A Framework for Understanding Circular Economy Monitoring: Insights from the Automotive Industry

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ABSTRACT

The United Nations' Sustainable Development Goals (SDGs) have paved the way toward a more sustainable future. The 2019 EU Green Deal and the 2020 EU Circular Economy Action Plan [1] introduce laws and regulations to facilitate and encourage the transition towards sustainability and a circular economy (CE). For the implementation of these regulatory measures, public authorities face the challenge to gain access to relevant business data for compliance monitoring. Digital infrastructures and access to business data (sources) such as the material composition of products are useful for compliance monitoring, however CE-relevant data is spread across multiple platforms of the supply chain partners and across multiple supply chains. Therefore, digital infrastructures and information-sharing arrangements need to be developed to create visibility and traceability for monitoring the circular economy flows. In this paper, we use a conceptual framework with four dimensions (context, actors, public value, and digital infrastructures) to analyze key actors and potential data of value they hold in their digital infrastructures to explore options for data-sharing solutions. By focusing predominantly on the actor dimension, we analyze a case study in the automotive industry, taking the perspective of two focal Dutch governmental actors: Customs and the Ministry of Infrastructure and Water Management. In our analysis, we also show how this actor dimension is linked to the other dimensions: context, public value, and digital infrastructures. These dimensions play an instrumental role in navigating through the complex actor-network in a systematic way toward identifying pathways for the development of digital infrastructures and data-sharing solutions for circular economy monitoring.

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CCS CONCEPTS

• **Circular Economy**; • **Digital Government**; • **Sustainability**;

KEYWORDS

Circular economy, Monitoring, Government, Digital Infrastructures, Automotive

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1 INTRODUCTION

The United Nations' Sustainable Development Goals[1] (SDGs) have paved the way toward a more sustainable future. In 2019 the European Commission published its ambitious Green Deal [2] "to transform the EU into a modern, resource-efficient and competitive economy with no net emissions of greenhouse gases by 2050. It will decouple economic growth from resource use and ensure that all EU regions and citizens participate in a socially just transition to a sustainable economic system. It also aims to protect, conserve and enhance the EU's natural capital, and to protect the health and well-being of citizens from environment-related risks and impacts" [3]. As follow-up, the EU Circular Economy Plan [1] was adopted in March 2020. This Action Plan introduced a large series of initiatives to further the transition from a linear towards a circular economy (CE). Examples are the Proposal for a Directive on Corporate Sustainability Due Diligence [4], the Proposal for Ecodesign Requirements for Sustainable Products and sector-specific regulations targeted at a.o. the textile [5], construction [6] and the vehicles sectors [1]. Businesses are challenged to comply with these generic and sector-specific regulations by moving from linear to circular material flows and to adopt circular business models. And Member States are set to transpose the EU Directives and guidelines into

[1]https://www.un.org/sustainabledevelopment/sustainable-development-goals

their national policies and targets. The CE and sustainability context confronts government organizations and businesses with new requirements and expectations about public values they need to address. For example, related to circularity, the Dutch Government has set ambitious targets to drastically reduce the use of primary raw materials and resource depletion by setting targets for 50% secondary raw material use in new products by 2030 and a waste free economy by 2050[2].

The ambitions toward a CE can be seen closely linked to SDG 12 on responsible production and consumption. A CE aims for moving away from the linear model of make, use, dispose and generate waste towards a more circular model where resources are reused or returned to the environment in an environmentally-friendly way and waste is minimized (see e.g. [7]).

To steer the implementation of policies toward achieving the objective of a CE, public organizations will need to adopt new monitoring activities which require data for monitoring purposes, as well as digital infrastructures on both the business and government side to allow for data-sharing. Looking at international trade, for example, government authorities at the border have traditionally focused on public values such as revenue collections from taxes and import duties and they also have a major role in addressing the safety and security concerns of importing goods [8]. To these ends, data about the goods, the value of the goods, as well as the true buyer and seller are needed. Businesses and customs organizations have been piloting digital infrastructures and data-sharing solutions (including blockchain-based infrastructures) to enable access to such data. CE objectives create new challenges for monitoring requirements related to circularity. For example, policy requirements about recycled content in new products will affect a wide range of products crossing borders. And policies to improve the EU resource resilience and recovery of critical raw materials will require much stricter control on materials that exit the EU. For CE monitoring purposes, this would require access to data not only about the goods, but also about the material composition of the goods and the production processes, which adds complexity to how to set up digital infrastructures to get access to such data.

To deal with these challenges, digitization will play an important role to enable visibility and traceability for CE monitoring. However, the practical implementation is very challenging, as information resides in multiple information systems and crosses different supply chains [9]. As many of these supply chains are global in nature, crossing multiple countries, jurisdictions and economic zones, enabling such visibility and traceability is challenging from both a technical, institutional, and organizational perspective.

In addition, the speed and urgency of the EU policy implementations are high, which means that national governments need to act fast to develop mechanisms to monitor the developments towards circularity and sustainability in their Member State. Innovations in digital trade infrastructures (such as data pipelines) [10, 11] for sharing business data on a voluntary basis with governments offer a promising starting point. However, these innovations were originally developed with other public values in mind (e.g., revenue collection, safety and security) and taking a limited scope into account (e.g., tracing the complete goods instead of their material composition and only designed for the goals of export and import processes). Therefor these digital infrastructures need to be extended [12, 13] to capture information on material composition and production processes, as well as details on the end-of-life requirements.

Other digital innovations that can address CE monitoring needs are related to data spaces, federated approaches as developed in the FEDeRATED[3] project , European cloud developments (such as Gaia-X[4]), identity and access management (eIDAS[5]) and government-driven blockchain infrastructures (such as EBSI[6]). Also, industry-specific data sharing architectures have been developed (such as Catena-X[7] for the automotive industry). More specific for CE and sustainability, regulatory requirements urge businesses and governments to look for practical solutions to implement Digital Product Passports that support data sharing of CE relevant information with businesses, consumers and authorities involved [14].

This collection of avenues for data-sharing solutions offers many opportunities but also creates a complex space to understand and navigate. From a government perspective, developments such as digital product passports are very useful to allow for access to additional data for CE monitoring but they also need to form part of the bigger picture as government organizations develop infrastructures and solutions for business-government information sharing for a wider range of public concerns. This raises the question of how to create data-sharing solutions and which are the opportunities for piggybacking on infrastructures and investments that businesses already make for their own business purposes?

In this article, we present a case study to demonstrate the complexity of developing the required business-government data-sharing solutions for CE monitoring. Building on several high-level frameworks that were recently developed in the context of information systems and applications for the CE, we present a framework with four dimensions. To demonstrate the framework, we analyze the case of monitoring the end-of-life phase of vehicles in the Netherlands, from the perspective of Dutch Customs and the Dutch Ministry of Infrastructure and Water Management (I&W). Both authorities have an interest in better understanding the potential of data-sharing solutions for CE monitoring. This becomes even more relevant with upcoming regulatory developments such as the revision of the End-of-Life of Vehicle directive (expected in 2023), the proposal for a new EU Batteries Regulation [15], as well as the proposal for the Regulation for Carbon Border Adjustment Mechanism [16]. These are explained in more detail in Section 3.

This paper is structured as follows. In section 2 we describe our conceptual framework. We present our case study method in Section 3. The results of the case analysis are presented in Section 4. In Section 5 we discuss our findings and implications for CE monitoring and we end the paper with conclusions and directions for further research.

[2] https://www.government.nl/topics/circular-economy/circular-dutch-economy-by-2050

[3] http://federatedplatforms.eu/
[4] https://gaia-x.eu/
[5] https://digital-strategy.ec.europa.eu/en/policies/eidas-regulation
[6] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Home
[7] https://catena-x.net/en

2 CONCEPTUAL FRAMEWORK FOR CE MONITORING

For our conceptual lens, we build upon several recent studies in the field of information systems for business-to-government data sharing (e.g., [8, 12, 13, 17, 18]). These frameworks have been developed with their own purpose in mind and zoom into specific directions such as technical design choices, government roles, or evaluation of digital infrastructures on elements of CE they cover. Nevertheless, they also contain elements useful for understanding CE monitoring, the role of government, and the potential of digital infrastructures to support CE. Based on these recent studies, we identified several dimensions that appeared relevant to our study and we combined these into a high-level framework that we use as a conceptual lens to demonstrate the complexity of our case analysis. This framework consists of four dimensions: the public value dimension, focusing on the public value creation that is steered by public policies; the context dimension, helping to scope the CE monitoring context by focusing on specific aspects; the actor dimension, exploring the ecosystem of actors that need to share data to have the complete picture of circular flows, and the digital infrastructures dimension that addresses the digital infrastructures that can connect the data. In the following paragraphs, we elaborate on these dimensions and the frameworks on which they are based.

2.1 Public value drivers for CE monitoring by policy developments in the CE context

As indicated in the introduction section, there is a strong driver for CE transition driven by EU policies by governments. To understand the role of government in the context of CE, Medaglia et al. (2022) [17] take a government-centric view and proposes a framework to examine the role of government in CE. This framework puts the government at the center and building on the NATO framework of government roles identifies four roles of government (Nodality, Authority, Treasure, and Organization) that government can play in the context of CE [17]. Based on a literature review, Medaglia et al. (2022) [17] observe that in the context of CE, governments often take the role of Authority by issuing policies and regulations, and the role of Treasure by e.g. providing subsidies to stimulate the execution of initiatives that align with the legislation. In particular, the role of authority is now very visible in EU legislations that are being introduced to stimulate the transition to economy CE.

These new regulatory requirements also put new demands and priorities on public organizations and on businesses with respect to public values they need to safeguard. In the context of international trade, Rukanova et al. (2023) [8] illustrate how governments need to deal with different public values (e.g. safety and security, revenue collection) and that each may put different requirements on information needs for monitoring purposes and the use of the digital infrastructures. The authors also argue that new information needs are likely to arise (e.g. information about material composition and recycled content in products) when the government put a higher priority on monitoring public values related to the CE or sustainability. Therefore, for understanding what is needed for CE monitoring it will be useful to take a specific public value perspective into account in order to understand the specifics of the information sharing and requirements towards the digital infrastructures. However, it is also highlighted that governments will have roles to fulfill that relate to more than one public value. Therefore, when new public values are added, they need to be also seen as part of the bigger picture of public values that governments address due to the strategies of engagement with stakeholders and IT investments.

2.2 Actors and the data in their proprietary systems

When looking at CE monitoring, governments will play a key role but understanding the wider actor context is important both from the point of view of processes that will be monitored, as well as from 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 be put in place to allow for data access.

In the literature review in the context of CE and the role of government, Madaglia et al. (2022) [17] paid specific attention to examine the role of government in relation to the wider CE ecosystem, taking into consideration a variety of actors, including businesses, NGOs, IT providers, customers, and research institutes. Rukanova et al. (2021a,b) [12, 13] identify additional actors such as auditors, banks, and insurance companies which could also have incentives to play a CE monitoring function. Such an actor analysis allows sketching the broader picture of actor interactions and how they play a role in the CE monitoring processes.

Studies have also taken specific approaches to use supply chain or circular economy processes and the business actors involved to trace information these parties hold [8, 18]. These studies focus on limited actor types (e.g. government and business) but then go into detail to identify specific types of business actors and types of data of value they may hold. This detailed actor approach allows us to zoom in and gain a better understanding of specific data these actors hold and the digital infrastructures holding this data and examine how this data can be of value.

2.3 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. Building on Van Engelenburg et al. (2020) [19], Rukanova et al. (2023) [8] analyze these multi-actor infrastructures in terms of the rights that parties have and the underlying technical design choices of such infrastructures. However, for CE monitoring it is likely that data will not reside in one platform or system but will be spread across multiple platforms. Kofos et al. (2022) [18] develop a circular economy visibility evaluation framework to help assess what data from the product lifecycle a specific (blockchain-based) platform holds. This framework is also developed from a CE monitoring perspective, taking different visibility levels into account (e.g. item, box, container level).When goods flow in the supply chains government authorities will have to perform the CE monitoring actions without always having direct access to the goods but they will need to risk assess the goods when they are in boxes or containers.

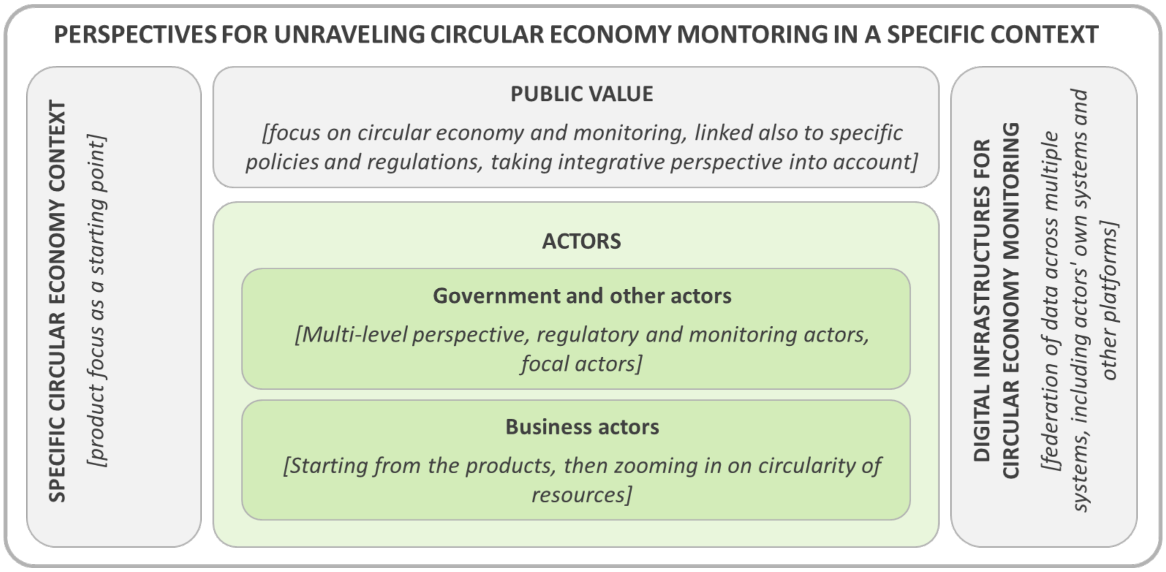

Figure 1: Conceptual framework for unraveling circular economy monitoring in a specific context

2.4 Specific CE Context

The data needed for CE monitoring can be related to the CE flows [12, 13]. These flows represent the phases of the use of resources (primary or secondary resources) for the production and use of products, as well as the processes of extended use, reuse-recycling, and how resources flow back into the biological sphere or re-enter a new cycle as secondary resources. Models and frameworks for analyzing CE flows such as the widely used CE diagram developed by the Ellen MacArthur Foundation[8] and the strategies for circularity as presented by Potting et al. (2016) [20] can be used to this end to identify specific CE flows. At the same time, the complexity can be huge, as CE monitoring can be done from multiple actors, perspectives, and contexts, especially when taking a multi-level perspective (e.g. [21]). Defining the CE context and the point of view of government allows examining scoping scenarios, moving from a more limited national scope that is in the realm of a single government toward a wider CE monitoring perspective which would require multi-government collaboration.

2.5 Conceptual framework to analyze CE monitoring

Building on the above discussion, Figure 1 presents the high-level conceptual framework for CE monitoring, which we use as a conceptual lens for our case analysis.

To make the dimensions more concrete for use in our case analysis, we elaborate on them as follows:

Specific circular economy context: This dimension is intended to draw the attention to the specific context of which CE flows and CE monitoring are analyzed and associated data needs. In our analysis, we will take the specific product at the center and will then look back and forth the CE flows towards the production processes and material used, as well as their end of life treatment;

[8]https://ellenmacarthurfoundation.org/circular-economy-diagram

Public Value: this dimension is to identify which public values are pursued with the CE monitoring and what policy developments drive these public values forward as priority areas. These depend on the particular context and scope of the chosen domain to which the CE regulations are applied;

Actors and their own systems: this dimension is to analyze the actors in the relevant ecosystem and the data that the key actors possess in their proprietary information systems that can be used for CE monitoring activities. This dimension also captures actors that are influencing policies or some other relevant developments;

Digital Infrastructures for CE Monitoring: this dimension is aimed to identify how to allow for access to data that resides in multiple platforms for the purposes of CE monitoring, which digital infrastructure can support the necessary data-sharing solution, or where the gap in required data is.

3 RESEARCH DESIGN

To demonstrate the complexity of developing data-sharing solutions for CE monitoring, we followed an interpretative and contextualist case study approach [22–24]. The case is in the automotive industry, which is subject to several EU regulatory initiatives to stimulate the circularity of materials that are used for vehicles. These initiatives entail new monitoring activities for customs authorities, which require them to explore data-sharing options to fulfill their tasks. In the following paragraphs, we introduce the case study context as well as our data collection and analysis approach. In terms of theory types [25], the framework that we developed is aimed at developing theories for: (1) analysis, and (2) explanation.

3.1 Case study context

Our case study is in the context of the EU-funded project DATAPIPE[9] which aims to support the Dutch Customs Administration

[9]https://www.tudelft.nl/datapipe

and the Dutch Ministry of Infrastructure and Water Management (I&W) to meet their responsibilities in the context of the CE. The project investigates how digital infrastructures that have been piloted in the context of international trade can be extended to support CE monitoring. The DATAPIPE project focuses on CE monitoring in the automotive industry. In this paper, we use the CE flows of complete vehicles (in the project the CE flows of vehicle parts and materials (metals, batteries, plastics, electronics and tires) will also be analyzed). The project's aim is to deliver a diagnostic problem analysis report and a blueprint for piloting data sharing in the ecosystem of CE stakeholders.

The automotive industry domain is interesting for analyzing CE monitoring as it is one of the major industries in the European economy that will be affected by the transition towards a CE. Part of this transition is stricter requirements that will be introduced to diminish the use of primary raw materials in new products, as well as better reuse and recycling of the materials at the end of life to ensure that valuable resources are not lost as waste. This has become more prominent in view of recent geopolitical developments and related to issues such as EU resilience and resource autonomy. The EU's objectives are to keep critical raw materials in the EU to ensure sufficient resources for the EU industries.

Another EU objective in the context of CE is to create a level playing field for European companies by introducing the Carbon Border Adjustment Mechanism (CBAM) [16]. This is relevant for the automotive industry for their access to resources such as steel. CBAM aims to prevent so-called 'carbon leakage', when producers move the production of materials to non-EU countries that are less strict on carbon emissions to avoid the EU levies on carbon emissions [16]. The first implementation phase applies to iron, steel, cement, fertilizers, aluminum, and electricity generation [16]. Whereas the Netherlands is not one of the major EU Member States involved in the manufacturing of cars, the Dutch port of Rotterdam plays a major role in the international trade flows when it comes to materials or vehicle parts used by the automotive industry. And also for the import and export of complete vehicles, Dutch customs plays an important role. In addition, the European Parliament and the Council announced a proposal for a regulation concerning batteries and waste batteries to reduce environmental, climate, and social impacts throughout all stages of the battery life cycle [15]. When adopted, this regulation may yield additional monitoring tasks for Dutch Customs for the import and export of batteries.

Also the sector-specific 2000 Directive on the End of Life Vehicles aimed at lowering the impact on the environment of discarded vehicles is being updated to include the circular use of materials [26]. Since 2000 the concept of extended producer responsibility (EPR) is applied: manufacturers or importers are responsible for the correct dismantling of the vehicles via proprietary or collective systems in the EU Member States. The EC's proposal for a renewed End of Life Vehicles Directive is expected in 2023[10].

In view of these regulatory developments that may yield new responsibilities for Dutch Customs, the intention is to assess the potential offered by digital infrastructures for CE monitoring. As they have been involved for many years in piloting digital infrastructures for monitoring the international trade flows for safety and security and fiscal purposes, they now explore what will be needed to use such infrastructures in the context of CE monitoring. The Dutch Ministry of I&W shares this interest, as they are involved in setting policy goals and drafting policies and legislations related to CE; e.g. including subsidies, and fiscal incentive schemes. However, without proper visibility of the CE flows achieving these goals and implementing the policies will be challenging.

3.2 Data collection and data analysis

The data collection on the case in the automotive industry started in September 2022. The research reported in this paper relates to what is called the Complete Vehicles module of the DATAPIPE project. Data collection based on desk research included a review of scientific papers, reports of national and international organizations with a specific focus on vehicles, their end-of-life treatment and circularity, legal documents and proposals for legislative changes as those listed in the previous section, and grey literature including newspaper articles and company websites. Data was also collected via individual discussions and workshops with representatives from the Dutch Customs and the Ministry of I&W to better understand their interests and links to the public value perspective, as well as with business representatives, especially involved in the end-of-life treatment of cars. The empirical data analysis was performed through the conceptual lens of the framework provided in Figure 1. In this paper we focus in depth at the actor dimension (central part of Figure 1) and then we discuss links to the other three dimensions.

4 RESULTS: UNRAVELLING THE COMPLEXITY OF THE ACTOR DIMENSION IN THE CONTEXT OF CIRCULAR ECONOMY MONITORING OF VEHICLES IN THE NETHERLANDS

In Figure 2 we provide an overview of the actor analysis for the case of end of life vehicles in the Netherlands, which we elaborate on in the following paragraphs.

4.1 Unravelling the primary and secondary business actors

In the bottom part of Figure 2 an overview of the identified primary and secondary business actors along the car's life cycle phases is presented. They are directly involved in the life cycle of the physical car and contribute to its production, distribution, usage, modification, and decomposition. Whereas primary business actors have an overview of the entire vehicle, secondary business actors rather deal with its single parts, components, and related materials. These secondary actors are connected to other industries and play a crucial role to close the loop towards a circular economy, as they hold information on up- and down-cycling as well as secondary usage of materials used in the car. Primary actors who deal with the entire vehicle obtain information relevant to its respective life cycle phases. This information is rather spread among the individual actors and partly kept private. For instance, the exact composition of the car (data held by the manufacturer), usage and private

[10]https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en, consulted January 20th 2023).

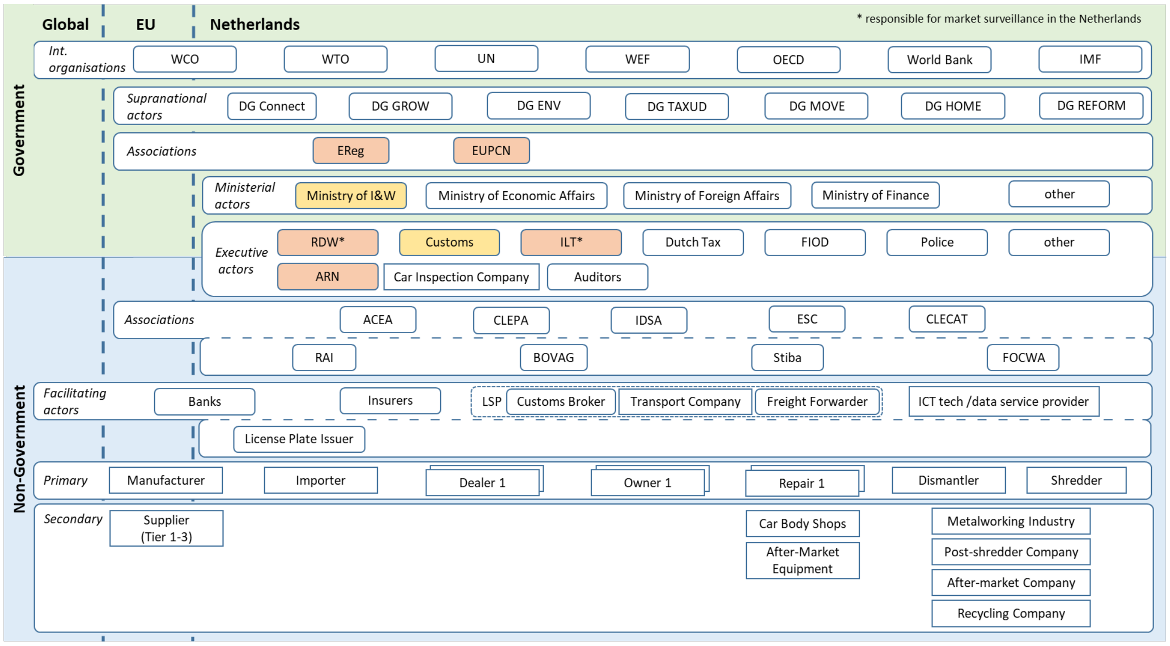

Figure 2: Actor analysis in the case of end of life vehicles in the Netherlands

modification information (car owner), or information about car components at the end of life (car dismantler). The manufacturers are an important node in this actor and information network. On the one hand, they have the closest relationship with other business actors like the importer, dealers, or repair shops. On the other hand, they are in a position to broaden their business model, and by means of digital applications, they can extend their knowledge about the usage phase. Not all data is concealed as business actors also provide information to authorities or other organizations such as type approval or technical inspection information. Extended use of those data sets can be an option to gain CE monitoring data about the car life cycle.

4.2 Unravelling the government actors setting policies and legislations with monitoring functions

In the upper part of Figure 2 the authorities involved are presented. The Dutch Customs Administration and the Ministry of I&W are two key stakeholders that have a role with respect to the circularity of the car and monitoring flows of cars across borders. In addition, a multitude of other actors is involved in the car life cycle. In our analysis, we selected the main actors who already possess important information that can contribute to the consolidation of relevant data for monitoring purposes. Thus, considering the cross-border transfer of cars[11], five main actors are identified (marked red in Figure 2), the description of their organization and their role in the monitoring process are described in Table 1.

These five actors mainly operate on a supranational or national government level and take responsibility for market surveillance. One exception is ARN, which is a self-regulatory initiative formed by the main Dutch car industry associations (BOVAG, RAI Vereniging, Stiba, FOCWA)[12]. Because of their shouldered sector-wide responsibility, ARN closely collaborates with Dutch Ministries, e.g., through regular reporting. Hence, the properties of the main actors can be summarized as:

- positioned within or close to the public sector
- high willingness to collaborate
- inherent motivation to improve the car‘s life cycle traceability.

Apart from the main actors, the involvement and knowledge of the other actors in the car life cycle are rather specific and dependent on the life cycle phase.

In the context of new regulations and cross-border collaboration, also the Directorate-Generals (DGs) on the EU level are involved. These EU governmental bodies are devoted to promoting the development and harmonization of their respective area of responsibility, e.g., by designing relevant legislation. As legislation regarding a car’s life cycle is rather event specific and does not address the entire life cycle at once, a range of different DGs are involved. Thus, from a monitoring perspective and for the development of data-sharing solutions, it is essential to understand which DGs are involved in which event of a car’s life cycle and which relevant data they possess, the Table in Annex 1 provides an overview.

[11]Here we take a broad view of processes including transfers within the national borders, across EU Member States and outside the EU.

[12]https://www.raivereniging.nl/artikel/positionpapers/recycling-auto%E2%80%99s-%E2%80%93-circulaire-economie.html; https://arn.nl/en/our-activities/

Table 1: Government actors who possess relevant data on the cross-border transfer of cars

Actor	Description	Role in Monitoring
EReg: Association of European Vehicle and Driver Registration Authorities	EReg aims to support European vehicle and driver registration authorities in improving and harmonizing registration and licensing policies. In this context, EReg mainly promotes knowledge exchange, joint developments and collaboration with non-EU organisations. The association is non-profit and based on voluntary cooperation.	As EReg tries to facilitate the cooperation between European registration authorities, they play an important role regarding the exchange of vehicle registration data between EU Member States. In this context, the European Car and Driving License Information System (EUCARIS) was established. EUCARIS is a treaty organization and IT data exchange platform, which enables all EU and EFTA countries to exchange mobility and transport-related information. As the usage of EUCARIS is based on individual treaties, the extent of information sharing can differ per Member State. As vehicle (parts) type approval data should also be exchanged for CE and become publicly available, EReg can also be a contact in this respect [27].
EUPCN: EU Product Compliance Network	EUPCN promotes collaboration and coordinates the market surveillance authorities of the EU Member States to exchange knowledge and enable joint enforcement of legislations. The network was established as part of the Market Surveillance Regulation (EU) 2019/1020 and all EU countries are represented in it [28].	Aiming at joining and harmonizing forces of market surveillance authorities, the network established a common platform (EU Information and Communication System for Market Surveillance, ICSMS) to share product investigations, inform each other about results and the measures taken, and to cooperate on cases with a cross-border component.
RDW: Rijksdienst voor Wegverkeer	RDW is an independent administrative body of the Dutch government and in charge of vehicle registration and status monitoring. Thus, RDW is part of the market surveillance bodies in the Netherlands. Moreover, they promote the knowledge and data exchange with other EU national registration authorities.	RDW is in charge of monitoring the car usage phase within the Netherlands: they take care of cars' and owners' (de-)registration and monitor the status of cars (e.g., technical conditions) throughout their life cycle. In addition, they are responsible for the approval of vehicles and vehicle parts on the Dutch and European market.
ILT: Inspectie Leefomgeving en Transport	ILT is the supervising agency of the Ministry of I&W. In the sectors of transport, infrastructure, environment and housing, the ILT promotes compliance with laws and regulations through licensing, enforcement (service, supervision and investigation) and by conducting research.	ILT is one of the Dutch market surveillance authorities regarding vehicles, next to RDW. In this duty they mainly aim to track the vehicle flows throughout their life cycle and status change. Among others, ILT investigates what happens with deregistered cars and if it is compliant to laws.
ARN: Auto Recycling Nederland	ARN is a self-regulatory initiative established by the Dutch automotive sector to coordinate the end-of-life collection and treatment of cars (dismantlers, recyclers, shredders, and post-shredders). ARN takes over the extended producer responsibility and is directly financed through a fee charged for cars entering the Dutch market. Next to coordination, ARN is also involved in monitoring and improving the end-of-life sector and reporting to authorities.	ARN keeps track of the end-of-life treatment of cars within their member network. This also includes the assurance of quality and alignment with standards and legislation. Thus, ARN has an overview of the amount and composition of cars treated within their network, as well as the current practices in end-of-life treatment.

4.3 National and international associations and facilitating actors

In the middle of Figure 2 an overview of relevant associations and facilitating actors is presented. In contrast to the primary and secondary business actors, they act as overarching instances in the industry to support the development in specific sub-sectors of the automotive industry. They can be independent from specific car brands and keep a general overview of the market. They represent the interests of individual business actors. Almost each of the phases in a car's life cycle is represented by an association, but a responsible party for the entire car life cycle is lacking. Despite collaboration between the associations, their individual interests can be separated.

In contrast, facilitating actors deal with transactions and processes in a car's life cycle and thus facilitate life cycle phases. These actors have data about the car when being transferred from one business actor to the other (e.g., via transport or financing activities) or keep track of the state of the car throughout the events of the car's life cycle (e.g., via insurances).

From a monitoring perspective these actors are relevant, because they possess information of the overall life cycle and sector, and they can promote the implementation of industry-wide developments.

5 DISCUSSION: REFLECTION ON THE ACTOR DIMENSION IN RELATION TO THE OTHER DIMENSIONS

Now that the actor dimension has been analyzed, we can map the link with the other dimensions in our conceptual framework (see Figure 3). The specific context dimension (in our case we focused on the Netherlands, the car, and the focal actors Customs and the Ministry of I&W) led to the search for actors in the actor dimension that may be relevant for CE monitoring, as indicated by relationship A in Figure 3. Our detailed analysis of the actor dimension revealed a whole universe of actors, making it complex to determine which actors and their data are useful for CE monitoring.

Therefore, as a next analytical step we look into the public value dimension. In Figure 3 we plotted the public value categories that currently play an important role when discussing circularity: (a) due diligence which focuses on the sourcing of materials and working conditions; (b) extended producer responsibility (EPR) which focuses on the end of life treatment of products to enhance circularity, (c) EU resilience goals, (d) level playing field for EU companies when it comes to competition with imports from non-EU companies; (e) green-house emission reduction, and (f) resource circularity. Whereas these public values may not be exhaustive and are not mutually exclusive, selecting a specific public value category can be instrumental in identifying the relevant actors, their relationships, and their access to data. In Figure 3 (see letter B) we show how selecting the public value related to EPR can lead to the selection of relevant actors. The numbered links in Figure 3 show the relevant relationships between the actors.

Starting from one of our focal actors (the Dutch Ministry of I&W) and looking at EPR allows us to trace relationships towards the supranational level (such as the relationship with DG ENVI which provides the legislation at EU level, (arrow 1), as well as to the national level by tracing the executive actors who deal with organizing the implementation (arrow 2a linking the Ministry with ARN, which organizes the EPR in the Netherlands), as well as to Customs (arrow 2b) which monitors the cross-border movement of cars outside the EU, as well as ILT (arrow 2c) which monitors the movement of cars between the Netherlands and other EU Member States. For monitoring and organizing the execution of the EPR, ARN needs to interact and get information from among others: the registration authorities (arrow 3a), the importers (arrow 3b), dismantlers (arrow 3c), and shredders (arrow 3d). In the figure, we also indicate some relationships (marked with R) which are important to understand as background information, as they may help to reveal additional data of value. For example, R1 shows the relationship between the Dutch registration authorities and DG GROW, which set requirements related to type approval when new types of cars are registered on the EU market, information that can be relevant for CE monitoring as well.

Customs is monitoring the cross-border movement of goods crossing the EU borders. At the moment they have limited responsibility for CE monitoring but changes in EU legislation may affect them and Customs would like to be prepared for the future. In the Netherlands, the Ministry of I&W can assign tasks to Customs to execute certain checks related to legislation that falls under its ministerial responsibilities. For example, potential changes in EU legislation related to the DG for Environment (ENVI), are likely to affect Dutch Customs when there are specific tasks related to crossing borders. Therefore, analyzing where relevant information about monitoring of end-of-life vehicles held by different actors and relationships is located (e.g. arrows 3a, 3b, 3c, and 3d) may hold relevant information for Customs for CE monitoring. In Figure 3 we also marked two relationships (R2 and R3) which are important from the point of view of Customs. DG TAXUD (R2) develops customs legislation that applies to the EU Member States' customs administrations.

At the international level, the World Customs Organization (WCO) plays an important role (R3), as they, together with the World Trade Organization (WTO) determine the updates of the Harmonized Systems codes. These codes are instrumental when defining customs duties for specific types of goods crossing borders: for customs risk analysis for fiscal matters such as payment of duties, but also for safety and security checks and they can be instrumental for monitoring CE aspects as well.

This example illustrates that by taking a specific *value dimension* it is possible to identify actors and relationships that are relevant from this specific public value aspect and following these relationships is instrumental to identify what data is available and what is missing for the CE monitoring with respect to this specific value. For other value aspects, other actors may be more relevant. For example, the due diligence aspect does not put a strong focus on the end of life of products but focuses more on the way they are produced (e.g. resources sourced, working conditions). Taking this public value will reveal other actors that hold relevant information about the resources and production processes. Therefore the *value dimension*, and focusing on different perspectives one at a time, will allow exploring CE monitoring needs in a very systematic way and looking for available data sources that can add value. As governments need to deal with more than one value category, exploring each of the value categories in isolation offers clarity in the first

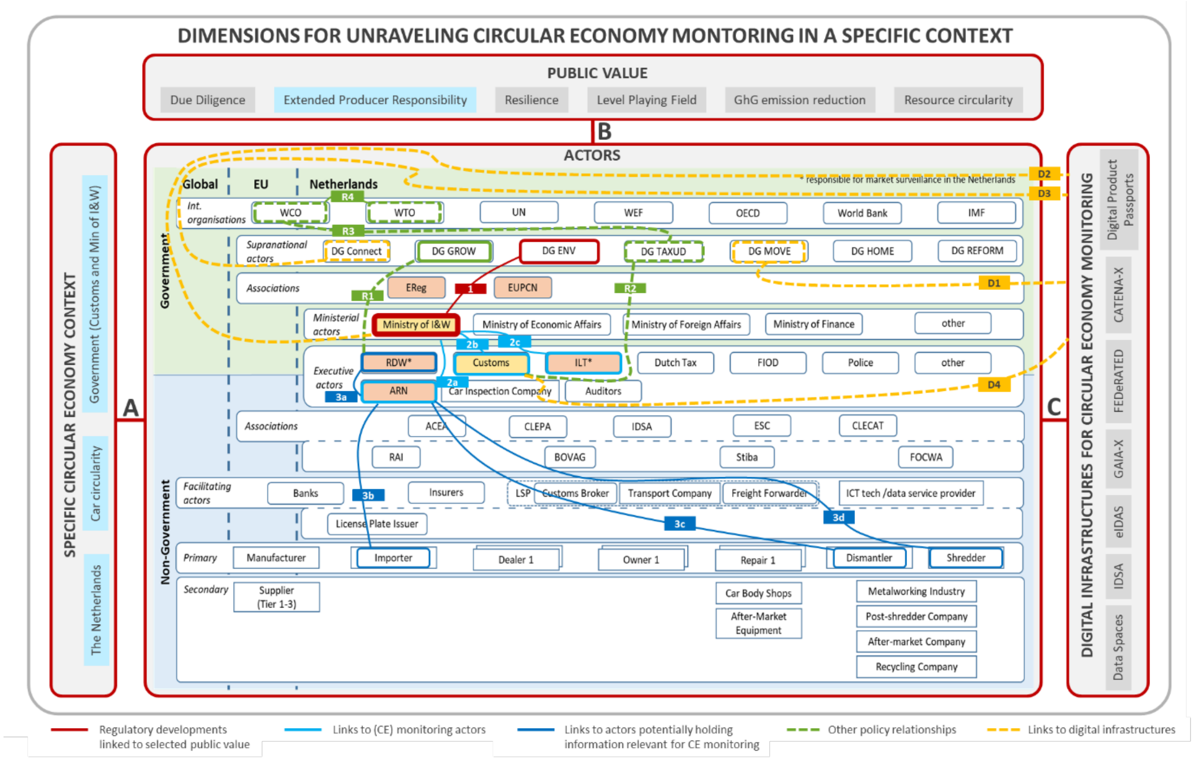

Figure 3: Case analysis: mapping the links between dimensions

instance, but subsequently overlaps between value categories can be analyzed.

For the *digital infrastructures dimension* we mapped a number of relationships in Figure 3 by means of the letter D. These are the links with the *actor dimension*, which are very important, as digital infrastructures require large-scale investments by a wider stakeholder community. These links map some important infrastructural developments and how key actors are involved. Examples are the development of data spaces such as the IDS by the International Data Space Association (IDSA), Gaia-X for European cloud services, as well as the industry-specific Catena-X initiative driven by the German automotive sector, the developments around identity and access management like eIDAS, as well as the FEDeRATED approach using a semantic model and architecture for sharing logistics data across different platforms. Finally, developments around digital product passports are also taking a prominent role in developing data-sharing solutions for CE monitoring

At the EU level, DG Connect plays a crucial role to steer developments in digital infrastructures, and DG Move is promoting developments for data sharing solutions related to logistics.

At a national level, the Ministry of I&W as well as Dutch Customs are involved. At the moment (January 2023) these developments are focused on laying the basis for data-sharing infrastructures and have no specific focus on CE monitoring, but they can be further extended toward data-sharing solutions for CE monitoring. Of particular importance are the links that both the Ministry of I&W and Dutch Customs have with respect to the FEDeRATED approach, which is also linked to the Digital Transport and Logistics Forum (DTLF) at DG MOVE. In addition, they are involved in a national digital infrastructure for logistics projects to establish a national basic data-sharing infrastructure. This infrastructure will be instrumental for (voluntary) data sharing of business data for CE monitoring purposes and can form a crucial basis for the extended data pipeline concept for CE monitoring.

6 CONCLUSION

Governments are setting high objectives and targets for a CE for which monitoring is a key challenge. Digital infrastructures play an important role to facilitate government organizations in CE monitoring tasks, however, it is not clear which actors may hold relevant information and how to develop data-sharing solutions. In this paper, building on earlier studies, we use the *circular economy context*, *actors*, *public value*, and *digital infrastructures* dimensions as a high-level conceptual lens for our case analysis of CE monitoring of cars in the Netherlands, taking as focal government actors the Dutch Customs and the Dutch Ministry of I&W. Taking this context as a starting point, in this paper we elaborated in detail the actor dimension and discussed key data sources actors hold. Our analysis shows how this actor dimension forms part of the bigger picture of the other dimensions, and how these other dimensions play an instrumental role in navigating through these complex actor networks in a systematic way toward identifying pathways that form the basis for the exploration of CE monitoring data-sharing solutions.

We present a couple of observations from a policy and practitioners' point of view. CE monitoring will require global efforts at many levels. Whereas our case is in one EU Member State to unravel the complexity on a national level, CE monitoring will require joint efforts of EU Member States and beyond. First, the insights from this study and the actor analysis, in particular, can be used for analyzing the dimensions and their relationships in other (EU) countries. Second, analysis of the national contexts in different EU Member States and their relationships with the supranational and international levels can show opportunities for collaboration and coordination for CE monitoring purposes.

A second observation is that as the digital infrastructure dimension plays a key role in enabling data sharing, international standards and harmonization are needed. Standards setting and harmonization are related to both the industry and the European Commission's policies for the circularity of vehicles. We see transformations in the industry and companies that are competing as Original Equipment Manufacturers (OEMs) can act jointly when it comes to the development of digital infrastructures and data-sharing solutions like Catena-X. These OEMs will have a growing interest in access to secondary raw materials for new production cycles. To this end, the quality of the secondary materials matters, rather than whether they come from the OEM's own products or from the end-of-life vehicles of their competitors. Ensuring that high-value raw materials are regained at the end of life and made available as high-value resources for the next automotive cycle can be a common interest across OEMs and an incentive to share information. The geopolitical conditions and developments around public values such as EU resilience and keeping valuable resources in the EU can act as an additional incentive for cooperation.

Finally, we reflect on CE monitoring from an implementation perspective. For ensuring the CE transition many different policies need to be implemented. To this end, pilots are instrumental to show what works or not. But even very advanced solutions that can work well in practice cannot be implemented if the proper policies are not in place. And the other way around. Therefore, research and pilots in the area of CE monitoring are crucial to match policies with practice.

This study is limited to the Dutch context and the automotive industry, we predominantly zoomed in on the actor dimension. Further research can proceed in a number of directions. First, future research can elaborate on the other dimensions such as the public value and the digital infrastructure dimensions. This will provide additional depth in the understanding of how the actor dimension relates in more detail to these other dimensions. Second, our framework identified four dimensions. Future research can critically evaluate these four dimensions and propose additional dimensions which are currently not covered. Third, applying the analysis to the context of other countries will allow for cross-country comparison. Fourth, at the moment the context dimension was limited to the Dutch context, and some links were provided to the supranational and global levels but limited attention was paid to the cross-border flows of cars and the international context. Future research can focus on cross-border cases. Finally, this analysis is limited to the automotive domain. Future studies can examine other domains such as e.g., CE monitoring of buildings or of aircrafts.

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ANNEX A. CAR LIFE CYCLE EVENTS, DIRECTORATE GENERAL INVOLVED AND DATA INVOLVED

Table Annex 1 Car life cycle events and the EU Directorate Generals involved, with the data they possess [29]

Car Life Cycle Event	Directorate General involved	Data involved
Design and type approval	GROW	Type Approval Data
Vehicle production	GROW	Certificate of Conformity (CoC)
Initial registration	MOVE, GROW	Certificate of Conformity (CoC), Vehicle Registration Data (VRD), Holder data
Import	GROW	Vehicle Registration Data (VRD), Vehicle Status Data (VSD)
Paid parking	TAXUD	Holder Data
Toll	MOVE	Holder Data
Traffic violation	MOVE, HOME	Limited set of Holder Data and Vehicle Registration Data (VRD)
Maintenance	GROW	Repair and Maintenance Information (RMI)
Periodic Technical Inspection	MOVE	Repair and Maintenance Information (RMI), inspection results, mileage
Vehicle modification	GROW, MOVE	Vehicle Registration Data (VRD)
Recall	GROW	Holder Data
Serious Accident	MOVE (damage, cause analysis), CNECT (eCall)	Vehicle Status Data (VSD)
Vehicle crime	HOME	Vehicle Registration Data (VRD), Vehicle Status Data (VSD), Holder Data
Export	GROW, MOVE	Vehicle Registration Data (VRD), Vehicle Status Data (VSD)
End of Life	ENV	Vehicle Status Data (VSD)

Legend:

CNECT = DG for Communications Networks, Content and Technology

ENV = DG for Environment

GROW = DG for Internal Market, Industry, Entrepreneurship and SMEs

HOME = DG for Migration and Home Affairs

MOVE = DG for Mobility and Transport

TAXUD = DG for Taxation and Customs Union