INDICATORS AND METHODS FOR MEASURING TRANSITION TO CLIMATE NEUTRAL CIRCULARITY

Task 5: Case-study group 1

Report for: DG RTD, Directorate B – Healthy Planet, Unit B1: Circular Economy & Biobased Systems

Ref. RTD/2022/OP/0003

Ricardo, Gemini Building, Fermi Avenue, Harwell, Oxfordshire, OX11 0QR, UK | +44(0)1235 75 3000 | www.ricardo.com
Registered company no. 08229264 | VAT no. GB 212 8365 24

Customer:
European Commission, DG RTD

Customer reference:
RTD/2022/OP/0003

Confidentiality, copyright and reproduction:

Ricardo reference:
ED16719

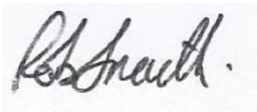
Contact:
Rob Snaith, 18 Blythswood Square, Glasgow, G2 4BG

T: +44 (0) 1235 753 029
E: rob.snaith@ricardo.com

Authors:
James Buckwell, Nicholas Tay, Archie Peters.

Approved by:
Rob Snaith

Signed



Date:
30th August 2024.

Ricardo is certified to ISO9001, ISO14001, ISO27001 and ISO45001.

CONTENTS

1. INTRODUCTION

The transition to a circular economy (CE) needs to occur on multiple levels, from households and individual consumers to national and cross-border ecosystems. Measuring and monitoring the development of this transition is an ambitious task and is ideally supported by indicators relevant to all steps in that process.

This case-study is one of 19 developed for a research project into "*Indicators and methods for measuring transition to climate neutral circularity, its benefits, challenges and trade-offs*". It provides a detailed summary of the development and testing programme conducted for Group 1 of the 'Batteries and Vehicles' sub-policy area during Task 5 of the project. The main purpose of this case-study is:

1. Provide an overview of the testing and monitoring method adopted for each indicator.
2. Outline the key results and performance of each indicator.
3. Highlight any challenges or lessons learnt from the identification, planning, delivery and analysis of the relevant methodology for each indicator.

The aim of Task 5 is to take the learnings of all other Tasks thus far and develop and test the new indicators identified in Tasks 3 and 4 as having potential to enable a deeper understanding of the 3 facets of circularity for the five key approaches. This case-study is a direct output of Task 5.

This case-study focuses on the following 4 indicators outlined in Table 1.

Table 1. Overview of case-study group 1

URN		Indicator name	Methodology	Level of implementation				
				European Union (EU)	National	City / Region	Companies	Household
BV1	1	Car-sharing frequency rates	• Citizen survey • Data analysis			X		
BV2	2	Virgin vs. recycled raw material used in the production of vehicles	• Stakeholder engagement				X	
BV3	3	Quantity of end-of-use batteries retained for reuse in the EU automotive industry	• Stakeholder engagement • Data analysis		X			
BV4	4	Ease of disassembly Metric	• Theoretical and proposed methodology for data analysis				X	

2. INDICATOR 1: CAR-SHARING FREQUENCY RATES

This indicator looked at car-sharing frequency, as a percentage of total car journeys, by EU city/region.

Car-sharing was defined for this metric as the sharing of a private vehicle between 2-6 individuals during the commute to/from a place of work. This was grouped into two formats: car-sharing schemes through workplaces/formal car-sharing schemes (formal), such as ShareNow, Cambio, and Partago, and "peer-to-peer" car-sharing which is not currently captured (referred to as informal).

The principle of car-sharing aligns with several principles and practices of the CE, like the sharing and reuse of existing assets, and ownership models that incentivise using goods for as long as possible. The indicator provides an indication of European citizen behaviour, relating to the ‘rethink’ aspect of CE strategy. Car-sharing systems allow for efficient resource use as car-sharing allows for multiple users to access the vehicle, reducing the overall number of cars required within a given area. This in turn leads to reduced consumption, waste, and carbon impacts. With congestion and pollution becoming critical issues in urban areas, car-sharing has been seen as a potential mitigation route, with many municipal authorities encouraging carsharing initiatives[1].

Further, the sharing of assets either informally or through Product-as-a-Service (PaaS) models has the potential to play a key role in the transition to a CE. These access-based models allow for goods to be shared across multiple users, helping to reduce the quantity of goods needed to be produced to meet demand. These models also often allow for ownership to be maintained by manufacturers and suppliers, allowing for thorough and accurate upkeep and repairs, helping to keep goods operating at a higher level for longer.

The ‘**S**hared mobility oppor**T**unities **A**nd challenges fo**R** European citie**S**’ (STARS) policy report outlines a number of policy targets and recommendations related to increasing the uptake of car-sharing initiatives. These recommendations include ensuring an EU legal framework for car-sharing, adopting a mix of car-sharing models, adopting car-sharing into parking management plans, and spreading the benefits of car-sharing – informing citizens and stakeholders.

Car-sharing demand is projected to increase in EU member states as alternative forms of convenient transport become increasingly popular[2]. This not only highlights the importance of understanding current use rates but also the ability to monitor and ensure these existing car-sharing infrastructures are able to keep up with current and future demand.

Monitoring the car-sharing frequency rates in certain regions provides the following key benefits:

- Better visibility into unreported, informal car-sharing usage.
- Monitoring of a high priority CE theme (“rethink” is high in the waste hierarchy) This is since car-sharing is a potential preventative measure, helping reduce the demand for privately owned cars.
- Monitoring car-sharing platforms and encouraging changes in ride-sharing behaviour. It requires a wider cultural shift in behaviour to start using a car-sharing option rather than use of one’s own vehicle.
- Monitoring benefits associated with car-sharing, such as urban pollution and waste.
- Provide insights that can be used to help inform and shape future targets and legislation associated with car-sharing.

2.1 KEY METHODOLOGY

2.1.1 Testing method

The system boundary for this indicator is outlined as the following: Car-sharing frequency rates will look at both “formalised” schemes i.e. through commuter’s employers, and “informal” schemes which are currently not being recorded, across EU member states.

In setting the system boundary, it was decided that for the testing period this indicator would only look at commutable journeys. This is due to the limited timeframe allowed for the testing of this indicator and the assumption that commutable journeys are most likely to facilitate car sharing. Similarly, car journeys with

[1] STARS, Recommendations to Help Policymakers Implement Car Sharing in Europe. (Official website for STARS, 2019). https://stars-h2020.eu/wp-content/uploads/2019/01/STARS-Policy-Brief-4-pages.pdf. Accessed 23rd April 2024.

[2] Deloitte, Car Sharing in Europe: Business Models, National Variations and Upcoming Disruptions. (Official website for Deloitte, 2017) https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-industrial-products/CIP-Automotive-Car-Sharing-in-Europe.pdf. Accessed 23rd April 2024.

individuals only from within the same household have not been deemed as being within scope during the testing of this indicator due to the frequency of this occurrence and the fact it is not likely to be a robust measure of circularity.

Whilst setting the system boundary, it was also determined that the indicator would measure the number of commutable car journeys per week shared with at least one other individual from outside their household, whilst also considering the number of individuals the journey is shared with.

The methodology employed for this indicator included analysis of data retrieved from an online survey of city/region citizens as well as the collection of data from formal car-sharing companies. Desktop research for existing statistics on car-sharing frequency was also utilised.

Consumer or business surveys provided a valuable tool to quantify sentiment, perception and behavioural factors of selected indicators, such as awareness of CE in general, perceived access to CE services or utilisation of said services. They allowed for snapshot analysis of current values for the indicator in question and, when developed into a systematic and consistent programme, transition progress over time. They provided a useful complement to hard statistical analysis and allow for the development of a much deeper understanding of many of the social and behavioural aspects which current CE monitoring frameworks do not capture.

In delivering surveys for this project, we followed widely understood best practice in the field, as codified by the EC in 2014. Our experience in delivering consumer and market analysis surveys, particularly in our support of over 100 individual businesses employing CE business models, has proven the benefit of these best practices, and we have built upon them further with modern technique insights. As such the surveys delivered through this project were designed with full consideration of the following key points:

- Clear definition of the explicit outcomes desired from the survey to provide insight on selected indicator(s).
- Mapping and selection of appropriate target sample groups to provide this insight. i.e. Who has the answers to the questions we want to ask?
- Sample size planning, to ensure statistically significant results where aggregation is expected, with as low a margin of error and as high a confidence level as possible. Careful consideration will be given to average survey response rates in the individual geography, sector or demographic being targeted, and engagement levels set accordingly to maximise the potential to achieve desired absolute response figures.
- Online surveys allow for a much greater reach and time efficiency, and this can compensate for the potentially for lower response rate than face-to-face or even telephone surveys.
- Clear communication of the purpose of the survey, with overall context for the study, the aims of understanding and promoting CE across the region and the ‘invitation’ to be involved in that transition.
- Precise, unambiguous wording of questions. This is especially important if surveys are covering more than one Member States, where as literal as possible translations will be employed.
- Questionnaires will be designed to allow for two time-separated samples (say at the beginning and end of the testing period, to assess the success of a particular trial intervention or measure) to be fully comparable.

Upon receipt and collation of responses the data was analysed and, where appropriate, developed into composite visualisations according to standard statistical analysis rules as described above.

2.1.2 Data collection method

The following data requirements were established to form relevant results:

- Total average weekly car journeys across EU member states.
- Average weekly journeys with car-sharing (between 2-6 individuals) through "formalised" car-sharing schemes. Collected from existing data collected by formal car-sharing schemes.
- Average weekly journeys with car-sharing (between 2-6 individuals) through "informal" car-sharing arrangements (collected through survey data).

Table 2. Data sources used for the data collection method

Data	Source
Data from surveys across EU member states on frequency of informal car-sharing schemes.	Data regarding the use of “informal car-sharing” was attained using a citizen survey circulated across Germany. The definition of “informal car sharing” considered for this survey was as the number of commutable (i.e. to a place of work) car journeys per week shared with at least one other individual from outside their household, whilst also considering the number of individuals the journey is shared with. The scope of this included what is commonly considered as “car-pooling”, where it has been organised on an ad-hoc or regular basis by colleagues at a place of work. The survey was disseminated by YouGov, achieving a sample size of 2000 respondents, with responses broken down by factors such as the respondent’s income and their location within Germany.
Formal car sharing statistics.	Whilst this data was ultimately not attained and therefore not used in the testing of this indicator, stakeholder in the form of formal car sharing schemes were contacted, and desk-based research was conducted in an attempt to gain data regarding the use of these schemes, although ultimately to no avail.

A composite data collection approach was taken through survey-based data collection, and official statistics/data from formalised car-sharing schemes. This approach was adopted with the intention that the data collected included that from "formal" schemes and also "informal" (private) car-sharing arrangements. To ensure the survey data collected was consistent it excluded larger vehicles carrying more than 6 people (e.g. minibuses and beyond). Data also excluded taxis.

Despite making multiple attempts to contact formal car-sharing schemes, paired with the use of desk-based research, the data was ultimately not able to be attained. As a result of this, the decision was made to only include data from informal car-sharing during the testing period of this indicator.

The data informing this analysis, and the conclusions drawn from it, were gathered in a nationally representative survey of citizens in Germany, conducted by YouGov Plc for the sole purpose of this project. The total sample size was 2000 adults, and the survey was undertaken between 28th February - 1st March 2024. The survey was carried out online. The figures have been weighted in accordance with the national demographic breakdown and are therefore representative of all German adults (aged 18+).

Germany was selected for the testing of this indicator due to the relatively high rate of car ownership, with around 580 cars per 1,000 inhabitants across the nation[3].

The citizen survey did not collect data on other modes of transport used during commuting, as this was deemed outside the scope of the indicator.

2.1.3 Calculations

Unfortunately, a lack of data from the “formal” car sharing schemes meant that calculations were not performed in the testing of this indicator, with the results of citizen survey’s instead providing the main source of insights. However, it was originally anticipated that the following calculation would be used:

$$Car\ sharing\ frequency\ rate\ = (Number\ of\ shared\ car\ journeys \div Total\ number\ of\ car\ journeys) \times 100$$

Due to the use of a citizen survey, no further calculations were required.

[3] De Statis, Car density at record high in 2021. (De Statis, 2022). https://www.destatis.de/EN/Press/2022/09/PE22_N058_51.html#:~:text=There%20were%20580%20passenger%20cars,517%20for%20all%20of%20Germany. Accessed April 2024.

2.1.4 Timeline

Table 3 below gives an overview of the plan and monitoring timeline for the development of this indicator.

Table 3. Gantt chart for BV1

WC	18-Dec	25-Dec	01-Jan	08-Jan	15-Jan	22-Jan	29-Jan	05-Feb	12-Feb	19-Feb	26-Feb	04-Mar	11-Mar	18-Mar	25-Mar	01-Apr
Task 1 - Identify formal car sharing schemes to contact																
Task 2 - Develop survey questions																
Task 3 - Distribute survey																
Task 4 - Contact formal car-sharing schemes and source data																
Task 5 - Analyse survey results																
Task 6 - Build simple Excel model & conduct calculations																
Task 7 - Conduct analysis of themes/trends																
Task 8 - Write up case study template																
Review period																
Key deliverables				Survey distribution										Initial draft case study		Draft case study

Legend

Task progress | Christmas holiday | Review period | Key deliverable

2.1.5 Data gaps and mitigation

As a result of the poor response rate from formal car-sharing schemes and a lack of reliable and robust data available online, it was decided that for the testing period only data from informal car-sharing would be included. This decision was made only after a prolonged and sustained campaign of contacting car-sharing schemes, and multiple desk-based research sessions provided no results. Whilst this did change the scope of the testing, the data received from the citizen survey is trusted to have a high degree of accuracy, therefore resulting in a medium level of confidence.

Table 4. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Lack of data from formalised car-sharing schemes.	Formal car-sharing schemes were contacted at regular intervals in an attempt to attain data. Desk based research was also undertaken with the goal of finding formal car-sharing data. The lack of incentive or motivation for car-sharing schemes to publicly provide this data was deemed to be the driving factor in this lack of success.	Medium

2.1.6 Quality review of analysis

- Prior to work beginning, the Project Director reviewed the proposed research methodology and ensured that the data collection plan was fit for purpose. Only once the research team had addressed any comments from the review process did they proceed to the data collection phase.
- In relation to the survey development and dissemination, the Project Manager reviewed the line of questioning for this indicator to ensure that it was clear, followable and able to generate reliable and robust results. In addition to this, respondents were also required to answer each question before being able to move on to ensure data validation of the survey.
- Once the survey has closed and the results had been analysed, the Quality Assurance Manager conducted a thorough internal quality assurance process on the Excel data set which pulled together the data from the survey and subsequent calculations. Any incoming data and assumptions were clearly logged, presenting survey data, user inputs, calculations, assumptions and results.

2.2 KEY ANALYSIS RESULTS

As the attainment of data from formal car-sharing schemes was unfortunately not achievable in the testing of this indicator, the citizen survey disseminated across Germany was the only available data stream and has therefore been used as the basis of the following analysis.

As well as receiving data regarding the general demographic of the respondent, the following datapoints were asked as part of the survey:

- Whether they took part in informal car sharing with colleagues during their commute in 2023.
- How many days a week it is estimated they shared their commute with another individual also travelling to work.
- The type of vehicle used to carry out these journeys.
- How many people were also involved in the shared journey on average.

These questions were selected with the goal of finding out about car-sharing uptake and frequency, as well as the number of individuals partaking in the journey, and the type of vehicle it is being undertaken in.

2.2.1 Analysis

Figure 1 displays the proportion of respondents that took part in informal car-sharing during their commute to work in 2023. The results show that the mode response for all regions and cities was ‘no’, meaning they did not engage in this type of informal car-sharing in 2023. Over half of participants from all regions selected this answer, except from Berlin where only 41% had not whilst 28% of respondents had engaged in informal car-sharing during their commute in 2023, double the proportion from any other region/city (Hessen, Rheinland-Pfalz, Saarland (14%)).

Figure 1. Proportion of respondents that took part in an informal car-sharing scheme during their commute in 2023, by region/city.

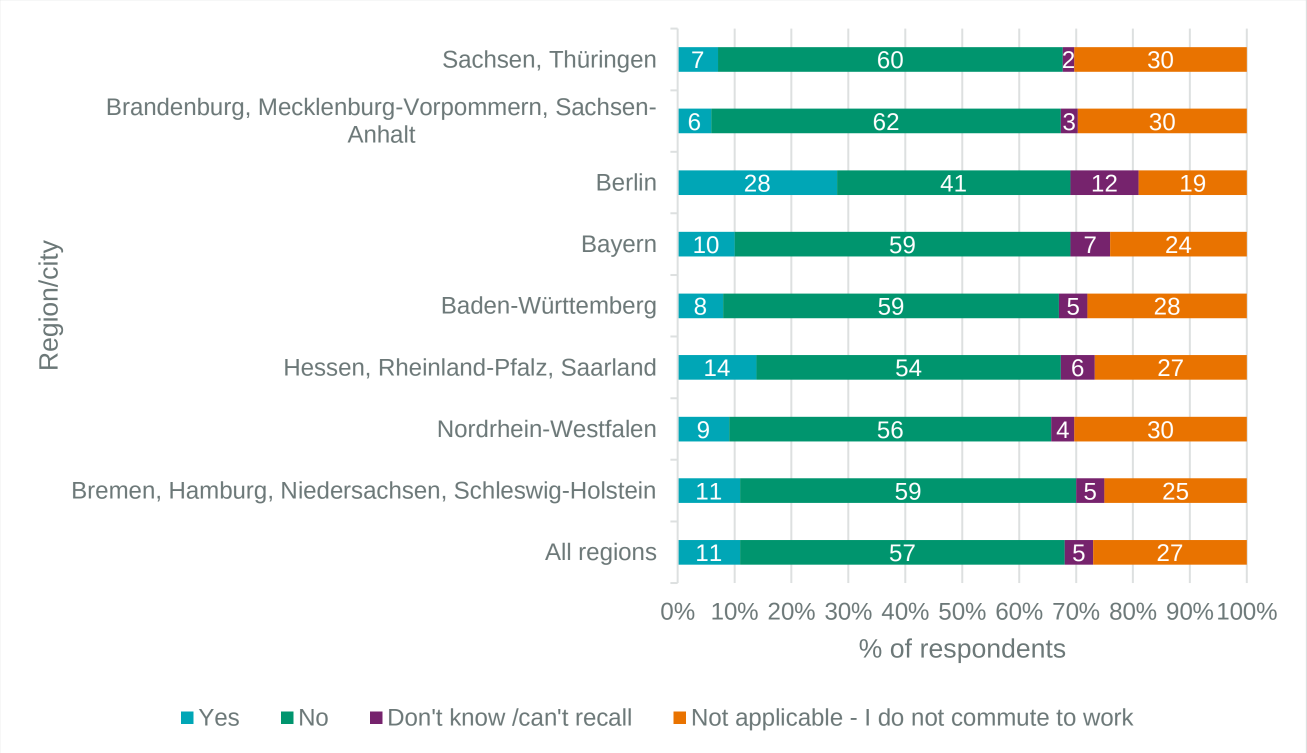


Figure 2 shows the proportion of respondents that took part in informal car-sharing during their commute to work in 2023, broken down by monthly household income. Similar to Figure 1, the results show that the mode response for all income levels was ‘no’, meaning they didn’t engage in informal car-sharing during their commute in 2023. 39% of respondents with a household income of more than €10,000 a month selected ‘yes’ in response to this question, more than double the proportion of respondents selecting this response for the €5,000 - €10,000 category (18%), the next highest scoring income bracket).

Figure 2. Proportion of respondents that took part in an informal car-sharing scheme during their commute in 2023, in relation to household income

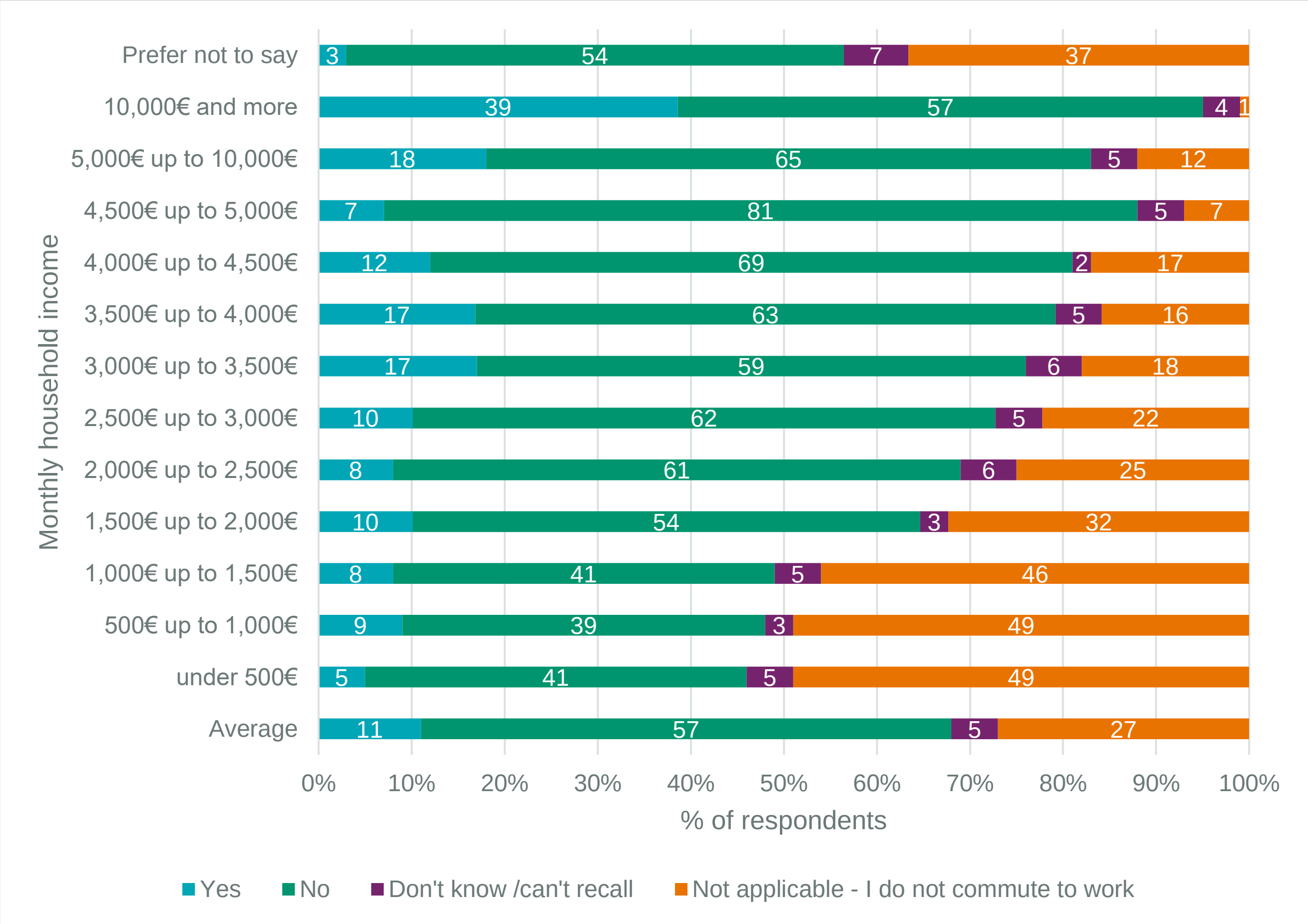


Figure 3 shows the days per week where a commute to work is shared with at least one other individual, broken down by the responses of each region/city. On average across all regions, 22% of respondents stated that on average in 2023 they shared their journey to work with another individual 3 days a week, 21% said they did this 2 days per week, 19% said 4 days per week, 15% did so 1 day a week, 11% did this 5 days a week, 3% did 7 days a week, and 2% said they did so 6 days a week.

Figure 3. Days per week where a journey to work is shared with at least one other individual, per region/city

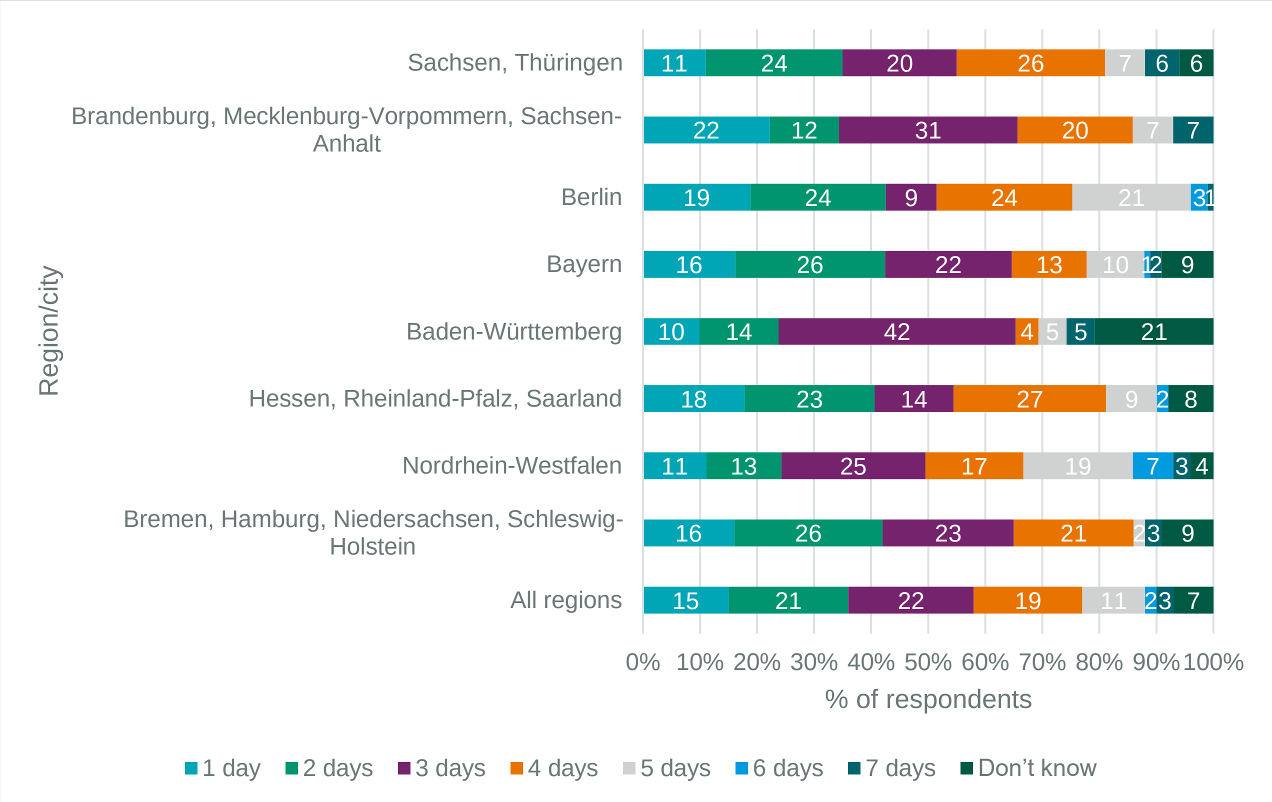


Figure 4 displays the days per week where a commute to work is shared with at least one other individual, with the responses broken down by income bracket. The figure shows that five income brackets selected 2 days as their mode response, four income brackets had 3 days as their mode response, three brackets selected 4 days the most, and it was only those with a monthly household income of less than €500 that selected 1 day as their mode response.

Figure 4. Days per week where a journey to work is shared with at least one other individual, in relation to household income

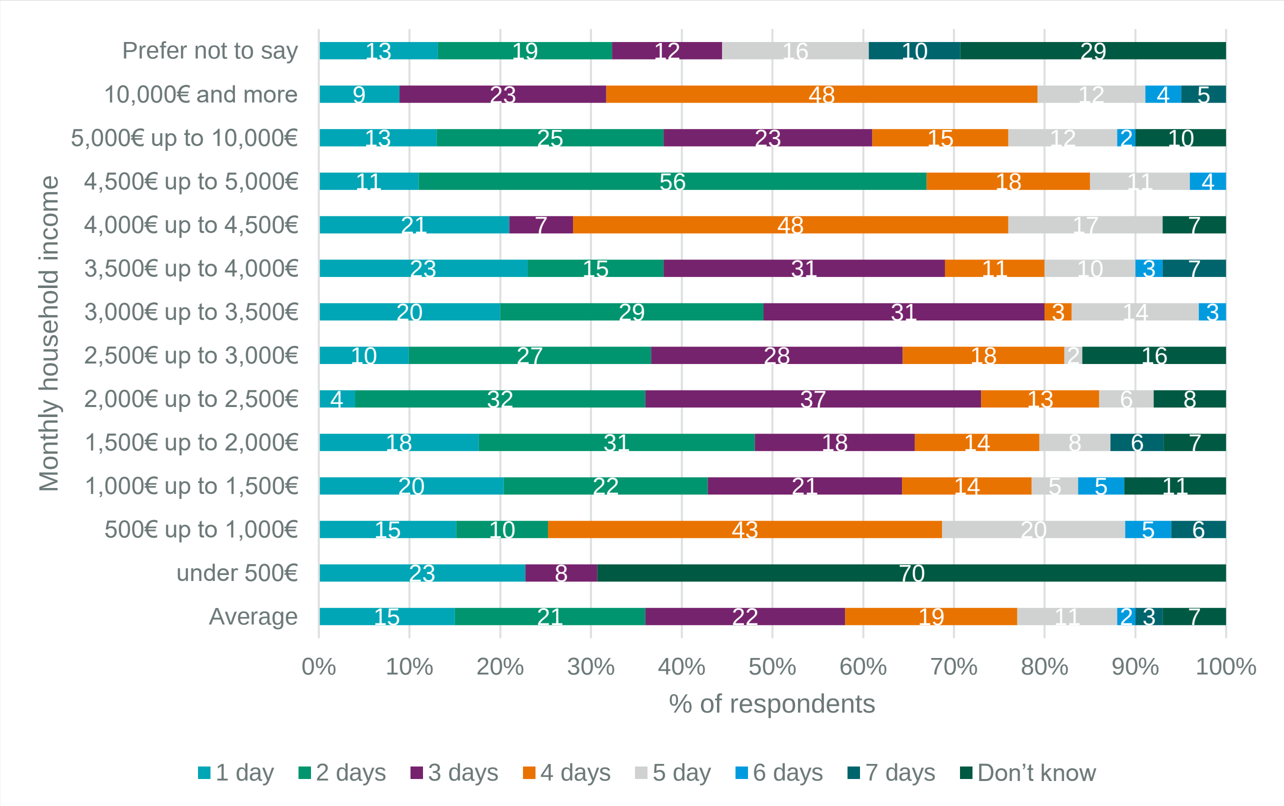


Figure 5 shows the type of vehicle used for respondents' commute to work, broken down by city/region. Across all regions, the most selected response from participants was that all journeys were in an ICE vehicle, with this figure peaking at 64% of respondents in the Bayern region. The Hessen, Rheinland-Pfalz, Saarland region saw 35% of respondents make all their journeys in an electric vehicle, the most of any region/city. No respondents from Baden-Württemberg, Berlin, and Brandenburg, Mecklenburg-Vorpommern, Sachsen-Anhalt said that most of their journeys were in an electric vehicle.

Figure 5. Vehicle type used for commute to work, per region/city

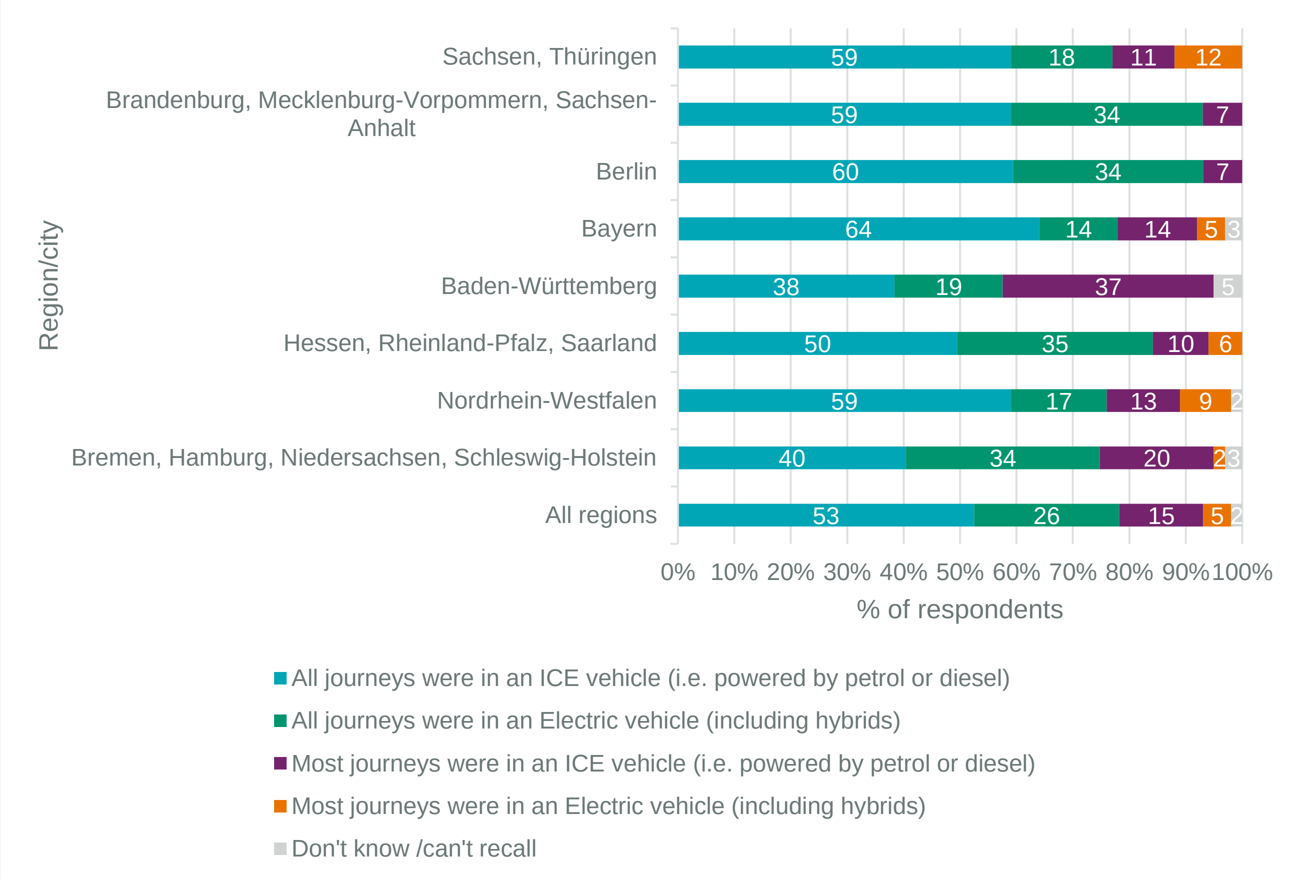


Figure 6 shows a similar pattern to Figure 5, with 12 of the 13 income brackets selecting ‘All journeys were in an ICE vehicle (i.e. powered by petrol or diesel)’, however the one anomaly was seen in the responses of those with a monthly household income of €10,000 and more, where 49% of respondents selected that ‘All journeys were in an Electric vehicle (including hybrids).

Figure 6. Vehicle type used for commute to work, in relation to household income

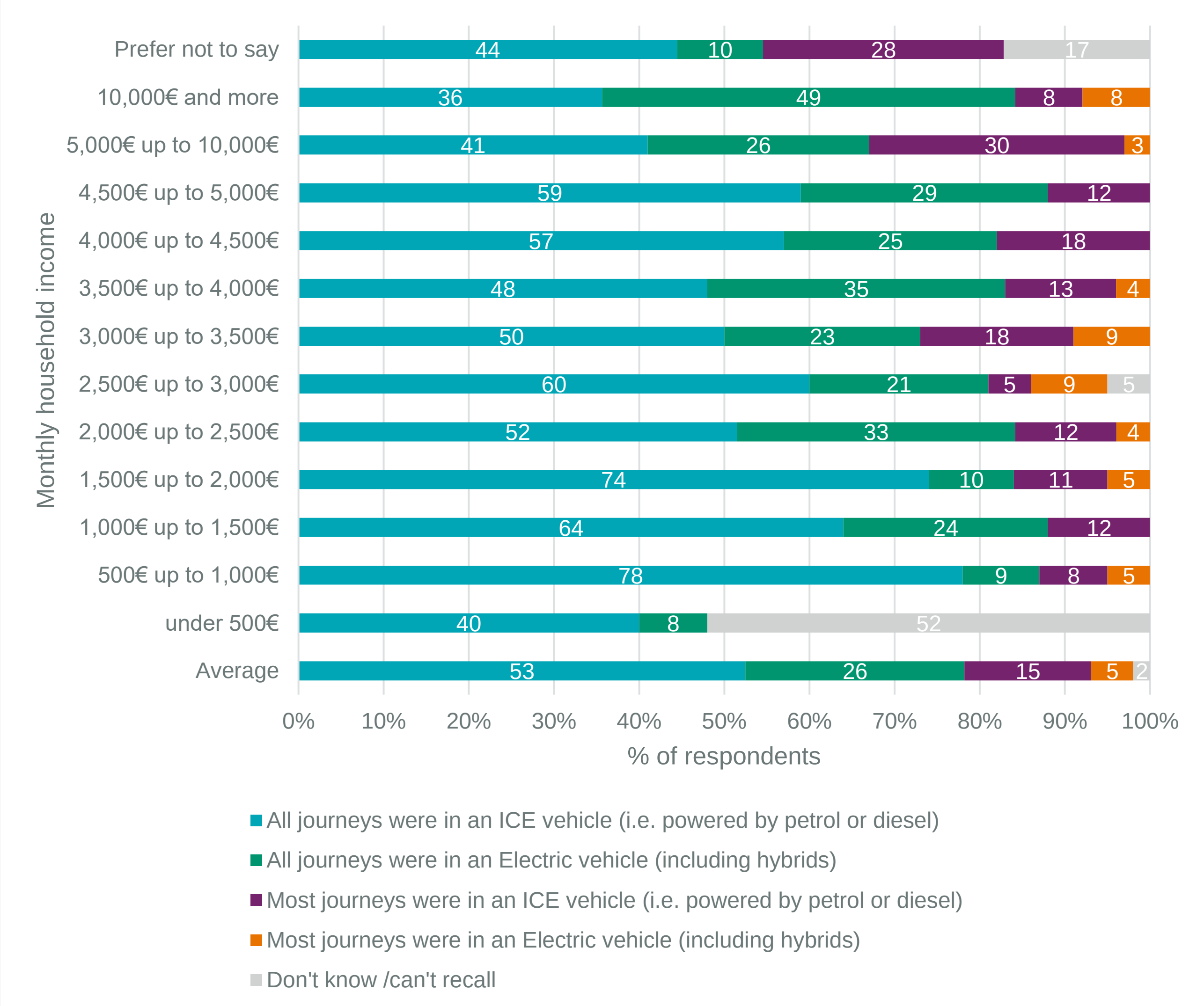
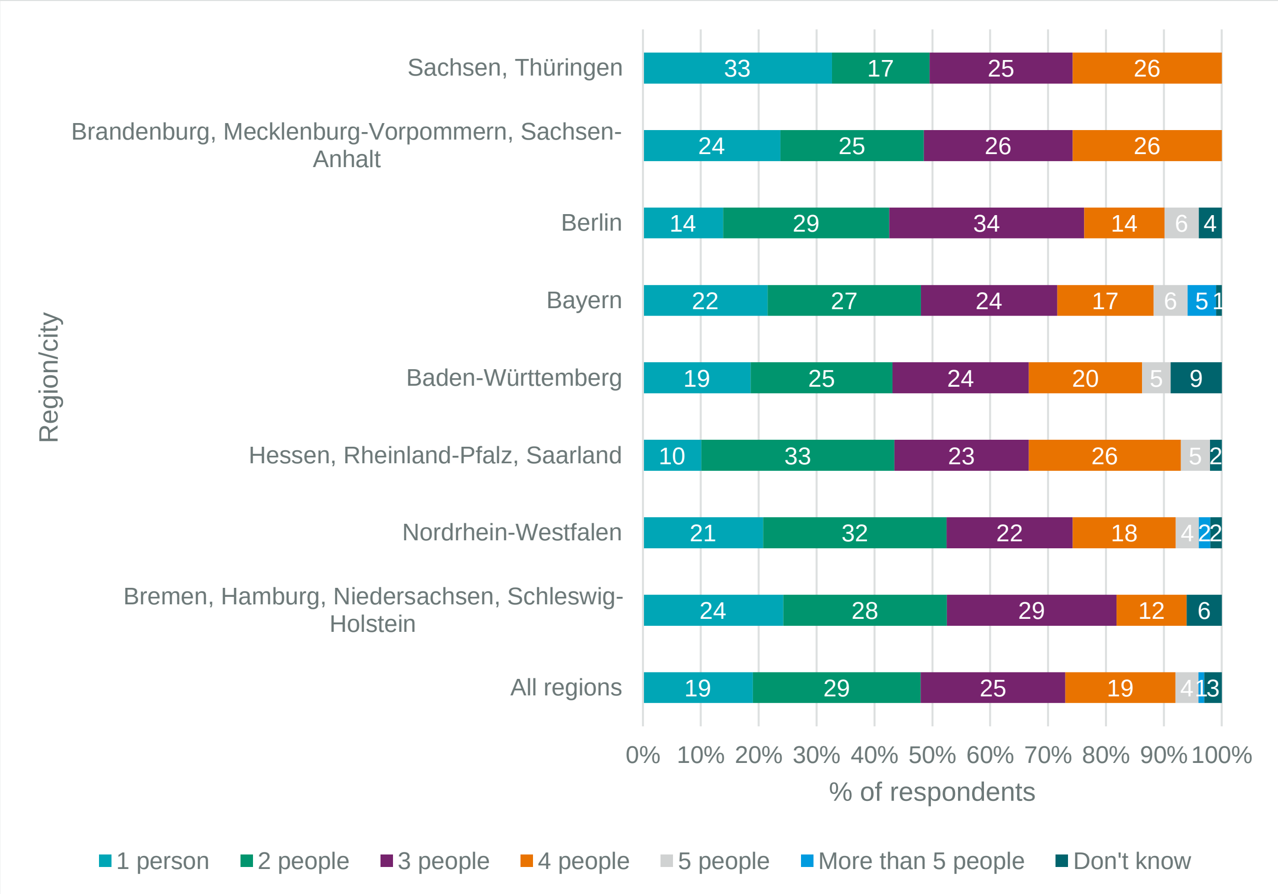


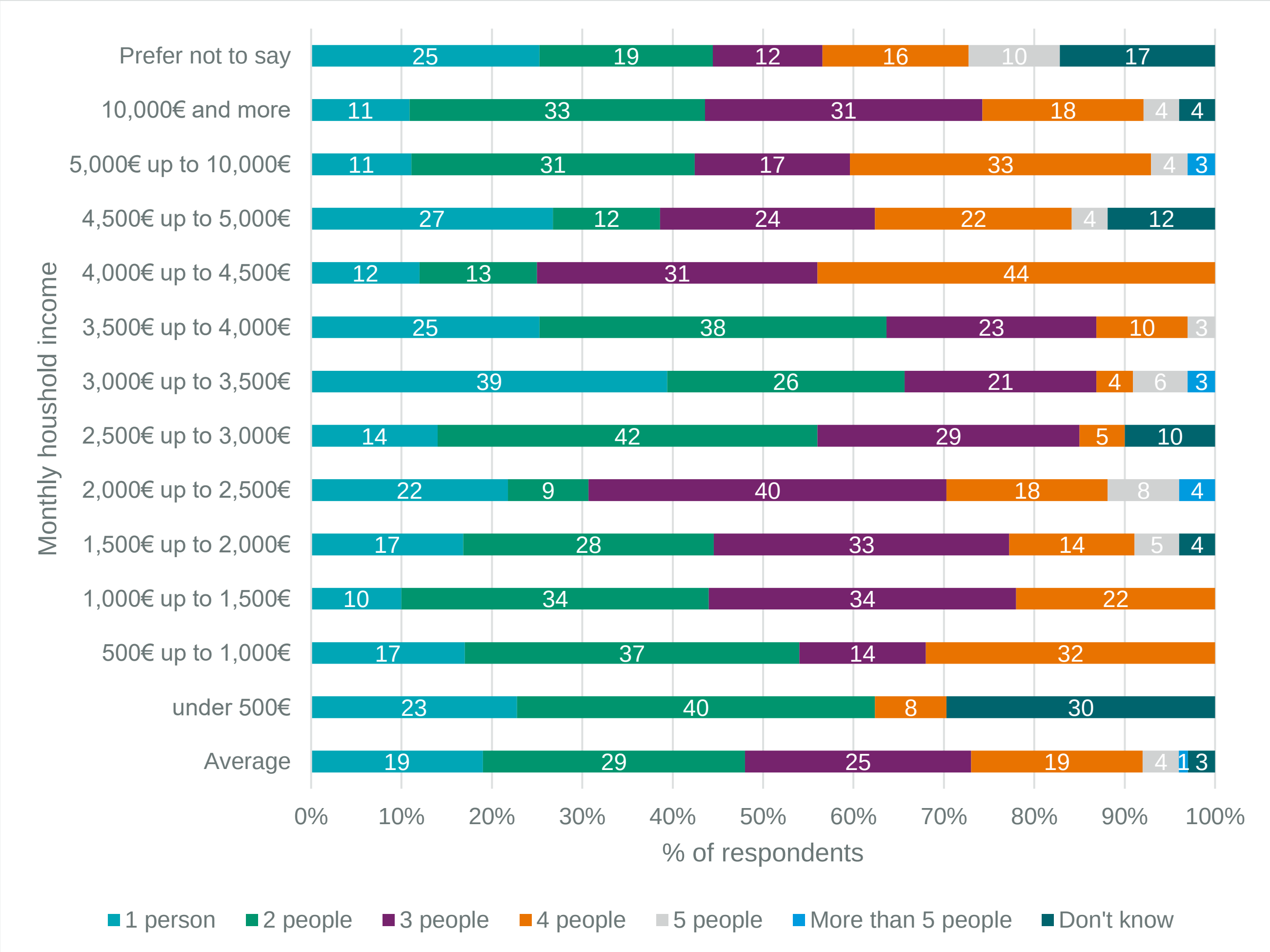
Figure 7 displays the average number of other people also present in shared commutes, broken down by region/city. The mode response for five of the eight regions was 2 people, the most popular response in Bremen, Hamburg, Niedersachsen, Schleswig-Holstein was 3 people (29%), Sachsen, Thüringen saw 33% respond with 1 person, and the mode responses for Brandenburg, Mecklenburg-Vorpommern, Sachsen-Anhalt were 3 people and 4 people both receiving 26%.

Figure 7. Average number of people also present in shared commute, per region/city.



As displayed in Figure 8, the mode response for six income groups was 2 people, three income groups selected ‘1 person’ as their most common response, whilst ‘3 people’ and ‘4 people’ were both the mode responses for two income groups. 10 of the groups had no respondents select the response of ‘More than 5 people’, with only 1% of the overall sample doing so.

Figure 8. Average number of people also present in shared commute, in relation to household income



Appendix 6.1 contains the survey analysis for this indicator.

2.2.2 Limitations

The following limitations were identified through the testing programme:

- Due to a lack of available data, the testing of the indicator was only able to cover informal car journeys measured via the citizen survey. However, even if formal car-sharing data was available, it is likely that this would not match the same format as the data collected via the citizen survey, making comparisons and analysis between the data sets difficult to carry out.
- Similarly, if data from formal car-sharing schemes was attained, it is likely that it would not have come with the same level of granularity as that received from the citizen survey, likely making it difficult to compare and analyse the data sets.
- Difficulties were experienced in attaining data pertaining to the total amount of journeys undertaken within Member States. It is also predicted that were this data available, it may have a high degree of inaccuracy, impacting the reliability of the overall indicator results.
- Due to time and resource restraints, we were only able to collect and analyse regional data within one Member State (i.e. Germany). This meant that we were only able to compare results from the specific regions within Germany, rather than specific regions within two Member States.
- After an initial review of the proposed questions for the citizen survey, it was recommended by YouGov (the survey disseminator) to offer a range of answers to respondents (i.e. option of 'most journeys were in an ICE vehicle, etc.) rather than allowing them free reign and offering a blank text box. Due to the experience that YouGov have in carrying out this type of survey, this recommendation was followed. Whilst this likely reduced the amount of guesswork from respondents, it also likely meant that some responses received were less accurate than they could have been otherwise.

2.2.3 Performance

During Task 4, the original indicator, also named “Car sharing frequency rates” was allocated a score of 12 against the RACER evaluation process, with this score reducing to 11 after the indicator had been tested. This was due to the indicator scoring lower than expected on the ‘Ease’ criterion. The reasoning behind the lower ‘Ease’ score was the difficulty in attaining data from formalised car-sharing schemes, as well as the total journeys taken across Member States.

Table 5. RACER evaluation

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	2	3	2	2	12
After Task 5 (following testing)	3	2	3	1	2	11

2.3 CHALLENGES AND LESSONS LEARNED

2.3.1 Challenges

Contacting the stakeholders for data on their car-sharing journeys proved to be a difficult process, with contact information hard to find via desk-based research. The initial categorisation of companies into the determined car-sharing types proved to be challenging due to the vagueness of the company website and the cross-category services they provided. Five different companies were identified across Germany, Netherlands and Belgium, but there was little success in contact attempts.

One stakeholder expressed the lack of incentive to provide information and recommended that Ricardo some kind of financial incentive to cover the costs of data gathering. No further response was received from this organisation.

The data collection related challenges for this indicator were mitigated by the survey response data available. For stakeholder’s who had poor contact links (i.e. through a website form) they were also contacted via LinkedIn, however this did not prove successful in receiving a response.

2.3.2 Lessons learned

Lessons learned were recorded throughout the process of creating and testing this indicator, which may be applied to inform future assessments of indicators:

- For indicators which are based on data from citizen surveys, a judgement needs to be made at the early stages of testing as to what level of data granularity is required. There is a direct trade-off between the level of granularity asked for and the burden on the respondent to answer the questions. Asking for actual numbers within an open-ended question format is a more burdensome approach and could lead to missing data, however it would result in more granular data. In comparison, using numerical ranges within a closed-ended question format would provide less granular data, but would alternatively be easier/quicker for the respondent to complete, which would likely result in higher response rates. Considering this, it is recommended to disseminate citizen surveys via a platform who can guarantee reaching the pre-determined response rate.
- Actions, such as the implementation of mandatory reporting, to incentivise the reporting of data may make the data collection process simpler in future. As previously mentioned, concerns around a lack of incentive to participate in this study were voiced by one stakeholder, so it is expected that without actions being implemented to remediate this, it is likely that this issue will also be experienced in future.

2.4 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is considered for further development, with significant work required to facilitate its progress.

Whilst the original indicator put forward for testing would help to support CE strategies that are higher up the waste hierarchy, such as refuse, rethink, and reduce, testing has proven that major changes are needed for the indicator to feasibly be considered for further development. The process found that data from formal car-sharing schemes was difficult to attain, and whilst this may be easier for the EC to collect, it is highly likely that data regarding the total number of car journeys undertaken by citizens within a Member State will not be available and is also likely to be susceptible to inaccuracy should it be collected. It is therefore recommended that going forward an alternative approach should be employed. This approach should come in the form of expanding the citizen survey to measure the use of formal car-sharing schemes. To ensure consistent results, this should be disseminated within the same survey as that collecting informal car-sharing data, but it is important to differentiate between the two within the questioning so analysis may be undertaken to compare the use of formal and informal schemes.

Further, the original indicator did not take the distance travelled in car journeys into account, instead only measuring the number of car journeys taken. This may lead to an ineffective indicator providing misleading results, e.g. two car journeys would account for the same in calculations, even if one was for a distance of 1 mile, and the other for a distance of 100 miles. Therefore, it is recommended that for the indicator to provide a more comprehensive assessment of circularity, it should be changed to measure the distance travelled in car-shares as a proportion of total distance travelled in cars. It is recommended that this data is collected using a citizen survey, and citizens should be given ample time to record their journey habits in order to minimise approximations and maximise accuracy. Expanding this scope would allow for more quantifiable data to be collected, as well as allowing for any patterns or trends to be highlighted and analysed.

Due to the informal nature of many car-sharing activities and the availability of many other sustainable modes of transport available, it has not been deemed necessary to define targets to support the implementation of this indicator.

To support improvements in the performance of this indicator, it is recommended that campaigns encouraging the use of car-sharing is implemented throughout Member States, building on existing work such as the Recovery and Resilience Facility backed 'Car-sharing and carpooling'[4] project, which focussed on campaigns promoting car-sharing and carpooling in Denmark.

Similarly, it is also recommended that legislation is implemented to incentivise the use of car-sharing schemes across Member States. This incentivisation may include tax breaks or other financial benefits such as reduced parking or congestion charges. The impact of this legislation may be assessed by yearly monitoring of this indicator.

Following the testing of this indicator, it was found that its original name 'Car-sharing frequency rates' was fit for purpose and that no variation was needed.

There are no direct crossovers with this indicator and the ones within the new EU monitoring framework for CE. However, quantifying the proportion of journeys that are undertaken in a car-share each year would indirectly support improvements across the following macro level indicators:

- **Material footprint:** i.e. a quantification of the demand for material extractions triggered by consumption and investment by households, governments and businesses across the EU. Increasing the use of car-sharing would support the EU and individual Member States material footprints to decrease by potentially reducing the demand for personal vehicles.
- **Consumption footprint:** i.e. the environmental impacts of EU and Member States consumption by combining data on consumption intensity and environmental impacts of representative products. Increasing the use of car-sharing may reduce the EU and Member State consumption footprint, as individuals/businesses may resultingly purchase fewer vehicles.

[4] Car-sharing and carpooling - European Commission (europa.eu)

Table 6. Summary of recommendations for BV1

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Data collection	Data on formal car-sharing journeys should also be collected using citizen surveys. This would allow for consistent and comparable data for the use of both formal and informal car-sharing	Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** EC. **Consulted:** Car-sharing schemes, citizens. **Informed:** Car-sharing schemes, citizens.
Expansion of indicator	In order to provide a more comprehensive assessment of circularity, the scope of the indicator should be expanded to also monitor the distances travelled when car-sharing.	Relevance and Credibility	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** EC. **Consulted:** Car-sharing schemes, citizens. **Informed:** Car-sharing schemes, citizens.
Legislation	Incentives encouraging the use of car-sharing.	Relevance, Acceptability, Credibility and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** National Governments. **Consulted:** National Governments, car-sharing schemes, citizens. **Informed:** All stakeholders within EU car-sharing industry.
Development of campaigns	Develop campaigns encouraging citizens to use car-sharing, including the resulting benefits and possible methods.	Relevance and Acceptability	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** National Governments. **Consulted:** National Governments, citizens. **Informed:** All stakeholders within EU car-sharing industry.

3. INDICATOR 2: VIRGIN VS. RECYCLED PLASTIC RAW MATERIAL USED IN THE PRODUCTION OF VEHICLES

This quantitative indicator looks at the percentage of virgin raw material versus recycled raw material used in the production of vehicles manufactured in EU Member States at the Point of Manufacture (POM) of the vehicle. The scope of this indicator is to consider the material content of vehicles currently manufactured and placed onto the market across EU Member States.

More specifically, this metric will consider the recycled content of any raw material used at the POM across EU Member States for any Internal Combustion Engine Vehicle (ICEV) or Battery Electric Vehicle (BEV) which does not come directly from a virgin source. This will include vehicles from the following "Euro Car Segment" category types: A-segment mini cars, B-segment small cars, C-segment medium cars, D-segment large cars, E-segment executive cars, F-segment luxury cars, S-segment sports coupés, M-segment multi-purpose cars, J-segment sport utility cars. (European Commission, 2013)

To monitor this metric, the focus will be on the plastic raw materials used in manufacturing vehicles. The metric originally aimed to assess all materials in vehicle production. However, during development, it was decided to limit the metric to plastic components only. This decision was based on several factors:

- The complexity and volume of data, calculations and assumptions needed to accurately determine the overall recycled content of a vehicle are substantial, particularly as this is the first time an indicator of this type is being implemented in the sector. Starting with a specific material group like plastics is more manageable.
- The existing initiatives (e.g. End-of Life Vehicles Directive) to introduce recycled plastic targets for vehicle manufactured in the EU.
- The reduced potential for error in calculating recycled content for various components.

However, developing this indicator towards monitoring the overall recycled content of vehicles should be highlighted as a longer-term goal.

This indicator being primarily focused around the “recycle” CE theme – widely considered the least favourable CE approach in the waste hierarchy/R-strategies[5] (due to its high energy demands). The R-strategies in order of hierarchy include: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover and landfill or incarnation (the least preferable and representative of a “Linear Economy”). (Malooley & Daphne, 2023)Despite this, the indicator has been considered crucial for several reasons. The main reason was that recycled content data for vehicles is one of the most reported CE metrics by automotive OEMs (Original Equipment Manufacturers – companies assembling and selling the vehicles to consumers) and Tier 1s in EU Member States. It is also a key metric in OEM public sustainability communications (e.g. Annual Corporate Sustainability Reporting).

The importance of this indicator is further emphasised by the recent European Commission (EC) draft End-of Life Vehicles (ELVs) Directive (proposed on 13th July 2023), which is likely to result in recycled plastic content targets across the automotive industry. This draft suggests setting a target that ***“at least 25% of plastic used to build a vehicle comes from recycling by 2031 for newly-type approved vehicles only – of which 25% is to come from closed-loop production, recycled ELVs.”*** Aligned with the Circular Economy Action Plan and the European Green Deal, the proposed ELV Directive will drive progression from the original directive in 2000. The indicator’s inclusion will equip the automotive sector to better prepare and comply with any forthcoming regulations on recycled plastic content that may be set by the EC. (Directorate-General for Environment, 2023).

Monitoring this indicator offers several benefits including:

- **High return on effort -** High availability/accessibility to data from a range of automotive OEMs across Europe. Consequently, limited resources would be needed for implementation.
- **Indication of urgency to for action -** Best indication of automotive OEMs taking short-term action to progress a CE.

[5] The R-strategies are a hierarchical list of approaches to circular economy – the position on the hierarchy indicating the “shortness” of the waste loop attributed to the approach. The shorter the waste loop, the more sustainable/circular the strategy is.

- **High acceptance and credibility –** Likely to be widely accepted and understood both within and outside the automotive sector as a reliable measurement of CE progress. It would also hold credibility amongst key industry stakeholders (e.g. policy makers).
- **High ease of implementation –** It is straightforward for OEMs/Tier 1s to provide reliable, quantitative evidence to support the data reported for this indicator.
- **Robustness of data –** The data required for reporting is also used in safety-critical technical design ensuring that the reported values are of high-quality and reliability.

3.1 KEY METHODOLOGY

3.1.1 Testing method

In developing the testing method, the initial step was to define the system boundary for the indicator. There were three key variables to be defined for the system boundary, which included:

1. **Extent of vehicle coverage**. The metric focused only on the recycled plastic material of vehicles that are currently being manufactured and placed onto the market across EU Member States. The term plastic refers to a broad range of synthetic and semi-synthetic materials.
2. **European OEMs included**. To streamline data collection, Ricardo targeted major automotive OEMs with manufacturing in the EU specifically:
   - Volkswagen.
   - Renault.
   - Stellantis.
   - Volvo.
   - Hyundai.
3. **Specific plastic types.** The Plastics Industry Trade Association (2016) estimates that roughly 39 basic types of plastic are used in vehicles, and that there are over 150-200 different technical plastic fractions in the average manufactured vehicle. Therefore, it was important to define the plastic types to monitor. Following research on plastics used in vehicle manufacture it was decided to focus on the eight most used plastics used by OEMs (by weight) in vehicle manufacturing for both ICEVs and BEVs. The ninth most used plastic type are specialist plastics, which are used in a smaller quantity. These were grouped as “Other plastics” and were not considered since the specification of this group would vary between vehicle models. These plastics are (European Commission, 2023):
   - Polypropylene (PP) – standard plastic.
   - Polyurethane (PUR) – standard plastic.
   - Polyamides (PA) – engineering plastic.
   - Polyethylene terephthalate (PET) – standard plastic.
   - Polyethylene (PE) – standard plastic.
   - Acrylonitrile butadiene styrene/styrene acrylonitrile resin (ABS/SAN) – engineering plastic.
   - Polyvinylchloride (PVC) – standard plastic.
   - Polycarbonate/Acrylonitrile butadiene styrene (PC/ABS).

Their usage is detailed in terms of estimated content in both ICEVs and BEVs in Table 7.

Table 7. Summary of estimated weight composition of top eight plastics used in passenger cars in EU (European Commission, 2023)

Plastic Type	Estimated plastic weight composition for passenger cars, as a percentage of total weight of respective plastic type used (%)	
	ICEV Representative Car (2021)	BEV Representative Car (2021)
PP	37.1	35.0
PUR	11.2	7.0

Plastic Type	Estimated plastic weight composition for passenger cars, as a percentage of total weight of respective plastic type used (%)	
	ICEV Representative Car (2021)	BEV Representative Car (2021)
PA	15.7	12.0
PET	4.5	5.0
PE	5.6	4.0
ABS/SAN	4.5	6.0
PVC	7.9	3.0
PC/ABS	10.0	6.0
Other plastics	3.5	22.0

It should be noted that due to market limitations, such as the technical unfeasibility of recycling, certain materials like elastomers, adhesives, thermosets, sealants, and coatings are not currently incorporating any recycled content by OEMs. Consequently, these were considered out of scope and out of the system boundary for testing this indicator.

The most appropriate assessment methodology selected for this indicator was ***"Method 3 - Material Flow Analysis"***. A Material Flow Analysis (MFA) details the flows of materials within a system boundary (which may be a country, region, organisation, product etc). It is a powerful tool for measurement of performance change, as well as giving the ability to compare current levels of circularity between one example of the 'system' and another. It facilitates the development of an evidence base to support the shift to a CE through identifying future policy direction and supporting interventions that could have the greatest impact.

MFA was selected as the best methodology for assessing the indicator as it provides a comprehensive view of material utilisation within a defined system boundary (e.g. in this case an automotive vehicle). MFA is vital for monitoring this metric as it helps to quantify and map the flow of materials, allowing for a detailed examination of how resources are used and reused within the automotive industry.

In the application of MFA for this indicator, it is important to keep as much granularity as possible in the data (likely to be predominantly available waste management data), so that the distinction can be made between reuse, recycling, and energy recovery (considered by some to still be part of the CE).

3.1.1.1 Key design parameters of an MFA

For an MFA approach to be effectively and consistently applied, it is necessary to set out some design principles that all aspects and iterations of the MFA should follow. The following is a non-exhaustive list of the parameters that will be considered:

1. **Sector taxonomy** – Classification of sectors within the economy to define and segment industries or markets relevant to the study.
2. **Material taxonomy** – Classification of each material (plastic type), with a unique description based on its individual characteristics.
3. **Geographical taxonomy** – Classification based on geographical origin characteristics.
4. **Reporting unit dimensions** (years, tonnes, m^3, etc) – Assignment of specific units or dimensions most appropriate for measuring the given parameter/parameters.
5. **Material compositional characteristics** – Any characteristics specific to the material with distinguish it from others.
6. **Life cycle stages at which data is available** – Stage of vehicle lifecycle at which the data is measured, recorded and subsequently available.
7. **Reporting parameters** – Defining what indicators the MFA aims to assess including:
    - Direct Material Inputs (DMI = Domestic Extraction + Imports). A measure of all the material inputs.
    - Domestic Material Consumption (DMC = DMI – Exports). The amount of material used in the regional economy.

- Physical Trade Balance (PTB = Imports – Exports). The net amount of material brought into the region.
- Material Footprint (MF = DMC/population). The amount of material consumed per capita.
- Absolute and relative decoupling (e.g. £GDP/tonne material throughput). A measure of whether economic growth is tied to material consumption.
- Secondary material use as a proportion of inputs to manufacturing.
- Material productivity. Economic output (GDP) produced per tonne of primary material consumed.

3.1.2 Data collection method

The data collection process used for this indicator was broken down into three key approaches, to maximise the chance of retrieving reliable data especially considering the potential challenges of non-responses or unwillingness to share data. The key approaches were:

1. **Data collection direct from automotive sector** – Identifying automotive OEMs representative where there is already established contact or potential for engagement.
2. **Identifying publicly available data** – Desk-based research to identify if the specific data required for this metric was already publicly available. This includes the web-scraping to identify any relevant data already available online.
3. **Internal partner engagement** – Identify where data may already be available from existing contacts that could be relevant and could be used as part of the testing process.

Initially, emails were issued to four automotive OEM contacts including a detailed data request and background information on the project, supported by a letter from DG-RTD. This resulted in a high no-response rate, and the few responses received indicated reluctance to share the required data due to commercial sensitivity and/or data privacy reasons.

Consequently, the data collection focus shifted on to approach 2, to determine if sufficient data was available publicly and was already being reported. The publicly available data was found to be limited, and not specific enough to be used for the indicator (i.e. affiliated with specific OEMs and plastic types). The data was also inconsistent in its format and lacked any specific evidence to back-up its validity. Furthermore, much of the data found consisted of just publicly communicated “ambitions” by OEMs of recycled content in vehicles, which posed reliability issues due to the lack of evidence being required to support the claims. One of the key sources used in researching this was the “Towards recycled plastic content targets in new passenger cars and light commercial vehicles (2023) report delivered by the EC’s Joint Research Centre.

Finally, the data collection efforts were focused on approach3, which was to see if appropriate data could be sourced through existing contacts and partnerships within Ricardo. Following this, it was found that Ricardo had recently delivered a project in2023 for an automotive client. This was a recycled content research and mapping exercise for a European automotive OEM. The project estimated the recycled plastic content for several automotive OEMs, manufacturing in the EU. These estimates were made based on insight from EU industry standards reported by relevant associations and studies; and additional insight from two external interviews. Upon reviewing this data within the Ricardo team, it was considered sufficient to proceed with an initial testing of the indicator as part of the project itself.

The data was sourced from several interviews conducted with automotive industry experts. This included a benchmarking of the different recycled plastic contents for 4 of the top 8 plastic types used in the manufacture of new vehicles, as outlined in Table 10.

- Polypropylene (PP).
- Polyamides (PA).
- Polyethylene terephthalate (PET).
- Acrylonitrile butadiene styrene (ABS).

Interviews were conducted over MS Teams with automotive industry experts. These automotive industry experts were professionals who have significant prior experience working in OEMs/Tier 1s across the European automotive sector. Contact was made with these professionals through a service platform called

"Alphasights"[6], which is a platform that connects professionals with expert knowledge for complex projects and decisions in targeted sectors. Professionals who were currently working at OEMs under study were not approached for this project to avoid conflicts of interest since they are considered competitors to the client for whom the original research was conducted. The strategic decision ensured the integrity and impartiality of the data collection process.

3.1.3 Calculations

The calculations below were intended to be used to measure the percentage of recycled plastic content in specific types of plastic used in vehicles. Examples are given below specifically PP, PUR and PA. This calculation would need to be repeated for all of the individual plastic types considered for calculation.

$$Recycled\ plastic\ content\ (\%)_{PP} = \frac{R1+R2+R3}{V+R1+R2+R3} \times 100$$

$$Recycled\ plastic\ content\ (\%)_{PUR} = \frac{R1+R2+R3}{V+R1+R2+R3} \times 100$$

$$Recycled\ plastic\ content\ (\%)_{PA} = \frac{R1+R2+R3}{V+R1+R2+R3} \times 100$$

Where:

- V = Weight of virgin material portion of purchased raw material (kg)
- R1 = Weight of recycled portion of purchased raw material (kg)
- R2 = Weight of post-industrial recycled material (kg)
- R3 = Weight of post-consumer recycled material (kg)*

**Note that R3 does not include the smaller post-industrial/consumer recycled portion of material in purchased raw material marketed as "mostly" virgin. R1 and R3 have been included separately to ensure all recycled material portions are captured in this calculation.*

Although the initial approach was clearly outlined, the final data analysis did not utilise these specific calculations due to several factors:

- **Data privacy concerns** with organisations unwilling to share detailed raw data.
- **Variability in recycled content** between different vehicle models and variations due to supply chain limitations of specific recycled plastics.
- **Material specifications** for vehicles are primarily based upon meeting certain performance criteria rather than meeting specific recycled content targets. This is of relevance with changing supply chain dynamics for recycled plastics across industries. This will be discussed further in Section 1.4.

3.1.4 Timeline

Table 8 below gives an overview of the plan and monitoring timeline for the development of this indicator.

[6] AlphaSights – online platform connecting clients with experts, sometimes referred to as an expert network.

Table 8. Gannt chart for BV2

W/C	18-Dec	25-Dec	01-Jan	08-Jan	15-Jan	22-Jan	29-Jan	05-Feb	12-Feb	19-Feb	26-Feb	04-Mar	11-Mar	18-Mar	25-Mar	01-Apr
Task 1 - Identify OEMs/Tier 1s to contact																
Task 2 - Contact OEMs/Tier 1s and source data																
Task 3 - Analyse data																
Task 4 - Build simple Excel model & conduct calculations																
Task 5 - Conduct analysis of themes/trends																
Task 6 - Write up case study template																
Review period																
Key deliverables				Source data										Initial draft		Draft case study

3.1.5 Data gaps and mitigation

To ensure robust and high-quality analysis of the data, the following QA procedure was conducted:

- Prior to work beginning, the Project Director reviewed the proposed research methodology and ensured that the data collection plan was fit for purpose. Only once the research team had addressed any comments from the review process did they proceed to the data collection phase.
- In relation to the email request development and dissemination, Project Manager reviewed the line of questioning for this indicator to ensure that it was clear, easy to follow and able to generate reliable and robust results. In addition to this, submission of a formal vehicle design specification sheet and/or Bills of Materials (BOM) from the OEMs/Tier 1s was requested alongside sharing of data.

Table 9 below summarises the identified data gaps which were encountered and the corresponding strategy to mitigate the gaps.

Table 9. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Components where OEMs are unsure of the recycled content, or do not currently have the information.	Engagement from the OEM/Ricardo directly with the Tier 1/Tier 2 suppliers to determine recycled content of components which is currently unknown.	High
2	No response or engagement from OEMs/Tier 1s in the "Approach1 – Data Collection from the Automotive Sector"	Persistent chasing of contacts over email and alternative contact methods for chasing (e.g. LinkedIn/Phone calls). Also, any identification of additional contacts within the OEMs and Tier 1s. No success, through these additional methods will result in increased efforts on Approach 2 of the data collection method.	Medium
3	Insufficient or no publicly available data suitable for use in monitoring of the indicators outlined, as part of Approach 2 for data collection.	Engagement with internal Ricardo experts from other business units ensure there are no alternative publicly available data sources which could be utilised. If not, increased efforts on Approach 3 of the data collection process should be done. This is further internal Ricardo/project partner engagement, to see where any useful data could be found.	Medium
4	Data unavailable for any/some of the top eight vehicle plastic types originally outlined.	Engagement with the targeted data source to gather data for the missing plastic. Otherwise, focus to be on data for those plastic types for which data is available.	Medium

3.1.6 Quality review of analysis

The intended QA approach for this indicator was to validate the recycled content data for vehicles, by requesting the submission of a formal vehicle design specification sheet and/or Bills of Materials (BOM) from the OEMs/Tier 1s who submitted the data. In practice, it was difficult to receive this for the purpose of testing since contacted stakeholders from the automotive sector already had concerns regarding data privacy and commercial sensitivity. To successfully progress this indicator in the future, it will be essential to have the appropriate data-sharing agreements in place, so OEMs/Tier 1s can comfortably submit evidence to back-up their recycled content claims. It is also likely that some sort of mandate will need to be put in place to ensure this data is submitted to support the credibility of the indicator and prevent any potential overestimation of recycled content to further commercial ambitions from a sustainability standpoint. This is discussed further in the “Lessons learnt” and “Conclusions” sections of this report.

3.2 KEY ANALYSIS RESULTS

3.2.1 Analysis

Table 10 provides a summary of the recycled content estimates for four major plastic types used in the manufacturing of new vehicles by European automotive OEMs. It should be noted that the MFA methodology originally outlined was not applied for this data collection and analysis process. This is since the data was provided in the final form, which did not require any of the associated calculations.

Table 10. Summary of recycled content for top 4 plastic types for European automotive OEMs (% by weight of total plastic-type weight)

Plastic Type	Recycled Content Estimate/Range (wt%)		
	Volkswagen	Renault	Stellantis
Polypropylene (PP)	15-20	~20	10-15
Polyamides (PA)	15-20	~15	<10
Polyethylene terephthalate (PET)	~20	~25	10-15
Acrylonitrile butadiene styrene (ABS)	~20	~20	~20%

Upon reviewing the data in Table 10, it is observed there is variability in the recycled content percentages among different OEMs for the same types of plastics. This is primarily due to the recycled content varying across different vehicle models, which will have different component material specifications and shares of plastic types. For example, while Volkswagen and Renault show higher recycled content in PP and PA (between 15-20 wt%, Stellantis reports lower percentages (in the 10-15 wt% range). This variation is also likely a result of differences in supply chain capabilities (e.g. specific recycled material supply agreements between OEM and Tier 2), recycling technologies or perhaps strategic priorities related to sustainability across these organisations. PET shows relatively high recycled content across all OEMs sampled, particularly with Renault with 25 wt%. PET is commonly recycled and used in various industries, which may contribute to its higher percentages and a more mature recycling infrastructure for PET.

3.2.2 Limitations

The main limitation with the data is that it was only based on what was collated from interviews with automotive industry experts without any technical evidence to substantiate their claims. This poses a challenge in verifying the accuracy of the data (which was not from specific individuals working at the OEMs listed).

A further limitation is that the data was only sourced for four out of the eight most common plastic types used in ICEV and BEV manufacturing, PP, PA, PET and ABS. This was because these were the only plastics requested in the original project the data was sourced from. Furthermore, data was only sourced for the plastic material component (no other materials) and contact was only made with a limited number of OEMs – these both present additional limitations.

A key uncertainty in the data provided is in recycled content percentages being provided as ranges for each of the respective OEMs, as opposed to precise and specific numbers for individual vehicle models. The variation is attributed to the expected differences in recycled content from model to model and the fluctuating availability of recycled plastic which affects the supply chain as demand increases in various sectors. Requirements for vehicle QA specifications are typically based upon meeting certain mechanical property requirements, rather than the specific sources of materials. Furthermore, due to the data source, direct communication with the investigation OEMs was not possible.

There is also potential limitation on the dependency of this indicator on voluntary data sharing. Being reliant primarily on data voluntarily provided by OEMs may result in a biased or incomplete data. The implementation of third-party audits or a verification process to enhance the credibility and accuracy of the data, would help in addressing this limitation on the validity of the data shared.

A further limitation is the technological and economic feasibility of recycling certain types of plastics – particularly given the cost sensitivity and manufacturing cost limitations of the automotive sector. This will likely influence the practicality of increasing recycled content and meeting potential targets. It would need to be managed carefully as this could potentially result in unrealistic expectations or targets that are not supported by current technology or market conditions. Furthermore, supply chain limitations of recycled materials could also come into play – particularly as other industries begin to compete for similar materials.

3.2.3 Performance

Table 11 below summarises the original RACER evaluations performed for this indicator, during the original assessment (as part of Task 4), and after Task 5 (following testing of the indicator). Two of the categories have dropped in their score following the new assessment after Task 5 testing and one of the categories increased in their score. This can be explained as follows:

- **Relevance (Score Change: +1) -** The "relevance" category score was increased since the original assessment. This was due to further research into the proposed EC's "End of Life Vehicle Directive", and the proposed targets set by this, indicating the importance of this measurement in potential future European legislation. Hence, making it of considerable relevance to progressing CE in the automotive sector.
- **Acceptability (Score Change: -1) –** The "acceptance" category score was decreased from the original assessment. This was because of the feedback received and limited progress that was made throughout the initial stakeholder engagement and data collection phases. It was discovered that despite the indicator itself being accepted as an appropriate metric of the CE, there were concerns from OEMs/Tier 1s around the commercial sensitivity and intellectual property (IP) of vehicle design, associated with the sharing of recycled content and/or design data. Therefore, it was decided to reduce the score as it is considered less acceptable by the stakeholders, considering the sharing of data needed for monitoring.
- **Ease (Score Change: -2) -** The "ease" category score was reduced from an original score of 3 to 1. This was since it was much less straightforward in collating the required data directly from those that held it, than was originally expected. It was required to focus on the final approach for the data collection to find appropriate data and this was following significant internal engagement. In practice, it is likely that the sharing of the data needed to monitor this indicator would need to be mandated from those that hold it themselves – this will be discussed further in the "Conclusions and Recommendations" section of the report.

Table 11. RACER evaluation

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	2	3	3	3	3	14
After Task 5 (following testing)	3	2	3	1	3	12

Overall, the indicator performed well in terms of its target area – this is despite there being significant challenges in sourcing the data. Among the indicators under the "Batteries and vehicles" topic, this can be considered as of high relevancy – due to its alignment with future EU policy; and the access to the recycled content data when applied at a larger scale. The data itself is available and being recorded – the challenge is regarding the willingness of the data owners to share it. It is expected, that when recycled content policy is introduced following the “End of Life Vehicles Directive” that reporting of this data itself will be mandated (along with appropriate evidence to validate reported data).

3.3 CHALLENGES AND LESSONS LEARNED

3.3.1 Challenges

Several challenges were encountered whilst developing this indicator primarily around sourcing useful data for the monitoring and validating the recycled content data that was collected. Several automotive OEM/Tier 1 contacts were contacted directly using email, with no response in most cases. Where contact was made, concerns were often expressed around the sensitivity of sharing the design data needed to validate any recycled content estimates. To address these concerns, a supporting endorsement letter from DG-RTD was provided to explain the importance and legitimacy of the project. However, despite this, there were still concerns around the sharing of sensitive data. In addition to the contacts made with select OEMs/Tier 1s, the European Association of Automotive Suppliers was also contacted for relevant data points, but also with no response.

A further challenge is the potential for inconsistencies in how recycled content could be defined and calculated among different OEMs, making it difficult to aggregate. It is recommended to establish clear definitions and standardised formats for the reporting of recycled content, applicable across all EU member states and automotive manufacturers.

3.3.2 Lessons learned

The following lessons learned were identified and recorded throughout the monitoring process of this indicator:

- **Mandating of reporting –** It is essential to mandate the reporting of recycled content, potentially with incentives, to ensure cooperation from the relevant stakeholders to effectively monitor the indicator. The introduction of recycled content targets for plastics, following the potential implementation of the ELV Directive, could facilitate this.
- **Supply chain demands –** It will be important to consider the implication of likely future supply chain demands and challenges on the individual and overall reported recycled content of OEMs. OEMs/Tier1s who have successfully secured certain recycled material supply agreements for vehicles manufactured in the EU will likely appear more successful against this metrics. If European OEMs/Tier 1s feel that their CE success is being measured based on maintaining the highest possible recycled content for various plastic types, it could be perceived that those OEMs/Tier 1s who have more favourable material supply agreements will always be considered to perform the best. This could result in a skewed acceptance of the metric.
- **Evidence to validate reporting –** Validation of any recycled plastic content reported from OEMs will be essential to maintaining the credibility and robustness of the indictor across the sector when implemented. The inability to obtain necessary evidence due to concerns over sharing sensitive design data highlights the need for OEMs to submit corresponding Bill of Materials" (BOM) or Material/Design Specification documents to confirm in the recycled content data.
- **Variability in recycled content reported –** It was observed that any recycled content reporting is always likely to be quoted as a range, as opposed to a specific number even when reporting for individual vehicle models. This is primarily due to variations in supply chain availability of recycled materials. Quality assurance testing of vehicles is always based upon vehicles components meeting certain material property requirements and not specific recycled content requirements.
- **Stronger engagement and collaboration with industry –** Further work should be done prior to collecting any data to build stronger relationships with industry associations to leverage their influence and network for data collection. This should result in improved long-term engagement from OEMs/Tier 1s and an increased willingness to share the relevant data to supporting monitoring of the indicator.

3.4 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is considered for further development, with minor work required to facilitate its progress.

In conclusion, it is recommended that this indicator is considered for further development, with minor work being required to facilitate its progress. Despite the RACER score of the indicator dropping from the original assessment, it can still be considered of high relevance, acceptability, and credibility towards achieving the EC's goal of 'true circularity'. This is primarily due to its direct alignment with the wider goals and proposed future regulations likely to result from the ELV Directive. It is expected that one of the key targets to be proposed from "at least 25% of plastic used to build a vehicle comes from recycling – of which 25% is to come from recycled ELVs".

The data on recycled plastic content, although presented as ranges and gathered primarily through interviews, indicates that such information is available. The primary challenge lies in the willingness and incentivisation for stakeholders to share this data. Consequently, it is essential that legislation is introduced which requires mandatory reporting of recycled plastic content, along with the submission of appropriate data which can evidence the data reported (e.g. material specifications/data sheets).

There were two areas in the RACER assessment that had a reduced score after testing – acceptability and ease of implementation. However, these can both be addressed and overcome through the expected future policy developments, hence it is considered that only minor work will be needed to facilitate its progress. The acceptability of the metric reduced because of the concerns raised in sharing the data – this would be overcome through recycled plastic content targets that highlight the importance of using more recycled materials. The perceived ease of the metric was impacted following testing due to challenges in retrieving the required data from OEMs which can be resolved through the introduction of regulation which mandates the reporting of recycled content in new vehicles.

To further improve the performance of this indicator, it is essential that legislation is also implemented to require the mandatory reporting of recycled plastic content data for new vehicles manufactured and sold in the EU. This may come in the form of tax incentives or subsidies for organisations that comply. This legislation should be aligned with that proposed in 2023's End of Life Vehicle Directive from the European Commission.

A notable limitation of the indicator is that it measures circularity based on the "recyclability" theme – considered one of the lowest priority circularity themes. Despite this, it is still highly recommended for implementation due to its ease of implementation and its role in measuring progress of the automotive's CE progress in the short term.

Following the testing of this indicator, it was found that its original name 'Virgin vs. recycled plastic raw material used in the production of vehicles' was fit for purpose and that no variation was needed.

A summary of the recommendations, timelines and key stakeholders needed for advancing this metric are summarised in

Table 12 below.

Table 12. Summary of recommendations for BV2

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Legislation	Introduction of a recycled plastics content target in new vehicles manufactured in the EU of, aligned with the proposed ELV Directive. Implementation of proposed target of: ***"at least 25% of plastic used to build a vehicle comes from recycling by 2031 for newly-type approved vehicles only – of which 25% is to come from closed-loop production, recycled ELVs."***	Credibility, Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s **Informed:** All stakeholders within EU automotive industry.
Legislation	Introduction of legislation to require the mandatory annual reporting of recycled plastic content (%) in vehicles manufactured and sold across EU Member States is essential to access data required to successfully implement this indicator.	Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Legislation	Introduction of legislation to require the submission of BOM, and/or material/vehicle design specifications alongside quoted recycled plastic content ranges, as evidence to confirm validity. Legislation mandating the submission of this evidence is essential to ensure reliable data is used when implementing this indicator.	Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Reporting	Encourage voluntary reporting of recycled plastic content prior to introduction of legislation in 2031.	Ease and Robustness	Short (<1.5 years)	**Responsible:** EC.

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
	This is to capture as much data as possible prior to the data being formally collected.			**Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Development and indicator scope	Scope of the indicator should be expanded to include other materials such as metals, electronics, textiles, and other materials critical to vehicle manufacturing. Development and implementation of a roadmap for gradually including other materials will provide a more comprehensive view for the metric.	Relevance and Credibility	Long (> 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Technology development	Develop a digital reporting platform where OEMs and Tier 1 suppliers can submit their data.	Ease and Robustness	Long (> 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Incentives	**Introduction of incentives** – Legal requirements will likely be introduced for annual reporting of recycled content as part of the ELV Directive, but it should be considered to include penalties for non-compliance (e.g. fines). Financial incentives should also be considered (e.g. tax incentives, access to innovation grants) for companies that exceed the minimum standards for using recycled materials in vehicle manufacturing.	Relevance and Acceptability	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Training and development	Develop and implement training programme for automotive manufacturers looking at the benefits and methodology for incorporating and monitoring recycled materials.	Credibility and Ease	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Technology development	Address concerns around data privacy issues - Develop an anonymised data reporting system or a secure data sharing platforms that protects confidential information.	Acceptability and Ease	Long (> 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.

4. INDICATOR 3: QUANTITY OF END-OF-USE BATTERIES RETAINED FOR REUSE IN THE EU AUTOMOTIVE INDUSTRY

This indicator measures the quantity of end-of-use batteries retained for reuse in the EU automotive industry. It considers all types of batteries used in electric vehicles (EVs) and internal combustion engine (ICEs) vehicles retained at end-of-life for those vehicles manufactured and sold across EU Member States. This includes lithium-ion batteries, nickel-metal batteries, lead-acid batteries, and ultracapacitors[7]. Batteries that have been recycled into new batteries are included in the scope of this indicator.

End-of-use batteries are those that may not be needed by their current owners or are able to function through Value Retention Processes (VRPs) offering other options for keeping these components in the market.

The CE is based on three key principles; eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature. This indicator relates to the elimination of waste by focussing on the reuse and recycling of batteries and battery components. It also supports the circulation of these batteries and components at their highest possible value, by keeping them within the automotive or other similar high-value industries. Finally, the re-use of end-of-use batteries reduces the need for virgin materials to be sourced, helping to preserve natural resources and mitigate the environmental impact of mining and extraction.

With ambitious EU legislation such as the European Green Deal[8] and the Sustainable and Smart Mobility Strategy[9] in place for reducing car emissions and promoting the uptake of EVs there will be increasing demand pressures on batteries and their raw materials. Monitoring recycling rates will help ease this demand and achieve EV related targets[10]. It will also help to track progress towards specific battery recovery and recycling targets like those set out in the new EU Batteries Regulation[11]. Targets that may be applied to batteries within the scope of this indicator include 'lithium recovery from waste batteries of 50% by the end of 2027 and 80% by the end of 2031', and 'mandatory minimum levels of recycled content for SLI (starting, light, and ignition) and EV batteries – initially set at 16% for cobalt, 85% for lead, 6% for lithium, and 6% for nickel'.

The EU is also reviewing industrial battery policy to enhance competitiveness globally. The battery supply chain is complex, involving numerous stakeholders from raw material extraction to manufacturing[12]. The new EU Batteries Regulation covers the whole lifecycle of batteries from production to reuse and recycling and includes targets to adopt recycling rates of up to 80% by 2031 for some battery types[13].

Monitoring this indicator will provide the following key benefits:

- Evaluates the effectiveness of existing systems and structures that facilitate the reuse and repurposing of batteries in the EU. This also includes assessing the efficiency of collection and disassembly processes.
- Reuse is an important aspect of the CE, and monitoring encourages practices that extend product life and reduce waste.
- Helps to analyse resource efficiency across different EU Member States. This includes evaluating the economic benefits and opportunities associated with increased implementation of battery reuse.

---

[7] U.S. Department of Energy, Batteries for Electric Vehicles. (Alternative Fuels Data Centre, n.d.). https://afdc.energy.gov/vehicles/electric-batteries#:~:text=Most%20plug%2Din%20hybrids%20and,hybrid%20electric%20vehicles%20(HEVs).. Accessed April 2024.

[8] European Commission, The European Green Deal. (Official website of the European Union, 2024). https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en#:~:text=The%20European%20Green%20Deal%20%E2%80%93%20A%20commitment%20to%20future%20generations&text=no%20net%20emissions%20of%20greenhouse,and%20no%20place%20left%20behind. Accessed April 2024.

[9] European Commission, Mobility Strategy. (Official website of the European Union, n.d.). https://transport.ec.europa.eu/transport-themes/mobility-strategy_en. Accessed April 2024.

[10] EEA, Electric Vehicles. (European Environment Agency, 2024). https://www.eea.europa.eu/en/topics/in-depth/electric-vehicles. Accessed March 2024.

[11] European Union, Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC (Text with EEA relevance). (EUR-Lex, 2023). https://eur-lex.europa.eu/eli/reg/2023/1542/oj. Accessed March 2024.

[12] ECA, The EU's industrial policy on batteries (European Court of Auditors, 2023). https://www.eca.europa.eu/ECAPublications/SR-2023-15/SR-2023-15_EN.pdf. Accessed March 2024.

[13] Council of the EU, Council adopts new regulation on batteries and waste batteries. (European Council, 2023). https://www.consilium.europa.eu/en/press/press-releases/2023/07/10/council-adopts-new-regulation-on-batteries-and-waste-batteries/. Accessed March 2024.

- By tracking the reuse of batteries, it is possible to assess the impact on the lifespan of products in the products in the automotive industry. This relates directly to improvements in material efficiency and energy efficiency as longer product lifespans reduce the need for virgin materials and energy consumption.
- Aligns with the goals set by the new EU Batteries Regulation helping to ensure that recycling and reuse targets are met.

4.1 KEY METHODOLOGY

4.1.1 Testing method

The system boundary for data collection was clearly defined to include all types of batteries from EV and ICE vehicles that reach the end-of-life. This encompasses vehicles manufactured and sold within EU Member States. The reuse of these batteries was not limited to the automotive industry, with all reuse activities being within scope of the indicator.

The scope covers vehicles across a broad range of Euro Car Segment categories including: A-segment mini cars, B-segment small cars, C-segment medium cars, D-segment large cars, E-segment executive cars, F-segment luxury cars, S-segment sports coupés, M-segment multi-purpose cars, J-segment sport utility cars[14]. These vehicle types cover all passenger cars operational in the EU.

4.1.2 Data collection method

Data was collected on the weight of batteries (all types) retained at vehicles end-of-life across all ICE and EV vehicles originally manufactured and sold across EU Member States. The data collection process involved stakeholder engagement with automotive OEM's, Tier 1 suppliers, and waste management companies.

Seven end-of-life battery waste management companies were contacted in total covering France (Suez and Indra), Netherlands (Stiba and ARN) and Belgium (Groupecomet, DIDIER, and Recuparts) with no response from any of the organisations. These organisations were selected due to the perceived reliability of attaining responses, as well as the large automotive industry in France, and the relatively high proportion of EVs in operation in the Netherlands[15] and Belgium[16], accounting for 44% and 41% of the total new car sales in each state respectively.

The low response rate could be due to the unreliability of the contact methods used, which included general website forms and ‘info’ email addresses that might not have reached the relevant staff members. Contact details for relevant individual members of staff were researched, but ultimately to no avail. In addition, efforts were made to contact the European Association of Automotive Suppliers for relevant data points, but this too did not yield any results.

These challenges were mitigated by regular follow-ups, though these efforts increasingly appeared unlikely to produce results. In response, desk top research was carried out to try find indicative figures that could offer insights for this indicator. However, this approach also proved challenging, with difficulty in accessing relevant and usable data.

Despite significant effort to collect data on end-of-life vehicle battery reuse across the EU, the only data obtained was from Auto Recycling Nederland (ARN)[17], which is the sole end-of-life vehicle sorting facility in the Netherlands. ARN take end-of-life vehicles from across the Netherlands, where they are then depolluted, dismantled, and shredded. Parts and materials (including batteries) from the vehicle are sent for further processing in the form of further shredding or recycling.

[14] European Commission, EU classification on vehicle types. (Official website of the European Union, n.d.). https://alternative-fuels-observatory.ec.europa.eu/general-information/vehicle-types. Accessed April 2024.

[15] Netherlands Enterprise Agency, Electric Vehicles Statistics in the Netherlands. (Netherlands Enterprise Agency, 2023). https://www.rvo.nl/sites/default/files/2023-01/Statistics-Electric-Vehicles-and-Charging-in-The-%20Netherlands-up-to-%20and-including-December-2022.pdf. Accessed April 2024.

[16] Mobia, Communique de presse. (Mobia, 2023). https://www.febiac.be/sites/default/files/media/file/2024-01/Bilan%202023.pdf. Accessed April 2024.

[17] Auto Recycling Nederland (n.d.). https://arn.nl/en/. Accessed March 2024.

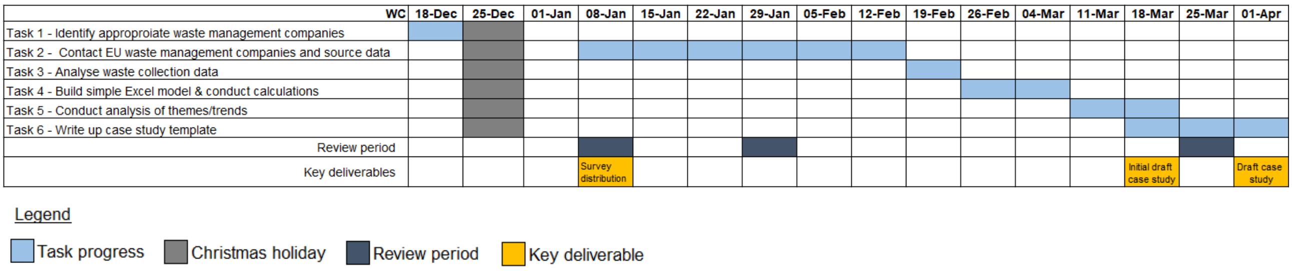
4.1.3 Calculations

Due to the nature of this indicator, calculations were not required.

4.1.4 Timeline

Table 13 below gives an overview of the plan and monitoring timeline for the development of this indicator.

Table 13. Gantt chart for BV3



4.1.5 Data gaps and mitigation

ARN processes end-of-life vehicle waste from the entire country. This centralised operation means that the data available could not be broken down by different regions within the Netherlands. Consequently, the information used to test the indicator was aggregated for the entire country.

Table 14. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Lack of data from multiple sources covering multiple Member States.	Initial contact with the selected group of stakeholders was made prior to the desk-based research to mitigate the risks of a delayed response. Follow-up emails were sent to the stakeholders after the desk-based research to ensure required data was not readily accessible. Unfortunately, no responses were received so data from ARN was used as data source.	Low
2	Lack of regional data.	In order to prevent the use of inaccurate assumptions regarding the regional split of end-of-use vehicle batteries processed by ARN, it was decided that the data would remain covering the Netherlands as a whole.	Medium

4.1.6 Quality review of analysis

The following QA procedure was conducted for this indicator:

- Prior to work beginning, the Project Director reviewed the proposed research methodology and ensure that the data collection plan is fit for purpose. Only once the research team had addressed any comments from the review process did they proceed to the data collection phase.
- The Quality Assurance Manager held responsibility for the quality of the final case study output. The Project Manager assisted the Quality Assurance Manager in judging the quality of the output and suggesting ways to improve.

4.2 KEY ANALYSIS RESULTS

4.2.1 Analysis

Due to the limited engagement from stakeholders and a lack of publicly available data, the analysis is limited to the information presented in Table 15 below. Table 15 shows that 127,537kg of end-of-life vehicle batteries were collected in the Netherlands in 2021, decreasing to 112,617kg in 2022. However, it is important to note that these figures are measured in weight. Consequently, a reduction in weight does not necessarily imply a decrease in the actual number of end-of-life batteries reused from 2021 to 2022. This is primarily since the weight of an EV battery can depend greatly upon the type of vehicle model and drive train associated with the vehicle model. Table 16 shows that the weight of batteries reused for an application other than in a car, such as for lighting a runway. In 2021 this value was 68,072kg, equating to 53% of the total weight collected. This number decreased significantly to 25,902kg in 2022, equating to just 23% of the total weight collected. With this decrease came a significant increase in the weight of batteries recycled in 2022, totalling 86,715kg (77% of the total weight collected), compared with 59,465kg recycled in 2021, accounting for 47% of the total weight collected. These recycling figures can be seen in Table 17.

Table 15. Weight of end-of-life vehicle batteries collected in the Netherlands (2021 – 2022)

Member State	Weight of EOL vehicle batteries collected 2021 (kg)[18]	Weight of EOL vehicle batteries collected 2022 (kg)[19]
The Netherlands	127,537	112,617

Table 16. Weight of end-of-life vehicle batteries reused in the Netherlands (2021 – 2022)

Member State	Weight of EOL vehicle batteries reused 2021 (kg)[20]	Weight of EOL vehicle batteries reused 2022 (kg)[21]
The Netherlands	68,072 (53%)	25,902 (23%)

Table 17. Weight of end-of-life vehicle batteries recycled in the Netherlands (2021 – 2022)

Member State	Weight of EOL vehicle batteries recycled 2021 (kg)[22]	Weight of EOL vehicle batteries recycled 2022 (kg)[23]
The Netherlands	59,465 (47%)	86,715 (77%)

[18] ARN, Recycling of car batteries. (Auto Recycling Nederland, 2022). https://duurzaamheidsverslag2021.arn.nl/en/batterijrecycling/recyclen-van-autobatterijen/. Accessed March 2024.

[19] ARN, Fewer end-of-life EV-batteries reused in 2022. (Auto Recycling Nederland, 2024). https://arn.nl/en/fewer-end-of-life-drive-batteries-reused-in-2022/. Accessed March 2024.

[20] ARN, Recycling of car batteries. (Auto Recycling Nederland, 2022). https://duurzaamheidsverslag2021.arn.nl/en/batterijrecycling/recyclen-van-autobatterijen/. Accessed March 2024.

[21] ARN, Fewer end-of-life EV-batteries reused in 2022. (Auto Recycling Nederland, 2024). https://arn.nl/en/fewer-end-of-life-drive-batteries-reused-in-2022/. Accessed March 2024.

[22] ARN, Recycling of car batteries. (Auto Recycling Nederland, 2022). https://duurzaamheidsverslag2021.arn.nl/en/batterijrecycling/recyclen-van-autobatterijen/. Accessed March 2024.

[23] ARN, Fewer end-of-life EV-batteries reused in 2022. (Auto Recycling Nederland, 2024). https://arn.nl/en/fewer-end-of-life-drive-batteries-reused-in-2022/. Accessed March 2024.

4.2.2 Limitations

The following limitations have been identified through the testing programme:

- **Limited data sources and geographical scope**. Due to a lack of available data, the testing of the indicator was only able to cover data from one source (ARN), in one country (Netherlands). This limitation prevented comparative analysis between Member States or even within different regions of the Netherlands as no other regional data was available. During the testing of this indicator, it was found that other Member States also only had one facility to cover the entire nation.
- **Data represented in weight only**. Data was only provided in terms of weight (kg), rather than the actual number of batteries reused. Whilst calculations could have been performed using assumptions of the battery weights, the inclusion of both ICE and EV vehicle batteries and the substantial differences in the weight of these respective batteries would have introduced significant inaccuracies.
- **Lack of granularity in the data**. Data was provided for all battery types together, rather than being broken down by individual battery type. Since factors such as lifespan and efficiency vary between different battery types, the data does not currently account for these differences.
- **External indicators not developed**. Factors such as changes in raw material prices and demand fluctuations for both new and used batteries will have an impact on battery reuse rates. Were these factors to be analysed, they may help to gain a better understanding of changes in reuse and recycling rates of batteries. However, these factors have not been considered in the testing of this indicator.

4.2.3 Performance

During Task 4, the original indicator was allocated a score of 12 against the RACER evaluation process, with this score reducing to 11 after the indicator has been tested. This was due to the indicator scoring lower than expected on the 'Ease' criterion. The reasoning behind the lower 'ease' score was the difficulty in attaining data. However, as there is a strong likelihood the data is in existence but just difficult to collect, this score may be increased in future should the data collection process become simplified and more fruitful.

Table 18. RACER evaluation

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	2	3	2	2	12
After Task 5 (following testing)	3	2	3	1	2	11

4.3 CHALLENGES AND LESSONS LEARNED

4.3.1 Challenges

As discussed in 'Data collection method', the key challenge was securing the cooperation of relevant stakeholders to share data. The exception was the data from Auto Recycling Nederland which while useful was limited to the Netherlands and could not provide a broader European perspective. Finding comparable data from other reuse or recycling organisations proved particularly challenging, highlighting the issue of data availability and transparency in the sector.

4.3.2 Lessons learned

Lessons learned were recorded throughout the process of creating and testing this indicator, which could help refine the future monitoring of the indicator:

- Whilst likely already being collected, the data required to test this indicator was very difficult to attain throughout the testing period. In future, incentives may be required to encourage stakeholders to cooperate in the data collection process. These incentives may be in the form of legislation and regulation, or the offer of financial compensation to organisations accurately reporting data.
- Data is currently collected in terms of weight, rather than number of batteries reused. This approach may not provide the most accurate or relevant insights for assessing the effectiveness of battery reuse. Future

efforts might benefit from also aligning the units of measurement with more relevant metrics, such as the actual number of batteries, which could provide clearer insights into reuse rates and resource efficiency.

- It was found that data regarding the weight of batteries reused/recycled is sometimes combined with other materials such as contaminated metal waste, paint and coolant. Whilst this wasn't the case for the data used in the Analysis section, meaning it didn't impact the testing of the indicator, it did make some other potential data sources unusable.

4.4 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is considered for further development, with minor work required to facilitate its progress.

The indicator designed to track the reuse of end-of-life vehicle batteries is critical for achieving the EC's goal of 'true circularity', aligning with key CE principles like refuse, reuse, and rethink. It is suggested that some minor changes are applied to facilitate its successful progress and eventual implementation. The data collection and desk-based research process found that a number of end-of-life vehicle battery sorting and reprocessing facilities cover large collection areas, making it difficult to collect regional data. Therefore, it is recommended that this indicator is measured at a national level.

To ensure reliable data availability, it is advisable to introduce legislation requiring the mandatory reporting of end-of-life vehicle battery reuse from all relevant stakeholders. This would not only allow for data to be easily attained, but it would also ensure that the data is collected and reported in a consistent manner across different organisations and Member States, making comparisons easier to gather. Further, this would help to address the issue of data being reported by weight, rather than the number of batteries. For ease of implementation, it is recommended that these mandatory reporting requirements are integrated into existing legislation such as the new EU Batteries Regulation or the End-of-Life Vehicles Directive[24].

Whilst it is recommended that data is reported by number of batteries in future, this does not mean that weight should stop being reported. A combination of both weight and number of batteries would likely give the best insight into the process and the benefits attained during reuse.

Aiding this legislation, it is also recommended that the EC develops and implements a standardised data collection and reporting framework across all Member States. By including definitions, standards, protocols and standardising the units of measurement used, this framework would work to ensure accurate and reliable data collection and reporting. As one of the key barriers experienced during the stakeholder engagement process was the confidentiality of data, the framework should also address the task of handling confidential data.

To support with the implementation of this indicator, it is recommended that targets associated specifically with the reuse of end-of-use batteries in the automotive industry in the EU are established, building on the overarching battery targets set out in the new EU Batteries Regulation. These targets would provide clear goals for stakeholders and enhance focus on achieving higher reuse rates, contributing directly to the CE. However, when setting these targets, it is important to consider disparities in the availability and quality of infrastructure across different Member States, meaning benchmarking exercises may need to be undertaken in order to produce ambitious but attainable targets.

In order to support the improvement in the performance of this indicator, it is recommended that legislation is also implemented to incentivise the reuse of end-of-life vehicle batteries. This may come in the form of tax incentives or subsidies for those organisations that actively participate in battery reuse.

In monitoring this target, it is vital that the EC regularly assess the efficiency and impact of reusing end-of-use batteries. As technology develops, reuse may become inefficient or have a suboptimal impact when compared with other methods of disposal. In the quest for a CE, it is important that these preferable disposal routes are prioritised at this point.

Following the testing of this indicator, it was found that its original name 'Quantity of end-of-use batteries retained for reuse in the EU automotive industry' was fit for purpose and that no variation was needed.

---

[24] European Commission, End-of-life Vehicles. (Official website of the European Union, n.d.). https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en#timeline. Accessed April 2024.

Table 19. Summary of recommendations for BV3

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Legislation	Legislation should be implemented to make data reporting mandatory for EOL vehicle battery handlers/processors.	Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC **Accountable:** National Governments. **Consulted:** National Governments, EOL vehicle battery handlers. **Informed:** All stakeholders within EU automotive industry.
Legislation	Legislation should be implemented to incentivise the reuse of EOL vehicle batteries.	Relevance and Credibility	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** National Governments. **Consulted:** National Governments, EOL vehicle battery handlers. **Informed:** All stakeholders within EU automotive industry.
Development of a framework	A framework should be developed and implemented to ensure standardised data collection and reporting practices across Member States.	Acceptability, Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** EC **Consulted:** National Governments, EOL vehicle battery handlers. **Informed:** EOL vehicle battery handlers.

There are no direct cross overs with this indicator and the ones within the new EU monitoring framework for CE. However, quantifying the weight/number of end-of-life vehicle batteries retained for reuse would indirectly support improvements across the following macro level indicators:

- **Material footprint:** i.e. a quantification of the demand for material extractions triggered by consumption and investment by households, governments and businesses across the EU. Increasing the amount/number of end-of-life vehicle batteries that are reused would support the EU and individual Member States material footprints to decrease by reducing the demand for virgin materials.
- **Circular material use rate:** i.e. the share of material recycled and fed back into the economy. Increasing the amount/number of end-of-life vehicle batteries that are reused would have a positive impact on the circular material use rate.
- **Recycling rate of all waste excluding major mineral waste:** i.e. treated waste which was sent to recovery operation other than energy recovery and backfilling. Increasing the amount/number of end-of-life vehicle batteries that are reused would increase the recycling rate of this waste stream.

5. INDICATOR 4: EASE OF DISASSEMBLY METRIC

5.1 INTRODUCTION AND BACKGROUND

The Ease of Disassembly Metric (eDIM) quantifies the time required to disassemble individual components from vehicles manufactured and sold within EU Member States. The metric processes the collected data through a novel calculation (no evidence from desk-based research of the metric being applied to the automotive sector before) that generates a single numerical value for each vehicle. This vehicle-specific value provides an overall measurement that indicates the relative ease of dismantling the respective vehicle at its End of Life (EoL).

This indicator will cover both Internal Combustion Engine Vehicles (ICEVs) and Battery Electric Vehicles (BEVs) manufactured and sold across EU member states. It is recommended that this should include vehicles from the following "Euro Car Segment" category types: A-segment mini cars, B-segment small cars, C-segment medium cars, D-segment large cars, E-segment executive cars, F-segment luxury cars, S-segment sports coupés, M-segment multi-purpose cars, J-segment sport utility cars. (European Commission, 2013)

It is important to clarify that this is a theoretical case study, it does not involve actual data collection but rather serves as a conceptual framework. This approach has been selected for the following reasons:

- It is a highly complex and technical indicator, which requires extensive technical knowledge of vehicle manufacturing and is beyond the scope of work needed to develop case studies for this project.
- A highly technical methodology would need to be developed prior to identifying the various data sources needed for the monitoring of the metric.
- A standardised method does not currently exist to calculate the eDIM in a definitive manner, with an appropriate trade-off between the accuracy of the calculated disassembly time and the effort needed to apply the method.
- Development of a methodology of this kind would need significant resource and input from experts in the automotive sector that is out of the scope of this project. Furthermore, any proposed methodology would need to be validated and approved by experts in the field of vehicle manufacturing.
- Initial engagement with key stakeholders and experts in the automotive industry indicated it would be extremely challenging (if not impossible) to retrieve the type of data required for this metric. The indicator would require large amounts of highly commercially sensitive manufacturing data including a significant number of datapoints which are not currently standardised or comprehensively recorded across all EU vehicle models. This would be dependent on the specific model's current EoL treatment approach.

Despite these challenges, prioritising the development of the eDIM is crucial. The theme of this indicator is focused on the circular design of vehicles which should be considered a high priority for embedding circularity in vehicles in the long-term. One of the key reasons for developing this indicator is that it addresses several of the highest-priority R-strategies. The R-strategies[25] are a hierarchical list of approaches to CE – the position on the hierarchy indicating the "shortness" of the waste loop attributed to the approach. (Malooly & Daphne, 2023) The shorter the waste loop, the more sustainable/circular the strategy is. Some of the R-strategies that this indicator addresses include:

1. **Refuse** – Optimising and facilitating the disassembly of vehicles at end of use (what would ordinarily be the EoL), subsequently improves the economic feasibility of vehicle life extension with associated cost reductions through reuse/repair/refurbish and remanufacture. Promotion of these high-priority CE themes will extend existing vehicle lifetimes, and reduce any unnecessary consumption required with the acquisition of new vehicles.
2. **Rethink** – This is connected to circular design and thinking about how vehicles are designed at their inception to best facilitate circular practices throughout their life and at the end of their life. Understanding the time taken/effectiveness of dismantling of a vehicle at the end of life, can facilitate

[25] Circularise, R-Strategies for a Circular Economy. (Official website for Circularise, 2023). https://www.circularise.com/blogs/r-strategies-for-a-circular-economy Accessed 23rd April 2024.

the better initial circular design of the vehicle to further optimise this and facilitate the overall lifetime extension of vehicles.

3. **Reduce** – Optimising vehicle design to facilitate disassembly can result in reductions in quantity of components and number of different raw materials needed in initial vehicle manufacturing.
4. **Reuse/Repair** – Improved ease of disassembly of vehicles will better facilitate vehicle lifetime extension through repair and reuse of existing vehicles.
5. **Refurbish/Remanufacture** – Improved ease of disassembly of vehicles will better facilitate refurbishment and remanufacturing opportunities for a range of vehicle components.

There are several high-priority CE benefits which have been identified for monitoring this indicator, which include:

- **Encourages product life extension of vehicles** – The harvesting of individual vehicle components at EoL (for reuse and/or repair), requires ease of access to the individual vehicle components themselves. Consequently, the economic feasibility of vehicle lifetime extension directly correlates with the cost reduction presented from the reduction in disassembly time of vehicles. Therefore, monitoring of this indicator will support CE development in industrialised regions, through encouraging lifetime extension of existing vehicles, rather than acquisition and consumption of raw materials in new vehicles.
- **Facilitates refurbishing and remanufacturing activities** – Encouraging improvements in the ease of disassembly supports remanufacturing and refurbishment activities of new vehicles.
- **Focuses on design CE theme** – Supports circular design through promoting design for disassembly, improving the circularity of vehicles at the point of manufacture, supporting higher-priority R-strategies (such as refurbishment and remanufacture) and is the most preferable approach to embedding circularity in manufacturing practices for the long-term.
- **Drives an improved recycling yield** – Efficiency in the disassembly of vehicles supports an increase in recycling yield and purity for critical raw materials (CRM), used in the manufacture of vehicles (which also often have the greatest environmental impact). This includes critical metals, precious metals and certain polymer types.
- **Legislation alignment** – This indicator is well aligned with expected future EU policy and legislation around circular design, and product life extension (which sits under one of the three outlined product design strategies – increase material efficiency, product life extension and improve recycling efficiency). The EC, along with several ecolabels (such as the Nordic Swan Ecolabel[26]), has been considering the inclusion of design for disassembly requirements in legislation or voluntary environmental instruments. In 2015, the EC introduced mandate M/543 which specifically suggests the development and implementation of one or more standard relating to the: *“ability to access or remove certain components, consumables or assemblies from products to facilitate repair or remanufacture or reuse.”* Consequently, the EC developed nine standards 5 years after the adoption of M/543. These are titled the EN 4555X set of standards, which vary at their stage of development and maturity – two of which are suitable for direct application to Critical Raw Materials (CRMs) and material efficiency. All other standards are product or product-group specific – however, none of these are currently relating to the automotive sector. (Bundgaard & Huulgaard, 2023) Additionally, this indicator is aligned with the EC’s proposed End of Life Vehicle (ELV) Directive from 2023. One of the proposed new rules from this includes: “*improve circular design of vehicles to facilitate removal of materials, parts and components for reuse and recycling*”. The ELV Directive proposes to monitor this indirectly, through the “reused” weight of materials “from de-pollution and dismantling (in tonnes per year) of end-of-life vehicles arising in the Member State and treated within the Member State”. An indicator measuring the eDIM, will support the effective monitoring of the impact of circular design on facilitating the removal of parts/components for reuse and recycling (European Commission, 2023).

[26] Nordic Ecolabel, Design for Recycling. (Official website for Nordic Ecolabel, n.d.) https://www.nordic-swan-ecolabel.org/nordic-ecolabelling/environmental-aspects/circular-economy-and-resource-efficiency/design-for-recycling/. Accessed 23rd April 2024.

5.1.1 Proposed methodology approach

Despite there being no agreed standard methodology for calculating the eDIM, and no examples of this applied to vehicle manufacture in Europe at present several academic research journals have proposed high-level methodologies for other sectors.

Current examples are seen almost exclusively for the electronics sector, the likely motivation for this being a result of the quantity of high value CRMs which are present in the electronic products manufactured. One of the most prominent of these methodologies was published in the "Resources, Conservation and Recycling" journal. This proposes a robust eDIM, which calculates the disassembly time based on the Maynard operation sequence technique (MOST) for electrical products (e.g. an LCD monitor). MOST is a time study technique, which improves productivity through efficient use of available time, proper sequencing of operation, line balancing and automation (Peeters, et al., 2018).

This study proposes the application of the following equation to calculate the overall dismantling time, eDIM (seconds) for the electrical product.:

$$eDIM = \sum_{i=1}^{i=n} (Tool\ Change_i + Identifying_i + Manipulation_i + Positioning_i + Disconnection_i + Removing_i)$$

In this equation, "i" represents the assigned component number, of which each individual component is assigned its own, individual component number and "n" is the total number of individual components which require their own, individual operation as part of the vehicle dismantling process. The sigma, "∑" symbol represents a mathematical operation which is taking the sum of each of the individual eDIM value for each distinct component within the overall product. The eDIM value for each individual component, consists of the sum of the time taken for individual component dismantling operations which are defined as outlined in Table 20 (Peeters, et al., 2018).

Table 20. Summary of the dismantling time types considered for each component in proposed eDIM method

Dismantling Time Type	Definition	Units
Tool Change	Total time required for tool change (e.g. if the tool differs between connectors)	Seconds
Identifying	Total time required to identify connectors (based on identifiability information)	Seconds
Manipulation	Total time required for product manipulation e.g. Undoing fasteners	Seconds
Positioning	Total time required for tool positioning in relation to the category of connectors used	Seconds
Disconnection	Total disconnection time of fasteners	Seconds
Removing	Total time for component removal-accounted once per component	Seconds

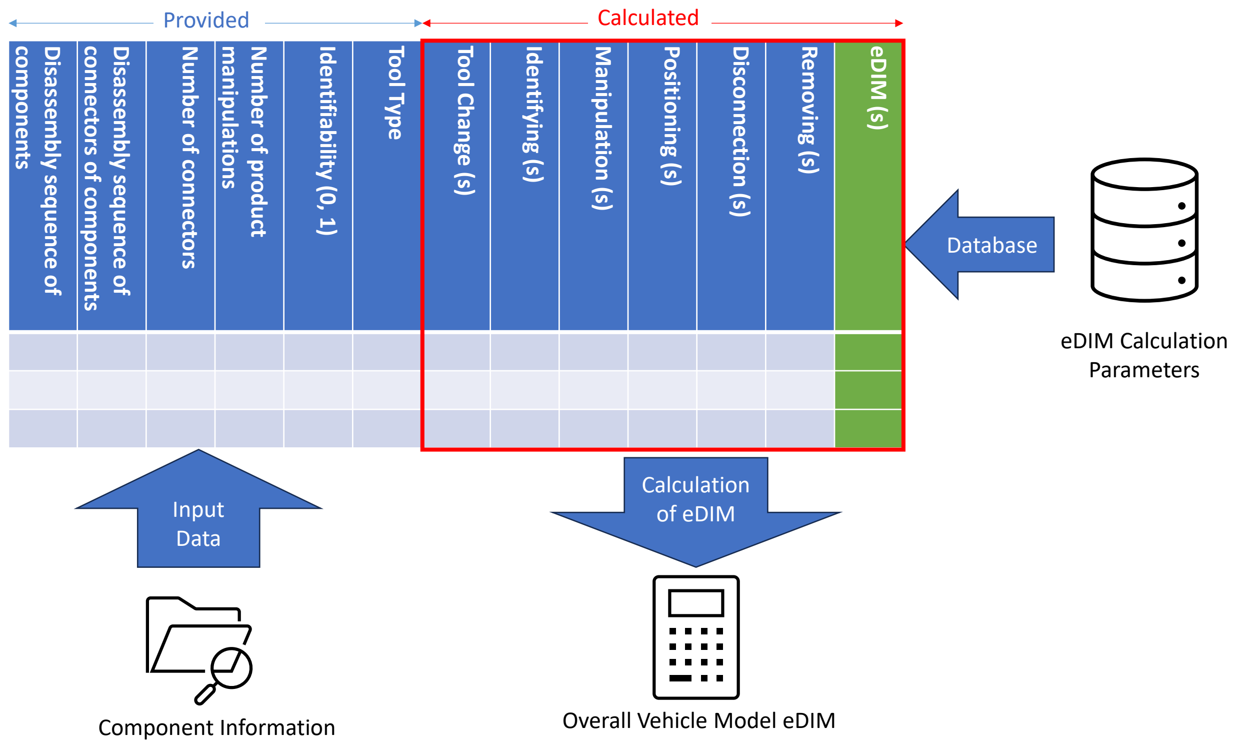
It is understood that each of the six individual dismantling time types outlined in Table 20 are relevant and transferable to the processes involved in automotive manufacturing. Sat behind each of these six values, are more detailed specific calculations considering extensive data sets, which are inputs. The data inputs to these will define the data which needs to be identified and collected to appropriately measure this metric. This will likely need to be modified based on the specific manufacturing operation and will need to be validated by automotive industry manufacturing experts.

Figure 9 below displays an infographic which illustrates how the eDIM methodology could be implemented in practice, facilitated using an Excel spreadsheet. It shows the provided "Input Data" that would be needed. This would need to be provided for each individual component which makes up the vehicle, where each row of the table would correspond to the data for the specific component. It also shows, highlighted in the red box, the six individual dismantling times, which are specific and assigned to each MOST operation-type, as summarised in Table 20.

It has been decided not to include the specific details and equations of these calculations for the purpose of this theoretical case study since they will be specific to the product type in question (in this case an LCD screen), and new/modified calculations would need to be developed for vehicle design. The design of these calculations would need expertise and extensive input from professionals working in automotive manufacturing. However, the high-level approach to this methodology is expected to be similar – with the same number of “calculated” outputs, used to calculate the final eDIM; and a similar number of “provided” data inputs (specific to each automotive component) that would need to be collected.

As shown in Figure 9, a second type of data input is the “eDIM Calculation Parameters”. These are specific parameters, which are used in the calculations that sit behind the individual dismantling time calculations. It is likely that these would need to be developed and verified as appropriate for use in the relevant calculation for vehicle dismantling. This development would require expertise from specialists in vehicle manufacturing and would need to be proven to be replicable across different vehicles models and multiple OEMs where the dismantling processes may vary.

Figure 9. Infographic representing the key data inputs and outputs for suggested eDIM methodology (Peeters, et al., 2018)



5.1.2 Performance

Table 21 below summarises the original RACER evaluations performed for this indicator, during the original assessment (as part of Task 4), and after Task 5 (following testing of the indicator). Two of the categories have dropped in their score following the new assessment after Task 5 testing. This can be explained as follows:

- **Acceptability (Score Change: -2) –** The “acceptance” category score was decreased from the original assessment. This was because of the limited progress that was made throughout the initial stakeholder engagement and data collection phases. It was discovered that despite the indicator itself being accepted as an appropriate metric of the CE, there were concerns from OEMs/Tier 1s around the commercial sensitivity of vehicle disassembly time data for individual components. Furthermore, there were questions over the whether the disassembly data was being recorded and measured. Additionally, it was discovered that there is no existing agreed methodology for calculating eDIM, let alone specifically for vehicles. For these reasons, the acceptability was reduced to a score of “1” since it seems less likely to be accepted by key stakeholder in the automotive sector.

- **Ease (Score Change: -1) –** The “ease” category score was reduced from an original score of 2 to 1, the lowest level of ease. This was since, even with a developed methodology, the stakeholder engagement work discovered significant concerns around the sharing of detailed manufacturing data, such as disassembly time.

Table 21. RACER evaluation for BV4

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	3	3	2	3	14
After Task 5 (following testing)	3	1	3	1	3	11

Overall, the indicator could be considered to perform well against its target area. The main reason for this is it its alignment with a several high-priority R-strategies: refuse, rethink, reduce, reuse/repair and remanufacture. Despite this, the indicator is highly complex and significant work is needed to bring it to a point where it can be practically implemented.

5.2 CHALLENGES AND LESSONS LEARNT

Despite this indicator not being formally tested, several potential challenges and limitations have been identified. Firstly, there is a potential limitation with the application of the MOST approach to the methodology– since it is a “time study technique”. Applying this methodology to reflect different vehicle model disassembly processes is likely to be challenging and could lead to an oversimplification of what is a highly complex operation. Furthermore, the vehicle disassembly process is likely to be much more complex compared to the product groups trialled with the indicator in academia e.g. electronics. For example, the disassembly of one vehicle component is likely to be dependent on the disassembly of other components first. Therefore, it is possible the process cannot be treated in the same manner as other product types that the methodology has previously been tested with. This is an area that will need to be considered in consultation with automotive manufacturing experts before development of a new methodology.

A further challenge is around the effectiveness of this indicator across the wide range of vehicle models manufactured in the EU, and whether specific elements of the calculation would need to be developed to account for the variability in vehicles and manufacturing processes. For example, the disassembly method of specific vehicles is likely to vary based on model, location of disassembly and the specific disassembly facility (and technology) available. This is a further area that will require extensive consultation with automotive manufacturing experts and engineers from automotive OEMs before methodology development, to ensure that the approach developed is applicable across all vehicle types considered.

There is also likely to be a challenge around the associated cost to OEMs of accurately measuring, developing, and implementing the calculation methodology and monitoring systems needed to satisfy any potential requirements of the indicator. For example, dependent on the existing systems at disassembly facilities, there may need to be procurement of new technologies to accurately track and analyse the disassembly process, Furthermore, the high level of detail in data collection is likely to be highly resource intensive for the OEMs. Consequently, any methodology development needs to be done in close consultation with automotive OEMs and their respective EoL facilities.

A longer-term challenge is likely to be around vehicle manufacturing and vehicle disassembly technology development. It is expected that as vehicle technology evolves, the manufacturing and disassembly processes will also change – requiring regular updates to the eDIM calculation methodology, to ensure it is aligned. This should be considered in any longer-term plans for the methodology – for example, with annual reviews of the methodology and its appropriateness in consultation with industry experts and OEMs.

5.3 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is not considered for further development, with significant work required to facilitate its progress.

In conclusion, it is recommended that this indicator is not considered for further development with significant work being required to facilitate its progress. Despite its alignment with high priority CE themes, the challenges around methodology and data collection are significant and are likely to present significant challenges in gaining consensus and support from key stakeholders in the automotive sector. Gaining "buy-in" from the automotive sector is critical to ensuring the success of this indicator – the sector needs to be prepared prior to development, ensuring the relevant data can be accessed. Considering this, it is advised the indicator isn't progressed at this stage. However, it is strongly recommended for reassessment in the future.

The recommendation for reassessment of this indicator is based on the high-priority CE theme of "circular design" that it considers. An ideal circularity metric for the automotive sector should address embedding circularity at the point of vehicle design. Measuring the ease of dismantling of a vehicle can be considered as one of the most effective ways to do this, as well as being one of the most effective ways to quantify vehicle life extension. The only alternative is tracking the lifetime of a vehicle from initial purchase to end of life – which is difficult to monitor and often informalised. Despite its potential, the indicator represents one of the more progressive yet challenging ways to assess circularity in vehicles. This is primarily due to the lack of an agreed methodology and concerns from OEMs around the sharing of vehicle dismantling data.

Following the testing of this indicator, it was found that its original name 'Ease of disassembly metric' was fit for purpose and that no variation was needed.

Table 22 below summarises the recommended actions to make the indicator suitable for implementation.

Table 22. Summary of recommendations for BV4

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Development of guidance	Development of a standardised eDIM calculation methodology. This should include research to gather existing methodologies related to eDIM from various sectors (including electronics) to develop the methodology, defining the specific metrics and parameters that will need to be included in the eDIM calculation. Pilot testing with a range of vehicle models should be conducted to validate the approach. This should be led by industry experts from within the EC – with the appropriate peer review from experts in the field of automotive manufacturing. Extensive stakeholder engagement should be done as part of this process, to ensure consensus. This is aligned with the recent recommendation from the EC to develop an agreed standard which measures disassembly in manufacturing. Furthermore, any eDIM-related methodology should align with existing and future regulations. For example, this could be incorporated into the ELV Directive, the Ecodesign Directive, or the Waste Framework Directive. It is expected that integrating new standards like eDIM into existing regulatory frameworks is likely to be a slow and challenging process.	Acceptability, Credibility, Ease and Robustness	Long (> 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s **Informed:** All stakeholders within EU automotive industry.

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
	The supply chain geography of vehicles should also be considered. Vehicles are often manufactured in one country and then sold across the world; therefore, international compliance will be important. Aligning this indicator with global standards to ensure compliance in all markets where the vehicles are sold will add an additional layer of complexity to progressing this indicator.			
Legislation	Introduction of EU-wide legislation for OEMs to work with stakeholders at vehicle EoL to record appropriate data for disassembly time of vehicle components. This should be aligned with methodology developed in the previous recommendation.	Acceptability, Ease and Robustness	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s **Informed:** All stakeholders within EU automotive industry.
Legislation	Introduction of legislation to require the submission of appropriate manufacturing data reports, as evidence to confirm validity of component disassembly times quoted.	Ease and Robustness	Long (> 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s, National Governments **Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s, National Governments **Informed:** All stakeholders within EU automotive industry.
Training and education	Appropriate training and education should be delivered to ensure that OEMs and key stakeholders understand the indicator and how to implement it effectively. This should also facilitate gathering input from key stakeholders on what would work best in	Acceptability, Credibility and Ease	Medium (1.5 – 5 years)	**Responsible:** EC. **Accountable:** European Automotive OEMs and Tier 1s

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
	practice. Achieving a consensus among stakeholders on the importance and implementation of eDIM is likely to be challenging – ensuring ongoing engagement will help to address this challenge.			**Consulted:** National Governments, European Automotive OEMs, Tier 1s and Tier 2s **Informed:** All stakeholders within EU automotive industry.

6. APPENDIX

6.1 INDICATOR 1 SURVEY ANALYSIS

See MS Excel document “DGRTD_BV1_Analysis_V01.00” provided alongside this report.

6.2 RACER ASSESSMENT MATRIX

Criterion	Description	1 (Poor)	2 (Neutral)	3 (Good)
Relevance	Refers to whether the indicator is closely linked to the objectives to be reached.	Does not support a better understanding of true circularity.	Supports a better understanding of true circularity.	Highly supportive towards gaining a better understanding of true circularity.
		Supports no value-added circular opportunities.	Supports lower value-added opportunities (i.e. metrics related to waste generation, recycling, waste management, etc.)	Supports higher value-added opportunities (i.e. all R-strategies above remanufacturing) and wider systemic change (e.g. indicators that encourage PSS or circular design).
		Not linked to the project objectives and/or European policy objectives (existing or upcoming).	Linked to the project objectives, but not to European policy objectives (existing and/or upcoming).	Fully aligned with project objectives and European policy objectives (existing and/or upcoming).
Acceptance	Refers to whether the indicator is perceived and used by key stakeholders (such as policymakers, civil society, and industry).	Poorly accepted by key stakeholders, e.g. due to the use of confidential data.	Relatively accepted by key stakeholders as the benefits of measuring are clear.	Key stakeholders are motived to report this indicator, due to mandatory legislative requirements (current or upcoming), potential commercial benefit or being in the public interest.
Credibility	Refers to whether the indicator is transparent, trustworthy and easy to interpret.	No defined methodology associated with this indicator and/or interpretation of the indicator is ambiguous.	Methodologies have been proposed or currently existing, but not for this particular indicator (e.g. in a research article).	There is an EU defined methodology.
		Difficult to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are not familiar with).	Moderately easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are aware of but are not confident in practical use).	Easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders already use and are confident in applying).
Ease	Refers to the easiness of measuring and monitoring the indicator.	No defined methodology associated with this indicator and/or interpretation of the indicator is ambiguous.	Methodologies have been proposed or currently existing, but not for this particular indicator (e.g. in a research article).	There is an EU defined methodology.
		Difficult to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are not familiar with).	Moderately easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are aware of but are not confident in practical use).	Easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders already use and are confident in applying).
Robustness	Refers to whether data is biased and comprehensively assesses circularity.	No consistent methodology and dataset are available.	A consistent methodology and dataset available.	A consistent methodology and dataset available.
			A composite/aggregated indicator (based on multiples dimensions).	A one-dimensional indicator.
			A proxy indicator.	

7. BIBLIOGRAPHY

Bundgaard, A. M., & Huulgaard, R. D. (2023). The role of standards in support of material efficiency requirements under. *Journal of Cleaner Production*. Retrieved from

Directorate-General for Environment. (2023, July 13). *Proposal for a Regulation on circularity requirements for vehicle design and on management of end-of-life vehicles*. Retrieved from European Commission - General Publications: https://environment.ec.europa.eu/publications/proposal-regulation-circularity-requirements-vehicle-design-and-management-end-life-vehicles_en

European Commission. (2013). *EU classification of vehicle types*. Retrieved from European Alternative Fuels Observatory: https://alternative-fuels-observatory.ec.europa.eu/general-information/vehicle-types

European Commission. (2013). *EU classification of vehicle types*. Retrieved from European Alternative Fuels Observatory: https://alternative-fuels-observatory.ec.europa.eu/general-information/vehicle-types

European Commission. (2023, July 13). *Directive on End-of-Life Vehicles (ELV Directive)*. Retrieved from European Commission: https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en

European Commission. (2023, July). *Towards recycled plastic content targets in new passenger cars and light commercial vehicles*. Retrieved from JRC Science for Policy Report: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi6ldHul9aFAxWpSkEAHcadBeYQFnoECBwQAQ&url=https%3A%2F%2Fpublications.jrc.ec.europa.eu%2Frepository%2Fbitstream%2FJRC129008%2FJRC129008_01.pdf&usg=AOvVaw0bNeZf9PDLfpklIGi37yXH&opi=8

Malooley, L., & Daphne, T. (2023). *R-Strategies for a Circular Economy*. Retrieved from Circularise: https://www.circularise.com/blogs/r-strategies-for-a-circular-economy

Malooly, L., & Daphne, T. (2023, November 9). *R-Strategies for a Circular Economy*. Retrieved from Circularise: https://www.circularise.com/blogs/r-strategies-for-a-circular-economy

Peeters, J. R., Vanegas, P., Cattrysse, D., Tecchio, P., Ardente, F., Mathieux, F., . . . Duflou, J. R. (2018). Ease of disassembly of products to support circular economy strategies. *Resources, Conservation and Recycling*.

T: +44 (0) 1235 75 3000

E: enquiry-ee@ricardo.com

W: www.ricardo.com