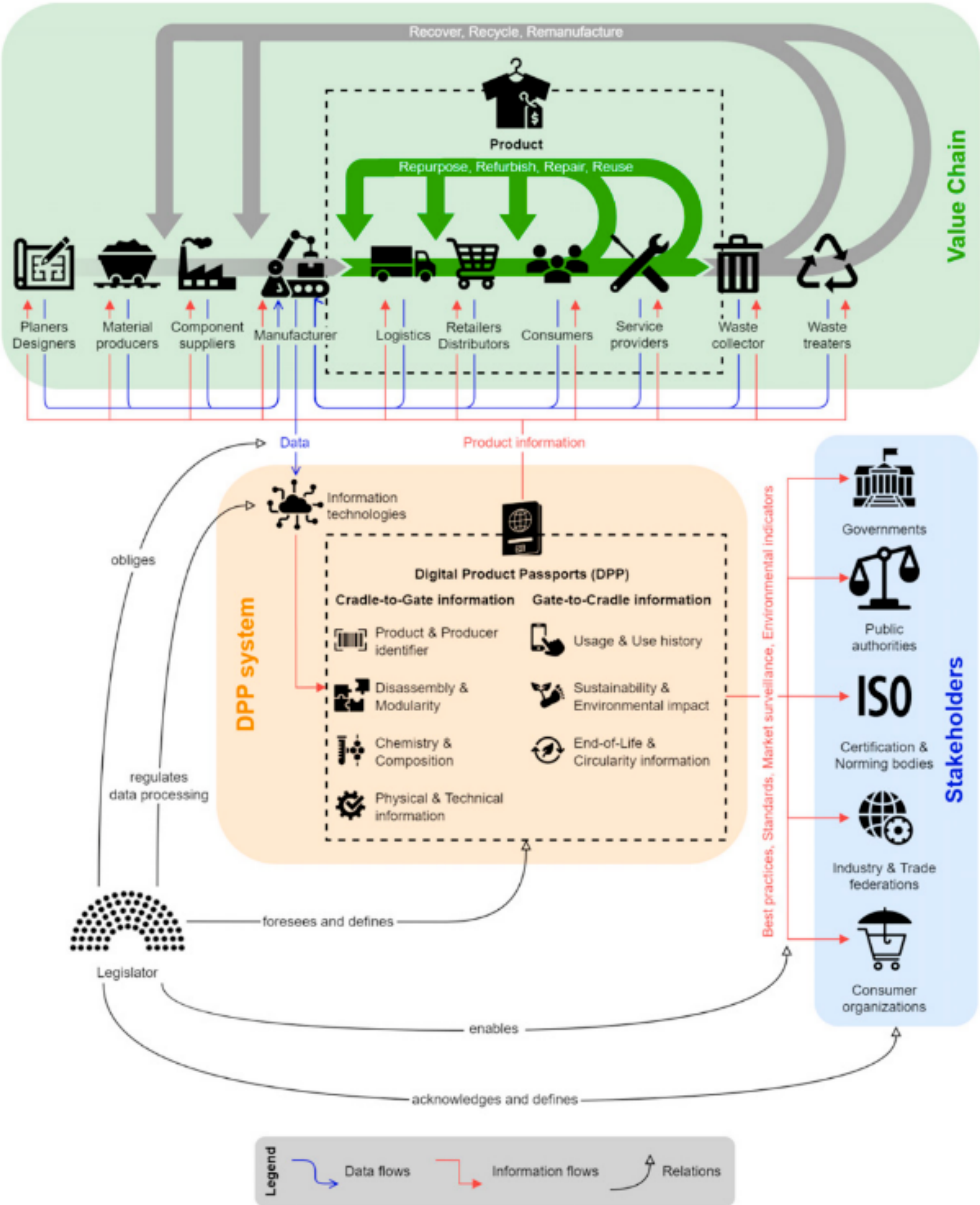

Figure 4 Overview of the DPP ecosystem (Ducuing & Reich, 2023, p.10)

2.3 Data Spaces

Data Spaces, an emerging concept particularly highlighted in the European Strategy for Data, are steering European initiatives towards a data-driven economy (Grothe, 2023; Scerri et al., 2022). Data Spaces are envisioned as a model for integrating data without requiring uniform database structures or physical data consolidation. Instead, they rely on decentralized data repositories, integrating data semantically as required (Grothe, 2023; Nagel & Lycklama, 2021). Beyond this technical view, Data Spaces are conceptualized as federated data ecosystems specific to an application domain, governed by mutual policies and standards. Users within these ecosystems can securely, transparently, and cohesively access data. Access and usage permissions are provided exclusively by the data's rightful owners. Data Spaces could be innovative for practical applications like dismantlers extracting components from End-of-Life Vehicles (ELVs), offering secure, transparent, and centralized access to crucial information.

2.3.1 International Data Space Association

The International Data Spaces Association (IDSA) is pioneering the future of the global digital economy through the development of International Data Spaces (IDS) (see section 2.3.1.1). IDSA's goal is to pave the way for a data-driven economy by establishing a framework for safe, autonomous data exchange among reliable entities (Grothe, 2023). This concept, known as 'data sovereignty,' is increasingly crucial as the ability to access and share data becomes a key determinant of success for businesses, governments, individuals, and entire economies. Historically, organizations have hoarded vast quantities of valuable data without the capability to manage, share, or capitalize on it independently. IDSA has outlined a reference architecture and a series of agreements designed to foster trust among partners and lay the groundwork for innovative business ventures, products, and services (Grothe, 2023).

2.3.1.1 International Data Spaces

International Data Spaces (IDS) promote data sovereignty and autonomous data sharing through standardized connections that transcend company borders (Pettenpohl et al., 2022). The IDS address several critical challenges in broad data utilization, including interoperability, transparency, trust, security, and widespread adoption. Data sovereignty is defined as the capacity of individuals or organizations to exercise complete autonomy over their data.
A Data Space represents a concept of data sharing without central storage, IDS ensures data remains at its origin, being shared only when necessary. This approach allows data providers to maintain sovereignty over their data until it is required. IDS ensures that data is accompanied by usage policies for system and user compliance (Pettenpohl et al., 2022). When needed, the IDS must ensure that usage policies are attached to the data, which systems and users can follow (Pettenpohl et al., 2022). In this regard, the IDS aims to meet the following goals:

- **Trust:** Essential for data sharing in a data ecosystem, trust encompasses confidence in the system and assurance that participants use shared data per the provider's usage policies. Trust forms the foundation of the IDS requiring certifications for all participants and software before accessing the ecosystem.

- **Security:** Intertwined with trust, security in the IDS must meet top standards to ensure trust and data sovereignty.

- **Data Sovereignty:** A fundamental principle of IDS, data sovereignty refers to an individual or entity's complete control over their data. This includes setting usage restrictions before sharing data, which data consumers must respect.

- **Data Ecosystems:** Facilitate new business models by aggregating data from various sources. No single actor possesses all the necessary data for innovative services, making a collaborative data space vital for these services.

- **Standardized Interoperability:** Crucial for building a data space, it ensures different ecosystems can exchange varied data types and formats. The interoperability of the IDS is standardized through a reference architecture model, semantic description of data and endpoints, and certification that enforces adherence to these standards, including compliance with DIN Spec 27070 for IDS Connectors.

2.3.1.2 Main concepts of IDS

The IDS Reference Architecture Model (IDS-RAM) incorporates a variety of elements, roles, and interactions, forming an infrastructure dedicated to sovereign data exchange, see Figure 5.

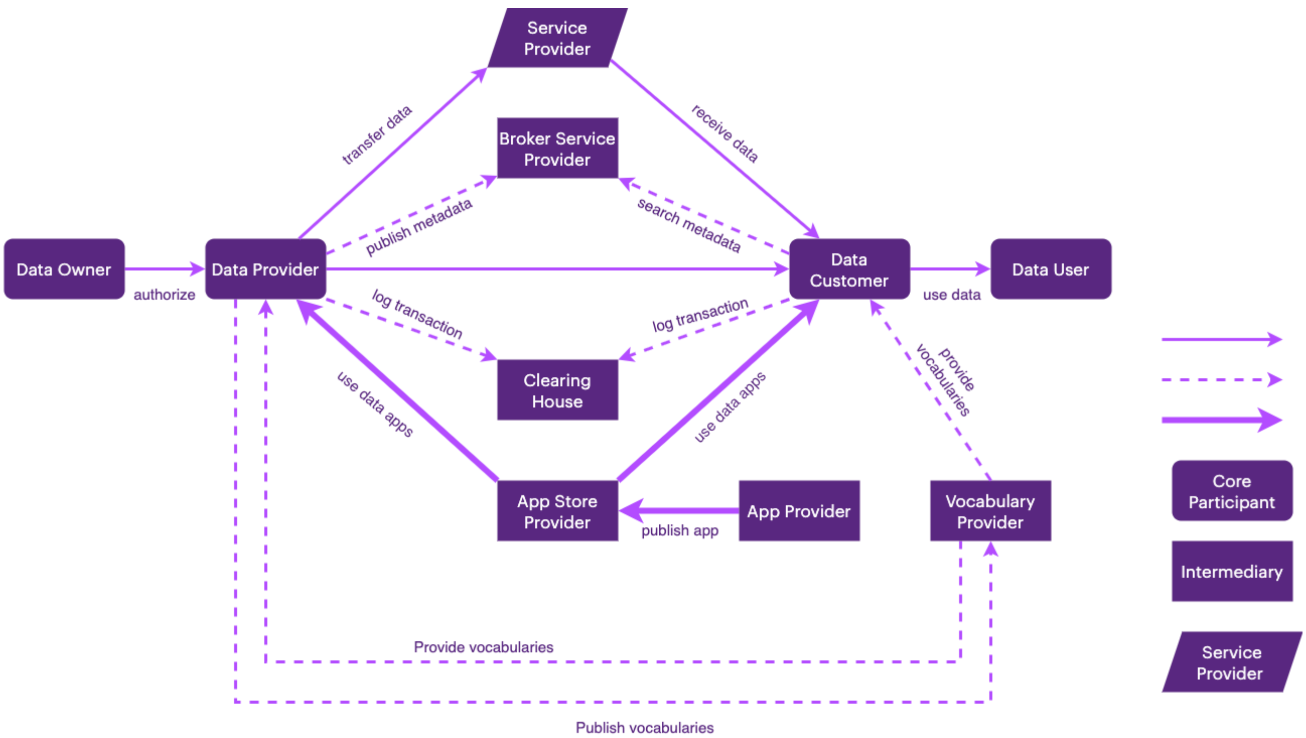

Figure 5 Roles and interactions in the IDS, based on Otto et al. (2023)

Participants can have different roles; these roles are assigned to different categories depending on the level of interaction and organization (Pettenpohl et al., 2022). A brief overview of these categories and corresponding roles are given in Table 2.

Table 2 International Data Space Categories (based on Pettenpohl et al., 2022)

Category 1	Core Participants	Data owner, data provider, data consumer, data user, app provider
Category 2	Intermediary participants	Metadata Broker Service Provider, Clearing House, Identity Provider, App Store, Vocabulary Provider
Category 3	Software and services	Software Provider, Service Provider
Category 4	Governance body	International Data Spaces Association, Certification Body and Evaluation Facility

A broad overview of all the above-mentioned roles is given in Appendix A – Core concepts IDS. Below the core concepts, and some of the above-mentioned roles, are elaborated upon.

Certification is a crucial requirement for core participants in the IDS, as depicted in Figure 4. This process, essential for most roles within the IDS, demands that organizations thoroughly evaluate their technical, physical, and organizational security measures (Otto, 2021). Further, all ecosystem components must undergo technical evaluation and certification to ensure compliance with IDS standards and the proper application of security measures. Independent third-party evaluation instills trust throughout the ecosystem by verifying correct implementation.

The IDS Connector plays a pivotal role in data transfer, managing the entire data exchange procedure between the internal data resources and enterprise systems of participating organizations. Data transmission occurs directly between the Connectors of the Data Provider and the Data Consumer, aligning with the peer-to-peer network concept. The architecture of the Connector leverages application container management technology to create a secure, isolated environment for distinct data services (Kourtis et al., 2022). The IDS Connector links industrial data clouds, individual company clouds, on-premises applications, and connected devices, thereby granting technical access to the IDS ecosystem (Otto, 2021). It also supplies metadata to the IDS Broker, including details like technical interface descriptions, authentication mechanisms, data sources, and related data usage policies.

Intermediary roles in the IDS include Broker Service Provider, Clearing House, App Store Provider, App Provider, and Vocabulary Provider. The Data Provider lists metadata through the IDS Broker for data exchanges. A Data Consumer can then explore this metadata to locate datasets meeting their needs (Otto, 2021; Pettenpohl et al., 2022). Data exchange is initiated if a Data Provider's terms align with a Data Consumer's requirements. The Connector records this transaction and forwards the data log to the Clearing House.

Data Apps, available in the App Store and deployed within the IDS Connector, can further process exchanged data. These apps facilitate data processing workflows, while the Vocabulary Provider supplies specific vocabularies for dataset annotation and description (Otto, 2021).

The Identity Provider authenticates all IDS participants, offering services to create, manage, and validate their identity information. This role is crucial for maintaining a trusted network within the IDS (Otto, 2021).

Furthermore, IT companies may offer software and services to IDS participants, including roles like Service Provider and App Provider. Service providers in the IDS can merge data from various sources or refine individual data assets, creating additional value for Data Consumers. The Governance Body, encompassing the Certification Body and Evaluation Facilities, supervises participant and core component certification, ensuring compliance and standardization within the IDS (Otto, 2021; Pettenpohl et al., 2022).

This chapter lays the theoretical foundation for this thesis by exploring the CE, DPPs, and the IDS initiative. It elaborates on the CE as a sustainable alternative to the traditional linear economy, highlighting its potential to minimize waste and optimize resource use, as reinforced by the UN's Sustainable Development Goals and the European Commission's Green Deal. The significance of CE monitoring for achieving these goals, especially in the automotive industry, is emphasized, pointing to the need for comprehensive data collection and sharing mechanisms. Furthermore, the chapter delves into the IDS as a pivotal element in fostering a data-driven economy, enabling secure and sovereign data exchange across organizational boundaries. It analyzes the IDS's architecture, roles, and functions, underscoring its relevance to CE monitoring by offering a framework for data sharing among various stakeholders within the CE ecosystem.

3 Research approach & methods

This chapter presents a structured approach to answering the main research question (MRQ) by breaking it into sub-research questions (SQ). This study aims to discover how the IDS can contribute to information sharing regarding WEEE in the automotive industry.

This thesis consists of five phases. First, this thesis uses the CE monitoring framework by Rukanova, Ubacht, et al. (2023), introduced in section 2.1.1, to explore the current situation and demonstrate the complexity of information sharing within the automotive industry (SQ1). Based on the findings, barriers will be identified, which will be used as input for the following phase. Second, requirements for WEEE information sharing in the automotive industry will be elicited based on the structured, defined requirements approach by Johannesson & Perjons (2014) (SQ2). For the requirements elicitation, the outcome of the previous phase will be used (SQ2-A). In addition, the legislative landscape will be investigated to gain more requirements from this point of view (SQ2-B). Also, interviews and informative conversations will be held with dismantling experts to gain more insights and requirements from their perspective (SQ2-C). Third, the IDS infrastructure is analyzed to see how and if it meets the information-sharing requirements (SQ3). The final two phases consist of the concluding phase; the MRQ will be answered here. The last and final phase is the discussion phase, where limitations will be discussed, the link with CoSEM will be elaborated upon, and the study's contribution will be given. The relationships between various methods are shown in a simplified overview of the research design in Figure 6 Simplified overview of the research design

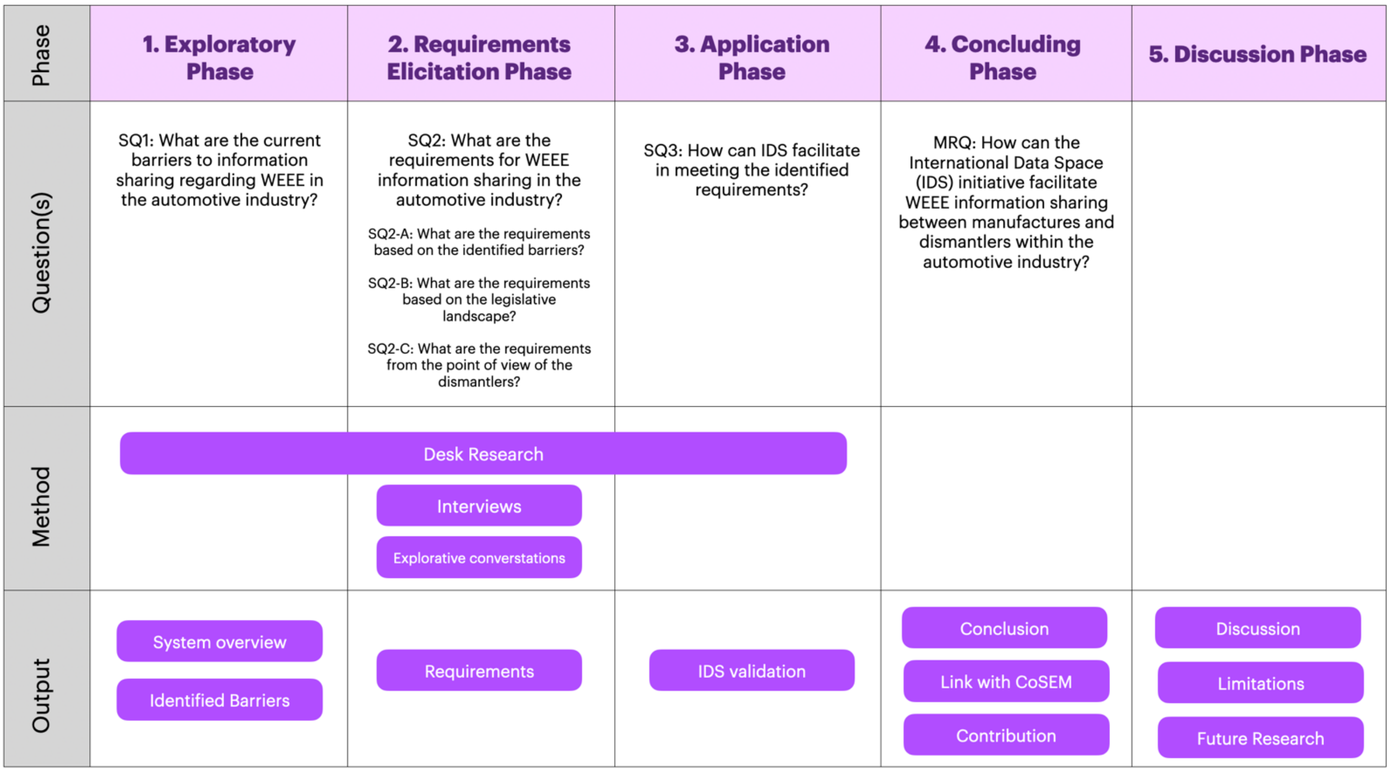

Figure 6 Simplified overview of the research design (own work)

The following sections will elaborate on the five phases. At the end of this chapter a more detailed research flow diagram is provided.

3.1 Exploratory phase

In this phase SQ1 will be answered:

What are the current barriers to information sharing regarding WEEE within the automotive industry?

This phase is about investigating and analyzing the current barriers regarding WEEE information sharing WEEE within the automotive industry, which can be seen as similar to the first phase of design science research (DSR) (Johannesson & Perjons, 2014). To accomplish this, a comprehensive system overview is given using the framework by Rukanova, Ubacht, et al. (2023) introduced in section 2.1.1. This framework contains elements helpful in understanding the CE monitoring in the ELV phase. It explores four dimensions: specific circular economy context, public value, actors and their systems, and digital infrastructures for CE monitoring. This framework will be used as a conceptual lens to demonstrate the complexity of WEEE information sharing in the automotive industry. The findings will result in a list of barriers, which will be used as input for SQ2.

In order to address this SQ1, desk research is conducted using existing studies and government and business reports on this topic. These are all forms of secondary data.

3.2 Requirements elicitation phase

In this phase SQ2 will be answered:

What requirements are essential for facilitating information sharing about WEEE in the automotive industry?

In this research phase, requirements will be elicited based on the define requirement approach by Johannesson & Perjons (2014) with an added evaluation phase, see Figure 7.

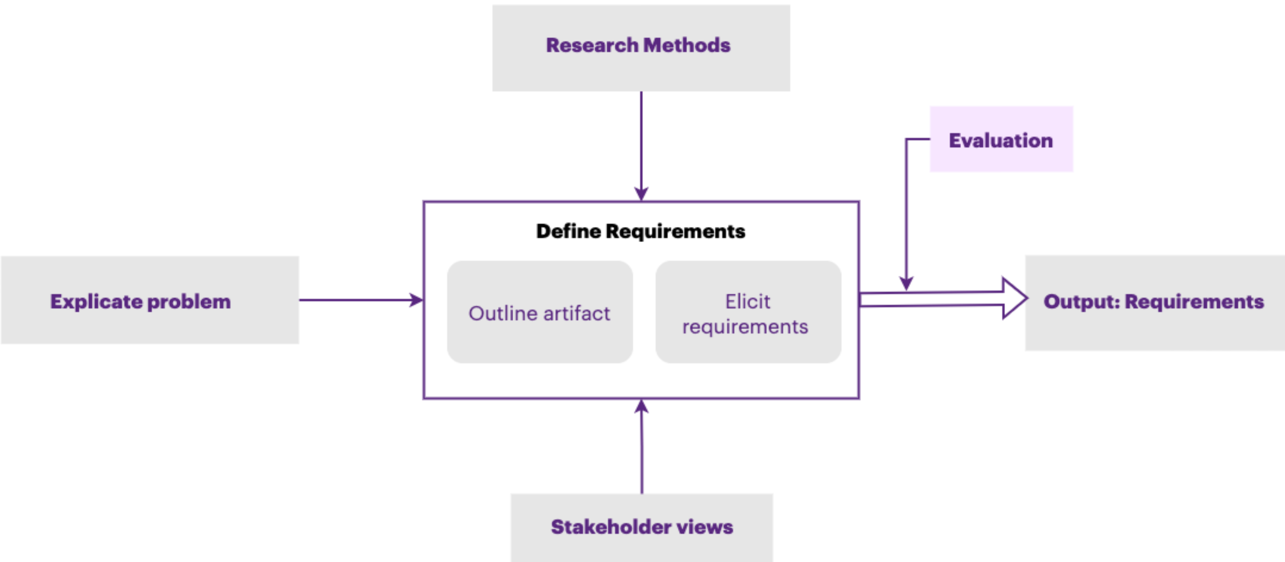

Figure 7 Define requirements approach by Johannesson & Perjons (2014) including evaluation

To answer SQ2 and to get requirements from three viewpoints, three sub-SQs are used. These questions and the research method are shown in Table 3.

Table 3 Sub-SQs and type of research

SQ-ID	SUB-SQ	RESEARCH METHOD
SQ2-A	What are the requirements based on the identified barriers?	Desk Research
SQ2-B	What are the requirements based on the legislative landscape?	Analysis of Regulations and Directives
SQ2-C	Wat are the requirements from the point of view of the dismantler?	Interviews

SQ2-A will be answered using the output from the previous chapter. This list of barriers will be translated into functional and non-functional requirements. SQ2-B will be answered by analyzing the legislative landscape. Different regulations and directives will be analyzed on what they mention about information sharing in the automotive industry, and after this, requirements will be derived from it. Finally, SQ2-C will be answered by conducting five interviews/explorative conversations with dismantling stakeholders. Their view is essential as they need to dismantle WEEE from ELVs.

Based on these three different inputs, two more dismantling stakeholders will evaluate a final list of requirements. This is a step added for this thesis, as shown in Figure 7.

3.3 Application phase

In this phase SQ3 will be answered:

How can IDS facilitate in meeting the identified requirements?

During this research phase feasibility of meeting the identified requirements in the previous section are explored for the International Data Space (IDS). The objective of this section is to assess the potential of this data space in addressing the information-sharing hurdles related to WEEE in the automotive industry. To accomplish this, academic articles, and documentation from de IDSA will be used. The answer to this research question will be used as input for the concluding phase.

3.4 Concluding phase

In this phase, the answers of the previous sub-questions will be used to answer the MRQ:

How can the International Data Space (IDS) initiative facilitate WEEE information sharing between manufactures and dismantlers within the automotive industry?

In this concluding phase all the research done in the previous phases will come together and a conclusion will be formed. Next to that, the link with CoSEM will be explained, and there will be elaborated upon the scientific and societal contribution of this thesis.

3.5 Discussion phase

In this final phase of the research, the research approach and the conclusions will be discussed. Next, to that the limitations of this research will be elaborated upon. Also, some ideas for future research will be shared.

3.6 Research Flow Diagram

The final thesis will be divided into eight chapters, presented in
Figure 8. All inputs and outputs per chapter are presented in the research flow diagram.

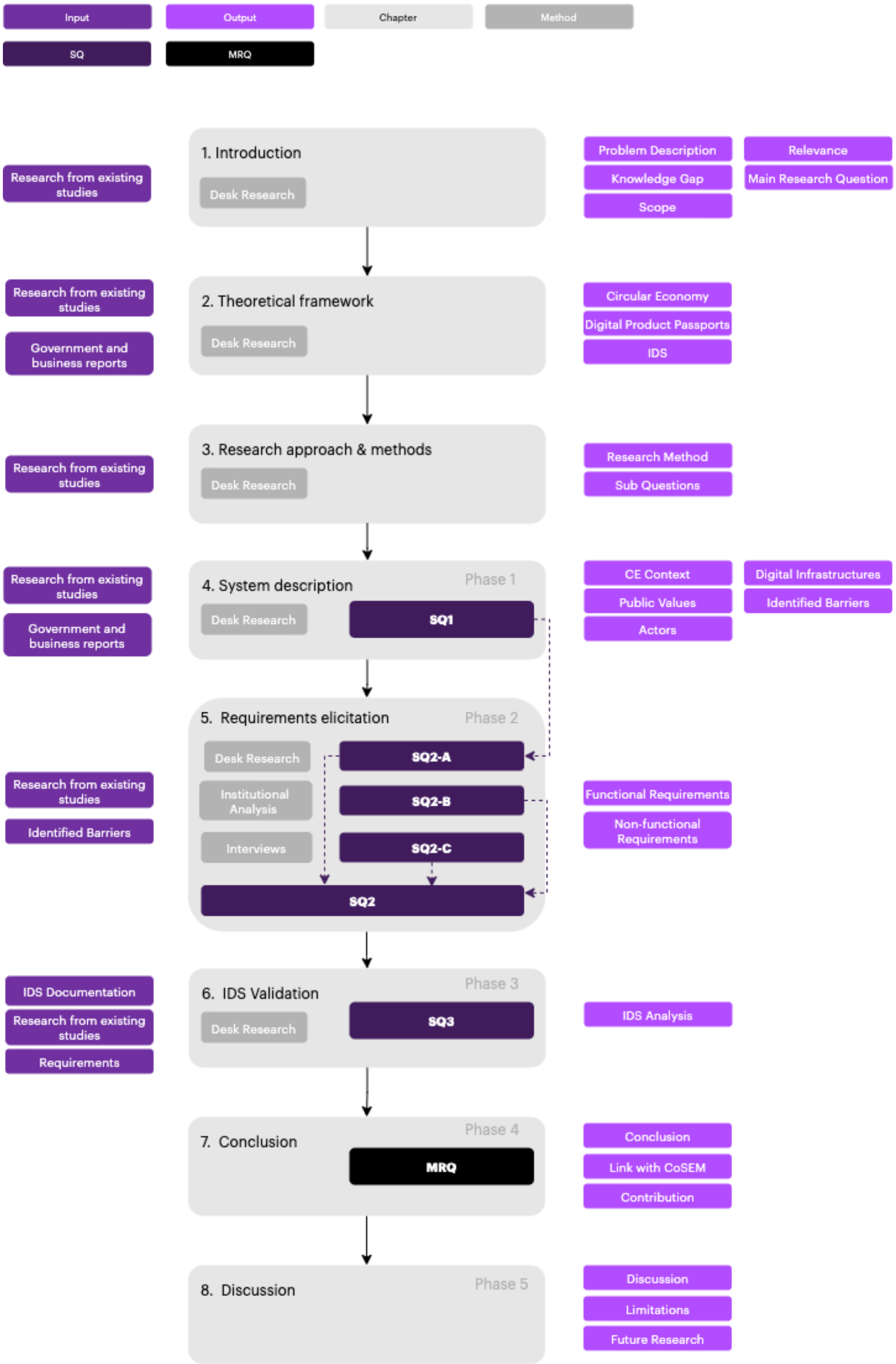

Figure 8 Research Flow Diagram

4 System Description

The theoretical background chapter provides a generic understanding of the CE, digital product passports, circular vehicle passports, and the basic concepts of the IDS. This chapter provides a system description to gain more insights into the current complexities and barriers regarding WEEE information sharing. This system description and the conceptual framework for CE monitoring by Rukanova, Ubacht, et al. (2023) is used (see Figure 3 in section 2.1.1). The following sub-question (SQ1) is addressed in this chapter:

What are the current barriers to information sharing regarding WEEE within the automotive industry?

As section 2.1.1 CE Monitoring mentions, this framework consists of four dimensions. First, the **specific circular economy context**. This dimension is intended to draw attention to the context in which CE flows and the associated data needs (Rukanova, Ubacht, et al., 2023). This analysis will study WEEE management in the ELV stage in the automotive industry in the circular economy context. This is the first section in this chapter.

The **public values** dimension identifies which public values are pursued with CE monitoring and what policy developments drive these public values (Rukanova, Ubacht, et al., 2023). These public values will be based on the designed policy options, steering the public values, from the new ELV Regulation (European Commission, 2023a); see section 4.2.

Next, the **actors'** dimension is to analyze the actors in the relevant ecosystem and the key actors' data in their proprietary information systems that can be used for CE monitoring activities (Rukanova, Ubacht, et al., 2023). This dimension also captures actors influencing policies or other relevant developments; see section 4.3.

Finally, the **digital infrastructures** dimension is aimed at identifying how to allow access to data that resides in multiple platforms for CE monitoring, which digital infrastructure can support the necessary data-sharing solution, or where the gap in required data is (Rukanova, Ubacht, et al., 2023). In this thesis, this dimension looks at the current information system and what their shortcomings are; see section 4.4.

The outcome of this chapter is a system overview demonstrating the complexities of WEEE information-sharing in the automotive industry. This results in a list of barriers. The conclusion of this chapter will be given in section 4.5.

4.1 Specific circular economy context

This section will provide an overview of the context of which the CE flow and the CE Monitoring are analyzed, which is based on the first dimension by Rukanova, Ubacht, et al. (2023), the circular economy context (see section 2.1.1). First, there will be looked at the current state of ELV management. Second, there will be looked at the how WEEE is currently handled in the automotive industry.

4.1.1 ELV management

The management of ELVs is currently regulated by the ELV directive 2000/53/EC (ELVD) (European Commission, 2000). Although ELV management practices can change at the local level from country to country (Tazi et al., 2023). The complexity of the industrial interrelationships involved in the ELV management system is shown in Figure 9.

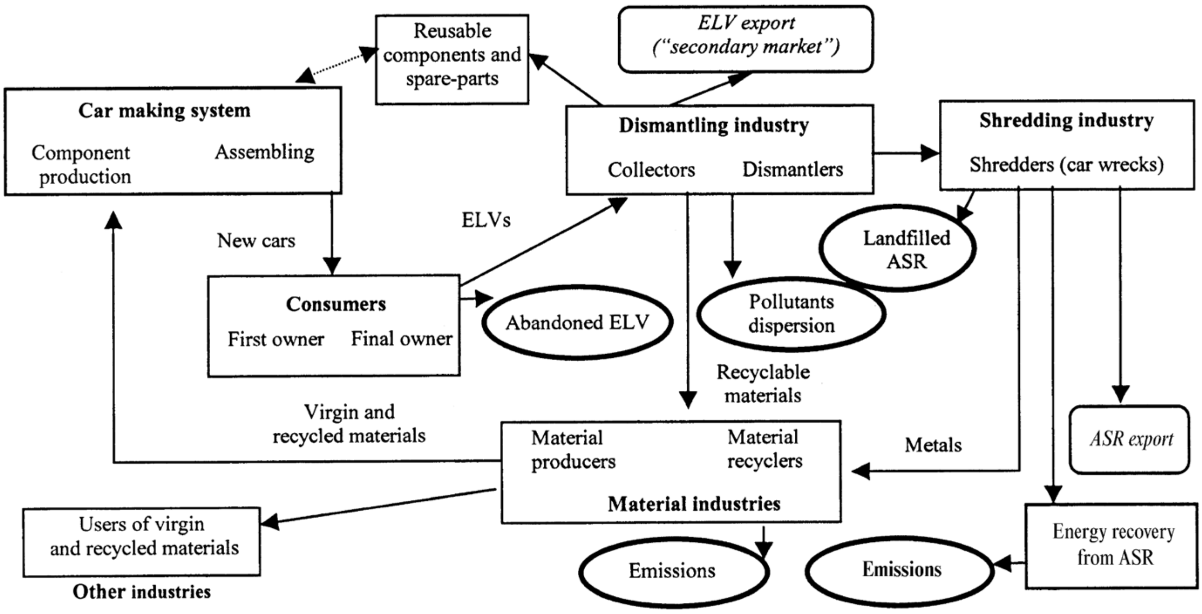

Figure 9 The ELV system (Mazzanti & Zoboli, 2005, p.323)

The process of depollution and dismantling of vehicles is primarily undertaken by dismantling industry. Pollutants dispersion involves removing all fluids, batteries, explosive components like airbags, and other specified components in accordance with the current ELVD. Dismantling includes taking out parts such as bumpers, catalysts, and tires for recycling or energy recovery. While some of these components are specified in the ELVD, others are removed by the dismantlers because these components can be sold (Mazzanti & Zoboli, 2005; Tazi et al., 2023). After these processes, what is left of the vehicle, often called the car hulk, is sent to a shredder facility. Here, it is broken down into shredder residues. These residues are sorted to separate ferrous and non-ferrous materials containing various materials. The sorting process may include Post-Shredder Technologies (PSTs) to enhance the purity and recycling quality at recycling facilities. The non-recyclable materials typically end up in incineration (with or without energy recovery) or landfills (Berzi et al., 2013; Tazi et al., 2023).

4.1.2 WEEE recovery within the Automotive Industry

There are five main categories of electronics in the automotive industry (Tazi et al., 2023):

1. Controllers: These components are responsible for executing control operations within a vehicle, utilizing data from sensors to command actuators. Typically incorporating Printed Circuit Boards (PCBs), controllers are a primary repository for valuable materials in vehicles.

2. Actuators: These components create movement, often powered by small electric motors. Actuators extensively use Permanent Magnets (PMs), which typically contain elements like Nd or Dy.

3. Sensors: Sensors are vital for gauging various physical aspects inside and around the vehicle. However, this category includes only minimal quantities of Critical Raw Materials (CRMs) and is widespread throughout the vehicle, making material recovery less feasible (Tazi et al., 2023).

4. Headlights: In modern vehicles, headlights are sophisticated systems that integrate actuators, sensors, and controllers. Their functions range from sensing ambient light levels to adjusting the direction of the light beam and managing actuator control.

5. Cables: Essential for connectivity, cables interlink various vehicle components, providing them with power, data, and operational commands. They are primarily composed of Copper (Cu) and plastic materials.

The majority of ELV recycling facilities lack specialized sorting capabilities for electronics components like Printed Circuit Boards (PCBs) and Electronic Control Units (ECUs). PCBs are among the most intricate, hazardous, and valuable components found in electronic waste. On average, they may comprise over 60 different elements, encompassing a range of heavy metals like Lead (Pb), Chromium (Cr), Cadmium (Cd), Mercury (Hg), and Arsenic (As), alongside toxic organic compounds (Cucchiella et al., 2015). ECUs stand out as some of the most valuable electronic devices integrated into contemporary vehicles. They possess the capability to read signals from sensors placed throughout a car and manage the operations of numerous sub-systems, including the engine, air conditioning, infotainment system, and safety devices, among others (Cucchiella et al., 2015). However, these PCBs and ECUs ultimately find their way into a waste stream known as SLF, destined for incineration (Cozza et al., 2023; Tazi et al., 2023). Consequently, in the standard recycling process, materials that would otherwise be recoverable in e-waste recycling facilities are treated as losses during ELV recycling. Figure 10 illustrates this, revealing that only iron (Fe), aluminum (Al), and copper (Cu) are salvaged in the standard procedure, while other CRMs are completely discarded. The limited recovery of electronics from ELVs can be viewed as challenge.

	Recovered materials from embedded electronics (%wt/component)										
	Fe	**Al**	**Cu**	**Au**	**Ag**	**Pd**	**PP**	**PMMA**	**ABS**	**PC/ABS**	**Losses**
Headlights	7.2	8.3	0.3	0	0	0	0	0	0	0	84.2
Actuators	25.2	20.2	1.3	0	0	0	0	0	0	0	53.3
Controllers	38.8	18.1	1.2	0	0	0	0	0	0	0	41.9
Cables	0	0	37.5	0	0	0	0	0	0	0	62.5

Figure 10 Baseline material recovery from the stream of the electronic categories (Tazi et al., 2023 p.15)

4.1.3 Institutional Landscape

In this section an overview is given on the institutional landscape for ELV and WEEE management. The selected Governing bodies, strategic frameworks and directives and regulations are chosen based on their application on the automotive industry and on ELVs and WEEE. A broad overview of the institutional landscape is given Figure 11.

4.1.3.1 Governing bodies & institutions

The United Nations proposed the 17 Sustainable Development Goals (SDGs) to address ecological, economic, and social challenges, with SDG 12 focusing on responsible production and consumption (Rukanova, Ubacht, et al., 2023). This goal aligns with the concept of a CE, which transitions from the traditional linear consumption model ("make, use, dispose") to a circular one emphasizing resource reuse, waste minimization, and environmentally friendly practices.

The EU is critical in environmental policy, also regarding ELV and WEEE management. It establishes comprehensive goals and targets for waste reduction, recycling, and sustainability that member states must meet (European Union, n.d.-a). The European Commission, within the EU's legislative framework, sets and enforces standards for, in this case, ELV and WEEE management, focusing on collection, recycling, and treatment to reduce environmental impacts, enhance material recovery, and steer towards a CE (European Union, n.d.-b).

The legislative process involves the EC proposing regulations, followed by discussions and amendments by the Council and the Parliament, who must reach a consensus on the legislation. This process ensures that the European

Economic and Social Committee (EESC) has a say and advises the EC on the final legislation, aiming for a balanced approach considering various perspectives and impacts (European Economic and Social Committee, n.d.).

4.1.3.2 Strategic Frameworks

Launched in 2019, the European Green Deal aims to transform the EU into a sustainable economy by 2050, targeting net-zero greenhouse gas emissions and decoupling economic growth from resource use. It seeks to ensure a suitable transition for all regions and citizens, enhance the EU's natural capital, and protect public health from environmental risks (Rukanova, Ubacht, et al., 2023). The Circular Economy Action Plan, a critical pillar of the Green Deal, proposes an agenda for a cleaner, competitive Europe by fostering stakeholder collaboration. It focuses on streamlining the regulatory framework for sustainability, maximizing new opportunities, and minimizing burdens during the transition. Together, these strategies represent the EU's ambitious commitment to environmental sustainability, economic resilience, and social equity (EU Commission, 2020).

4.1.3.3 Directives and regulations

Type-approval of Motor Vehicles with Regard to their Reusability, Recyclability and Recoverability Directive

Directive 2005/64/EC, mandates that vehicles be designed for the reuse, recycling, and recovery of parts and materials at the end of their lifecycle, aiming to minimize waste from end-of-life vehicles (European Commission, 2005). This EU legislation applies to new and existing models of cars, station wagons, people carriers, and light commercial vehicles, requiring that new vehicles sold in the EU must be capable of being reused and recycled to at least 85% by mass, and reused or recovered to at least 95% by mass. Manufacturers are obligated to develop strategies to meet these reusability, recyclability, and recoverability standards, receiving a certificate of compliance from national authorities if their strategies are deemed satisfactory. The directive prohibits the reuse of specific components like airbags and seat belts in new vehicles due to safety and environmental concerns and excludes special purpose vehicles and those produced in small series (European Commission, 2005).

Eco Design Requirements for Energy-related products Directive

Directive 2009/125/EC establishes an EU-wide legal framework for setting eco-design requirements for energy-related products, ensuring efficient and consistent methodology that aligns with national initiatives, whether voluntary or regulatory (European Commission, 2009). This directive mandates that products consuming energy meet specific eco-design standards throughout their lifecycle—from raw material extraction to manufacturing, distribution, use, and end-of-life disposal—before they can be marketed or used within the EU. It does not, however, cover transportation for people or goods. Eco-design requirements assess various environmental aspects at each product lifecycle stage, including materials and energy use, emissions, waste, and the potential for reuse, recycling, and recovery. Manufacturers are required to create an ecological profile for their products to explore alternative design options. Products meeting these standards are marked with the CE label, allowing them to be sold across the EU (European Commission, 2009).

Critical Raw Materials Act

The Critical Raw Materials Act (CRMA) establishes a regulatory framework within the EU to enhance the selection and implementation of strategic raw materials projects, coordinate the monitoring of supply chains, and mitigate supply (European Commission, 2023b). Its main goal is to bolster domestic capabilities and promote the circularity of critical raw material supply chains. The act legally formalizes the list of critical and strategic raw materials, incorporating a criticality assessment based on economic significance and supply risk, which will be periodically reviewed to update the list. Additionally, the CRMA sets benchmarks for the EU to achieve by 2030, including sourcing at least 10% of its annual consumption from within the EU, processing and refining at least 40% within the EU, obtaining at least 15% from recycling, and ensuring no more than 65% of any critical raw material is sourced from a single non-EU country at any processing stage (European Commission, 2023b).

ELV Directive

The ELV directive focuses on minimizing waste from ELVs and their components by encouraging reuse, recycling, and recovery. It aims to improve the environmental performance across the vehicle life cycle, requiring vehicle and equipment manufacturers to design products for easy dismantling and high recyclability—targeting new vehicles to be at least 85% reusable/recyclable and 95% reusable/recoverable by weight. The directive restricts hazardous substances such as lead, mercury, cadmium, and hexavalent chromium (European Commission, 2000).

Manufacturers, importers, and distributors must create systems for ELV collection and ensure vehicle owners can return ELVs without charge, under most circumstances, to waste treatment facilities, receiving a certificate of destruction for deregistration. Waste treatment operators are mandated to have a permit, remove hazardous substances initially, and focus on maximizing reuse and recycling. The directive sets ambitious annual targets for the reuse, recycling, and recovery of ELVs, applicable to passenger cars and small trucks, with specific exclusions. It demands that manufacturers cover the ELV treatment costs, promoting environmentally friendly disposal and recycling practices (European Commission, 2000).

WEEE Directive

The directive is designed to safeguard the environment and human health by promoting sustainable practices in the production and consumption of electrical and electronic goods (European Commission, 2012). It aims to reduce the generation of WEEE, enhance the recycling and recovery rates of WEEE, and facilitate the efficient utilization of resources and recovery of valuable secondary raw materials. It categorizes WEEE into different types, excluding items such as military equipment, filament bulbs, and active implantable medical devices.

EU member states are required to foster cooperation between manufacturers and recyclers to ensure electronic goods are designed for reuse, easy dismantling, or recovery. They must prevent the disposal of WEEE in unsorted municipal waste streams, implement free return systems for households and retailers, and prohibit the improper disposal of WEEE. The directive sets ambitious collection targets: 45% by 2016, rising to 65% by 2019, or 85% of the generated WEEE, with provisions for certain countries to have extended timelines based on their infrastructure and consumption levels (European Commission, 2012).

ELV Regulation

The proposed ELV Regulation addresses the environmental impact of the evolving automotive sector, particularly as it moves towards zero-emission mobility and the increased use of electronics in vehicles (European Commission, 2023a). This shift results in a higher demand for copper and critical raw materials, such as rare earth elements used in e-drive motors, alongside advanced materials like composite plastics and high-grade alloys. These developments raise the environmental footprint of vehicle production due to the energy-intensive processes required to extract and process primary materials. The regulation aims to support the automotive industry in designing end-of-life treatment. It proposes to replace two existing directives—the ELV Directive, which mandates environmentally sound treatment of end-of-life vehicles, and the 3R type-approval Directive, which links vehicle design to recyclability—with a single, modernized legal framework. This new regulation seeks to enhance the EU's legislative approach by setting specific recycling targets, addressing the issue of vehicles of 'unknown whereabouts,' and fostering sustainability within the automotive and recycling industries (European Commission, 2023a).

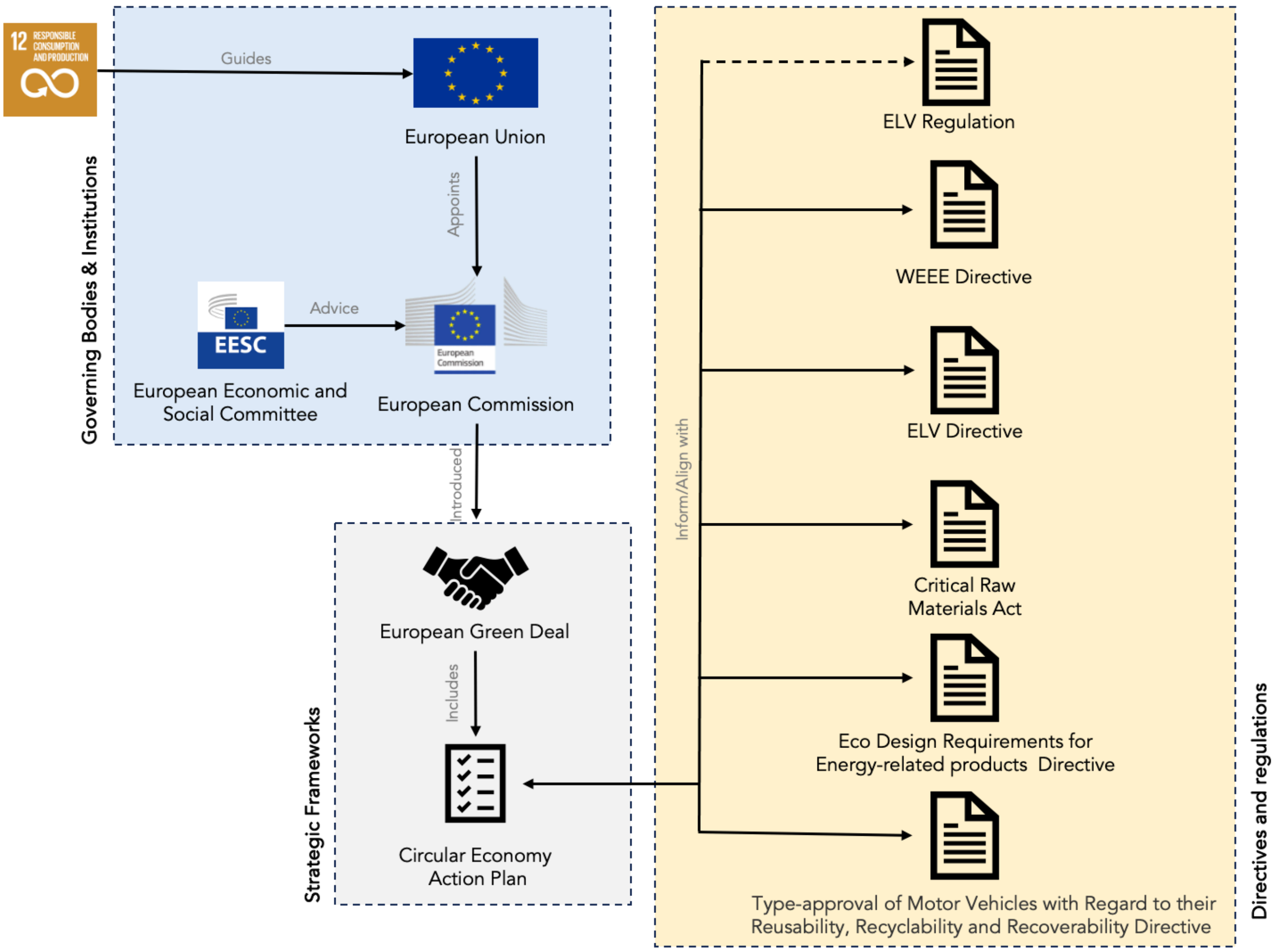

Figure 11 Institutional Landscape (own work)

In conclusion, the European Union's legislative landscape is evolving to meet sustainability challenges, particularly in the automotive and electronic sectors. The proposed ELV Regulation, the European Green Deal, and the Circular Economy Action Plan represent a significant shift towards a more sustainable and circular economy. These initiatives aim to reduce the environmental impact of products throughout their lifecycle, from design to disposal, by encouraging reuse, recycling, and recovery. The ELV Regulation, by consolidating existing directives, seeks to address the specific challenges posed by the increasing complexity and material demands of modern vehicles. With directives on eco-design, critical raw materials, and waste electrical and electronic equipment, the EU is laying down a comprehensive framework that aims to minimize waste, promote resource efficiency, and ensure that economic growth is aligned with environmental sustainability.

4.2 Promoting public values

As highlighted in section 2.1, The Circular Economythe transition to a CE is driven by European policies and government initiatives. Medaglia et al. (2022) in their literature review noted that governments often play the role of an authoritative body, enacting policies and regulations to facilitate this transition. This authoritative role is particularly evident in the new European legislations aimed at promoting the CE.

These emerging regulatory frameworks impose new obligations and priorities on both public and private organizations, especially regarding the protection of public values. Rukanova, van Engelenburg, et al. (2023) pointed out that governments must navigate various public values, each imposing distinct requirements on information needs for monitoring purposes and the utilization of digital infrastructures. The article also suggests that new needs are likely to emerge, applicable to industries like automotive. This includes requirements for information on material composition and recycled content in vehicles, especially when governments emphasize monitoring public values related to CE or sustainability.

The proposal for the ELV Regulation specifies six policy options which will steer the public values: design circular, use recycled content, treat better, collect more, extended producer responsibility, and cover more vehicles (European Commission, 2023a). In this analysis, only the policy options that directly influences information sharing with dismantlers is taken into account. The justification of this can be found in Appendix B – Justification for public values. The identified policy values will be further elaborated upon in the following sections.

4.2.1 Designing for circularity

The strategy involves immediate obligations for vehicle manufacturers to provide comprehensive and accessible dismantling and recycling information. This includes data on the CRMs used in vehicles, the proportion of recycled materials, and their location in new vehicles (European Commission, 2023a). Future actions include:

- revising recyclability and reusability calculation methods at the vehicle type-approval stage and,
- creating a circular vehicle passport,
- integrating circularity into the type-approval process for new vehicle types.

4.2.2 Improved treatment processes

The proposed ELV regulation calls for a stricter recycling definition, prohibiting landfill disposal of automotive shredder residue, and setting ambitious goals to enhance the recovery of critical components from ELVs without imposing undue costs on treatment facilities. This will enhance the retrieval of CRMs and elevate the quality of recycled plastics, steel, and aluminum (European Commission, 2023a).

4.2.3 Enhanced collection

The most ambitious policy option suggests delineating responsibilities for destruction certificates, defining criteria to distinguish between used vehicles and ELVs, and implementing new enforcement mechanisms. These measures are anticipated to increase the legally treated ELVs within the EU, aligning with the 'do no significant harm' principle and restricting the export of inoperable vehicles (European Commission, 2023a).

4.2.4 Inclusive coverage of vehicles

The preferred policy option gradually expands the scope of EU regulations to encompass a broader range of vehicles, mandating manufacturers to disclose vehicle composition information. It introduces minimum treatment standards for end-of-life vehicles across various categories, including lorries, buses, and trailers, aiming to reduce the environmental footprint associated with vehicle production and disposal (European Commission, 2023a).

4.3 Actors

When looking at the CE monitoring context (see section Specific circular economy context), it is important to understand the wider actor context. Both from the point of view of processes that will be monitored, as well as the point of view of potential data sources actors may hold from a CE monitoring perspective, as well as from the point of view of digital infrastructures that will need to put in place and allow for data access (Rukanova et al., 2023) . A detailed actor approach will allow to zoom in and gain better understanding of specific data these actors hold and the digital infrastructures holding this data and examine how this data can be of value.

Figure 12 delineates the main actors in the automotive industry, this figure is based on the situation in the Netherlands. The actors are divided into three different groups: government actors, executive actors, and business actors. There will be elaborated on the actors within these dimensions in the following sections.

4.3.1 Government actors

4.3.1.1 European Union

The European Union (EU), through its legislative and governance structures, provides a broad framework for environmental policies, including the management of ELVs and WEEE. It sets the overarching goals and targets for waste reduction, recycling rates, and sustainability practices that member states must achieve.

4.3.1.2 European Commission

The European Commission formulates and enforces regulations for managing ELVs and WEEE, setting collection, recycling, and treatment standards to lessen environmental impact and promote material recovery. It ensures EU member states comply with these standards.

4.3.1.3 EReg

EReg assists European vehicle and driver registration authorities in enhancing and synchronizing registration and licensing policies through knowledge sharing, joint initiatives, and collaboration with non-EU bodies. It operates as a non-profit entity based on voluntary collaboration.

4.3.1.4 Ministry of I&W

The Dutch Ministry of Infrastructure and Water Management develops national ELV and WEEE policies in line with EU directives governing waste management and recycling efforts in the Netherlands.

4.3.2 Executive Actors

4.3.2.1 RDW

The RDW, an autonomous Dutch government agency, oversees vehicle registration and status tracking. It is integral to the market surveillance in the Netherlands and facilitates information exchange with other EU national registration authorities.

4.3.2.2 ARN

ARN, founded by the Dutch automotive industry, manages the collection and processing of end-of-life vehicles, implementing extended producer responsibility, and is financed by a market entry fee for vehicles in the Netherlands. Besides coordination, ARN also engages in sector monitoring, enhancement, and reporting to governmental bodies.

4.3.2.3 ILT

The ILT, under the Ministry of I&W, ensures adherence to regulations in transport, infrastructure, environment, and housing sectors through licensing, enforcement, and research activities.

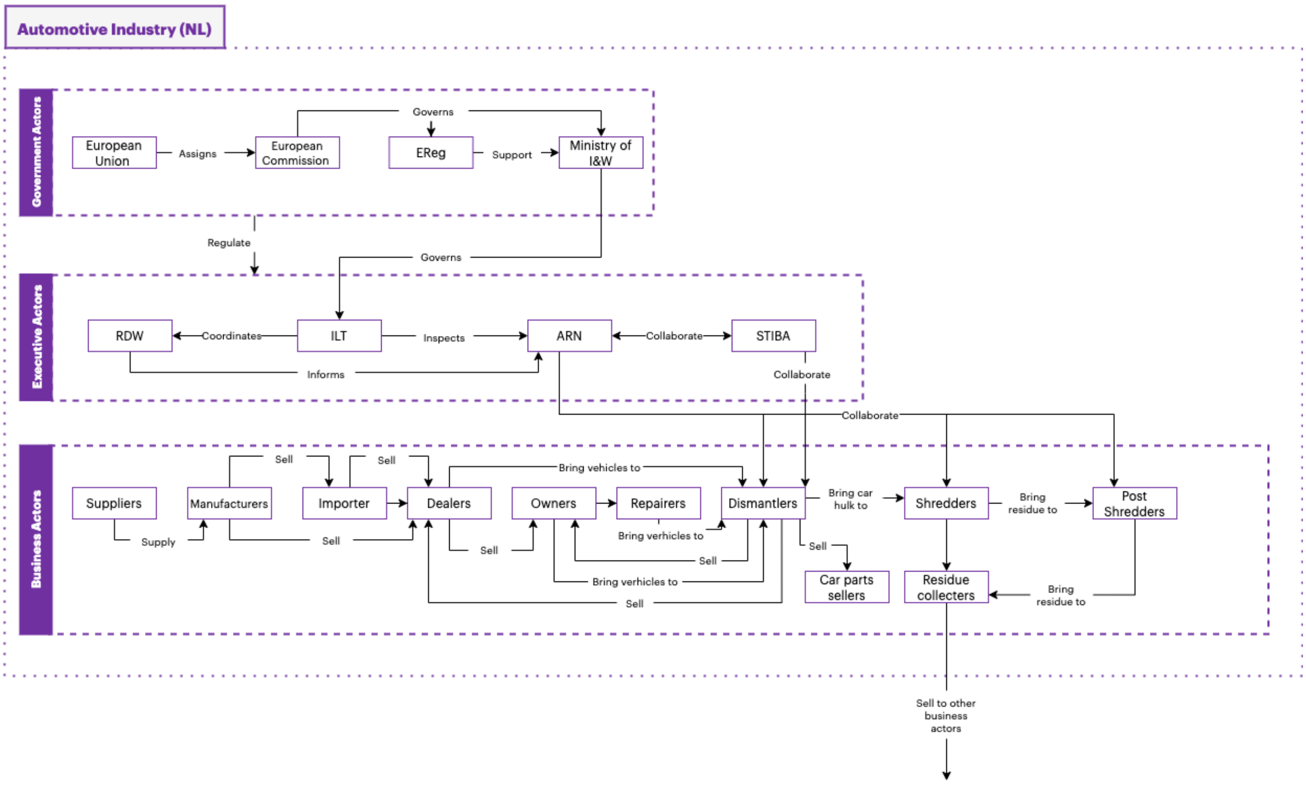

Figure 12 Overview of actors and their interactions (own work)

4.3.3 Business actors

The four most relevant business actors for this thesis, that involved in the ELV management are elaborated upon below. A full overview of all business actors can be found in Appendix C – Business actors.

4.3.3.1 Suppliers

Automotive suppliers provide vital parts and systems to Original Equipment Manufacturers (OEMs), supplying components such as engines, electronics, brakes, and interior parts necessary for vehicle assembly.

4.3.3.2 Manufacturers

Car manufacturers, also known as OEM, are companies that design, produce, assemble, and sell automotive vehicles. They are a critical part of the global economy. Examples are Volkswagen, BMW, Tesla and Volvo.

4.3.3.3 Dismantlers

In the automotive industry car dismantlers are businesses who are specialized in taking apart ELVs to recover usable parts for resale or reuse. They play a crucial role in the automotive recycling industry, extracting and recycling materials.

4.3.3.4 Shredders

Shredding companies are businesses that use industrial shredders to break down various materials, in this case ELVs, into smaller fragments. This process facilitates the separation and recycling of different materials, such as plastics and metals and other CRMs.

4.3.4 Potential actor conflicts regarding information sharing

When investigating all the actors involved in this CE context, multiple conflicts between certain actors could arise. In this section will be elaborated upon which conflicts between which actors could arise.

4.3.4.1 Manufacturers and dismantlers

Legenvre & Hameri (2023) suggest manufacturers withhold detailed information, such as component locations, from for instance dismantlers, to protect their competitive advantage. In the article by Legenvre & Hameri (2023), multiple informants in the automotive industry were interviewed. One of these interviewees mentioned that their company is reluctant to share a complete bill of materials or reveal supplier names and locations. Another interviewee suggested that inventory information can reveal future investments to competitors.

However, selective revealing the information coupled with digital governance can protect data ecosystems and participants. Revealing ELV data should be done after a certain amount of time when the information is less sensitive (Legenvre & Hameri, 2023). ELV are, in general, older vehicle models, therefore data on these older models should be shared. Digital technologies combined with proper human and algorithmic governance can further help the resistance to change.

4.3.4.2 Suppliers, manufacturers and executive actors

Increasing supply chain transparency and data on the makeup of automotive electronic components poses specific challenges. Suppliers and manufacturers may be reluctant to share precise information due to potential conflicts with proprietary rights, including intellectual property and trade secrets, as Ducuing & Reich (2023) note. This resistance can create complex legal issues for executive bodies like ARN in the Netherlands, whose role includes ensuring compliance with directives and regulations.

4.3.4.3 Executive actors and dismantlers, shredders, and post shredders

The destination of recycled materials post-processing by dismantlers, shredders, and post-shredders is currently unavailable. However, it is becoming increasingly important with the upcoming ELV regulation, DPPs, and the Circular Economy Action Plan. Ubacht et al. (2023) argue that additional documentation requests can inadvertently raise business administrative burdens. Executive actors must procure this data through partnerships with recycling stakeholders. However, the increased reporting and data collection could add to their administrative workload, potentially hindering cooperation with these business actors.

4.3.5 Other insights

In exploring the stakeholders engaged in WEEE recycling within the automotive sector, it becomes apparent that no current actors are specifically tasked with recycling electronic waste from End-of-Life Vehicles (ELVs). Tazi et al. (2023) highlight that most elements of electronic components in vehicles are incinerated rather than recycled. While there are some executive organizations in the Netherlands, such as 'Stichting OPEN' do not participate in this supply chain. Consequently, there is a lack of data collection on the electronics present in the automotive industry.

4.4 Digital Infrastructures

For CE monitoring, complex multi-actor infrastructures that serve multiple actors need to be developed or adapted to connect the data that resides in the information systems of the actors in the ecosystem. The automotive industry has increasingly relied on data usage, as recognized by stakeholders (KPMG, 2020). Data sharing is crucial for the CE (Rukanova, Ubacht, et al., 2023). However, some manufacturers see it as a competitive threat. Research on data infrastructures and challenges in supply chains is limited (Legenvre & Hameri, 2023). This section will discuss the automotive industry's current and upcoming data-sharing initiatives.

4.4.1 Current State of Data Sharing in the Automotive

Data storage and sharing are essential in efficiently dismantling and recycling ELVs. According to the current ELVD and the upcoming ELV Regulation, there exists an imperative for manufacturers to facilitate the dismantling and recovery of ELVs by providing dismantlers with essential dismantling information, particularly concerning hazardous materials (Mügge et al., 2023; Rosa & Terzi, 2023). Therefore, the automotive industry has established several databases over the past decades for exchanging product and material data of vehicles. The two most prominent databases are the International Material Data System (IMDS) and the International Dismantling Information System (IDIS). Both will be explained in the sections below.

4.4.1.1 International Material Data System

Several car manufacturers, including Audi, BMW, and Opel, collaborated on a project to develop the concept for electronic material data collection, which laid the foundation for today's International Material Data System (IMDS) (Cozza et al., 2023; Li et al., 2017; Mügge et al., 2023; Oliveira, 2023). IMDS is now the global standard for exchanging and managing material data in the automotive value chain, adopted by nearly all global OEMs (Berzi et al., 2013). The database holds data on the chemical components of products, semi-finished items, and materials, obtained from external suppliers (see Figure 13). However, manual data entry has resulted in many inconsistent material notations.

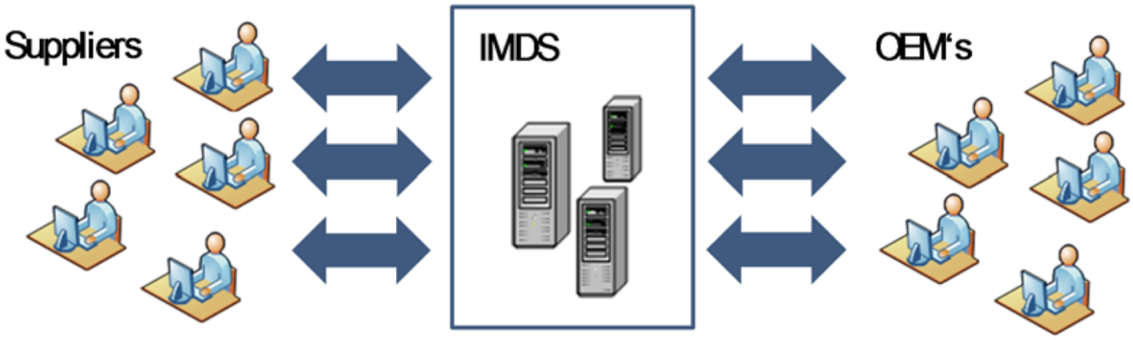

Figure 13 Schema of the interaction between suppliers and OEMs through IMDS (Janus et al., 2012, p.650)

The inconsistency of material notations in the IMDS database leads to a high redundancy and an inflated number of material data sets in the IMDS (Janus et al., 2012). This also makes the integration of IMDS with the internally used product data management system and product lifecycle management system very challenging. Next to that, data sets are complex to evaluate. To make the material information available for governance monitoring in the automotive industry, a standardization of the material notations within a database is essential.

Overall, the IMDS systems have much information regarding the materials within vehicles. However, this data is not publicly available (Gerrard & Kandlikar, 2006). Some automotive manufacturers perceive it as a threat to their competitive advantage (Legenvre & Hameri, 2023). Therefore, another system Information system was introduced, especially for dismantlers, IDIS (Berzi et al., 2013).

4.4.1.2 International Dismantling Information System

Efficient dismantling processes rely on the ability of dismantlers to locate and access valuable components within ELVs. However, pertinent information concerning precious metals and Rare Earth Elements (REE) content in car components is currently unavailable to dismantlers (Arnold et al., 2021). Vehicle manufacturers mainly use IMDS. However, these data are typically inaccessible to dismantlers. Instead, dismantlers depend on the IDIS database. The difference between IMDS and IDIS is explained in Table 4. The IDIS database is a central information system used for ELV management. The IDIS offers information on pretreatment and dismantling for dismantlers and recyclers, ensuring that environmental and safety standards are upheld during the dismantling process (Jäger-Roschko & Petersen, 2022). Information in the IDIS is sourced directly from the manufacturer and includes details about safety-relevant components as per the ELV Directive (Mügge et al., 2023). This system involves the active participation of global automotive manufacturers who provide information about their vehicles, facilitating recycling efforts. The stored data should encompasses material specifications of components, individual part masses, and detailed dismantling procedures, including the necessary tools for each step (Nowakowski, 2018). The difference between the IMDS and the IDIS is elaborated upon in Table 4.

However, there are some complaints about this system, according to the research by Baron et al. (2023), these are listed below.

Lack of Detail

Dismantlers have expressed that while IDIS is rich in information, it often lacks the necessary detail for effective dismantling (Baron et al., 2023). Specifically, information regarding parts with reuse potential is not adequately provided. The primary goal of IDIS is to facilitate rapid dismantling, sometimes at the expense of preserving the functionality of components.

Non-Homogeneous Data

Dismantlers face challenges due to the inconsistent level of data across different vehicle models in IDIS. This inconsistency affects the dismantling process, especially when dealing with specific parts or components secured with digital locks (Baron et al., 2023). The current system requires dismantlers to register for multiple manufacturing systems, each incurring separate costs. This fragmented approach is particularly burdensome for facilities dealing with multiple vehicle brands, leading to prohibitive costs based on the frequency of system access. Additionally, while information on hazardous substances might be available, it lacks specificity at the component level in individual models.

User Interface Issues

Research by Elliott et al. (2019) revealed that out of approximately 12,000 dismantlers in the EU, just over half are registered with IDIS, and it's unclear if all registered users actively utilize the available information. According to Baron et al. (2023) IDIS's interface design is inconsistent and not user-friendly. The interface layout varies depending on the type of information sought, for instance, accessing auxiliary battery data requires navigating through different sections. This design is primarily based on the information structure provided by manufacturers, rather than being tailored to the needs of waste management and dismantling processes. As a result, dismantlers often encounter information that is too general or lacks the necessary depth for practical application. Screenshots of the IDS system are provided in Appendix D – IDIS.

Table 4 Difference between IMDS and IDIS

	IMDS	IDIS
PURPOSE	Designed to track and manage information about the materials used in vehicle parts to ensure compliance with regulations regarding the use of hazardous materials in automobiles.	Its main purpose is to assist authorized treatment facilities (ATFs) in safely and efficiently disassembling ELVs and ensuring proper disposal of hazardous materials.
USER BASE	Vehicle manufacturers, suppliers, and regulatory bodies.	Vehicle manufacturers, and ATFs
DATA CONTENT	Types of metals, plastics, and chemicals used.	Instructions on the dismantling of vehicles

4.5 Answering SQ1: information sharing barriers

In Table 4 an overview of identified barriers is provided to answer SQ1 *What are the current barriers to information sharing regarding WEEE within the automotive industry?*

In addressing SQ1, a socio-technical approach was used based on the Framework by Rukanova et al. (2023). This approach offers a comprehensive perspective on the interactions between technology, society, and legislation within the circular economy context. During the system analysis, valuable insights were gained concerning global ELV management and the current practice of WEEE recycling in the automotive industry. Next, the new ELV Regulation proposal offers an opportunity to address this issue, delving into crucial values and aspects, but an information-sharing infrastructure needs to be established to support these objectives. Actors within this ecosystem play a significant role, and it is noteworthy that no experts are currently actively managing WEEE within ELVs. Dismantling companies primarily rely on the shredding processes, resulting in losing CRMs. Also, multiple potential stakeholder conflicts, especially concerning information sharing, were identified. Manufacturers, for instance, may be reluctant to share data for various reasons.

Table 4 outlines the identified barriers to information sharing regarding WEEE in the automotive industry, categorized by different dimensions such as Circular Economy Context (CE), Public Value (PV), Actors (AC), and Digital Infrastructure (DI). These barriers, sourced from a range of studies conducted between 2006 and 2023.

Barrier **B1** identifies a critical issue of incomplete documentation, where dismantlers lack the necessary data to identify and process EEE, thereby hindering proper recycling efforts. This problem is primarily related to the digital infrastructure dimension, as noted by several studies including Tazi et al. (2023) and Arnold et al. (2021).

Barrier **B2** points out the limited recovery of electronics in ELVs, with recycling facilities struggling to sort ELV electronics effectively, resulting in the loss of valuable printed circuit boards PCBs and ECUs, a challenge that was elaborated upon in section 4.1.2.

The lack of harmonization (**B3**) across global ELV practices leads to inconsistent processing and data storage. Similarly, barriers **B4** through **B9** underscore various issues such as information gaps between manufacturers and dismantlers, inconsistent data entry, perception of competitive threat, supply chain transparency conflicts, administrative burdens, lack of standardization, and restricted data accessibility. These barriers encompass challenges related to actors (section 4.3.4) in the recycling process and digital infrastructure (4.4), indicating obstacles in achieving efficient recycling practices and the expansion of the circular economy.

Overall, the table highlights the multifaceted challenges in WEEE information sharing , underscoring the need for improved documentation, harmonization, transparency, and standardization to overcome these barriers and enhance component recovery and recycling efforts.

Table 5 All 11 identified barriers though the system analysis

ID	BARRIER	DESCRIPTION	DIMENSION(S) CE = CIRCULAR ECONOMY CONTEXT PV = PUBLIC VALUE AC = ACTORS DI = DIGITAL INFRASTRUCTURE	SOURCE(S)
B1	**Incomplete documentation**	Dismantlers lack critical data for identifying and processing EEE, impeding proper recycling and component recovery.	DI	Tazi et al. (2023), Arnold et al. (2021), Williams et al. (2020), Li et al. (2017)
B2	**Limited recovery of electronics in ELVs**	Recycling facilities cannot sort ELV electronics, losing valuable PCBs and ECUs.	CE	Berzi et al. (2013), Cozza et al. (2023), Tazi et al. (2023)
B3	**Lack of harmonization**	Diverse global ELV practices cause inconsistent processing, monitoring, and data storage.	CE, DI	Baron et al. (2023), Mügge et al. (2023)
B4	**Information gap between manufacturers and dismantlers**	Manufacturers and dismantlers struggle with a significant information gap on vehicle component details, hampering recycling efforts.	AC, DI	Tazi et al. (2023), Baron et al. (2023), Arnold et al. (2021)
B5	**Inconsistent data entry**	IDIS and IMDS inconsistent data entry leads to chaotic, non-uniform information, making specific part identification difficult for dismantlers.	AC, DI	Oliveira (2023), Baron et al. (2023), Li et al. (2017),
B6	**Perception of competitive threat**	Manufacturer's view data sharing as a threat to their competitive advantage, making them hesitant to share detailed information.	AC	Walden et al. (2021),
B7	**Administrative burden**	Additional documentation requests could burden businesses, with executive bodies facing pushback when enforcing new regulations.	AC, DI	Ubacht et al. (2023)
B8	**Lack of standardization**	Both IMDS and IDIS lack standardized data entry methods, resulting in disorganized and inconsistent data across the industry.	DI	Baron et al. (2023), Li et al. (2017), Janus et al. (2012)
B9	**Restricted data accessibility**	The information within the IMDS is not publicly available, limiting the ability of all stakeholders to use this data for recycling and CE monitoring.	DI	Baron et al. (2023) Walden et al. (2021), Gerrard & Kandlikar (2006)

This comprehensive system analysis serves as a valuable input for the elicitation of requirements in chapter 5.

5 Requirement Elicitation

This chapter established requirements for information sharing regarding WEEE in ELVs within the automotive industry. The outcome of this chapter is a list of requirements. These requirements are meant to address the current needs for an information-sharing infrastructure from different viewpoints.

This chapter will answer SQ2:

"What requirements are necessary to enable effective information sharing for dismantlers regarding WEEE within the automotive industry?"

A combination of desk research and interviews are applied to elicit the requirements. The reasoning behind the methods used is given in section 5.1.

The requirements will be provided in a breakdown structure numbering (e.g., 1., 1.1, 1.1.1). This provides a structure to follow the line of research. The higher-level functions provide general functions that the information-sharing infrastructure should have; the lower-lever requirements specify these functions.

SQ2 will be answered with three sub-SQs based on the different viewpoints.

SQ2-A*: What are the requirements based on the identified barriers?*
This question will be answered based on the identified barriers from the system analysis done in Chapter 4, see section 5.2.

SQ2-B: *What are the requirements based on the legislative landscape?*
This question will be answered based on analyzing three legislative documents: the ELV Regulation, the WEEE Directive, and the CRM Act, see section 5.3.

SQ2-C: *What are the requirements from the point of view of the dismantler?*
This question is answered based on the interviews and informative conversations conducted with different stakeholders in the field, see section 5.4.

The requirements gained from these three methods will be combined in section 5.5, which results in one list of requirements. These will then be reviewed by two experts in the field of ELV dismantling in section 5.6. The reviewed requirements will then be used to answer SQ2 (section 5.7).

The answer of this SQ2 will be used in chapter 6, where is investigated how the IDS aligns with these identified requirements.

5.1 Requirements elicitation process

Figure 14 presents a comprehensive overview of the requirements elicitation process, inspired by the define requirements methodology outlined by Johannesson & Perjons (2014). The explicated problem represents issues highlighted in earlier chapters, notably the inefficient handling of WEEE in ELVs. A significant concern is the incineration of WEEE, leading to the loss of CRMs. Additionally, there's an identified gap in the information available to car dismantlers. The existing databases lack crucial data needed for efficient dismantling, and car manufacturers have shown reluctance in sharing this information. The proposal of new ELV Regulation underscores the necessity for more detailed information about the location of CRMs in vehicles, which are mostly within WEEE components. An improved framework for information sharing infrastructure, such as the IDS, could potentially enhance manufacturers' willingness to share data. However, for this to be effective, the specific information needs of the dismantlers must be considered and addressed.

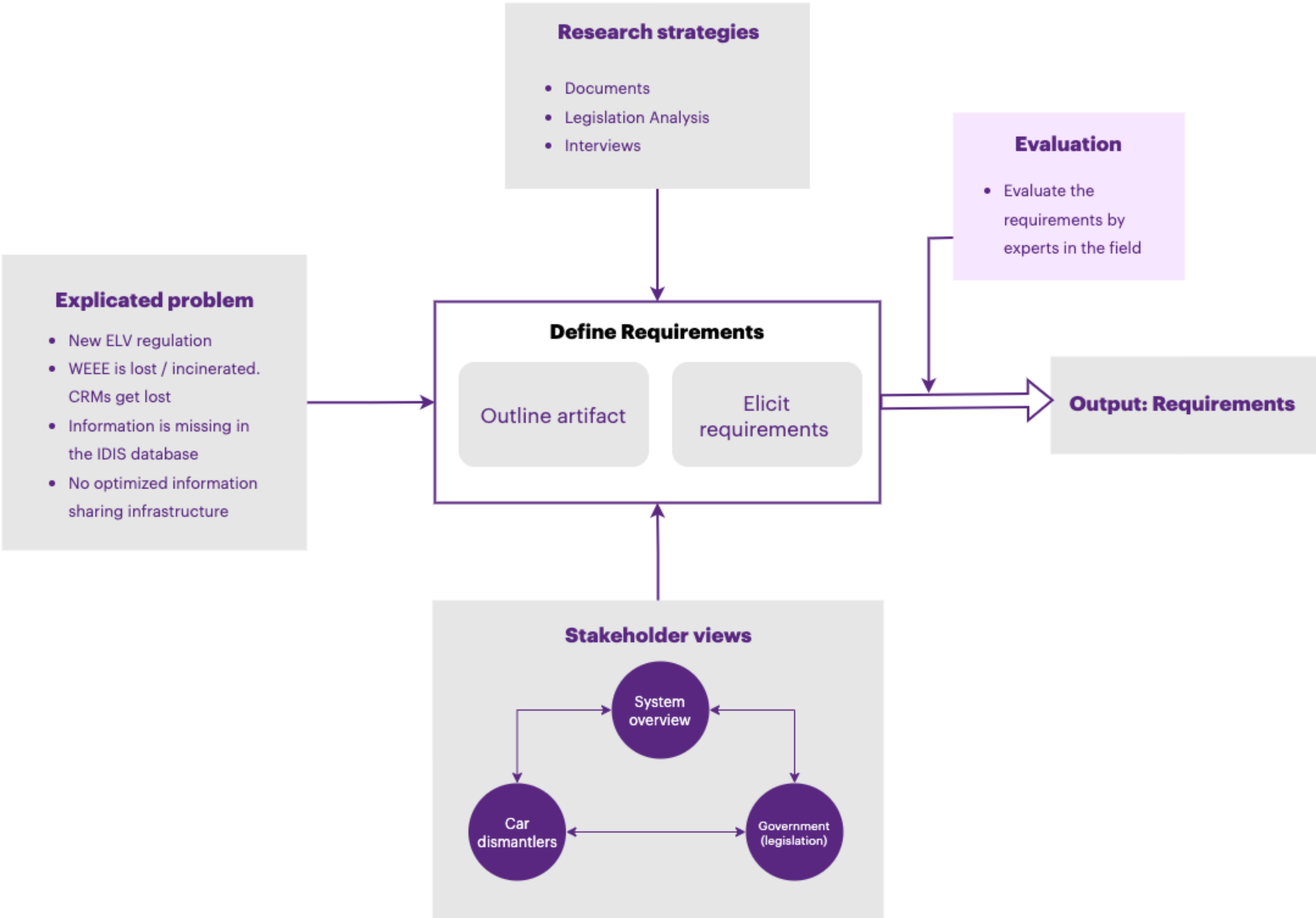

Figure 14 Requirements Elicitation overview based on Johannesson & Perjons (2014)

The requirements can be divided into two main categories: functional requirements and non-functional requirements. Functional requirements refer to the functions of the artifact and depend on the problem to be addressed as well as the needs and wants of the stakeholders. It can be said that functional artifacts cover the tasks to be executed and drive the architecture. The non-functional requirements are those requirements that are not functional and encompass both structural and environmental requirements (Johannesson & Perjons, 2014). Structural requirements pertaining to structure and environmental requirements pertaining to the environment are usually more generic.

The following three research strategies are used to elicit the requirements.

Barrier analysis

This analysis will be done based on barriers identified in the previous chapter, based on the desk research. According to Johannesson & Perjons (2014) document studies can complement other methods of requirements elicitation, or can be an alternative when access to stakeholders is limited. Documents can expose contradictions in practice and, therefore, be a valuable source for identifying and defining barriers (Johannesson & Perjons, 2014). For this analysis the identified barriers in Table 5 were used. Based on these barriers, the requirements will be elicited. The final list of so called 'document requirements' is shown in Table 6.

ELV Regulation, WEEE Directive and CRM Act analysis

There are multiple legislative documents, such as directives and regulations, that state requirements regarding ELV, WEEE, and CRM information sharing. The upcoming ELV Regulation is an example of a regulation containing multiple requirements. Also, the WEEE Directive and CRM Act contain requirements that must be considered in this field. Analyzing the requirements within these legislative documents will result in a list of requirements. These 'legislative requirements are shown in Table 7.

Interview analysis

Interviews may be the most common method for gathering requirements, according to Johannesson & Perjons (2014) and Robertson (2001). Interviews take a direct approach to eliciting requirements by asking stakeholders about features they would like to see included in the outlined artifact. In this case, two informative conversations were held with the ARN and the TNO about this topic. The ARN manages the collection and processing of end-of-life vehicles, and the TNO is an independent research organization in the Netherlands that focuses on applying scientific knowledge to address practical problems in industry, government, and societal sectors. Also, two car dismantlers were interviewed, and a senior legal professional at STIBA was interviewed. Based on these interviews more requirements are elicited. A list of these requirements is shown in Table 9.

After these three different analyses, the recruitments will be combined in section 5.5. These requirements will be used during an evaluation (section Evaluation and revision) with two experts regarding dismantling in the automotive industry.

The final set of requirements will be given in section 5.6.

5.2 Requirements elicitation: based on identified barriers

As mentioned in section 5.1 the elicited document requirements are based on the barriers identified in Table 5. In this section there will be referred to this table and the Barrier_IDs. The aim of this section is answering SQ2-A.

The first two barriers in Table 5 are **B1 Incomplete documentation**, meaning that dismantlers lack critical and detailed data for identifying and processing EEE, and **B2 Limited recovery of electronics from ELVs**. These barriers together form the basis for the first requirements: *D1 The information sharing infrastructure should provide access to EEE vehicle data for dismantlers, D1.1 The information sharing infrastructure should provide detailed component data, and D1.2 the information sharing infrastructure should provide location data of components.* These requirements will help dismantlers with a more efficient dismantling process.

Recognizing the operational challenges often faced by car dismantlers, the new information sharing infrastructure should reduce the administrative workload. Reducing the administrative burden is also important for manufacturers, as currently they have to maintain the IDIS and IMDS. This could also be more efficient. This is identified as barrier **B8 Administrative burden**. Based on this barrier requirement, *D2 The interface of the information sharing architecture should be easy to use for dismantlers,* and *D2.1 The information sharing infrastructure should minimize the administrative burden*. In addition, *D2.2 The information sharing infrastructure should standardize the data entry process* is based on barriers **B3 Lack of harmonization**, **B5 Inconsistent data entry** and **B9 Lack of standardization.** These three barriers are all about standardization and a good data entry process. **B10 Restricted data accessibility** state that the crucial information is not publicly available for all stakeholders, including dismantlers. Therefore, the following requirement was elicited, *D2.3 The information sharing infrastructure should be free of charge for stakeholders like dismantling companies and institutional organizations*.

Balancing the need for transparency with the protection of intellectual property rights is another crucial aspect that needs to be considered. This is also stated by the following barriers: **B6 Perception of competitive threat**, and **B7 Supply chain transparency conflicts**. Combining these two barriers resulted in requirement *D3 The information sharing infrastructure facilitate digital data sovereignty*. The combination of the barriers **B6 Perception of competitive threat** and **B10 Restricted data accessibility** resulted in the requirement *D3.1 The information sharing infrastructure should facilitate access control, and D3.2 The information sharing infrastructure should facilitate usage control.*

Table 6 presents a list of requirements derived from the system analysis to identify the barriers. The requirements are categorized as either functional or non-functional requirements. Additionally, the related Barrier IDs from Table 5 are given to specify the sources of each requirement.

Table 6 List of requirements barrier analysis

ID	REQUIREMENT	TYPE	RELATED BARRIER ID
D1.	The information sharing infrastructure should provide access to EEE vehicle data for dismantlers	Functional	B1
D.1.1	The information sharing infrastructure should provide detailed component data	Functional	B1
D1.2	The information sharing infrastructure should provide location data of components	Functional	B1
D2.	The interface of the information sharing infrastructure should be easy to use for dismantlers	Non-Functional	B8
D2.1	The information sharing infrastructure should minimize the administrative burden	Non-Functional	B8
D2.2	The information sharing infrastructure should standardize the data entry process	Non-Functional	B3, B5, B8
D2.3	The information sharing infrastructure should be free of charge for stakeholders like dismantling companies and institutional organizations	Non-Functional	B9
D3.	The information sharing infrastructure facilitate digital data sovereignty	Non-functional	B6,
D3.1	The information sharing infrastructure should facilitate access control	Functional	B6, B9
D3.2	The information sharing infrastructure should facilitate usage control	Functional	B6, B9

B2 and **B4** are not considered in this table as these are too general for these requirements.

5.3 Requirements elicitation: based on the ELV Regulation, WEEE Directive and the CRM Act

The institutional requirements are based on the ELV Regulation (ELVR), the WEEE Directive (WEEED), and the CRM Act (CRMA). The choice of these three legislations is elaborated upon in Appendix D.

These regulations/directives focus on enhancing the accessibility and utility of information for vehicle dismantling, recycling, and critical material recovery. The aim of this section is answering SQ2-B.

According to the **ELVR**, the dismantling sector called for more ambitious legislation on dismantling information sharing from manufacturers. One of the measures in the ELVR proposal is providing dismantling information to ELV treatment operators (including dismantlers). Based on this, the first requirement was identified as *L1 The information sharing infrastructure should provide access to fundamental dismantling information*. Requirements *L1.1 The information on the use and the location of CRMs in ELVs should be provided,* and *L1.2 The information on the share of recycled content within the vehicle should be provided*, were also based on the **ELVR**. It states the following:

> *"The preferred option contains short-term obligations for vehicle manufacturers to make available detailed and user-friendly dismantling and recycling information, including the use and location of CRMs in vehicles and information on the share of recycled content in new vehicles."* (European Commission, 2023a)

Next to that, according to the **ELVR**, manufacturers must provide information on the safe removal and replacement of parts, components, and materials contained in vehicles. Similar statements about the safe removal of parts and materials are mentioned in the **WEEED** and the **CRMA**. Therefore, the following requirement is *L1.3 The information on the safe removal and replacement of parts, components, and materials contained in vehicles should be provided.* Finally, requirement *L1.4, The information for dismantlers should be accessible free of charge*, is based on Article 11(2) from the **ELVR** and Article 18(5) from the **CRMA**.

> *"Article 11 obliges manufacturers to provide information on the safe removal and replacement of parts, components and materials contained in vehicles. This information must be accessible free of charge to waste management operators and repair and maintenance operators."* (European Commission, 2023a)

Based on the above-mentioned quote from the **ELVR**, and the statement by the **CRMA** that CRM information should be publicly available in a user-friendly digital from the following two requirements were elicited: *L3 The information sharing infrastructure should facilitate user friendly dismantling and recycling information*, and *L3.1 The information sharing infrastructure must provide easy access to dismantling information.*

The only regulation that makes statements about interoperability is the **ELVR**. According to the **ELVR,** increased digitalization, including interoperability with a single window system, will increase the efficiency of both enforcement authorities and businesses. It also states in ELVR PO4-Collect More (4B) that there should be interoperability of vehicle registries amongst Member States. These statements resulted in the following requirements: *L2 The information sharing infrastructure facilitates interoperability between information systems*, and *L2.1 The information sharing infrastructure should ensure interoperability between national vehicle registries.*

Article 13 of the **ELVR** state that a circularity passport should be established, a digital tool used to improve the provision of information on vehicle data. This shall be used as a data carrier for such vehicle information. Therefore, the following requirement is derived*: L4 The information sharing infrastructure facilitates a circularity vehicle passport.* In Article 13(4) multiple requirements are given about compliance with open standards, transferability, and machine-readability, structuredness and searchability. This resulted in more requirements*, L4.1 The information included in this circularity vehicle passport should be based on open standards, L4.2 The information included in this circularity vehicle passport should be transferable through an open interoperable data exchange network without vender lock in*, and *L4.3 The information included in this circularity vehicle passport should be machine-readable, structured, and searchable.*

According to the **WEEED**, for producers of electrical and electronic equipment, there are specific requirements for online registration in national registers. This resulted in requirement L5 The information sharing infrastructure facilitates each EEE producer to enter their activities online in their national register. All the requirements are mentioned in Annex X of the **WEEED**. It includes providing comprehensive details such as the producer's name, address, national identification code (including E.U. tax or national tax number), type of electrical and electronic equipment (EEE), brand name, and how the producer fulfills its responsibilities. A declaration affirming the accuracy of this information is also required. Based on Annex X from the **WEEED** the following requirements were derived: *L5.1 The information submitted upon registration should include name and address of the producer, L5.2 The information submitted upon registration should include the national identification code, including EU tax number of national tax number of the producer, L5.3 The information submitted upon registration should include type of EEE, L5.4 The information submitted upon registration should include brand name, L5.5 The information submitted upon registration should include information on how the producer meets its responsibilities*, and *L5.6 The information submitted upon registration should include a declaration stating that the information is true*

Lastly, a comprehensive database is envisaged, as stated in the **CRMA**, to include all relevant information to promote the recovery of CRMs, aligning with the broader objectives of resource efficiency and sustainability in the vehicle life cycle. This resulted in the final institutional requirement *L6 The information sharing infrastructure includes a database containing all information relevant to promote recovery of CRMs.*

Table 7 presents the list of the requirements derived from an analysis of three regulations in a structured manner, categorizing them as either functional or non-functional. Additionally, the table specifies the sources for each requirement.

Table 7 List of requirements institutional analysis

ID	REQUIREMENT	TYPE	SOURCE
L1.	The information sharing infrastructure should provide access to fundamental dismantling information	Functional	ELVR
L1.1	The information on the use and the location of CRMs in ELVs should be provided	Functional	ELVR
L1.2	The information on the share of recycled content within the vehicle should be provided	Functional	ELVR
L1.3	The information on the safe removal and replacements of parts, components, and materials contained in vehicles should be provided	Functional	ELVR, WEEED, CRMA
L1.4	The information for dismantlers should be accessible free of charge	Non-Functional	ELVR, CRMA
L2.	The information sharing infrastructure facilitates interoperability between information systems	Non-Functional	ELVR
L2.1	The information sharing infrastructure should ensure interoperability between national vehicle registries	Non-Functional	ELVR
L3.	The information sharing infrastructure should facilitate user friendly dismantling and recycling information	Non-Functional	ELVR, CRMA
L3.1	The information sharing infrastructure must provide easy access to dismantling information	Functional	ELVR
L4.	The information sharing infrastructure facilitates a circularity vehicle passport	Functional	ELVR

ID	REQUIREMENT	TYPE	SOURCE
L4.1	The information included in this circularity vehicle passport should be based on open standards	Non-Functional	ELVR
L4.2	The information included in this circularity vehicle passport should be transferable through an open interoperable data exchange network without vender lock in	Non-Functional	ELVR
L4.3	The information included in this circularity vehicle passport should be machine-readable, structured, and searchable	Non-Functional	ELVR
L5.	The information sharing infrastructure facilitates each EEE producer to enter their activities online in their national register	Functional	WEEED
L5.1	The information submitted upon registration should include name and address of the producer	Functional	WEEED
L5.2	The information submitted upon registration should include the national identification code, including EU tax number of national tax number of the producer	Functional	WEEED
L5.3	The information submitted upon registration should include type of EEE	Functional	WEEED
L5.4	The information submitted upon registration should include brand name	Functional	WEEED
L5.5	The information submitted upon registration should include information on how the producer meets its responsibilities	Functional	WEEED
L5.6	The information submitted upon registration should include a declaration stating that the information is accurate	Functional	WEEED
L6.	The information sharing infrastructure includes a database containing all information relevant to promote recovery of CRMs	Functional	CRMA

5.4 Requirements elicitation: based on the interviews

Three interviews, and two explorative conversations, were conducted to elicit the requirements from the perspective of the dismantlers. The processes of the selection of interviewees and the data analysis are elaborated on in the following sections. After that, the process of eliciting the requirements is discussed in section 5.4.5. The aim of this section is answering SQ2-C.

5.4.1 Selection of interviewees

The interview/conversation partners were accessed with three different methods. The first interviewee was accessed through the available network. The interviewee works for the for the ARN. Therefore, it was possible to plan an explorative conversation early in the process. This conversational partner from the ARN provided access to another expert conversation partner from the TNO, which was the second method.

Finally, the last three interviewees, the car dismantling companies and the STIBA, where accessed through searching Google for dismantling companies in the Netherlands. During the selection process of these dismantling companies, there was looked at the labels and certifications and collaborative partners. If these companies were recognized by the ARN and RDW an e-mail was sent to 14 dismantling companies with the question if they are willing to participate in this research. Finally, three different dismantlers were interviewed.

5.4.2 Interview Medium

Some interviews were conducted online and others offline. It depended on the preferences of the interviewees. The informative conversations (1 online and 1 offline) where not recorded and held in Dutch. After these conversations a conversational report was created where the conversations were translated to English. This report was sent to the participants. Here they judge see if everything was interpreted in the right manner, and they could make changes if they wanted to. These conversations did not follow a specific structure. Summaries of the explorative conversations can be found in Appendix F – Explorative Conversations.

The interviews with the dismantling companies (2 online and 1 offline) were recorded through a mobile device and/or Microsoft Teams. The provided questions and the consent form can be found in Appendix G – Interviews. The interviews were conducted in a semi-structured manner to provide consistency of discussed topics and the gain more insights into the requirements from the car dismantlers viewpoint. Next to that, it allowed for individual comments of the different interview partners.

5.4.3 Data analysis

To analyse the data properly the interviews were transcribed. These transcripts are not shared in the appendix of this thesis but could be accessed by the thesis supervisors. The transcripts were loaded into the software program Atlas.ti for further analysis through coding. First, open coding used to break data into discrete parts and create codes which were labeled. Second, axial coding was used to draw the connections between the codes by grouping them intro categories.

5.4.4 Interviewees

In this study, five participants were selected to ensure diverse perspectives and expertise on this topic. The details of the participants can be found in Table 8.

Table 8 Overview of Interviewees

ID	DATE	EXPERTISE	TYPE
P1	02-10-2023	Experienced innovation coordinator at the ARN	Explorative Conversation
P2	15-11-2023	Circular Electronics professional from the TNO	Explorative Conversation
P3	11-12-2023	A professional and certified car dismantling company with many years of experience	Interview
P4	11-12-2023	A professional and certified car dismantling company with many years of experience	Interview
P5	05-01-2023	Legal professional at STIBA	Interview

5.4.5 Requirement Elicitation

Based on these interviews, **P1, P3, P4**, and **P5** stated that the current information systems, mainly IDIS, lack accurate information about car components, including electronics. Within the IDIS database, it is not even clickable. However, as mentioned in the previous sections, this information is vital. Therefore, the first requirement addresses this lack of information*: I1 The information sharing infrastructure should facilitate access to detailed dismantling information*, and *I1.2 The information sharing infrastructure should facilitate EEE dismantling information*. According to **P3**, specific safety data for electric vehicles must also be included, which resulted in *requirement I1.2 The information sharing infrastructure should include specific safety data for electric vehicles.*

Next to that, information about component numbers is currently not clear. **P4** and **P5** stated the following about this during the interview:

> *P4: "We want to know the component numbering. They also create modification numbers, but manufacturers are reluctant to share them. [...] Now I have to investigate what a certain component does, making it harder for me to sell these."*

> *P5: "There are two important things. One is simply the component numbers. A component number is not a fixed entity. If there is a small modification to a component, it already gets a new number. [...] Then, I do not want just to know a component number; I also need to know the entire history of the component number and understand the interchangeability — so I know where this part could be used."*

Based on these statements the following requirement was elicited: *I1.3 The information sharing infrastructure should provide data about interchangeability of components*. This means components with different numbers, but the same functionalities should be linked.

Another interested finding, pointed out by **P5**, is that insights are needed into the digital procedures for component activation and updates, streamlining the integration of components into new vehicles. This is particularly pertinent as vehicles become increasingly digital and interconnected.

> *P5: "If I have to transfer the windshield wiper motor from one modern car to another, for example, from a Volvo or Peugeot to another identical Volvo or Peugeot, then I need to ensure that it is fully registered before it can be used. You have to digitally enroll the component because you can install it and connect the plug, but then the car will say, "I do not have a windshield wiper motor; it is not there."*

This finding led the formulation of requirement I1.4 The information sharing infrastructure should provide information about digital procedures for component activation.

During the informative conversation with **P1**, it was mentioned that, currently, there is no standardized way to enter data into IDIS. This was also pointed out in the interviews with **P4** and **P5**. This resulted in *requirement I2 The information sharing infrastructure should ensure standardized data and uniformity*. Next, **P1** mentioned that the data lacks specificity; while some OEMs may note using materials like aluminum or plastic, the exact type is not always specified. This lack of detail can impact the recycling process and the eventual application of the recycled material. Ambiguous information complicates the recycling attempt. Therefore, requirement *I2.1 The information on CRMs should be specific and non-ambiguous*, was formulated.

Finally, obtaining data through the current system presents usability challenges for dismantlers, as highlighted by both **P4** and **P5. P5** stated the following about this:

> *P5: "We benefit from a system that is not only user-friendly but also has a fixed, standardized, and sensible format, ensuring everything is easily locatable. This way, a dismantler, even with dirty hands or wearing gloves, only needs to click three times to access the information. They*

should not have to sit down, clean themselves off, and spend an hour sighing deeply while navigating IDIS. Frankly, if that is the case, we simply will not use it."

This statement resulted in another requirement *I3 The information sharing infrastructure should be easy to use for dismantling companies*.

Also, for institutional organizations, the data about electronics recycling within the automotive industry is not easy to access. According to the informative conversation with **P2**, the data they use is from the ProSUM (Prospecting Secondary raw materials in the Urban mine and Mining wastes, 2015-2017) project. This project will deliver the First Urban Mine Knowledge Data Platform, serving as a comprehensive repository for all accessible data and insights regarding the generation, inventory, circulation, and processing of WEEE, ELVs, batteries, and mining wastes (Løvik et al., 2021).

However, this data is also not available to everyone. Therefore, the final requirement is *I3.2 The data within the information sharing infrastructure should be easily accessible for dismantling and institutional organizations*.

Table 9 presents the list of requirements derived from the interviews and the informative conversations in a structured manner, categorizing them as either functional or non-functional. Additionally, the table specifies which interviewee was the source for the requirement.

Table 9 List of interview requirements

ID	REQUIREMENT	TYPE	SOURCE
I1.	The information sharing infrastructure should facilitate access to detailed dismantling information	Functional	P1, P3, P4, P5
I1.1	The information sharing infrastructure should facilitate EEE dismantling information	Functional	P1, P3
I1.2	The information sharing infrastructure should include specific safety data for electric vehicles	Functional	P3
I1.3	The information sharing infrastructure should provide data about interchangeability of components	Functional	P4, P5
I1.4	The information sharing infrastructure should provide information about digital procedures for component activation	Functional	P5
I2	The information sharing infrastructure should ensure standardized data and uniformity	Non-Functional	P1, P4, P5
I2.1	The information on CRMs should be specific and non-ambiguous	Functional	P1
I3.	The information sharing infrastructure should be easy to use for dismantling companies	Non-Functional	P4, P5
I3.1	The information sharing infrastructure should have a user-friendly and accessible interface	Non-Functional	P5
I3.2	The data within the information sharing infrastructure should be easily accessible for dismantling and institutional organizations	Non-Functional	P2

An overview of the related requirements and interview quotes is given in G.3 Interview Analysis.

5.5 Combine Requirements

In this section, the outcomes of the previous sections are combined into one requirement list. All final requirements be shortly discussed, and the tables show the related requirement IDs based on the previous sections.

5.5.1 Requirement 1: The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers.

This first requirement is related to the requirements D1, L1 and I1. All these requirements address that the information sharing infrastructure should facilitate access to detailed dismantling information for dismantlers. Based on this requirement multiple sub requirements were formulated; these requirements can be found in Table 10. All of these requirements were already explained in earlier sections. Requirement *1.1.3 The information should include data about the type of EEE, the brand name, and how the supplier meets responsibilities*, is new and related to L5, L5.1, L5.2, L5.3, L5.4, L5.5, L5.6. These were all combined as one requirement as it all represent a type of EEE data.

Table 10 Overview of requirement 1

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
1	The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers	B1, B11	ELVR	P1, P3, P4, P5	D1, L1, I1
1.1	The information on detailed EEE component data should be available for dismantlers	B1		P1, P3	D1.1
1.1.1	The information should include detailed data about the location of these EEE components	B1	ELVR, WEEED		D1.2, L1.1
1.1.2	The information should include information on component and material identification regarding EEE		WEEED		I1.1
1.1.3	The information should include data about the type of EEE, the brand name, and how the supplier meets responsibilities		WEEED		L5, L5.1, L5.2, L5.3, L5.4, L5.5, L5.6
1.1.4	The information sharing infrastructure should provide data about interchangeability of components			P5	I1.3
1.2	The information should include the share of recycled content within a vehicle		ELVR		L.1.2
1.3	The information should include information on the safe removal of parts, components, and materials within ELVs		ELVR, WEEED, CRMA	P3	L1.3, I1.2
1.4	The information should include information relevant to promote recovery of CRMs		CRMA		L7
1.5	The information should include information about digital procedures for component activation			P5	I1.4

5.5.2 Requirement 2: The information sharing infrastructure should be easy to use for dismantlers

As was clearly highlighted by the quote of P5 in section *Requirement Elicitation* the information sharing structure interface should be easy to use. Requirement 2 is based on requirement I3. To accomplish this requirement, the information should be accessible in a user-friendly manner, the data entry process should be standardized, the administrative burden must be low, and the information should be free of charge. An overview of requirement 2 is given in Table 11.

Table 11 Overview of requirement 2

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
2.	The information sharing infrastructure should be easy to use for dismantlers			P4, P5	I3
2.1	The information should be accessible in a user-friendly manner	B8	ELVR, CRMA	P5	L3, I3.1
2.2	The information sharing infrastructure should minimize the administrative burden for dismantlers and manufacturers	B8			D2.1
2.3	The information sharing infrastructure should have a standardized data entry process	B6, B9		P1, P2, P4, P5	D2.2, I2, I2.1
2.4	The information for dismantlers should be accessible free of charge	B9	ELVR, WEEED		D2.3, L1.4

5.5.3 Requirement 3: The information sharing infrastructure facilitate digital data sovereignty.

Requirement 3 is fully based on the document analysis (D3). There multiple barriers were highlighted about the unwillingness of manufactures to share component and material data. To increase the willingness of manufactures to share data in the future, the information infrastructure should facilitate access control. An overview of requirement 4 is given in Table 12.

Table 12 Overview of requirement 3

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
3	The information sharing infrastructure facilitate digital data sovereignty	B6			D3
3.1	The information sharing infrastructure should facilitate access control	B6, B9			D3.1
3.2	The information sharing infrastructure should facilitate usage control	B6, B9			D3.2

5.5.4 Requirement 4: The information sharing infrastructure should provide interoperability between information systems.

Requirement 4 about the interoperability is based on the ELVR (L2). This requirement did not come forward in the other two perspectives. Section 5.3 dives deeper into these requirement(s). An overview of requirement 4 is given in Table 13.

Table 13 Overview of requirement 4

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
4.	The information sharing infrastructure should provide interoperability between information systems E		ELVR		L2
4.1	The information sharing infrastructure should ensure interoperability between national vehicle registries		ELVR		L2.1

5.5.5 Requirement 5: The information sharing infrastructure should facilitate a circularity vehicle passport.

Requirement 5 is about the circularity vehicle passport; this requirement is also fully based on the ELVR (L4). This requirement did not come forward in the other two perspectives. Section 5.3 dives deeper into these requirement(s). An overview of requirement 5 is given in Table 14.

Table 14 Overview of requirement 5

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
5.	The information sharing infrastructure facilitates a circularity vehicle passport		ELVR		L4.
5.1	The information included in this circularity vehicle passport should be based on open standards		ELVR		L4.1
5.2	The information included in this circularity vehicle passport should be transferable through an open interoperable data exchange network without vender lock in		ELVR		L4.2
5.3	The information included in this circularity vehicle passport should be machine-readable, structured, and searchable		ELVR		L4.3

5.6 Evaluation and revision

In this section, the elicited list of requirements will be revised after evaluation. The outcome of this section is a list of revised requirements which can be used as input for chapter 6.

Table 15 Evaluation Participants

ID	DATE	EXPERTISE
P5	05-01-2023	Legal professional at a Dutch organization dedicated to car dismantling
P6	12-01-2023	Professional in the field of reuse and recycling in the automotive industry

The evaluation was planned with two experts, P5 and P6. P5 also participated in the interview. P6 was only questioned to evaluate the requirements.

During this evaluation, each requirement was evaluated. During the sessions the retrieved requirements were mentioned, and the evaluators gave immediate feedback. The experts' evaluations and comments are systemically collected. Table 17 Revised list of requirements provides an extensive revision table including the remarks of these two experts.

5.6.1 Insights from the evaluation

Based on the revision of the information requirements in discussion with the two experts, general conclusions are drawn in this section.

Based on the discussion with **P5**, there are three main types of information the dismantlers need:

1. **Digital Information:** This is information on how to install and update EEE components in vehicles. It is also about learning vehicles to use certain EEE. This is crucial for the reuse of specific components.
2. **Component Information:** This is information about vehicle components, their functionality, and their location.
3. **Material Information:** This is information about the material composition of vehicles.

These three information types are essential for dismantlers to understand how to reuse or recycle specific vehicle components. This insight from **P5** resulted in restructuring requirement *1 The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers*, in three different information needs, access to digital information, access to component information, and access to material information.

P5 also mentioned that *requirement 1.2 The information should include the share of recycled content within a vehicle is provided* (Table 10) is not a crucial requirement for the dismantlers. **P5** mentioned it would be nice to have but not necessary for the dismantlers. Therefore, this requirement is not included in the list of final requirements.

Another interesting insight, which both **P5** and **P6** mentioned, was about requirement *2.2 he information for dismantlers should be accessible free of charge.* In both discussions, they mentioned that the information does not have to be available free of charge and that dismantlers are willing to pay for this information as this helps them make their processes more efficient. Therefore, requirement 2.2 was also not included in the final list of requirements.

Requirement *1.2.3 The information sharing infrastructure should provide data about the interchangeability of components* (Table 16) emphasized in both evaluations that information about this would increase the efficiency of the dismantling branch. Finally, it became clear that the experts approved most of the requirements derived from the three perspectives.

Table 16 Restructuring of requirement 1 based on the evaluation.

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
1	The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers	B1, B9	ELVR	P1, P3, P4, P5	D1, L1, I1
1.1	The information sharing infrastructure should provide access to digital information			P5, P6	I1.4
1.1.1	The information should include information about digital procedures for component activation			P5	I1.4

ID	REQUIREMENT	DOCUMENT SOURCES	INSTITUTIONAL SOURCES	INTERVIEW	RELATED REQ_IDS
1.2	The information sharing infrastructure should provide access to component information	B1		P1, P3	D1.1
1.2.1	The information should include detailed data about the location of these EEE components	B1	ELVR, WEEED		D1.2, L1.1
1.2.2	The information should include data about the type of EEE, the brand name, and how the supplier meets responsibilities		WEEED		L5, L5.1, L5.2, L5.3, L5.4, L5.5, L5.6
1.2.3	The information sharing infrastructure should provide data about interchangeability of components			P5	I1.3
1.2.4	The information should include information on the safe removal of components		ELVR, WEEED, CRMA	P3	L1.3, I1.2
1.3	The information sharing infrastructure should provide access to material information		WEEED		I1.1
1.3.1	The information should include information relevant to promote recovery of CRMs		CRMA		L7
1.3.2	The information should include information on the safe removal of materials		ELVR, WEEED, CRMA	P3	L1.3, I1.2

Table 17 shows an overview of the revised requirements based on the two experts' evaluations. The "✓" means that the experts approve the requirement, and no adjustments are needed. The Δ sign means that an adjustment is made to formulate a requirement. The + means that a requirement is added based on the evaluation with the experts. Also, two requirements are removed; a "-" symbol indicates this. Finally, some requirements were also undiscussed, or the expert mentioned that he/she had no knowledge about them, this is indicated by a “°”-symbol. These requirements are left in the final list.

Table 17 Revised list of requirements

ID	REQUIREMENT	REVISION ✓ = APPROVED Δ = CHANGED + = ADDED - = REMOVED ° = NOT DISCUSSED	REVISON
1	The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers	✓	
1.1	The information sharing infrastructure should provide access to digital information	+	This requirement was added based to the feedback of P5 stating that dismantlers need three different types of information
1.1.1	The information should include information about digital procedures for component activation	✓	
1.2	The information sharing infrastructure should provide access to component information	+	This requirement was added due to the feedback of P5, see revision requirement 1.1
1.2.1	The information should include detailed data about the location of these EEE components	✓	
1.2.2	The information should include data about the type of EEE, the brand name, and how the supplier meets responsibilities	✓	

ID	REQUIREMENT	REVISION ✓ = APPROVED Δ = CHANGED + = ADDED - = REMOVED ° = NOT DISCUSSED	REVISON
1.2.3	The information sharing infrastructure should provide data about interchangeability of components	✓	
1.2.4	The information should include information on the safe removal of components	Δ	This requirement was adjusted to fit the new component requirement 1.2
1.3	The information sharing infrastructure should provide access to material information	+	This requirement was added due to the feedback of P5, see revision requirement 1.1
1.3.1	The information should include information relevant to promote recovery of CRMs	✓	
1.3.2	The information should include information on the safe removal of materials	Δ	This requirement was adjusted to fit the new component requirement 1.3
1.4	~~The information should include the share of recycled content within a vehicle~~	-	Based on evaluation P5 and P6 this was not considered relevant
2.	The information sharing infrastructure should be easy to use for dismantlers	✓	
2.1	The information should be accessible in a user-friendly manner	✓	
2.2	~~The information for dismantlers should be accessible free of charge~~	-	This requirement was removed based on the revision by P5 and P6, both stating that it is no problem for dismantlers to pay for this information as it is part of their business model. Having a good information sharing infrastructure would help them to save money
2.2	The information sharing infrastructure should minimize the administrative burden for dismantlers and manufacturers	✓	
2.3	The information sharing infrastructure should have a standardized data entry process	°	
3	The information sharing infrastructure should balance transparency and intellectual property rights	°	
3.1	The information sharing infrastructure should facilitate access control	°	
3.2	The information sharing infrastructure should enforce multi-factor authentication (MFA) for all users accessing the data space	°	
4.	The information sharing infrastructure should provide interoperability between information systems	✓	
4.1	The information sharing infrastructure should ensure interoperability between national vehicle registries	✓	
4.2	The information sharing infrastructure provide interoperability with a single window system	✓	
5.	The information sharing infrastructure facilitates a circularity vehicle passport	✓	
5.1	The information included in this circularity vehicle passport should be based on open standards	°	
5.2	The information included in this circularity vehicle passport should be transferable through an open interoperable data exchange network without vender lock in	°	
5.3	The information included in this circularity vehicle passport should be machine-readable, structured, and searchable	°	

5.7 Answering SQ2

This analysis has effectively addressed SQ2 and its associated sub-questions (SQ2-A, SQ2-B, and SQ2-C), focusing on the necessity for an adequate information-sharing infrastructure in the automotive industry.

SQ2-A examined the requirements based on identified barriers, revealing needs such as access to detailed EEE vehicle data, ease of use, and the minimization of administrative burdens. This analysis, based on the identified barriers in Chapter 4, identified specific functional and non-functional requirements (see Table 6 List of requirements barrier analysis)

SQ2-B, about the legislative landscape, highlighted the influence of regulatory frameworks on information-sharing requirements. Analysis of the ELV Regulation, the WEEE Directive, and the CRM Act introduced requirements emphasizing fundamental dismantling information, user-friendly interfaces, interoperability among various systems, and the circular vehicle passport. These legislative requirements underline the importance of compliance and standardization in information sharing. The list of these requirements can be found in Table 7 List of requirements institutional analysis.

SQ2-C, focused on the dismantlers' perspective, underscored practical insights into the day-to-day challenges faced in the field. Interviews with stakeholders illuminated the need for specific, actionable, and easily accessible information about components, materials, and digital information. The insights from these interviews were critical in shaping realistic and directly relevant requirements for the end users. The final list of these requirements can be found in Table 9 List of interview requirements.

The combined requirements from these diverse methods have resulted in a refined list addressing key information-sharing aspects in the automotive dismantling sector, answering **SQ2**: *What requirements are essential for facilitating information sharing about WEEE in the automotive industry?*

This list was reviewed and revised by experts in the ELV dismantling sector, as presented in Table 17.

In summary, the requirements established in this chapter form a basis to enhance the information-sharing infrastructure within the automotive industry. These requirements address current challenges and anticipate future needs, ensuring that the dismantling process is efficient, compliant, and aligned with sustainable practices. The outcomes of this chapter will be used in analyzing IDS in Chapter 6, specifically evaluating how it aligns with these identified requirements.

6 IDS for dismantlers

In this chapter the IDS is analyzed based on the elicited requirements in chapter 5.

The outcome of this chapter is an overview of how IDS can meet these requirements. This allows me to answer SQ3:

How can IDS facilitate in meeting the identified requirements?

The International Data Space (IDS) is a Data Space leveraging existing standards, technologies, and governance models well accepted in the data economy to facilitate secure and standardized data exchange and linkage in trusted business ecosystems. It thereby offers a foundation for developing intelligent service scenarios and enabling inventive cross-organizational business processes, all while ensuring data sovereignty for the owners of the data (Otto et al., 2019). Section 2.3.1.1 and Appendix A – Core concepts IDS provide a broader explanation of IDS and its core concepts.

This chapter will investigate how the IDS meets the five requirements elicited in chapter 5. An overview of the results is given in section 6.7

6.1 Requirement 1: Access to fundamental dismantling information

Manufacturers' input is needed for dismantlers to gain access to fundamental dismantling information. Currently, as mentioned in section *Potential actor conflicts regarding information sharing* manufacturers are not always sharing the necessary data. How the Data Space could contribute to manufacturers securely sharing more data is further elaborated in section 6.3. However, for dismantlers to get value from the data space, the WEEE information shared within it should meet requirements 1.1, 1.2, and 1.3 and their sub-requirements (see Table 17).

Manufacturers and suppliers must become part of the Data Space and start with providing data. Next, the dismantling companies must also be added to the Data Space. Therefore, there will be looked into the onboarding (i.e., what to do to be granted access to the IDS and a Data Provider of Data Customer) process is one of the three major processes in the process layer (Otto et al., 2023c, 2019)

Next, the data the dismantlers need should also be made available. This depends on the manufacturers and suppliers and what they are willing to share within the data space. To answer how the Data Space will meet these requirements, if they do share the data, there will be looked at how manufacturers can offer their data and share this with the dismantlers. And how vocabularies play a role.

So, to measure if IDS meets Requirement 1, and the sub-requirements will be elaborated on the onboarding process, offering process, and how vocabularies could be used.

6.1.1 Onboarding

The onboarding process requires of two preparational steps for an organization to act as a Data Provider or Data Consumer within the IDS. The first step is registration and certification of the organization, the second step is acquiring a certified IDS connector (Otto et al., 2023c). When the preparational steps are done, an organization can instantiate an arbitrary number of IDS connector instances with the following two steps: provisioning and configuring the connector, and the availability setup. These four aforementioned steps are elaborated upon below.

6.1.1.1 Registration and certification of dismantlers and manufacturers

If the dismantler or manufacturer wants to operate an IDS Connector in order to exchange data in the IDS, some preliminary actions are required. These are necessary for all participants, and involve the Certification Body, Evaluation Facilities, the Dynamic Attribute Provisioning Service (DAPS), and the Participant Information Service (ParIS) (Otto et al., 2023b). Figure 15 illustrates the roles and the interactions required for issuing a digital identity in the IDS.

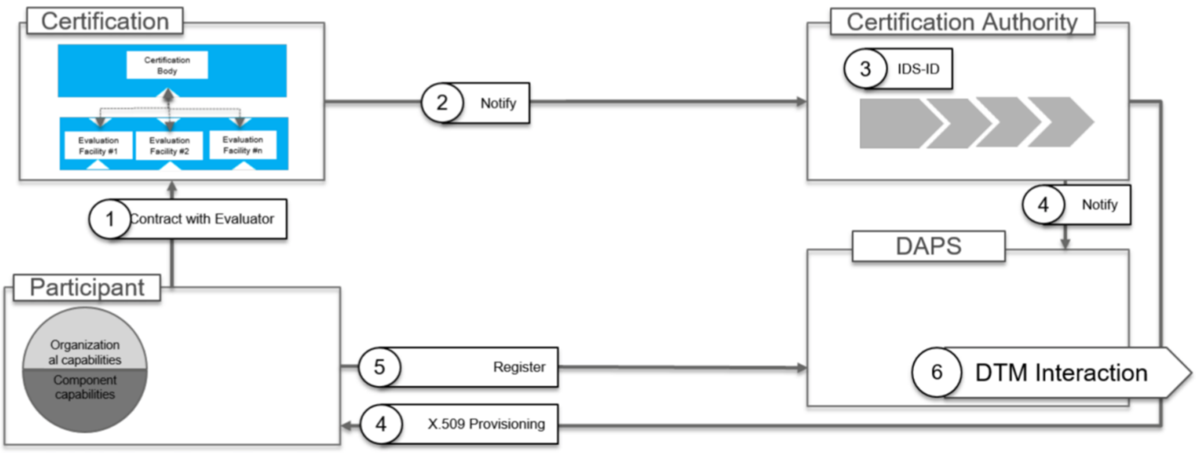

Figure 15 Interactions required for issuing a digital identity (Otto et al, 2023)

Participants

In the IDS, every participant and most roles necessitate certification, encompassing both the organizational competencies of the participant and the technical proficiency of the core technical components (Otto et al., 2023b). The organizational capabilities aspect of the certification assesses the dismantlers organizational strengths and capabilities. It may include evaluating the participant's ability to adhere to the governance, policies, and standards set by the IDS. It might also involve the dismantler's data handling and management capability. The technical capabilities of a dismantler could include ensuring that any software, hardware, or systems used for data exchange within the IDS are up to the required standards for performance, security, and compatibility. For a dismantler to arrange this as an IDS participant can be challenging. As was mentioned during the interview with **P5**, dismantlers are not tech-savvy. Most of their organizations do not have IT departments that manage these aspects. STIBA could play a role in this, by supporting the dismantlers. In 2021, they worked on the interests of the dismantlers regarding vehicle data, and ICT systems to make these available for dismantlers (Cabri et al., 2021).

For successful data exchange, manufacturers must also apply for IDS to share the data with the dismantlers. The same certification process applies to them. Manufacturers are generally larger companies with IT teams, making it easier for them to become part of the IDS.

Certification

An operational environment or core component certification involves the Certification Body and an Evaluation Facility. Evaluation of an operation environment or a core component is executed upon the participant's request and relies on the contract between the participant and the Evaluation Facility (Otto et al., 2023b). In the same way, a Service Provider can request an evaluation of a component. In this process, the Certification Body supervises the Evaluation Facility involved.

Certificate Authority

The Certificate Authority is tasked with issuing, validating, and revoking digital certificates within this sector. For a participant - be it a dismantler or a manufacturer - to receive a digital certificate, they must possess a valid certification for their operational environment and the core component they use (Otto et al., 2023b). The Certificate Authority is responsible for providing a unique IDS-ID corresponding to the specific pairing of an operational environment and a core component. This IDS-ID effectively serves as a digital identity in the automotive information-sharing network. The validity of the digital certificate is directly tied to the validity of the two underlying certifications - the operational environment certification and the core component certification (Otto et al., 2023b). The digital certificate will not exceed the validity period of either of these certifications.

Dynamic Attribute Provisioning Service (DAPS)
This service receives essential master data and security profile information, which includes the details of the digital certificate (such as the public key and IDS-ID) provided by the Certificate Authority (CA) (Otto et al., 2023b). Whether manufacturers or dismantlers, participants in this industry are required to register with the DAPS after successfully integrating the digital certificate into their operational component.

Participant Information Service
A key value proposition of the IDS is its facilitation of business interactions between previously unrelated participants like manufacturers and dismantlers (Otto et al., 2023b). This is especially crucial for companies that may have never engaged with each other in either the digital or physical realm but are now initiating business agreements based solely on the trust established through the IDS. This trust is technically fostered by a verifiable identity management process executed through the Certification Authority and the DAPS. These entities equip each participant with the necessary attributes and cryptographic proofs for secure IDS handshakes(Otto et al., 2023b).

However, establishing a secure communication channel is the foundational requirement for business interactions. Participants also need to understand the business workflow status of their counterparts. Critical business information, such as tax identification numbers, VAT numbers, and registered addresses, is essential for tasks like invoice generation and understanding jurisdictional responsibilities for conflict resolution (Otto et al., 2023b).

This vital information is provided and maintained by a support organization within the IDS, a legal entity that administers the ecosystem. This organization introduces new participants by creating their digital identity while registering security-critical information at the DAPS and business-relevant attributes at the Participant Information Service (ParIS). ParIS grants access to these attributes to other IDS participants and connects the unique participant identifier – a URI – with additional metadata.

Unlike other IDS components, the reliability of information provided by ParIS is not based on technical measures like signatures or certificates. Instead, it relies on the administrative process overseen by the Support Organization. As a result, any request to change information in the ParIS database must be manually verified before implementation.

Dynamic Trust Monitoring (DTM)
Continuous participant monitoring is crucial to assessing the trustworthiness of all entities within the automotive ecosystem. The Dynamic Trust Monitoring (DTM) system implements a monitoring function for every IDS component in the automotive industry (Otto et al., 2023b). The DTM communicates with the DAPS to inform each participant involved in a data exchange about the current trust level of the other party. This ongoing trust assessment is vital to maintain the integrity and security of information exchanges between manufacturers and dismantlers in the automotive sector.

6.1.1.2 Acquiring a certified IDS Connector

The dismantlers and manufactures need to either request an IDS Connector from a Software Provider, or implement its own (Otto et al., 2023c). The IDS Connector is the core technical component for becoming part of the IDS. It must pass the IDS Component Certification to ensure an adequate level of security and interoperability before it can be instantiated and used in the IDS.

6.1.1.3 Connector configuration and provisioning

Each connector that participates in the IDS ecosystem must be unique and provide a self-description for other IDS participants to read and a connection should be made between existing systems with the IDS connector.

Self-Description of Connectors

Furthermore, it is imperative for each connector in the automotive industry's IDS ecosystem to provide a Self-Description. This description, created by the respective organization at the onset of the IDS Connector configuration and provisioning process, allows other IDS participants to understand the capabilities and attributes of the connector (Otto et al., 2023c). For heightened levels of trust, connectors should be provisioned with signed metadata. This metadata serves as a proof of the certification levels of both the IDS connector and the organization operating it, ensuring a higher degree of reliability and trustworthiness in the network.

System Integration and Data Exchange Enablement

Another critical step for manufactures and dismantlers is the integration and connection of their existing systems with the IDS Connector. This step involves creating appropriate IDS metadata, such as Usage Policies, and ensuring that data exchange capabilities are enabled. To facilitate this integration and enhance the functionality of the data exchange, the use of IDS Apps is recommended (Otto et al., 2023c). These apps can significantly streamline the process of integrating existing systems with the IDS Connector, thereby promoting efficient and secure data sharing practices in the automotive industry.

6.1.1.4 Availability Setup

Ultimately, the IDS connector needs to be accessible to other participants within the IDS data ecosystem. It is up to both the dismantlers and manufacturers to determine if they want to publicly declare their IDS connector and associated data resources within this ecosystem.

An overview of the full onboarding process for manufacturers and dismantlers to become participant in the IDS is provided in Figure 16.

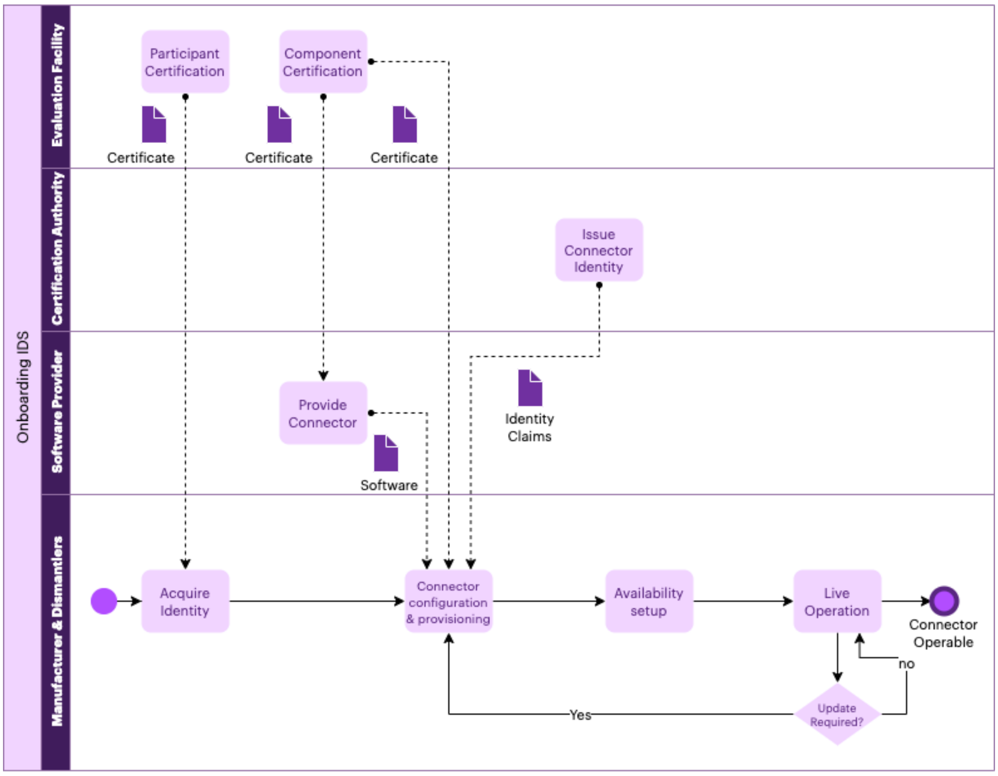

Figure 16 Onboarding process based on Otto et al. (2023)

6.1.2 Offering data

For manufactures to share data in a Data Space, multiple steps still need to be taken. In the easiest way, the manufacturer knows the dismantling companies where they want to share data with directly at the beginning and directly provide information about available data assets. This bidirectional exchange bypasses most of the IDS infrastructure components and keeps the additional efforts to a minimum (Otto et al., 2023d).

For the case of WEEE information sharing between manufacturers and dismantlers in the Netherlands, it would be a suitable option to make data sharing directly possible when the dismantler is partnered with the ARN and/or STIBA. This way, the manufacturer can be assured that these are reliable dismantling companies.

6.1.3 Vocabulary hub

In the automotive industry, the necessary WEEE information sharing between dismantlers and manufactures can be facilitated using the IDS Information Model. This model utilizes an Resource Description Framework (RDF) ontology for explicit identifiers and formalized concept definitions (Otto et al., 2023f). For a well-functioning data sharing ecosystem in the automotive industry, a fundamental core vocabulary is essential for all participants' data descriptions and exchange processes. Additionally, domain-specific vocabularies can be incorporated to expand core concepts, offering detailed information about the provided or requested data. These vocabularies could include the information requirements mentioned in Requirement 1.

Typically, the IDS Ontology is employed and actualized by knowledge engineers, ontology specialists, or information architects. It establishes a fundamental 'core model' that is domain-neutral and utilizes both standard and bespoke third-party vocabularies for articulating specific facts. In line with standard practices, it often reuses existing domain vocabularies and standards to enhance its acceptance and interoperability. (Grothe, 2023).

6.1.4 Meeting requirement 1

As mentioned in section *Requirement 1: Access to* fundamental dismantling information, the accessibility of the fundamental dismantling information for dismantlers by the IDS is investigated based on how dismantlers and manufactures onboard to the Data Space, how data can be offered, and how vocabularies play a role in sharing the necessary data.

Requirement *1 The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers* consists of many sub requirements which are based on specific information needs. Whether or not this information will be shared depends on the manufacturers and suppliers. However, because of the benefits that a Data Space brings, these companies might be willing to share more information. This aspect will be described in full in section 6.3

The IDS framework, especially the Vocabulary Hub can host vocabularies that include detailed dismantling information. It allows for creation, publication, and maintenance of specialized vocabularies that can cater to the specific needs of dismantlers.

Table 18 IDS and requirement 1

<table>
<tr><th>ID</th><th>REQUIREMENT</th><th>DESCRIPTION OF IDS</th></tr>
<tr><td>1</td><td>The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers</td><td>Dismantlers can onboard and access IDS when following the onboarding process shown in Figure 16.
However, for dismantlers to onboard, a specialized IT team is necessary, which most of the dismantling companies do not have. An option is to hire external IT teams to onboard to the IDS as a project, and for maintenance.</td></tr>
<tr><td>1.1</td><td>The information sharing infrastructure should provide access to digital information</td><td rowspan="6">The IDS Vocabulary Hub meets various information sharing requirements by enabling the creation and sharing of specific vocabularies. These vocabularies can cover digital procedures for component activation, component information, details on WEEE components' location, types, brand names, supplier responsibilities, component interchangeability, and safety information for component and material removal.</td></tr>
<tr><td>1.1.1</td><td>The information should include information about digital procedures for component activation</td></tr>
<tr><td>1.2</td><td>The information sharing infrastructure should provide access to component information</td></tr>
<tr><td>1.2.1</td><td>The information should include detailed data about the location of these EEE components</td></tr>
<tr><td>1.2.2</td><td>The information should include data about the type of EEE, the brand name, and how the supplier meets responsibilities</td></tr>
<tr><td>1.2.3</td><td>The information sharing infrastructure should provide data about interchangeability of components</td></tr>
</table>

ID	REQUIREMENT	DESCRIPTION OF IDS
1.2.4	The information should include information on the safe removal of components	
1.3	The information sharing infrastructure should provide access to material information	
1.3.1	The information should include information relevant to promote recovery of CRMs	
1.3.2	The information should include information on the safe removal of materials	

6.2 Requirement 2: Ease of use for dismantlers

For dismantlers to use the dismantling information properly it is an important requirement that the system is easy to use. According to the IDSA rulebook, one of the guiding principles and underlying values is easy to use. Meaning low deployment threshold for companies and initiatives with a focus on portability and replicability (Steinbuß, 2022). This is in line with requirement 2. The identified aspects to this are the user friendliness, the minimization of the administrative burden for both dismantlers and manufactures, and a standardized data entry process.

6.2.1 User friendliness

When exchanging data, the Connector must receive data from an enterprise backend system, either through a push-mechanism or a pull-mechanism. The data can be provided via an interface or pushed directly to other participants.

Currently, there are no examples that can be tried to evaluate the user-friendliness of IDS as a infrastructure for EEE information sharing. Although, the onboarding process is complex, with the use of the IDS system it is not necessary to log-on to all the different databases that were used before (see section 4.4.1). Therefore, it can be expected that the IDS is more user friendly then the current way of searching for EEE information for dismantlers.

For manufacturers it can also be considered more user friendly. Currently, they have to maintain at least two databases, the IMDS and the IDIS. However, with the use of the IDS it is possible to use only one interface and use access and usage management to control who can access the data. There will be elaborated on this in section 6.3.1.

6.2.2 Administrative Burden

The administrative burden for retrieving EEE information for dismantlers is high as was mentioned during multiple interviews. They must search multiple databases, and because there is a lack of interchangeability, they often cannot find which components correspond with the componentID's given by the manufactures. This was mentioned during the interviews, more elaboration on this can be found in section 5.4.5.

When using the IDS data space there will still be some kind of administrative burden for dismantlers and manufactures, however, there is now only one client/interface they can use to find all the necessary data. Which will decrease the time spend on administrative tasks.

It is important to note, that during the setup of the IDS the administrative burden will be high as mentioned in section 6.1.4.

6.2.3 Standardization

Standardized data exchange between participants is a fundamental aspect of the IDS (Steinbuß, 2022). As mentioned before, there is no standardized way for dismantlers to retrieve EEE data. They must search multiple data bases and may still not find the data they are looking for. This costs a lot of time, therefore a standardized format, in which they can retrieve the data from the Data Provider in a standardized manner is needed.

The IDS can meet the requirement of a standardized data sharing process through several key features. First, IDS employs a standardized vocabulary (see section 6.1.3) and ontologies, enabling consistent data description and interpretations across different organizations and systems. Second, IDS is designed with interoperability at its core (will be further elaborated upon in section 6.4), which means it can integrate with various systems and platforms. This is achieved using common data formats and protocols

6.2.3.1 Role of vocabularies

Vocabularies can ensure clear and consistent communication in the context of information sharing in the automotive industry (Otto et al., 2023f), particularly between dismantlers and manufacturers. The dismantlers currently face challenges using varied terms and identification numbers for identical components, leading to confusion and hindering the reuse or recycling of these components. Implementing semantic models within an Information IDS could offer a viable solution. These models provide clear definitions and understandings of the shared data, which is crucial for handling usage policies, especially if these policies are contingent on the data's meaning. Moreover, semantic data models facilitate optional functions like billing and auditing.

For data sharing between dismantlers and manufacturers, these vocabularies can be used to create a standardized approach to data sharing, ensuring that all participants interpret policies and data assets consistently.

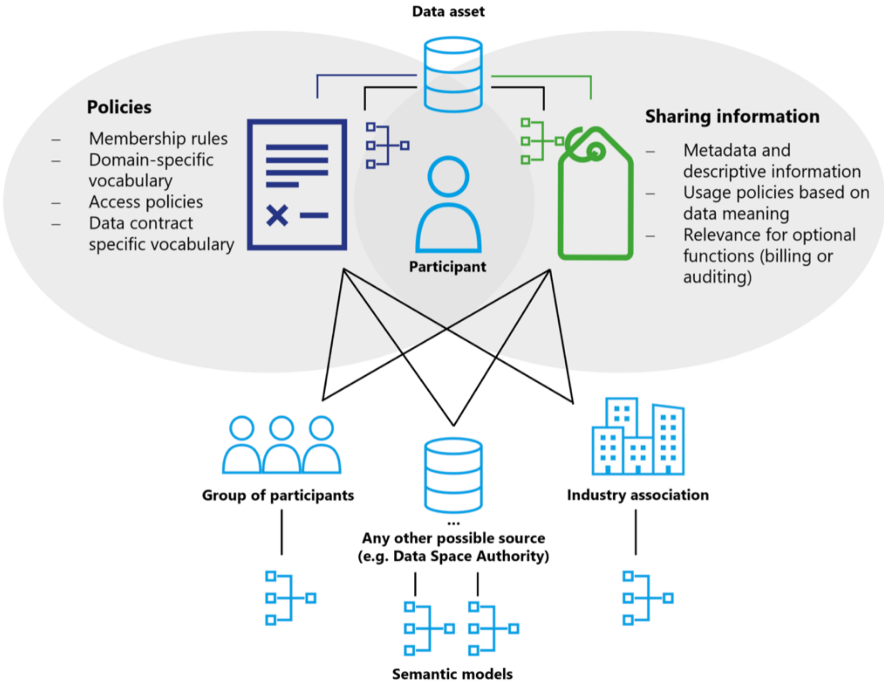

Figure 17 Vocabularies and their relationship to data assets (Retrieved from Steinbuss, 2022)

6.2.4 Meeting Requirement 2

Requirement *2 The information sharing infrastructure should be easy to use for dismantlers*, can be met by the IDS when the Data Space is up and running, as the IDS provides a single interface to get access to different Data Providers at once. This way dismantlers do not have to log into different systems to access the information. It is important to note, that the user-friendliness (Requirement 2.1) is hard to evaluate as no prototype can be tested during this thesis. However, considering the decrease in administrative burden (Requirement 2.2), it can be said that this new data sharing infrastructure is more user-friendly.

Next to that, requirement *2.3 The information sharing infrastructure should have a standardized data sharing process*, is met when implementing IDS into the realm of EEE information sharing within the automotive industry, as IDS uses a common vocabulary and ontologies for consistent data.

Table 19 IDS and requirement 2

ID	REQUIREMENT	DESCRIPTION OF IDS
2.	The information sharing infrastructure should be easy to use for dismantlers	• The IDS facilitates ease of use by enabling dismantlers to access data through **a single interface**. This unified approach contrasts with the previous need to log into multiple databases, thereby simplifying the process. • While a prototype for testing user-friendliness is not available, the reduction in the number of interfaces points towards a more user-friendly system.

2.1	The information should be accessible in a user-friendly manner	• The IDS design, which allows for data to be received from enterprise backend systems via push or pull mechanisms, is expected to be **more user-friendly** than the current methods of data retrieval. • For manufacturers, the IDS offers a **simplified process** by consolidating data access through one interface instead of maintaining multiple databases.
2.2	The information sharing infrastructure should minimize the administrative burden for dismantlers and manufacturers	• The IDS can **reduce the administrative burden** for both dismantlers and manufacturers by streamlining data access into a single client/interface. This leads to a decrease in time spent on administrative tasks. • It's important to note that initially, during the setup of the IDS, there may be a **higher administrative burden**, but this is expected to decrease in the operational phase.
2.3	The information sharing infrastructure should have a standardized data sharing process	• The IDS meets the need for standardized data exchange by employing a **common vocabulary and ontologies**, ensuring consistent data description and interpretation across various systems.

6.3 Requirement 3: Facilitate digital data sovereignty

For manufacturers to start sharing more EEE vehicle data with dismantler, there needs to be a balance between transparency and IP rights. Data sovereignty, finding a balance between the need for protecting one's data and the need for sharing one's data (Otto et al., 2023a), is considered a key capability for manufactures to start sharing more data.

Therefore, in this section there will be looked into how the IDS will meet requirement 3. First, access control is analysed and after that there is looked into usage control.

6.3.1 Access control

In general, access control restricts access to resources. The term authorization is the process of granting permission to resources. Several access control models exist, such as Discretionary Access Control (DAC), Mandatory Access Control (MAC), Role-Based Access Control (RBAC), Attribute-Based Access Control (ABAC), etc. Although such a plethora of access control models exists, RBAC and ABAC are most commonly used models (Otto et al., 2019).

The XACML (eXtensible Access Control Markup Language) standard is used to introduce commonly used terms in the field of access control. XACML is a policy language to express ABAC rules (Otto et al., 2019). The main building blocks of the language are subject, action, resource, and environment:

- The subject describes who is accessing a data set (e.g. a dismantler)
- The action describes what the subject wants to do with the data asset (e.g. read)
- The resource describes the data asset (e.g. ECU location information)
- The environment specifies the context of the action (e.g. time, location)

6.3.1.1 Policy Enforcement

Data usage restrictions in the IDS are primarily enforced through technical means rather than just organizational rules or legal contracts. This approach adds security by monitoring and intercepting system actions at control points, known as Policy Enforcement Points (PEPs) (Otto et al., 2019). Decisions on these actions, whether to permit, deny, or modify them, are made by a decision engine, referred to as a Policy Decision Point (PDP). The PEP component encapsulates this enforcement mechanism, ensuring robust control over data usage within the IDS.

Policy Enforcement Point (PEP): The PEP is responsible for intercepting a user's access request to a resource, making a decision request to the PDP, and enforcing the decision that is returned (Otto et al., 2019).

Policy Decision Point (PDP): The PDP evaluates access requests against authorization policies and makes a decision to permit or deny the request. It receives data from the PEP and may use additional context information from the PIP to make its decision (Otto et al., 2019).

Policy Information Point (PIP): The PIP is the component that provides additional information (context information) that may be needed by the PDP to make a decision. This information can be any relevant data that is not contained in the initial request (Otto et al., 2019).

Policy Administration Point (PAP): The PAP is the component where policies are created and managed. It is responsible for the lifecycle of policies, including their creation, deployment, and revocation (Otto et al., 2019).

Figure 18 illustrates the data-flow model of XACML and the main actors or components to implement it (PEP, PDP, PIP, PAP).

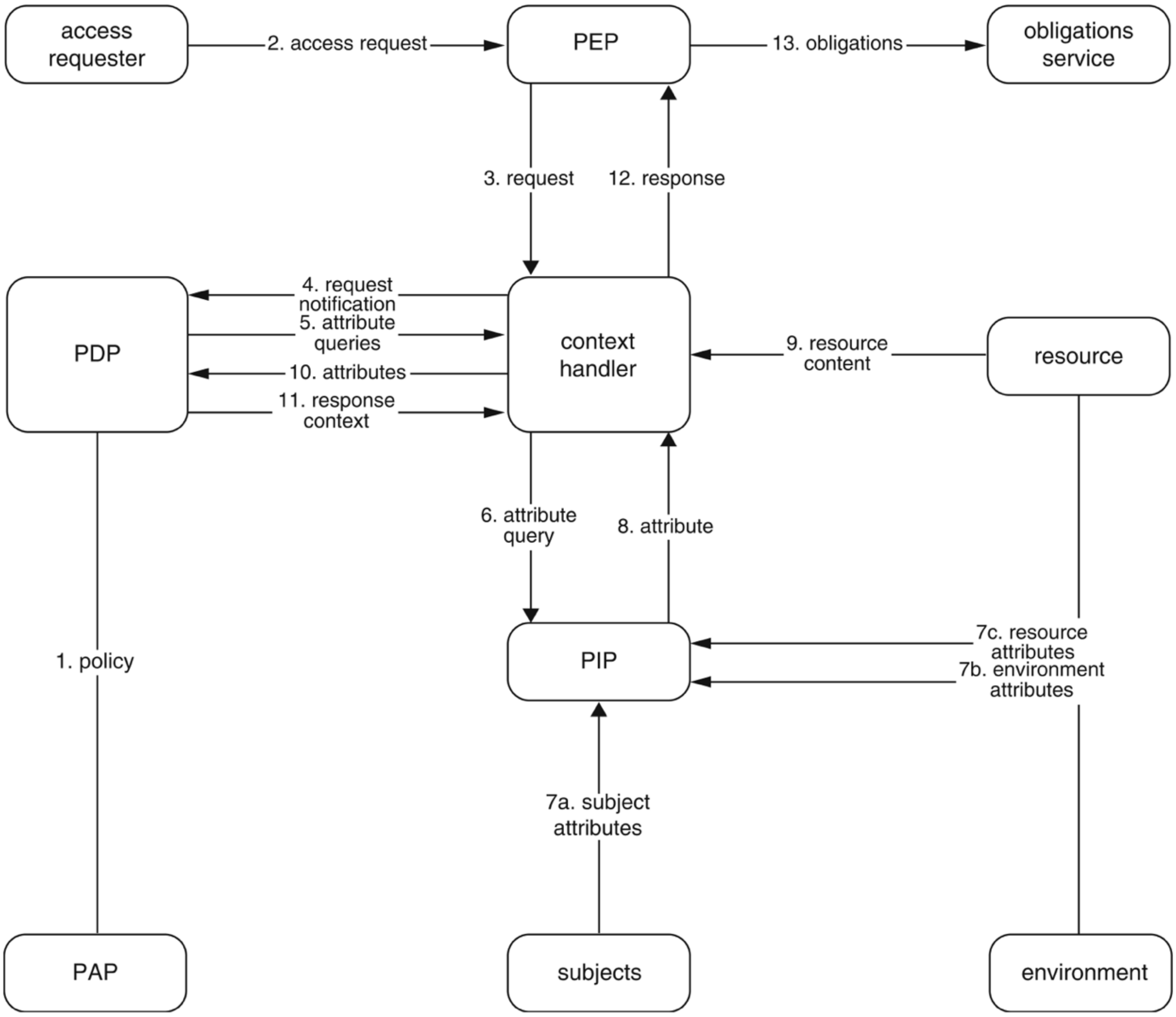

Figure 18 XACML data flow illustration (Retrieved from Otto et al., 2019, p.82)

6.3.2 Usage control

Unlike access control, which limits entry to specific resources, the IDS framework includes control over data usage. This involves implementing constraints on data utilization once access is permitted (Otto et al., 2019). The key aim is to append specific policies to the data, delineating their usage limits and actively overseeing how the data is processed, compiled, or spread within the IDS.

Such control over data usage equips participants in IDS to construct an architecture that upholds data sovereignty. These usage control methods also track data movements, facilitating auditing processes that verify adherence to data usage compliance (Duisberg, 2022; Otto et al., 2019; Pettenpohl et al., 2022).

There are multiple examples that illustrate that next to data access control, also usage control is needed. For the automotive industry the following examples apply:

- Secrecy: classified data must not be forwarded to nodes which cannot have the respective clearance.
- Integrity: Critical data can only be modified by trusted nodes or services.

- Time to Live: Data must be deleted or altered after a given period of time.
- Separation of Duty: Data sets, for instance from competitive organizations, must be kept separated (e.g., no joining operation or processing within the same service).
- Usage scope: Data may only serve as input for data pipes within the Connector; it must never leave the Connector and be sent to an external endpoint (Otto et al., 2019).

6.3.3 Meeting Requirement 3

The concept of data sovereignty is central to Requirement 3, underscoring the need to find a balance between protecting and sharing data. This is essential for manufacturers to begin sharing more information with dismantlers. The IDS architecture, with its technical enforcement mechanisms, ensures that data usage is stringently controlled and monitored. This approach honors intellectual property rights and fosters transparency in data sharing, thereby meeting the essential aspects of Requirement 3.

The IDS implements various access control models, notably Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC), using the XACML standard. XACML's comprehensive framework, which encompasses subjects, actions, resources, and environmental factors, ensures that only authorized parties gain access to specific data sets. This structured approach to access control aligns perfectly with the needs of the information sharing infrastructure, thereby satisfying Requirement 3.1.

For Requirement 3.2, the IDS's usage control mechanisms are of paramount importance. These mechanisms include policies attached to data that specify usage restrictions and a continuous control over how data is processed, aggregated, or disseminated within the IDS. This ensures that data sovereignty is respected, and that data usage adheres to established policies. Specific examples within the automotive industry, such as ensuring data secrecy, maintaining data integrity, setting data lifetimes, enforcing separation of duties, and defining usage scopes, demonstrate the nature of this usage control within the IDS. This detailed approach to usage control effectively meets Requirement 3.2, ensuring that the information sharing infrastructure between dismantlers and manufacturers is both secure and efficient, while respecting the critical balance between transparency and intellectual property rights.

Table 20 IDS and requirement 3

ID	REQUIREMENT	DESCRIPTION OF IDS
3	The information sharing infrastructure should balance transparency and intellectual property rights	• The IDS architecture, through its technical enforcement mechanisms, ensures that **data usage is strictly controlled and monitored**. This approach respects intellectual property rights while promoting transparency in data sharing.
3.1	The information sharing infrastructure should facilitate access control	• The IDS implements various access control models, notably RBAC (Role-Based Access Control) and ABAC (Attribute-Based Access Control), using the XACML standard. • XACML's framework, which includes subjects, actions, resources, and environment, can **ensure that only authorized parties have access** to specific data sets, thereby fulfilling the requirement for facilitated access control.
3.2	The information sharing infrastructure should facilitate usage control	• The usage control mechanisms in IDS, which include policies attached to data specifying usage restrictions and continuous control of data processing, address the requirement for usage control. These mechanisms **ensure that data sovereignty is not violated** and that data usage complies with set policies.

6.4 Requirement 4: Interoperability between information systems

In the automotive industry, where data sharing between manufacturers and dismantlers is vital, achieving interoperability is a key focus of the Industrial Data Spaces (IDS), as identified as requirement 4. The IDS Connector, serving as the central technical component, is instrumental in standardizing this data exchange, enabling effective communication and information transfer within the IDS network (Otto et al., 2023e, 2019).

Semantic interoperability, the cornerstone of this data exchange, ensures that IT systems can exchange data with a clear, universally understood meaning (Otto et al., 2023e). This is crucial in the federated IDS network, where manufacturers must express their data offerings or requirements using a shared vocabulary. The use of a common vocabulary, standardized across the network, is essential to avoid integration efforts due to vocabulary mismatches.

The process of achieving semantic interoperability in the data sharing between manufacturers and dismantlers within the IDS involves several key steps:

1. Design time vocabulary publishing: Data providers, such as manufacturers, may publish a new vocabulary or reference an existing one during the design phase of the IDS data sharing process.

2. Vocabulary loading: Before invoking a data operation, the data consumer's (dismantler's) connector loads one or more vocabularies in preparation for data exchange.

3. Schema Validation: The data consumer's connector validates the received data schema using appropriate measures, ensuring compatibility with the provided schema.

4. Interface Implementation: Based on the loaded vocabularies, the data consumer implements the necessary interfaces to facilitate data transfer, as described in the IDS framework.

5. Data Transfer and Validation: After the data transfer, the received data is validated against the referenced vocabularies. If the data does not conform, the consumer’s connector may reject it.

6. Post-Transfer Data Treatment: Additional treatment of the data, such as through ETL (Extract, Transform, Load) tooling, may be necessary. During this phase, connectors can utilize Data Apps for efficient processing.

This process ensures that both manufacturers and dismantlers can share and receive data in a seamless, standardized manner, minimizing ambiguity and integration efforts.

6.4.1 Meeting Requirement 4

This section investigated if the IDS infrastructure could meet requirements 4 and 4.1 and address these requirements adeptly through its standardized approach to interoperability.

For Requirement 4, the IDS architecture, emphasizing semantic interoperability and adopting a common vocabulary, is purpose-built to provide seamless interoperability between diverse information systems. This is achieved by standardizing how data is shared and interpreted within the network, ensuring that different IT systems, such as manufacturers and dismantlers in the automotive sector, can communicate effectively. The role of the IDS Connector and the Information Model within this framework is crucial, as they enable the exchange of digital resources within a trusted ecosystem, thereby meeting the essential aspects of requirement 4.

Regarding requirement 4.1, the IDS framework lays the groundwork for achieving interoperability between national vehicle registries. While the IDS can facilitate this level of interoperability, the practical application to national vehicle registries involves additional steps. These registries must be integrated into the IDS network for this interoperability to be realized. This integration depends on the willingness and collaborative efforts of stakeholders managing these registries. Each registry would require individual incorporation into the IDS architecture, and appropriate data-sharing protocols conforming to IDS standards would need to be established. Therefore, while IDS presents the foundational capability for interoperability with national vehicle registries, fulfilling this requirement hinges on the execution of integration efforts and the establishment of cooperative data-sharing arrangements.

Table 21 IDS and requirement 4

ID	REQUIREMENT	DESCRIPTION OF IDS
4.	The information sharing infrastructure should provide interoperability between information systems	• The IDS infrastructure, with its emphasis on semantic interoperability and the use of a common vocabulary, is specifically designed to provide interoperability between different information systems. By standardizing how data is shared and interpreted between manufacturers and dismantlers in the automotive industry, **IDS can ensure that disparate IT systems can effectively communicate and exchange data**. • The use of the IDS Connector and the Information Model within the IDS framework plays a crucial role in this interoperability, enabling various systems to exchange digital resources within a trusted ecosystem. Thus, this requirement is met through the IDS's standardized interoperability approach.
4.1	The information sharing infrastructure should ensure interoperability between national vehicle registries	• The IDS's **framework provides the necessary infrastructure for interoperability between diverse data systems**, which in theory includes national vehicle registries. However, the application of IDS to national vehicle registries specifically would require these registries to be integrated into the IDS architecture. • This means that while the IDS infrastructure is capable of facilitating interoperability between national vehicle registries, **achieving this would depend on the willingness and implementation efforts of the stakeholders managing these registries**. Each registry would need to be individually integrated into the IDS network, and data sharing protocols would need to be established in accordance with IDS standards. Therefore, while IDS provides the foundational capability, the realization of interoperability in this context is contingent upon actual implementation and integration efforts.

In summary, the IDS infrastructure meets Requirement 4 by providing a platform for interoperable data exchange between various information systems within the automotive sector. It also has the potential to fulfill Requirement 4.1, subject to integrating national vehicle registries into its network and establishing compatible data-sharing protocols.

6.5 Requirement 5: Facilitate circularity passport

The recent proposal for the ELV Regulation introduces the concept of a circularity vehicle passport for all vehicles, encompassing specific requirements (requirement 5). To determine whether these requirements can be met, an examination of the IDS framework is necessary. This investigation will focus on assessing the capacity of IDS to facilitate a circularity vehicle passport, particularly in terms of its compliance with open standard requirements.

Additionally, it will evaluate the ability of IDS to enable the transfer of information through an open and interoperable data exchange network, free from vendor lock-in. Furthermore, the analysis will consider whether IDS can effectively provide data that is machine-readable, structured, and searchable, all of which are critical for the successful implementation and functionality of the circularity vehicle passport as per the proposed ELV regulation.

6.5.1 Open standards

The IDS can meet the requirement for a circularity vehicle passport based on open standards by adhering to its guiding principles and leveraging its secure data exchange framework. IDS aims to create a global open standard for data sovereignty, which is industry agnostic and integrates with existing systems and standards.

By utilizing the IDS Reference Architecture Model and the agreements set forth in the IDSA Rulebook, data within the circularity vehicle passport can be exchanged securely and in a standardized manner (Otto et al., 2023f). The IDS Connector, as a core technical component, ensures interoperability and security, meeting the open standards requirement. The IDS initiative's commitment to open standards ensures that the information in the circularity vehicle passport is free to use, developed through an open process, and based on transparent decision-making.

Furthermore, the IDS Certification Scheme ensures that all components and participants adhere to the defined standards, which are based on best practices from internationally recognized certification concepts. This certification process guarantees that the data exchanged, such as that within a circularity vehicle passport, is reliable and follows the open standards principle.

6.5.2 No vender lock-in

The information included in a circularity vehicle passport should be transferable through an open interoperable data exchange network without vendor lock-in by adhering to the principles of the IDS ecosystem, which emphasizes the use of open standards for data sovereignty and interoperability (Otto et al., 2023f). This ensures that data can be exchanged freely without being tied to proprietary systems. The IDS-RAM and the IDS Scheme facilitate secure exchange and easy linkage of data within business ecosystems, supporting the transfer of data with unambiguous, shared meaning (semantic interoperability), and without being restricted to a specific protocol.

6.5.3 Machine readable

To meet the requirement of having machine-readable, structured, and searchable information, the IDS can utilize the IDS Information Model, which is the central vocabulary that all parties of any IDS share (Otto et al., 2023f). This model supports the description, publication, and identification of data products and reusable data processing software, ensuring that the terms of the vocabulary are machine-readable. Additionally, the IDS Vocabulary Hub can be used to host, maintain, publish, and document additional vocabularies, making them available for lookups and ensuring they are machine-readable.

6.5.4 Meeting Requirement 5

The IDS framework can be designed to meet Requirement 5, facilitating a circularity vehicle passport. By leveraging the IDS Reference Architecture Model and the IDSA Rulebook, IDS ensures that data within the circularity vehicle passport is exchanged securely and standardized. This adherence to open standards is pivotal, not only for ensuring the interoperability and security of data exchange but also for guaranteeing the relevance and utility of the data within the circularity vehicle passport.

For Requirement 5.1, which specifies that the information in the circularity vehicle passport should be based on open standards, IDS's commitment to creating a global open standard for data sovereignty is particularly relevant. This approach is industry-agnostic and can integrate seamlessly with existing systems and standards. The IDS Certification Scheme further supports this commitment, ensuring that all components and participants within the network adhere to these open standards, thus providing a reliable and transparent data exchange process.

Addressing Requirement 5.2, the principles of the IDS ecosystem, which emphasize open standards for data sovereignty and interoperability, facilitate the transfer of information through an open, interoperable data exchange network without vendor lock-in. This ensures that data can be exchanged freely and is not restricted to proprietary systems, which is crucial for maintaining an open and versatile information-sharing environment.

Finally, Requirement 5.3, which demands that the information in the circularity vehicle passport be machine-readable, structured, and searchable, is met using the IDS Information Model. This model acts as the central vocabulary for all IDS participants and supports the description, publication, and identification of data products and reusable data processing software. The terms of this vocabulary are designed to be machine-readable, ensuring efficient data processing and interpretation. The IDS Vocabulary Hub enhances this capability by hosting, maintaining, publishing, and documenting additional vocabularies, making them readily available for lookups and ensuring they are machine-readable, structured, and searchable.

Table 22 IDS and requirement 5

ID	REQUIREMENT	DESCRIPTION OF IDS
5.	The information sharing infrastructure facilitates a circularity vehicle passport	• The IDS framework, with its emphasis on secure data exchange and adherence to open standards, is **capable of facilitating a circularity vehicle passport**. By leveraging the IDS Reference Architecture Model and the IDSA Rulebook, data within the passport can be exchanged in a secure and standardized manner.
5.1	The information included in this circularity vehicle passport should be based on open standards	• The IDS's commitment to creating a global open standard for data sovereignty can **ensure that the information in the circularity vehicle passport adheres to open standards**. This approach is industry-agnostic and integrates with existing systems and standards. The IDS Certification Scheme further ensures that all components and participants adhere to these standards, providing reliability and transparency.
5.2	The information included in this circularity vehicle passport should be transferable through an open interoperable data exchange network without vender lock in	• The IDS ecosystem's principles of open standards for data sovereignty and interoperability enable the transfer of information through an open, interoperable data exchange network. This approach ensures that data can be exchanged freely without being tied to proprietary systems, fulfilling the requirement of no vendor lock-in.
5.3	The information included in this circularity vehicle passport should be machine-readable, structured, and searchable	• Utilizing the IDS Information Model, which serves as the central vocabulary for IDS participants, the framework **ensures that the terms of the vocabulary are machine-readable**. This model supports the description, publication, and identification of data products and reusable data processing software. The IDS Vocabulary Hub further enhances this capability by hosting, maintaining, publishing, and documenting additional vocabularies, ensuring they are machine-readable and available for lookups.

In conclusion, the IDS framework can meet the requirements for a circularity vehicle passport, ensuring that information is exchanged based on open standards, is transferable through an open, interoperable network without vendor lock-in, and is machine-readable, structured, and searchable.

6.6 Information sharing process with IDS

This section outlines the comprehensive data-sharing process within the IDS, specifically for WEEE information in the automotive sector. First, it is crucial to ensure that dismantlers and manufacturers are integrated into the system, as depicted in Figure 16 Onboarding process based on Otto et al. (2023). Appropriate access and usage controls are established, as detailed in Section 6.3.

There are three critical steps in the data-sharing process. Firstly, (1) dismantlers must identify a relevant Data Provider for their specific needs. Once (2) a suitable provider is identified, the Data Consumer and Provider can initiate data exchange. The third and final step (3) involves recording the transaction details at a clearing house. Figure 18 provides a detailed illustration of this data-sharing procedure, which will be further explored in the subsequent sections, demonstrating how it is implemented within the IDS framework.

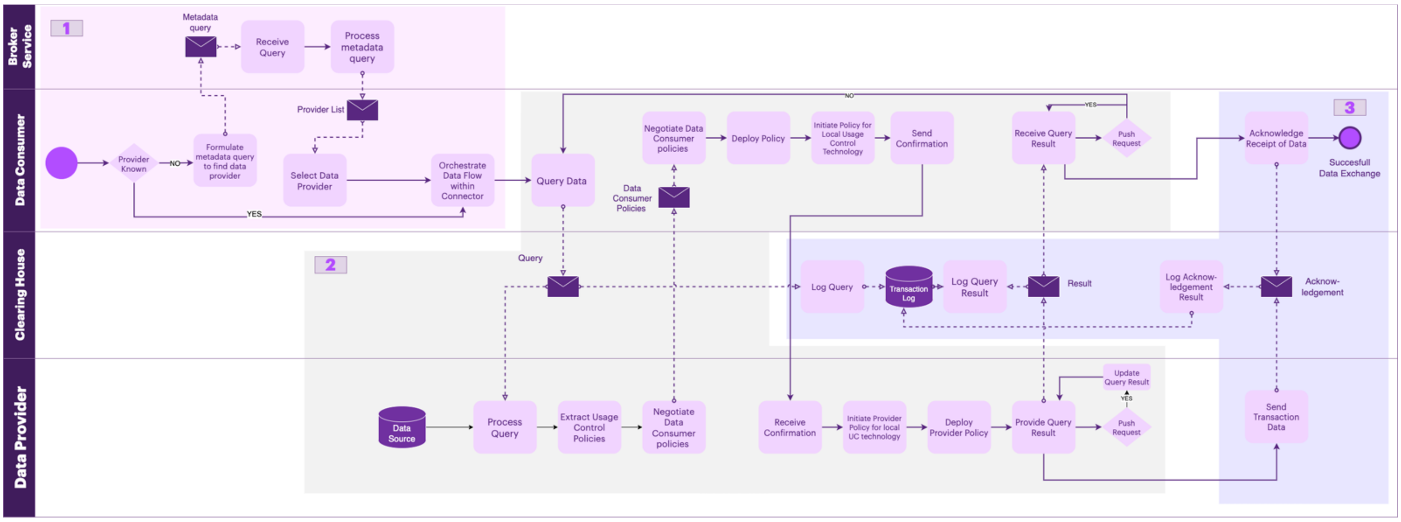

Figure 19 Full overview of the data sharing process between manufacturers and dismantlers (Own work based on Otto et al. 2023)

A larger image of figure 18 can be found in Appendix H.

6.6.1 Find Data Provider

A suitable Data Provider must be found for the dismantler who wants information about a particular vehicle that needs to be depolluted and dismantled. There are two scenarios, which are explained below.

6.6.1.1 The Data Provider is not known

When a Data Provider is not known beforehand, the dismantler has to formulate a metadata query to find a suitable Provider in the catalogs of an IDS Metadata Broker (Otto et al., 2023e). The Broker then compiles a list of metadata describing different data sources in the IDS. The query result may differ depending on the requesting IDS connector due to filtering the displayed data according to usage policies defined by the Data Provider (Otto et al., 2023d). From this list, the dismantler selects the Data Provider most suitable. When the right Data Provider is found, the negotiation process with the Data Provider can start.

This could occur when the dismantler wants to know more about whether an EEE component can also be used on another vehicle than what was extracted.

6.6.1.2 The Data Provider is known

If the Data Provider is already known to the dismantler, the dismantler can configure its Connector to connect directly to the corresponding Connector of the Data Provider.

This could occur when the dismantler wants more dismantling information about the safe dissemble of a specific Printed Circuit Board within a vehicle.

6.6.2 Query Data

The process of managing data is part of the Query Data sub-process. Usage policies derived from the query results are necessary for data exchange between the dismantlers and the Data Provider. They must negotiate and agree on a data usage policy through an automated process facilitated by their respective Connectors (Otto et al., 2023e). Such a usage policy could be that the dismantler only had access to this data for a few hours and that a new query has to be done after this. Once agreed, this policy is implemented within both Connectors, enabling the Data Provider to securely transmit the requested data to the Data Consumer (dismantler). If there is no agreement, the data exchange cannot occur.

6.6.3 Log Transaction Details

The last step involves recording the transaction specifics at the clearing house. In this phase, both the data consumer and data provider must communicate with the clearing house to verify the completion of the transaction (Otto et al., 2023e). The Clearing House then records details of the data request and the outcome (or related metadata) to monitor the type of data exchanged. This documentation allows the manufacturer or any other data provider to levy a nominal fee on the dismantler for the data supplied.

An important note. This information-sharing overview is mainly based on sharing between the manufacturer as a Data Provider and the dismantler as a Data Consumer. It is also possible to have other stakeholders engaged; for instance, in the Netherlands, the ARN could act as a Data Consumer and the dismantler as a Data Provider for information sharing about compliance with the rules set by the ARN. Also, as mentioned in section 4.4.1 other databases could be involved as Data Providers within the IDS.

6.7 Answering SQ3

This chapter focused on evaluating if the requirements identified in chapter 5 can be met by the International Data Spaces, guided by **SQ3**. This evaluation was done based on document research on the capabilities of the IDS as information sharing architecture. Overall, the IDS meets most of the identified requirements for WEEE information sharing well, as the IDS is designed to address specific needs related to data access, ease of use, and interoperability, thereby being able to enhance information-sharing practices in the automotive sector.

Requirement 1: Getting access to IDS

The onboarding process, including registration, certification, and operational setup, were elaborated upon to see if this is feasible for dismantlers and manufacturers. However, dismantlers to achieve this, external IT support is required due to, in general, limited IT expertise within dismantling companies. This assumption is based on the interviews and experiences with the dismantling companies. For manufacturers, on the other hand, which are often substantial companies with in-house IT teams, this will be less of a problem. They have the people to set this up.

Requirement 2: User-friendliness
It is also expected that with the use of the IDS, and with a single interface for accessing all the data, will simplify the process for dismantlers. Despite a testable prototype's absence, reducing the data access complexity suggests a more intuitive experience. Next to that, the IDS has the potential to minimize the administrative burden, especially considering the current challenges dismantlers face in navigating multiple databases. However, during the initial setup phase of the IDS, there might be a higher administrative burden.

Requirement 3: Data sovereignty
The IDS architecture addresses the need to balance transparency and intellectual property rights. Access control mechanisms, such as RBAC and ABAC, ensure that access to data is controlled and restricted to authorized entities. Extending these mechanisms to usage control is critical for managing data processing and dissemination, respecting intellectual property rights, and complying with usage policies. The IDS's focus on technical enforcement mechanisms provides a robust framework for controlling and monitoring data usage. This dual focus on access and usage control enhances the security and integrity of data exchange and ensures a respectful balance between transparency and intellectual property rights for manufacturers willing to share their data.

Requirement 4: Interoperability
The IDS Connector standardizes data exchange and ensures effective communication within the network. The process for achieving semantic interoperability involves comprehensive steps that ensure data is shared in a universally understood format, reducing integration efforts and ambiguity. The IDS's focus on semantic interoperability and adopting a common vocabulary ensures interoperability between diverse information systems. For national vehicle registries, the IDS could be implemented for interoperability, but practical application involves additional steps and stakeholder collaboration.

Requirement 5: Circularity vehicle passports
The IDS framework could facilitate a circular vehicle passport, adhering to open standards, and ensuring free data transfer through an open and interoperable network. The IDS Information Model and Vocabulary Hub are crucial in ensuring that information in the passport is machine-readable, structured, and searchable.

In conclusion, the IDS meets the various requirements. It enhances data-sharing practices, contributing to sustainable practices and could foster a more collaborative and productive relationships between manufacturers and dismantlers.

7 Conclusions

In this chapter, the answer to the main research question is presented based on the findings made through the research process. Next to that, the societal and scientific contribution is pointed out. Finally, the link of this thesis to the CoSEM master is provided.

7.1 Answering the MRQ

This section summarizes the conclusion of each SRQ and answers the MRQ.

This thesis started with identifying the barriers for WEEE information sharing in the automotive industry. This was done using the framework by Rukanova et al. (2023), dividing the system overview in four dimensions: CE context, public value, actors, and digital infrastructures. These dimensions helped with identifying the barriers, which resulted in a list of 10 different barriers which are summarized in Table 23. Next, this chapter helped to get a broader understanding of the current situation.

Table 23 Summarized list of barriers

ID	BARRIER	DESCRIPTION
B1	Incomplete documentation	Dismantlers lack critical data for identifying and processing EEE, impeding proper recycling and component recovery.
B2	Limited recovery of electronics in ELVs	Recycling facilities cannot sort ELV electronics, losing valuable PCBs and ECUs.
B3	Lack of harmonization	Diverse global ELV practices cause inconsistent processing, monitoring, and data storage.
B4	Information gap between manufacturers and dismantlers	Manufacturers and dismantlers struggle with a significant information gap on vehicle component details, hampering recycling efforts.
B5	Inconsistent data entry	IDIS and IMDS inconsistent data entry leads to chaotic, non-uniform information, making specific part identification difficult for dismantlers.
B6	Perception of competitive threat	Manufacturer's view data sharing as a threat to their competitive advantage, making them hesitant to share detailed information.
B7	Supply chain transparency conflicts	Suppliers and manufacturers resist revealing electronic component compositions, fearing intellectual property conflicts and legal issues.
B8	Administrative burden	Additional documentation requests could burden businesses, with executive bodies facing pushback when enforcing new regulations.
B9	Lack of standardization	Both IMDS and IDIS lack standardized data entry methods, resulting in disorganized and inconsistent data across the industry.
B10	Restricted data accessibility	The information within the IMDS is not publicly available, limiting the ability of all stakeholders to use this data for recycling and CE monitoring.

Next, based on these barriers mentioned above, an institutional analysis and multiple interviews, 5 main requirements were elicited, these were divided in several sub-requirements. These requirements were evaluated by two experts in the field. The final list of requirements contained a total of 23 requirements regarding WEEE information-sharing in the automotive industry. An overview of these requirements in provided in Table 24.

Table 24 Summarized overview of requirements

ID	REQUIREMENT
1	The information sharing infrastructure should ensure access to fundamental dismantling information for dismantlers
1.1	The information sharing infrastructure should provide access to digital information
1.1.1	The information should include information about digital procedures for component activation
1.2	The information sharing infrastructure should provide access to component information
1.2.1	The information should include detailed data about the location of these EEE components
1.2.2	The information should include data about the type of EEE, the brand name, and how the supplier meets responsibilities
1.2.3	The information sharing infrastructure should provide data about interchangeability of components
1.2.4	The information should include information on the safe removal of components
1.3	The information sharing infrastructure should provide access to material information
1.3.1	The information should include information relevant to promote recovery of CRMs
2.	The information sharing infrastructure should be easy to use for dismantlers
2.1	The information should be accessible in a user-friendly manner
2.2	The information sharing infrastructure should minimize the administrative burden for dismantlers and manufacturers
2.3	The information sharing infrastructure should have a standardized data entry process
3	The information sharing infrastructure should balance transparency and intellectual property rights
3.1	The information sharing infrastructure should facilitate access control
3.2	The information sharing infrastructure should facilitate usage control
4.	The information sharing infrastructure should provide interoperability between information systems
4.1	The information sharing infrastructure should ensure interoperability between national vehicle registries
5.	The information sharing infrastructure facilitates a circularity vehicle passport
5.1	The information included in this circularity vehicle passport should be based on open standards
5.2	The information included in this circularity vehicle passport should be transferable through an open interoperable data exchange network without vender lock in
5.3	The information included in this circularity vehicle passport should be machine-readable, structured, and searchable

Having the final requirements identified and having a broader understanding of the overall system, the thesis proceeded to evaluate the IDS, and see how this new information-sharing initiative was contributes to meeting these requirements. This was analyzed using multiple IDS documents which consists of detailed information about the different core concepts of the IDS and how these can be applied.

To answer the MRQ:

How can the International Data Space (IDS) initiative facilitate WEEE information sharing between manufactures and dismantlers within the automotive industry?

The thesis answered the question by investigating how the IDS meets the identified requirements. The IDS initiative can be an information sharing solution for facilitating WEEE information sharing between manufacturers and dismantlers within the automotive industry. Its core strength lies in providing a secure, standardized platform for data exchange and ensuring data sovereignty, which is important for manufactures (according to the literature) for sharing sensitive information. However, it is important to acknowledge existing limitations and prospects for effectively implementing the IDS. Despite its promising capabilities, the IDS's success hinges on all stakeholders' active participation and commitment. Manufacturers and dismantlers must be prepared to invest the necessary resources—time, knowledge, and finances—to leverage this digital infrastructure fully. The research highlighted a challenge for dismantlers, who typically have limited technical expertise, necessitating significant investments in training or external IT partnerships to facilitate their integration into the IDS ecosystem.

Moreover, the thesis emphasizes the crucial role of regulatory bodies in facilitating this initiative. Without appropriate regulatory incentives, manufacturers may remain hesitant to share vital data. The new ELV proposal represents a positive move forward, yet further regulatory support is essential for encouraging widespread adoption of the IDS.

The thesis does not provide specific details on the exact timeline for the implementation phase. As more information is needed to ascertain when the automotive industry can expect its full deployment. Similarly, the development and integration of the ontology into the IDS framework are recognized as essential for aligning the system with the specific needs of dismantlers. However, the thesis does not detail the current status of this ontology's development or how far along it is in the process of being fully integrated and operational within IDS. In section 8.2.1 recommendations are given on future research topics regarding the ontologies.

In summary, while this thesis highlights the potential of IDS in enhancing WEEE information sharing between manufacturers and dismantlers, it suggests that a more detailed examination of IDS's limitations, the completion timeline of the Reference Architecture Model, and the progress of the automotive ontology would be beneficial for a comprehensive understanding of IDS's role in supporting circular economy practices within the automotive industry.

7.2 Societal contribution

The societal contribution of this thesis is multifaceted, primarily focusing on enhancing information sharing of WEEE data in the automotive industry. This improvement directly influences the broader objectives of sustainable development and circular economy.

Firstly, this thesis addresses this recycling aspect by identifying the specific information requirements for dismantlers. Dismantlers play a vital role in the end-of-life phase of vehicles, where accurate and timely information is vital for efficient recycling and recovery of materials. By streamlining the flow of information from manufacturers to dismantlers, the thesis investigated an information-sharing infrastructure that could improve information-sharing, which result in optimized use of resources. This could benefit the environment by minimizing the ecological footprint of automotive waste and support the industry in becoming more sustainable.

Implementing the new ELV Regulation is another area where this thesis contributes. The research provides insights into implementing certain aspects of these regulations effectively. By aligning the information-sharing processes with the requirements of the ELV Regulation, the thesis can help ensure that the automotive industry complies with the latest environmental standards. This compliance is a legal necessity and a step towards fostering a more environmentally conscious and sustainable industry practice.

Finally, the thesis contributes to the future of the circular economy. The circular economy model emphasizes the reuse, recycling, and recovery of materials to minimize waste and resource depletion. By facilitating effective information sharing between manufacturers and dismantlers and aligning it with current regulations, the thesis lays down a practical pathway for the automotive industry to integrate circular economy principles into its operations. This integration is essential for transitioning to a more sustainable economic model, optimizing resource utilization, and minimizing environmental impact.

7.3 Scientific contribution

This thesis makes several contributions to the WEEE information sharing within the automotive industry. It addresses the knowledge gaps specified in section 1.1 by thoroughly identifying and navigating the challenges that obstruct information sharing between manufacturers and dismantlers. The research is grounded in a literature review, highlighting the need for improved information-sharing practices to support the goals of a CE.

The exploration of knowledge gaps, as discussed by Cozza et al. (2023), Rosa & Terzi (2023), Walden et al. (2021), and others, underscores the industry's challenges in aligning technological advancements with CE objectives. This thesis bridges these gaps by identifying barriers to WEEE information sharing and proposing actionable solutions by integrating digital infrastructures like the IDS.

Moreover, the thesis delineates five main requirements for an adequate information-sharing infrastructure, elaborated into several sub-requirements, which industry experts validated. This comprehensive list of requirements is a blueprint for developing or enhancing information-sharing systems within the automotive sector. It emphasizes the need for accessible, user-friendly, and secure platforms that respect intellectual property rights while promoting transparency and interoperability.

The scientific contribution of this thesis is further solidified through the evaluation of the IDS initiative. By analyzing how IDS aligns with the identified requirements, the research presents a compelling case for the potential of this initiative to facilitate WEEE information sharing between manufacturers and dismantlers. The IDS offers a secure, standardized platform for data exchange that can address many of the barriers identified in this study.

Additionally, the thesis acknowledges the practical challenges of implementing such digital solutions, particularly from the dismantlers' perspective, who may lack the technical expertise to engage with complex information systems. The need for regulatory incentives and the involvement of all stakeholders, including regulatory bodies, is also highlighted as essential for the success of initiatives like IDS.

In conclusion, this thesis advances the understanding of the barriers to adequate WEEE information sharing in the automotive industry. It proposes a viable pathway to overcoming these challenges through digitalization and collaborative efforts. It addresses the identified knowledge gaps and provides an example for practical implementation, thereby contributing to the current sustainability, IS, and circular economy literature.

7.4 Link with CoSEM

This thesis explores the complexities of WEEE information sharing in the context of ELVs within the automotive industry, focusing on the role of the IDS data space as an intervention in a system with uncertainties. By adopting the Complex Systems Engineering and Management (CoSEM) perspective, this research goes beyond technical solutions to include regulatory, economic, and human factors, acknowledging the multifaceted nature of the challenge.

Incorporating insights from various fields – including academia, law, and society – this study offers a comprehensive analysis that reflects the CoSEM program's emphasis on integrated and holistic approaches to problem-solving. It recognizes the socio-technical dimensions of information-sharing, presenting a nuanced understanding that combines technical proficiency with an appreciation for the broader system's complexities and uncertainties.

8 Discussion

In this chapter the limitations of the thesis are discussed, followed by recommendations for future research and a reflection of the research process.

8.1 Limitations

This thesis, while contributing to both scientific and societal knowledge, is not without its limitations. These limitations primarily arise from the research methods and information sources employed during the study.

8.1.1 Limitations of Desk Research

The use of desk research to address specific questions (SQ1 and SQ3) has inherent limitations. For instance, analyzing academic articles, which is a form of desk research, or other grey literature often provides a limited practical perspective, as it relies on how others how have collected and interpreted data under specific conditions. Additionally, the potential for bounded rationality and researcher bias in interpreting this secondary data cannot be overlooked.

8.1.2 Limitations of Interviews

Despite conducting two explorative conversations, three interviews, and two evaluations, the limited number of interviews and evaluations may affect the reliability of the outcomes. More interviews and evaluations could have provided a more robust understanding and better results, particularly in the requirements elicitation phase.

Furthermore, the absence of interviews with data space experts is a limitation. Insights from experts with more knowledge on topics such as the IDS would have offered a deeper understanding of how the IDS could be utilized to enhance information sharing in the automotive industry. Additionally, the thesis primarily focuses on the perspective of dismantlers, overlooking the viewpoint of manufactures, who are crucial stakeholders in data possession and sharing. Therefore, the viewpoint of the manufactures in the automotive industry is also interesting for further research, see section Viewpoint of manufacturers.

8.1.3 Limitations of the Chosen Sample

The research was limited to the dismantlers that operate in the Netherlands. An evaluator mentioned that in the United States, information sharing in the automotive industry is more advanced. However, this aspect was not explored in the thesis. The automotive industry is vast and encompasses a large ecosystem, implying that many perspectives, particularly international ones, were not included in this study. This limitation suggests that the findings may not fully represent the global scenario of WEEE information sharing in the automotive industry thereby affecting the generalizability of the conclusions.

8.2 Recommendations

8.2.1 Recommendations for future research

8.2.1.1 Focus on other countries

In this thesis, the focus was primarily on the Dutch dismantling companies. However, during one of the evaluations, it was mentioned that in countries like the United States (US), there are more initiatives regarding information sharing in the automotive industry for dismantlers. During this evaluation it was also mentioned that the current information sharing practices in the US is more efficient that the practices in Europe. This presents an interesting avenue for further research. Additionally, exploring other markets, such as China, could offer valuable insights into how different regions approach the same challenges and opportunities in the industry.

Future Research Questions:

1. How do the strategies and initiatives for information sharing among automotive dismantlers in the United States compare to those in the Netherlands, and what best practices can be adopted?
2. What are the specific characteristics and challenges of the Chinese market for automotive dismantlers in terms of information sharing and industry practices?

8.2.1.2 Ontologies

Throughout the interviews and the process of writing this thesis, it became clear that many dismantlers are currently lacking essential information. The information needs of dismantlers could be further explored. Moreover, for the effective implementation of data spaces (IDS or another data space) and their vocabularies, the design of ontologies is crucial. This has been previously undertaken in a thesis concerning the textile industry by Goedkoop (2023), but it is equally relevant in the context of electronics in vehicles and other vehicle components.

Future Research Questions:

1. In what ways can the creation and implementation of ontologies improve the efficiency and effectiveness of information sharing in the automotive industry?
2. How can the experiences and lessons learned from ontology design in the textile industry be applied and adapted for the automotive industry?
3. How can a prototype automotive-ontology be structured for IDS to maximize its contribution to providing circular data?

8.2.1.3 Viewpoint of manufacturers

Manufacturers are the primary source of all vehicle data, yet they are often not willing to share this data for various reasons as mentioned multiple times in this thesis. Understanding why manufacturers in the automotive industry are reluctant to share data is interesting. This research could build on the initial assumptions made in this thesis, which were based on interviews, and investigate their validity. Additionally, manufacturers will have their own requirements and perspectives regarding an information sharing infrastructure. While this thesis considered intellectual property based on desk research, conducting interviews and further exploration in this area could provide more comprehensive insights and requirements from the manufacturers' viewpoint.

Future Research Questions:

1. What are the underlying factors contributing to the reluctance of automotive industry manufacturers to share data, and how can these barriers be overcome?
2. What are the specific requirements and expectations of manufacturers concerning the information sharing infrastructure in the automotive industry?
3. How does the issue of intellectual property influence manufacturers' willingness to share information, and what strategies can be developed to address these concerns?

8.2.1.4 Other digital infrastructures

There is a wide array of new digital information sharing infrastructures currently under development, such as GAIA-X, Data Sharing Coalition, iSHARE, The European Spatial Data Infrastructure, and more. Exploring these other infrastructures could provide valuable insights and aid in decision-making processes within the automotive industry. This is particularly relevant for the management of end-of-life vehicles (ELVs) and could have broader implications for the industry.

Future Research Questions:

1. How do emerging digital infrastructures compare in improving information sharing in the automotive industry?
2. In what ways can new digital information sharing platforms transform the automotive dismantling industry?

8.3 Reflection on research process

The research process of this thesis has been an enlightening journey, filled with numerous lessons and insights. It was not only an exploration of the specific topic but also a deeper understanding of the research process itself.

One of the main lessons learned during this research was the necessity of adapting to changes. Initially, the plan was to compare various information sharing infrastructures. However, due to time constraints and an underestimation of the workload, it became necessary to refine the focus to the IDS and its role in enhancing WEEE information sharing in the ELV stage. This adjustment, although challenging to accept at times, was an essential part of the research journey. The guidance from my professor was very useful in helping me understand that such shifts are a natural part of research. Despite being forewarned at the beginning, experiencing these changes firsthand was still somewhat surprising.

Another key insight was the importance of scoping the research and defining a clear research problem. My excitement about the topic occasionally led me to delve into interesting but irrelevant papers and resources. This exploration, while sometimes broadening my understanding, often distracted me from the core thesis topic and consumed valuable time. Similarly, during interviews, the attraction of interesting but unrelated topics sometimes caused a loss of focus, resulting in longer interviews and additional time spent on transcription and coding.

Finally, one of the most crucial lessons for me was to embrace the complexity of the research process, with its ups and downs, and strive to simplify it as much as possible. Initially, I attempted to cover an extensive range of topics, including Data Spaces, Blockchain, digital product passports, CE monitoring, ELV regulations, and more. This approach led to an overload of information, making it difficult for readers to grasp the direction and purpose of my research. Eventually, I learned to maintain a balance by focusing more deeply on the essential areas while providing a high-level overview of less critical aspects. This approach helped in addressing the main research question more effectively without overwhelming the reader with excessive detail.

In summary, the research process was a dynamic and evolving journey that taught me the value of adaptability, the importance of maintaining focus, and the need to simplify complex ideas for clarity and coherence. These lessons will be invaluable for my future research endeavors

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Appendix A – Core concepts IDS

Broad explanation of the different categories within the IDS and the different roles, based on Table 2.

A.1 Category 1: Core Participant

Core Participants are involved and required every time data is exchanged in the International Data Spaces. Roles assigned to this category are Data Supplier and Data Customer.

Data Owner
A data owner, either a legal or natural person, has the authority and control over data, highlighted by their ability to set usage policies and grant data access. Responsibilities include creating usage contracts, determining payment models, and providing data access. While typically a data owner also serves as a data provider, there are exceptions, such as when data management is delegated to an external provider or trustee. In such cases, the owner's role is primarily to authorize a data provider to share data with consumers, formalized through a contract outlining usage policies, which can be digital rather than paper based.

Data Provider
A Data Provider is an entity that facilitates data exchange between a Data Owner and a Data Consumer, often being the Data Owner itself. They are responsible for making data accessible, complying with the IDS Reference Architecture Model, and may submit metadata to a Broker Service Provider for data discovery and retrieval. Beyond mere facilitation, Data Providers may log transaction details for billing or conflict resolution, use Data Apps to enhance or modify data, and assist Data Consumers lacking technical infrastructure by connecting them to the IDS through a Service Provider.

Data User
A Data User is a legal entity authorized to use the data of a Data Owner according to the defined usage policy. Typically, a Data User is synonymous with a Data Consumer, but there are situations where these roles differ. For instance, in a scenario where a patient uses a web-based system for managing personal health data and allows a health coach access to this data, the health coach would be the Data User. In contrast, the provider of the web-based system, receiving data from a hospital, would be the Data Consumer. This distinction highlights the different roles and rights in data usage within legal frameworks.

Data Customer
A Data Consumer is an entity that receives data from a Data Provider. Functioning as the counterpart to the Data Provider in business processes, the Data Consumer engages in activities parallel to those of the Data Provider. Prior to establishing a connection with a Data Provider, a Data Consumer may explore available datasets by consulting a Broker Service Provider for necessary metadata. Alternatively, a direct connection with a Data Provider is possible if the Data Consumer already possesses the required information. Similar to a Data Provider, the Data Consumer can log transaction details at a Clearing House, use Data Apps to enhance or process the received data, and employ a Service Provider for connectivity to IDS, especially if lacking the requisite technical infrastructure.

A.2 Category 2: Intermediary

Intermediaries act as trusted entities. Roles assigned to this category are Metadata Broker, Service Provider, Clearing House, App Store, Vocabulary Provider, and Identity Provider. Only trusted organizations should assume these roles.

Metadata Broker

A Broker acts as a mediator and information manager, linking data providers with data users. Its primary function is to facilitate the discovery and exchange of data by acting as a registry for data sources. The Broker allows data providers to publish their data sources, while giving data users the ability to search through these sources efficiently. Additionally, it provides essential functions for both parties to negotiate and agree upon the terms of data provision and usage. This service is critical but not exclusive in the IDS, meaning there can be multiple Brokers, possibly specializing in different domains. The Broker's role is focused on managing metadata – it receives metadata from data providers, stores it in an internal repository, and makes it available for structured querying by data consumers. Once a data consumer has obtained the necessary metadata about a data provider from the Broker, the Broker's role in the specific data exchange process concludes.

Clearing House

A Clearing House serves as an intermediary, overseeing and facilitating the clearing and settlement of both financial and data exchange transactions. Its primary role is to log all activities related to data exchanges. After a data exchange is completed, both the data provider and the consumer confirm the transfer by logging transaction details with the Clearing House. This logged information is crucial for billing purposes and can also be instrumental in resolving any conflicts, such as verifying the receipt of data packages. Although separate from broker services, the Clearing House may still be operated by the same organization, as both roles involve acting as a trusted intermediary. Additionally, the Clearing House supports rollback of transactions in cases of faulty or incomplete data exchanges and provides reports on these transactions for billing and conflict resolution. This supervision by the Clearing House is conducted without infringing upon the data sovereignty of the owners.

App Store

An App Store functions as a digital marketplace where participants can develop and share software, particularly data services. It enables software developers to describe and make their data services available to other participants. Users of the App Store can search for, retrieve, and download these data services. The App Store also provides mechanisms for payment and rating of these services. Data Apps, a key offering of the App Store, are applications designed to be deployed within the IDS Connector, facilitating various data processing tasks like transformation, aggregation, or analysis. These Data Apps can undergo certification by approved bodies, ensuring they meet IDS standards. The App Store, which can be operated by IDS members, is responsible for managing and providing information about these Data Apps, including their metadata, and must itself adhere to separate certification standards to align with IDS requirements.

Vocabulary Provider

A Vocabulary Provider in IDS plays a crucial role in managing and offering vocabularies, such as ontologies, reference data models, or metadata elements, which are essential for accurately annotating and describing datasets. This provider is responsible for supplying the Information Model of the IDS, forming the foundation for data source descriptions. Besides this, the Vocabulary Provider also caters to domain-specific needs by creating and making available specialized vocabularies. It supports these functions through a central repository for schema and vocabulary information, collaborative versioning tools for creating, maintaining, and archiving vocabularies and schemas, and mechanisms for linking the data transferred by the Connector with the relevant vocabulary information. This service ensures that data within the IDS is well-defined and consistently understood across different participants.

Identity Provider

An Identity Provider in the IDS is a crucial service for creating, maintaining, managing, monitoring, and validating identity information of IDS participants. This role is vital for the secure operation of IDS, ensuring that only authorized entities access data. The Identity Provider encompasses a Certification Authority, which manages digital certificates for IDS participants, a Dynamic Attribute Provisioning Service (DAPS) for handling dynamic attributes, and a Dynamic Trust Monitoring service for continuous security and behavior monitoring. It uses X509v3 certificates for authentication and dynamic tokens issued from an attribute server for identity attribute exchange, thereby maintaining collective trust and preventing unauthorized data access.

A.3 Category 3: Software and Services

Service Provider

If a participant does not deploy the technical infrastructure required for participation in the IDS itself, it may transfer the data to be made available in the IDS to a Service Provider hosting the required infrastructure for other organizations. This role includes also providers offering additional data services (e.g., for data analysis, data integration, data cleansing, or semantic enrichment) to improve the quality of the data exchanged in the IDS.

Software Provider

A Software Provider provides software for implementing the functionality required by the IDS. Unlike data apps, software is not provided by the App Store, but delivered over the Software Providers' usual distribution channels, and used on the basis of individual agreements between the Software Provider and the user (e.g., a data consumer, a data provider, or a Broker Service Provider).

A.4 Category 4: Governance Body

The IDS is governed by the Certification Body and the International Data Spaces Association.

Certification Body and Evaluation Facility

The Certification Body and the Evaluation Facility are in charge of the certification of the participants and the technical core components in the IDS.

International Data Spaces Association

The International Data Spaces Association is a nonprofit organization promoting the continuous development of Data Spaces. It supports and governs the development of the Reference Architecture Model. The International Data Spaces Association is currently organized across several working groups, each one addressing a specific topic (e.g., architecture, use cases and requirements, or certification). Members of the Association are primarily large industrial enterprises, IT companies, SMEs, research institutions, and industry associations.

Appendix B – Justification for public values

Here an overview of the policy measures from the ELV Regulation are shown in table 25. For section 4.2 only the public values drivers/promotors are taken into account that have measures for information sharing or ELV management.

Table 25 Policy options and measures (European Commission, 2023)

Policy Options	No	Measures
PO1 Design Circular	1A	M1 - Ensure that new 3RTA rules provide for proper implementation of circularity requirements for new vehicle types
		M2 - Empowerment for the Commission to develop a refined methodology to determine compliance with 3R-requirements
		M3 - Provision of basic dismantling information to ELV treatment operators
		M4a - Declaration on substances of concern verified by 3R type-approval authorities
		M5a - Restrictions of substances under the revised ELV Directive
	1B	M4b - Mandatory declaration on recycled content of plastics, steel, aluminium
		M5b - Restrictions of substances under REACH and other existing legislation
		M6 - Obligation for vehicle manufacturers to develop circularity strategies
		M7 - Design requirements for new vehicles to facilitate the removal of components
	1C	M4c - Mandatory declaration on recycled content for materials, other than plastics, including CRMs, steel, aluminium
		M5c - Hybrid approach: maintenance of current restrictions under ELV with new restrictions under REACH
		M8 - Establishment of a digital Circularity Vehicle Passport
PO2 Use Recycled Content	2A	M9a - Mandatory recycled content targets for plastic used in vehicles - 6% recycled plastics content by 2031, 10% by 2035 at fleet-level, of which 25% of recycled material from closed loop production, calculation and verification rules
		M10a – Empower the Commission to set a mandatory recycled content target for steel, including calculation and verification rules, based on a dedicated feasibility study
	2B	M9b – Recycled plastics content: 25% in 2031 for newly type-approved vehicles only, of which 25% from closed loop production, calculation and verification rules
		M10b - Steel recycled content: 20% in newly type-approved vehicles, calculation and verification rules
	2C	M9c – Recycled plastics content: 30% in 2031 for newly type-approved vehicles only, of which 25% from closed loop production, calculation and verification rules
		M10c - Steel recycled content: 30% in newly type-approved vehicles, of which 15% from closed loop production, calculation and verification rules
		M11 - Empower the Commission to set mandatory recycled content targets for other materials (aluminium alloys, CRMs), feasibility study, target levels calculation and verification rules
PO3 Treat Better	3A	M12- Aligning the definition of recycling and aligning the calculation methodology for recycling rates with other waste legislation

		M13a - Mandatory removal of certain parts/components prior to shredding to encourage their recycling or reuse, ‘list A’
		M14a – New definition of 'remanufacturing' and new monitoring requirements for reuse/ remanufacturing
		M16a - Ban on the landfilling of automotive waste residues from shredding operations
	3B	M13b - Mandatory removal of a longer list of components, including those that contain a high concentration of valuable metals or CRMs, ‘list B’
		M14b - Market support for the use of spare parts
		M15b - Recycling targets for plastics – 30%
		M16b - Ban on mixed shredding of ELVs with WEEE and packaging waste
	3C	M13c - Mandatory removal of additional components, ‘list C’
		M15c - Glass – 70% recycling as container glass quality or equivalent
		M16c - Setting requirements on post shredder technologies to improve the quantity and quality of metal scrap recovered from ELVs
PO4 Collect More	4A	M17a - Reporting by Member States on missing vehicles, vehicle registration, the import and export of used vehicles, incentives to encourage delivery to an authorised treatment facility and penalties
		M18 - Obligations for dismantlers, recyclers to check and report on ELVs, certificates of destruction
		M19a – Setting minimum requirements for sector inspections and enforcement action (including non-binding Correspondents Guidelines No9)
	4B	M17b – Setting fines for the ELV sector if an ELV is sold to illegal dismantlers and for dealers (and electronic platforms) dealing with dismantled (used) spare parts from non-authorised facilities
		M19b - Clearer definition of ELVs to ensure that there is a better distinction between used vehicles and ELVs (binding CG9)
		M20 - Improving the information contained in national vehicle registries and making them interoperable
	4C	M19c - Provide or making available information on vehicle identification and roadworthiness to customs authorities (vehicle identification number)
		M21 - Export requirements for used vehicles linked to roadworthiness
	4D	Includes measures M17b, M18, M19a-c, M20, M21of PO4A, PO4B and PO4C (cumulative)
PO5 EPR	5A	M22 - Requirement for the Member States to establish collective or individual EPR schemes, including monitoring compliance costs and minimum financial obligations
		M23 - Reporting obligations for producers
	5B	M24 - Harmonised modulation of EPR fees
		M25 - Transfer of the EPR fees/ guarantees (cross-border EPR)
	5C	M26 – Setting up national deposit refund schemes
		M27 - Harmonised Green Public Procurement criteria (voluntary)
PO6 Cover more vehicles	6A	M28 - Provision of information to dismantlers and recyclers
	6B	M30a - Mandatory treatment of end-of-life L3e-L7e-category vehicles, lorries (N2, N3) and buses (M2, M3) and trailers (O) at authorised treatment facilities
		M30b – Export requirements for used vehicles linked to roadworthiness status of lorries (N2, N3) and buses (M2, M3) and trailers (O)

		M31b – Minimum EPR requirements for end-of-life L3e-L7e category, lorries (N2, N3) and buses (M2, M3) and trailers (O)
		M32 – Review clause on the regulatory extension of 3RTA scope to new vehicles
	6C	M31c – Full application of EPR and advanced economic incentives
		M33 – Full scope application of the new 3RTA and end-of-life treatment requirements to additional vehicle categories

Appendix C – Business actors

In this appendix an overview is given of all business actors mentioned in Figure 12.

Table 26 Business actors overview

Actor	Role
Suppliers	They provide the raw materials and components necessary for manufacturing vehicles. This includes everything from metal and plastic to electronic components.
Manufactures	Responsible for designing and assembling vehicles. They combine parts provided by various suppliers to create the final product – the cars.
Importers	These actors are involved in bringing vehicles from manufacturers (often in other countries) into a domestic market. They handle the logistics and regulatory compliance of transporting these vehicles across borders.
Dealers	They are the retail face of the automotive industry, selling new and used vehicles to consumers. Dealerships often provide additional services like financing options, warranties, and vehicle maintenance.
Owners	These are individuals or entities who purchase and use the vehicles. Owners are responsible for the maintenance, insurance, and proper use of their vehicles.
Repairers	They provide maintenance and repair services for vehicles. This can range from routine maintenance (like oil changes and tire rotations) to more complex repairs involving engine work or collision damage.
Dismantlers	Specialize in deconstructing vehicles at the end of their life cycle. They carefully remove reusable parts, fluids, and hazardous materials before the vehicle is shredded for recycling.
Shredders	These actors play a crucial role in recycling vehicles. They use large machinery to shred decommissioned vehicles into smaller pieces, separating out recyclable materials like metal.
Post Shredders	They handle the materials after the initial shredding process. Post-shredders sort out the different types of materials (metals, plastics, etc.) and prepare them for recycling or proper disposal.
Car part sellers	This group includes both retailers and wholesalers who sell new or used car parts. These parts can come from manufacturers, dismantled vehicles, or other sources.
Residue collectors	They are responsible for collecting and properly disposing of or recycling the non-metallic residue (like plastics, glass, and fluids) left over from the shredding and post-shredding processes.

Appendix D – IDIS

In this appendix screenshots of the IDIS system are provided. In Figure 20 can be seen that a lot of EEE information is missing (as it is grey). In Figure 21 can be seen that the data about the available components in minimal.

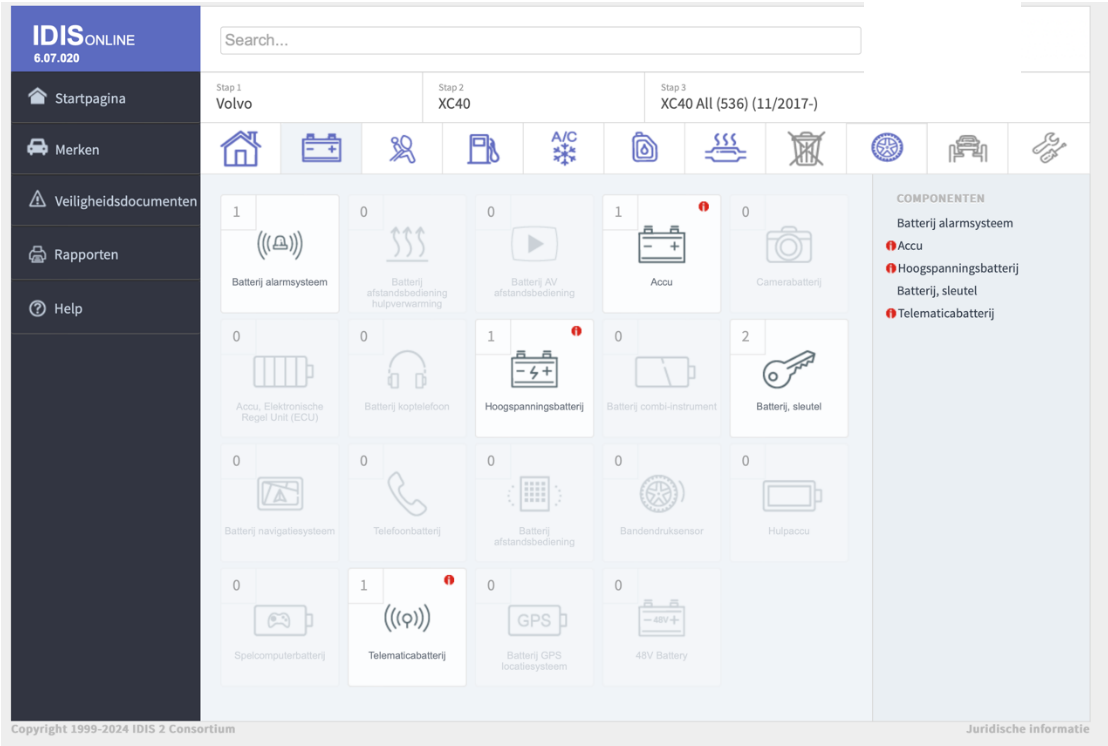

Figure 20 IDS Screenshot Information regarding EEE

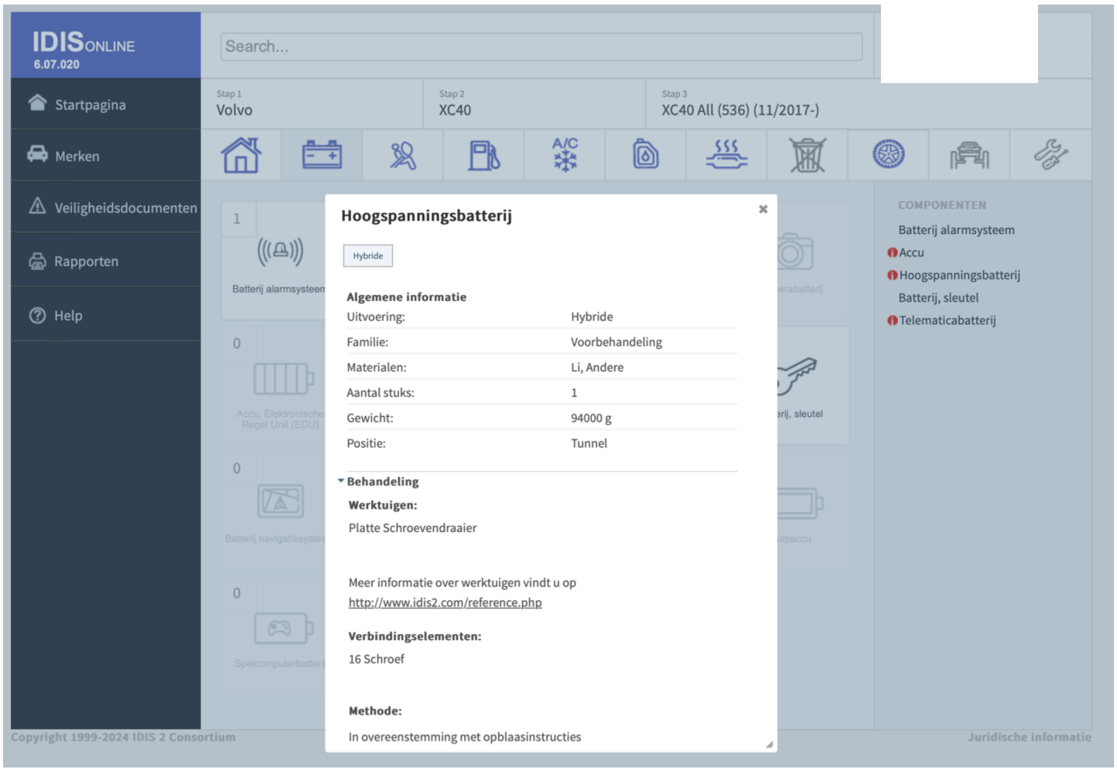

Figure 21 IDS Screenshot limited dismantling and component data

Appendix E – Overview of legislation analysis

The ELV Directive (ELVD) 2000/53/EC is a regulatory framework established by the EU with the objective of managing ELVs and their components in an environmentally responsible manner. It seeks to minimize waste by promoting the reuse, recycling, and recovery of ELVs while enhancing the environmental performance of all stakeholders involved in the vehicle life cycle. The ELVD's complexity, involving environmental, resource, waste management, and socio-economic aspects in vehicles, necessitates alignment with broader EU policies (especially on circular economy) and international agreements (Williams et al., 2020). There is a lot of overlap with existing policies such as the Waste Framework Directive (WFD), Waste Shipment Directive (WSR), Waste Electronical and Electronic Equipment (WEEE) Directive, Batteries Directive, and the European List of Waste Directive on the Recyclability and Recoverability of Road Vehicles. An overview of this is given in Figure 21. The focus lies on the red rectangle, all that comes after EoL.

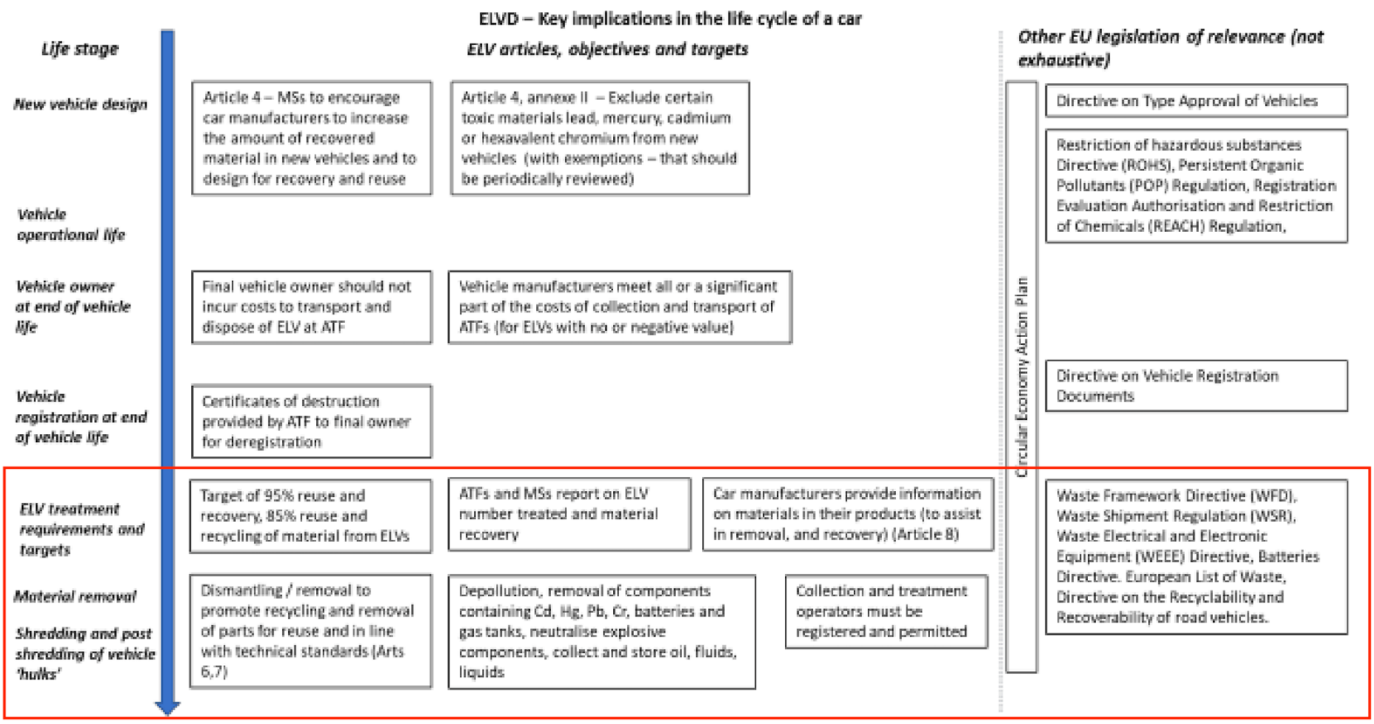

Figure 22 Summary of the ELVD and cross over with other EU legislation (Williams et al., 2020, p.25)

The ELVD and the European List of Waste Directive on the Recyclability and Recoverability of Road Vehicles will be replaced by the new ELV regulation that is in proposal. Therefore, instead of the ELVD and the European List of Waste Directive on the Recyclability and Recoverability of Road Vehicles, the ELV Regulation will be taken into account from here. Consequently, this analysis will primarily consider the forthcoming ELV Regulation, and the regulations identified in the red rectangle in Figure 22. Table 27 provides a detailed overview of these regulations, including the new Critical Raw Materials (CRM) Act and the ELV Regulations, highlighting the specific legislation that addresses End-of-Life Vehicles (ELVs), electronics, and CRMs. Notably, the WEEE Directive, the CRM Act, and the ELV Regulation all mention these aspects. Therefore, these three will be used in the requirement elicitation process detailed in **Fout! Verwijzingsbron niet gevonden.**.

Table 27 Analysis of Regulations related to the ELVD

LEGISLATION	OBJECTIVE	ELV	ELECTRONICS	CRMS
Waste Framework Directive (WFD)	This EU framework mandates proper waste treatment to safeguard the environment and health, prioritizing resource efficiency through recycling and recovery.			X
Waste Shipment Directive (WSR)	Sets waste shipment control rules to enhance environmental protection, incorporating Basel Convention and OECD's 2001 decision on transboundary waste movements into EU law.	X		
Waste Electronical and Electronic Equipment (WEEE) Directive	Aims to safeguard the environment and health through eco-friendly production, consumption, and EEE waste reduction, enhancing resource efficiency and recycling.	X	X	X
CRM Act	The objective is to enhance the resilience and sustainability of the European critical raw materials value chain, diversify imports, bolster monitoring and mitigation of supply disruptions, and promote environmental protection and circularity in the EU market.	X	X	X
ELV Regulation	Establish a closer link between the design requirements for vehicles and the provisions concerning ELV management, thus enabling the smooth functioning of the single market. Therefore,	X	X	X
Batteries Directive	The directive bans high-mercury and cadmium batteries, encourages recycling, and reduces hazardous substance discharge into the environment, especially mercury, cadmium, and lead.	X		

Appendix F – Explorative Conversations

F.1 Explorative Conversation ARN

Type: Informative conversation
Topic: Recycling of ELVs with a focus on WEEE
Date: 02-10-2023
Participant: Experienced innovation coordinator at the ARN

In a recent conversation with the Innovation Coordinator from ARN, various subjects concerning recycling within the automotive sector were discussed. The following report of the conversation offers an overview of these topics including more information about then ARN, legislation, current methodologies of WEEE recycling in vehicles, and challenges regarding information sharing. In conclusion, the ARN mentioned four needs to enhance ARN's future approach to WEEE recycling. These discussed topics are highlighted in the sections below.

About ARN
Auto Recycling Nederland (ARN) is a foundation situated in the Netherlands dedicated to recycling of End-of-Life Vehicles (ELVs) and EV batteries. Initiated by the Dutch automotive sector, ARN's primary mandate is to align the recycling and repurposing of vehicles in the Netherlands with the environmental standards set by the European Directive on ELVs. In accordance with this directive a minimum of 95% of a vehicle's weight must be either recycled or recovered; ARN surpasses this requirement, achieving a rate of approximately 98%.

ARN oversees a comprehensive system, spanning from the retrieval of decommissioned vehicles and extraction of residual fluids, such as automotive oils, to the recycling of components and materials. To attain these elevated recycling rates, ARN has partnerships with an extensive network of entities, including, dismantling companies, waste collectors, shredder companies, and recycling partners.

Legislation
The current legislative framework lacks comprehensive clarity regarding the treatment of all materials incorporated in an automobile. Emphasis primarily centers on specific components, including steel, tires, and batteries (which is also ambiguous). New legislation called ELV Regulation, is set to offer enhanced specificity beyond the current ELV directive. For example, this regulation mandates that a designated proportion of newly manufactured vehicles incorporate recycled materials. Furthermore, it is expected to explain the handling of CRMs and WEEE in the automotive sector. The implementation date for this regulation remains undetermined.

WEEE
In the automotive sector, a pressing concern is the limited recycling of in-car electronics. While metals such as aluminum (Al) and copper (Cu) undergo recycling during the shredding phase, other Critical Raw Materials (CRMs) present in Printed Circuit Boards (PCBs) and other electronics are often incinerated instead of being recycled. This arises from the lack of proper dismantling of these electronics. Furthermore, Rare Earth Permanent Magnets (REPMs), integral to components like e-drive motors, are lost as residues in the shredding process. ARN has noted that the WEEE directive, which should address these issues, remains overlooked during the current recycling process. However, the new ELV regulation foresees in the treatment of automotive WEEE.

Regarding electronics, there's a pronounced disparity between supply and demand. A significant number of vehicles entering the shredding process are over two decades old, equipped with now-obsolete technologies like cassette and

CD players. Given the lack of contemporary relevance and market demand for such items, dismantlers often overlook these parts, seeing no profit due to the absence of potential buyers.

Information sharing

The ARN emphasizes that the existing documentation on automotive materials (including electronics) is incomplete. They primarily rely on the IDIS database. Notably, it is the duty of the OEMs to populate this database with relevant information. The absence of standardized methods for this input results in an unorganized and non-uniform database. Moreover, the data lacks specificity; while some OEMs may note the use of materials like aluminum or plastic, the exact type isn't always specified. This lack of detail can impact the recycling process and the eventual application of the recycled material. Ambiguous information complicates the recycling attempt.

To initiate the recycling of automotive electronics, the Innovation Coordinator of ARN mentioned the following four needs during the conversation:

- Implement the forthcoming ELV regulation as it offers clearer guidelines on managing WEEE within vehicles.
- Prioritize the dismantling of electronics instead of shredding them to preserve CRMs.
- Enhance the clarity and comprehensiveness of information related to CRMs in vehicles, including electronics.
- Collaborate with partners specialized in WEEE recycling.

F.2 Explorative Conversation TNO

Type: Informative conversation
Topic: The current state of WEEE recycling in the Netherlands
Date: 15-11-2023
Participants: Circular Electronics professional from the TNO

In a recent conversation with the Circular Electronics professional from the TNO
, various subjects concerning recycling of WEEE in the Netherlands and Europe were discussed. The following report of the conversation offers an overview of these topics.

Are there similar organizations to ARN that focus on WEEE in the Netherlands and are involved with the implementation of the WEEE Directive?

In the Netherlands, Stichting OPEN is actively engaged in matters similar to ARN, including reporting to the EU. Stichting OPEN is an organization managing the recycling of electrical equipment in the Netherlands. Additionally, Stichting Open has become a significant organization in this area. Stibat offers responsible services and solutions that contribute to a circular economy. There is substantial collaboration with TNO and Stibat, and a joint project is underway to identify Critical Raw Materials (CRMs) present in electronics. The Ministry of Economic Affairs and climate is also involved in these initiatives, reflecting a comprehensive approach to the implementation of the WEEE Directive in the country.

Do you have an understanding of where EEE manufacturers currently store their data regarding the components and CRMs they use?

The data that is used by the TNO for a current project is mainly from the ProSUM project. This project delivers the first urban mine knowledge data platform, a centralized database of all available data and information on stocks, flows and treatment of WEEE, ELVs and batteries and mining wastes (in the EU, data up to 2015, estimates up to 2020. They state that the availability of primary and secondary raw materials data, easily accessible in one platform, will provide the foundation for improving Europe’s position on raw material supply, with the ability to accommodate more wastes and resources in future. This data is valuable as it consists of material, component, and element data. ProSUM published their findings on different waste streams up to 2015. Afterward UNITAR continued this work, however there is no data available after 2015.

However, the data within the ProSUM database is not accessible to everyone. TNO can currently only use some visualizations, however, real access to the data is not the case. Which is unfortunate based on the objective of ProSUM, to create a centralized database of all available information on different waste streams and materials for improving Europe’s position on raw material supply, and providing a user friendly access to data and intelligence on mineral resources.

Next to the ProSUM visualizations, also academic articles are used as a data source by the TNO.

Do you have an understanding of what currently happens with electronics in the automotive industry during the End-of-Life Vehicle (ELV) phase?

As mentioned in a previous conversation with Thorsten, currently nothing happens with EEE in ELVs. Most of the CRMs are lost in the shredder. According to Susanne, the primary focus is on materials that yield the highest returns, such as coper and steel. However, other components that are less lucrative are often not recycled or repurposed, indicating a gap in the ELV process where only certain materials are reclaimed, leaving others without a clear end-of-life pathway.

What is done with recycled CRMs now, where do they go? Are there specific stakeholders who take this on? Do we ensure in the Netherlands that this is actually reused?

The path that recycled Critical Raw Materials (CRMs) take is somewhat obscure. The European Union has an interest in retaining all these materials within its borders, but this notion is somewhat impractical given that many CRMs are processed outside of Europe. In PCB recycling, it's estimated that only a fraction of the possible elements is actually reclaimed—perhaps just one or two out of ten.

The initiative "CLOSING THE LOOP" may offer insights into this issue, though detailed data on the post-recycling fate of materials is lacking. Companies like Umicore are involved in the recycling process and express a desire for more transparency about the life cycle of recycled materials. The Producer Responsibility Organization (PRO) framework for electronics is complex due to the involvement of many small players, whereas the automotive sector presents a more streamlined and clearer picture.

The TNO also mentioned that currently the data on what happens to the recycled materials is missing and they would like to know more about this.

Appendix G – Interviews

G.1 Interview Protocol

This appendix presents the structured interview protocol designed for this research, which focuses on examining the existing practices and challenges in data sharing, specifically concerning electronics in End-of-Life Vehicles (ELVs). The core objective of these interviews is to pinpoint crucial requirements needed to streamline the information sharing process for dismantlers. This is intended to facilitate more efficient and effective dismantling of Critical Raw Materials (CRMs) from automotive vehicles, enhancing both the process and outcomes for dismantling companies. The structured approach of these interviews aims to gather in-depth insights while addressing the specific needs and challenges faced in the ELV dismantling sector.

Introduction

- Welcome participant
- Explain the purpose of this interview
- Confirm consent

Interview questions

1. How do you currently obtain information for dismantling ELVs? Can you detail the process, including any specific databases or tools used?

2. Are there challenges in accessing or utilizing this information?
    a. If so, what improvements would make the process easier for you?

3. How complete and accurate is the data you receive from these sources?
    a. Are there instances where you lack information about certain car components?

4. What are the primary components you focus on dismantling in ELVs?
    a. (If not mentioned) Have you considered dismantling electronic components such as PCBs, ECUs, or magnets?
    b. What are the current barriers for you regarding this?

5. Are you planning to, or are you open to, expanding your dismantling processes to include electronics and critical raw materials? Why or why not?

6. How aware are you of the upcoming ELV Regulation, especially regarding the need to dismantle electronics that contains CRMs from cars?
    a. Do you for see any challenges regarding with the implementation of this regulation?

7. Considering the new regulation, have you established any partnerships with electronic dismantlers yet, or are you planning to?

8. Dismantling cars is an important step for the recycling of ELVs. Are you currently being monitored on where each of the dismantled component end up?

a. Where and to whom do you have to upload this information?
b. How is the administrative burden of this task?

Thank you for your time. After summarizing this interview, I will share the this with you for your approval. If you are interested, I will also share my final thesis document with you. Thanks again for your participation.

G.2 Interview Consent Form

Beste [Patricipant_Name],

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd *'Enhancing compliance Monitoring in ELV recycling: Comparing Data Space Initiatives for Effective WEEE Information Sharing Among Car Dismantlers'* (working title). Dit onderzoek wordt uitgevoerd door Angel Aardse van de TU Delft en wordt begeleid door Dr. Jolien Ubacht. Dit onderzoek is ter afronding van mijn masteropleiding Complex Systems Engineering and Management aan de TU Delft.

Het doel van dit onderzoek is bestuderen en analyseren hoe data spaces kunnen helpen bij het delen van informatie over oude elektrische en elektronische apparaten (WEEE) in de auto-industrie ten behoeve van de circulaire economie. We willen vooral kijken hoe dit kan helpen bij het volgen en naleven van de nieuwe ELV-regelgeving. Deze regelgeving gaat over het recyclen van belangrijke grondstoffen in auto's, die zich voornamelijk bevinden in elektronische auto-onderdelen.

Het interview zal ongeveer 30 minuten in beslag nemen. Het interview zal opgenomen worden en er zal een transcript worden gemaakt. De audio opname en het transcript zijn niet publiekelijk toegankelijk. Enkel de hoofdonderzoeker (Angel Aardse, ik) en de begeleider van deze scriptie (Dr. Jolien Ubacht) zullen toegang hebben tot deze data.

De data zal worden gebruikt om waardevolle conclusies te kunnen trekken en om een beeld te krijgen van welke informatie er nog nodig is voor het implementeren van deze nieuwe ELV-regelgeving.

Zoals bij elk interview is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. We minimaliseren de risico's door de opnames die worden gemaakt niet up te loaden naar een openbare Cloud omgeving en apart te houden van de publiek toegankelijke data. Daarnaast worden ook de transcripten van het interview geanonimiseerd. De audiobestanden en de transcripten zullen één maand na het afronden van het onderzoek worden verwijderd.

Uw deelname aan dit onderzoek is volledig vrijwillig, en <u>u kunt zich elk moment terugtrekken zonder reden op te geven</u>. U bent vrij om vragen niet te beantwoorden.

Graag wil ik u vragen om uw handtekening, om te bevestigen dat u akkoord bent met bovenstaande.
Mochten er onduidelijkheden zijn of vragen, neem dan gerust contact met mij op.

Angel Aardse
a.r.aardse@student.tudelft.nl

Signatures

____________________ ____________________ ________

Name of participant Signature Date

G.3 Interview Analysis

Table 28 Examples of codes related to the interview requirements

ID	REQUIREMENT	EXAMPLES OF QUOTES (IN DUTCH)
I1.	The information sharing infrastructure should facilitate access to detailed dismantling information	• "Het kan natuurlijk ook dat ze niet alle data vrijgeven. Want ja, daar hebben wij wel eens vaker over gezegd, voor ons zou het ook makkelijk zijn om te zien waar alle componenten zich bevinden. Maar de dealer zegt ja leuk, je gaat ook een beetje in hun vaarwater zitten, natuurlijk." • "Dat wordt niet gedeeld door de fabrikanten, Dat is een verschrikking."
I1.1	The information sharing infrastructure should facilitate EEE dismantling information	• "ECU, die staan er niet in allemaal." • "En je ziet het ook er staat niets. Niets over de componenten staat erin."
I1.2	The information sharing infrastructure should include specific safety data for electric vehicles	• "Nee we doen eigenlijk helemaal niets. Alleen veiligheid. Wij zijn zeg maar... Waar staat die [zoekt certificaat] voor de veilig demonteren van voertuigen heb ik gehaald, dus dat ik me certificaat heb voor als die auto's binnenkomen, en deze veilig spanningsloos kan zetten en dat IDIS systeem is eigenlijk alleen maar voor airbags eigenlijk waar het gebruikt wordt en hoog volt batterijen voor de rest kijkt niemand in IDIS."
I1.3	The information sharing infrastructure should provide data about interchangeability of components	• "De onderdeel nummering. Ja zoals wij dat noemen, weet je even een onderdeelnummer, maar ze maken ook modificatie nummers en ze willen heel slecht delen." • "Het ene is gewoon de onderdeelnummers. En dan zal ik jou vertellen? Een onderdeelnummer is geen vast gegeven. Als we een kleine modificatie aan een onderdeel is, krijgt hij. Al een ander nummer."
I1.4	The information sharing infrastructure should provide information about digital procedures for component activation	• "Als je een ruitenwissermotor uit een moderne auto haalt, bijvoorbeeld een Peugeot of Volkswagen, en deze in een exact gelijk model plaatst, werkt hij vaak niet. Dit komt omdat je hem eerst digitaal moet aanmelden. Het is vergelijkbaar met bepaalde processen op je laptop. Je kunt de motor wel plaatsen en de stekkerverbinding maken, maar zonder digitale registratie herkent de auto de ruitenwissermotor niet en geeft aan dat deze ontbreekt." • "Elk jaar moet je de computer updaten, waarbij sommige merken in de standaardupdate zijn opgenomen en voor andere merken een aparte update vereist is."
I2	The information sharing infrastructure should ensure standardized data and uniformity	• "Het andere probleem met IDIS is dat het geen standaardformaat kent."
I2.1	The information on CRMs should be specific and non-ambiguous	• "Bovendien ontbreekt het aan specifieke gegevens; hoewel sommige autofabrikanten het gebruik van materialen zoals aluminium of plastic vermelden, wordt het exacte type niet altijd gespecificeerd. Dit gebrek aan details kan het recyclageproces en de uiteindelijke toepassing van het gerecyclede materiaal beïnvloeden. Vage informatie maakt het recyclageproces ingewikkelder."

ID	REQUIREMENT	EXAMPLES OF QUOTES (IN DUTCH)
I3.	The information sharing infrastructure should be easy to use for dismantling companies	• “Het systeem is niet gebruiksvriendelijk omdat het geen vast en logisch formaat heeft, waardoor informatie moeilijk te vinden is. Een medewerker van een demontagebedrijf, zelfs met vuile handen of handschoenen aan, zou idealiter slechts drie keer hoeven te klikken om de benodigde informatie te krijgen. In plaats daarvan moet hij zich eerst schoonmaken, zich voorbereiden, diep zuchten, en dan een uur spenderen in IDIS. Als dat het geval is, dan zullen wij het systeem helaas niet gebruiken.”
I3.1	The information sharing infrastructure should have a user-friendly and accessible interface	
I3.2	The data within the information sharing infrastructure should be easily accessible for dismantling and institutional organizations	• “Nee, wij vinden dat IDIS een te omslachtig programma” (P4)

Appendix H – IDS Data Sharing Process

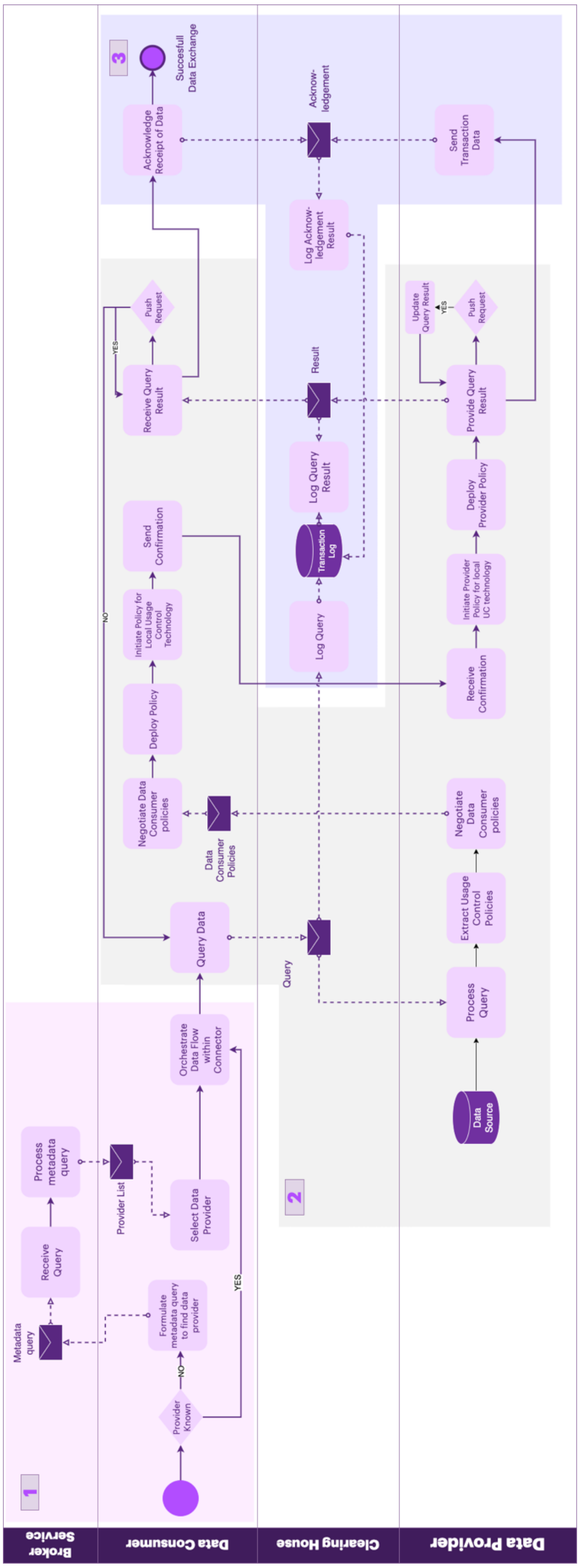

Figure 23: The data sharing process