CIRCULAR ECONOMY LAWS AS A MEANS, NOT AN END: THE CASE OF SUSTAINABLE CAR SHARING

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SUMMARY

The circular economy has gone mainstream as a goal in the transitions toward a more sustainable society. Often, however, laws that promote a circular economy remain vague or narrowly focused on resource efficiency, obscuring the fact that they have multiple environmental effects and can lead to environmental trade offs. This Article examines how to properly frame circular economy laws for sustainability, focusing on product-service systems generally and the case of car sharing in particular. Its analysis shows that a circular economy is not to be framed as an end, but as a means of striving for environmental sustainability.

The circular economy has gone mainstream as a normative framing in the transition toward a more sustainable society. The European Commission launched the Circular Economy Action Plan in 2015[1] as an "essential contribution to the EU's [European Union's] efforts to develop a sustainable, low carbon, resource efficient and competitive society."[2] An updated version of the Circular Economy Action Plan forms a key element of the European Green Deal,[3] the Commission's overarching growth strategy for 2030. The Green Deal envisions an action plan that "will include a 'sustainable products' policy to support circular design for all products."[4]

The EU's circular economy policies will foster new business models, supporting the "renting and sharing of goods and services."[5] Product-service systems (PSSs) such as car sharing are prominent examples of circular business models in the action plan.[6] A PSS refers to a business model comprising a mix of "tangible products" and "intangible services" as a means of fulfilling consumer needs and reducing environmental impacts.[7] PSSs' potential to promote sustainability is based on the premise that the combination of products and services as a value offering allows a firm to decouple its profit from the production and sale of physical goods, and rather to focus on the provision of the desired function or performance. This creates possibilities for more sustainable resource consumption and other environmental benefits.

An important sector where circular economy strategies have been recently expanded is transportation. The focus is extending from vehicles and batteries, which are already regulated as products[8] and are identified in the Circular Economy Action Plan as a key product value chain, to new business models.[9] The importance of transportation in contributing to various environmental and health problems, such as air pollution-related illnesses, and now predomi-

1. *Commission Communication to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, Closing the Loop—An EU Action Plan for the Circular Economy*, COM (2015) 614 final (Dec. 2, 2015).
2. *Id*. at 2.
3. *Commission Communication to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, the European Green Deal*, at 7, COM (2019) 640 final (Dec. 11, 2019) [hereinafter *European Green Deal*].
4. *Id*.
5. *Id*. at 8.
6. *Commission Communication to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, a New Circular Economy Action Plan for a Cleaner and More Competitive Europe*, at 4, 8, COM (2020) 98 final (Mar. 11, 2020) [hereinafter *New Circular Economy Action Plan*].
7. Arnold Tukker, *Product Services for a Resource-Efficient and Circular Economy—A Review*, 97 J. Cleaner Prod. 76 (2015).
8. *See* Parliament and Commission Directive 2000/53/EC of September 2000 on End-of Life Vehicles, 2000 O.J. (L269), 34; Parliament and Council Directive 2006/66/EC of 6 September 2006 on Batteries and Accumulators and Waste Batteries and Accumulators and repealing Directive 91/157/EEC, 2006 O.J. (L266), 1.
9. *New Circular Economy Action Plan*, *supra* note 6, at 8.

nantly climate change, is well established.[10] Governance of transportation from a circular economy perspective at a systems level is, however, novel.[11] Framing the sector as an issue of the circular economy and PSS is an important proposal, considering its complex and intertwined environmental impacts. An analysis of the topic allows us to illustrate the conceptual challenges of a "circular economy" framing in the development of law, while we can also propose ways to address its complexities with appropriate legal and policy instruments in practice.

Our analysis of PSSs in transportation in this Article has three interrelated research objectives. First, our objective is to analyze in descriptive terms how a PSS as an enabler of a circular economy strategy can improve sustainability in the context of transportation. We focus here on car sharing as a case study on access-based PSSs in the sector.

Underlying our descriptive analysis is the critical assumption that "circular economy" may have become a panacea. On the one hand, it is not always clear what, if any, are the exact environmental objectives that a circular economy strategy is ultimately striving to reach. The European Green Deal, for example, presents the circular economy as a distinct objective in addition to climate neutrality, although it also contributes to greenhouse gas (GHG) savings.[12] Similarly, in the Commission proposal for a new Battery Regulation, the promotion of a circular economy is an objective separate from the reduction of the environmental impacts throughout the battery's life cycle.[13] It is thus sometimes as if a circular economy strategy in itself, not sustainability, were the perennial objective.

This vagueness persists also at the level of the means to implement a circular economy strategy, such as PSSs. The conflation of economic objectives in the pursuit of a sustainable circular economy further contributes to the vagueness of the strategy. An economic focus may lead to a policy "drift," pushing the strategy's environmental objectives from a priority to a compromise with the economic aims, or to understanding them merely as part of a cost-benefit-based optimization.[14]

The Battery Regulation proposal, for example, is explicit that environmental considerations are only complementary to the aim of a smooth internal market, not a main objective.[15] While changing the legal basis from Article 191 of the Treaty on the Functioning of the European Union (Environment) to Article 114 (Internal market), the proposed law depicts the addressed environmental problems as failures on the single market.[16] In the worst case, a circular economy framing may overlook environmental sustainability altogether.

On the other hand, even if taken into account, the precise environmental objectives may have been considered inadequately. Using again the proposal for a new Battery Regulation as an example, the proposal assumes that increased circularity lowers the environmental impacts of batteries.[17] Increased material recovery targets or recycled content requirements, defined in Articles 57 and 8, respectively, are however only proxies of environmental impacts.[18] While resource efficiency is a central consideration in circular economy strategies, it does not always translate into net environmental sustainability.

The interrelationships between the different environmental impacts beyond resource efficiency deserve particular attention. The Battery Regulation thus proposes a mandatory carbon footprint declaration for electric vehicle (EV) batteries from July 2024, and a carbon threshold from July 2027.[19] It is crucial to look at these interactions at a sufficient level of detail, while not losing sight of the "net" impacts. The matter is exacerbated when considering transportation as a contextualized service.[20]

Building on the conceptual analysis, the Article's second objective is to propose and refine regulatory instruments with which PSSs in transportation can lead to environmentally optimal outcomes. We aim to characterize regulation in ways that would alleviate the above-described problem of vagueness.

Our third objective is methodological: to determine an analytical approach through which to first describe and then to assess PSSs as a circular economy strategy in transportation. We revisit for that purpose a classic in the field of policy analysis: intervention theory. The three-step approach of intervention theories allows us to bring the most pertinent aspects of PSSs in transportation to the forefront systematically and in detail, and it guides our suggestions in filling the identified regulatory shortcomings and gaps in the policies to support PSSs.

We proceed as follows: Part I on our methodology provides a general overview of PSSs, and in particular car sharing as an access-based PSS. The part also introduces intervention theories as our analytical framework. Part II then applies intervention theories to the process of designing policies for car sharing, aimed at producing positive environmental impacts.

In Section II.A, we determine the predominant environmental problems in transportation and analyze the contributions and limitations of a resource efficiency-

10. Gerald Berger et al., *Sustainable Mobility—Challenges for a Complex Transition*, 16 J. Env't Pol'y & Plan. 303 (2014).
11. Walter Leal Filho et al., *Framing Electric Mobility for Urban Sustainability in a Circular Economy Context: An Overview of the Literature*, 13 Sustainability 7786 (2021).
12. *European Green Deal*, *supra* note 3, at 4-9.
13. *Commission Proposal for a Regulation of the European Parliament and of the Council Concerning Batteries and Waste Batteries, Repealing Directive 2006/66/EC and Amending Regulation (EU) No 2019/1020*, at 2, COM (2020) 798 final (Dec. 10, 2020) [hereinafter *Proposal for Batteries Regulation*].
14. Benjamin Cashore & Steven Bernstein, *Bringing the Environment Back In: Overcoming the Tragedy of the Diffusion of the Commons Metaphor*, Persps. on Pol. (2022), https://www.cambridge.org/core/journals/perspectives-on-politics/article/bringing-the-environment-back-in-overcoming-the-tragedy-of-the-diffusion-of-the-commons-metaphor/911192B7F4AD934C8FD771B00F9D529C.
15. *Proposal for Batteries Regulation*, *supra* note 13, at 4.
16. *Id*. at 3.
17. *Id*. at 4.
18. Jorge Vendries et al., *The Significance of Environmental Attributes as Indicators of the Life Cycle Environmental Impacts of Packaging and Food Service Ware*, 54 Env't Sci. Tech. 5356 (2020).
19. *Proposal for Batteries Regulation*, *supra* note 13, art. 7, Annex II.
20. Jan Konietzko et al., *A Tool to Analyze, Ideate, and Develop Circular Innovation Ecosystems*, 12 Sustainability 417 (2020).

focused circular economy framing toward solving these problems. In Section II.B, we analyze how car sharing could offer a societally desirable outcome to address the identified environmental problems. Finally, Section II.C sets out the laws and policies that can support the achievement of the desired outcomes in car sharing. In Part III, we conclude with observations about developing sustainable circular economy law, while using intervention theories as guidance.

I. An Intervention Theory Analysis on Regulation of Car Sharing

A. Circular Economy in Transportation: Car Sharing as an Access-Based PSS

The literature on the circular economy builds on the importance of strategies for maintaining the value of materials at their highest level (stock optimization), including product life-extension strategies.[21] Various life-cycle-extension-based business models that decouple value creation from the consumption of primary resources have been developed.[22] This work has also influenced the development of PSSs for sustainability. PSSs may enable a move away from the fast replacement cycles predominant in linear production-consumption systems.

The different types of PSSs represent increasing responsibility on the part of the PSS provider over the underlying product and control over its use. The increased responsibility and control, and the shift of profit drivers in PSSs, create different opportunities and incentives for manufacturers to undertake resource efficiency strategies.[23] PSS business models where the provider retains ownership over the product create business incentives for producers to extend the life-span of their products to minimize asset investment,[24] shifting the focus of economic activities away from extractive and manufacturing industries, which have a high environmental impact, to labor-intensive industries (e.g., repair, reuse, reconditioning).[25] This allows the economy to reduce the rate of depletion of natural resources and of waste as well as avoid the environmental impacts related to extraction and production.

PSSs where the costs to deliver a service are borne by the PSS provider create incentives to improve his or her processes. Increased operational efficiency to reduce resource use is a way of driving down operational costs.[26] PSS business models also create other opportunities for the minimization of material consumption, such as maximizing asset use or closing resource loops.[27] PSS business models can further incentivize dematerialization objectives through the application of lean principles by designing out waste in the manufacturing and operation stages of a PSS.[28]

There are three main categories of PSSs, based on how they aim to satisfy consumer needs: product-oriented, use-oriented, and results-oriented PSSs.[29] Of the three, this Article focuses on the second group, use-oriented (i.e., access-based) PSSs. A use-oriented PSS means, in brief, selling the consumer access to or ability to use a product, rather than transferring its ownership. The type of use can vary depending on whether the product is made available to a single user (e.g., this involves a product leasing arrangement with the user having unlimited and individual access to the product) or multiple users, either through consecutive use (e.g., car sharing) or simultaneous use (i.e., product pooling).

In this Article, we focus on a specific type of use-oriented PSS, namely car sharing. In the context of the circular economy approach to transportation, car sharing is among the models of servitization that has increased its significance in the past decade, most notably in South America, Europe, and Asia.[30] In car sharing, transport needs are satisfied by giving users access to a fleet of vehicles, which are owned and maintained by the service provider.[31] The change in ownership that car sharing entails is the crux of servitization.

The resource efficiency premise of access-based PSSs like car sharing is that, by providing access to or allowing the use of a product rather than owning it, the PSS satisfies multiple user needs while using the same physical asset. This implies a potential to reduce the resources required during the production of the necessary assets. By retaining ownership over the underlying product, a PSS provider is

21. Fenna Blomsma & Geraldine Brennan, *The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity*, 21 J. Indus. Ecology 603 (2017); Denise Reike et al., *The Circular Economy: New or Refurbished as CE 3.0?—Exploring Controversies in the Conceptualization of the Circular Economy Through a Focus on History and Resource Value Retention Options*, 135 Res. Conservation & Recycling 246 (2018); Walter R. Stahel, *Policy for Material Efficiency—Sustainable Taxation as a Departure From the Throwaway Society*, 371 Phil. Transactions Royal Soc'y A: Mathematical Physical & Eng'g Scis. 20110567 (2013).
22. Nancy M.P. Bocken et al., *Product Design and Business Model Strategies for a Circular Economy*, 33 J. Indus. & Prod. Eng'g 308 (2016); Walter R. Stahel, The Performance Economy (2d ed. 2010).
23. *See* Louise Laumann Kjaer et al., *Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth From Resource Consumption?*, 23 J. Indus. Ecology 22 (2019).
24. Bocken et al., *supra* note 22, at 312-13.
25. Walter R. Stahel, Product-Life Factor (1982), http://www.product-life.org/en/major-publications/the-product-life-factor.
26. Carlo Vezzoli et al., *New Design Challenges to Widely Implement "Sustainable Product-Service Systems,"* 97 J. Cleaner Prod. 1, 2 (2015).
27. *Id*. at 2; Kjaer et al., *supra* note 23, at 26-27.
28. David Romero & Monica Rossi, *Towards Circular Lean Product-Service Systems*, 64 Procedia CIRP 13 (2017).
29. Arnold Tukker, *Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences From SusProNet*, 13 Bus. Strategy & Env't 246 (2004); Tukker, *supra* note 7.
30. Susan Shaheen et al., Innovative Mobility: Carsharing Outlook, Carsharing Market Overview, Analysis, and Trends (2018), https://escholarship.org/uc/item/1mw8n13h; Susan Shaheen & Adam Cohen, Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends (2016), http://innovativemobility.org/wp-content/uploads/2016/02/Innovative-Mobility-Industry-Outlook_World-2016-Final.pdf; Susan Shaheen & Adam Cohen, Innovative Mobility: Carsharing Outlook—Carsharing Market Overview, Analysis, and Trends (2020), https://escholarship.org/uc/item/61q03282.
31. Susan Shaheen et al., Shared Mobility Policy Playbook: Carsharing 9 (2019), https://escholarship.org/uc/item/5rm2t387.

able to exercise control over its maintenance, upgrade, and terms of use, making it possible to extend the lifetime of the product and its parts. Access-based PSSs also enable highly efficient, but often more expensive, technologies to become accessible and economical to maintain to individual consumers and service providers, respectively, as a result of economies of scale.[32]

Despite the resource efficiency potential of this type of PSS, its overall environmental sustainability is not guaranteed given the possible shifting of environmental burdens to a different phase of a product's life cycle[33] when implementing resource efficiency strategies, as well as the uncertainties of user behavior.[34] This complexity makes it essential to analyze PSS models holistically.[35]

As for car sharing as an example of an access-based PSS in transportation, in simplified terms, the underlying logic is that transport needs can be satisfied more environmentally, if the tangible products (motor vehicles) required to do so are not owned by each individual (or household) separately. If individualized transportation is procured as a service, transport needs among different users can be satisfied while using fewer cars, which can potentially reduce vehicle stock over time. In car sharing, individuals typically get access to a vehicle by joining an organization that maintains a fleet of cars and light trucks, which the members of the organization then have the right to drive for a distance- and/or time-based fee.[36]

In this Article, we demonstrate that car sharing as a circular economy strategy can indeed lead to environmental benefits. This requires nonetheless a careful framing of the problems to be addressed, which is key to designing effective regulatory interventions to support car sharing as an environmentally sustainable circular economy strategy.

B. Intervention Theory

In this Article, we use intervention theory as our analytical framework for studying the design of PSS policies in transportation, with car sharing as our case study. Intervention theory involves analyzing policy design from the perspective of three interrelated perspectives: the theory of the problem, theory of desired outcomes, and theory of intervention.[37] The three perspectives are in essence steps in causation. They try to explain the origin of the problem and, based on this definition, what actions will influence behavior to produce the desired outcome.

The theory of the problem involves identifying and delimiting the undesirable circumstances that need to be alleviated and their causes. The problem definition provides the anchor to a regulatory response. It sets out the kinds of evidence that are relevant for a response and by which to measure solutions that are to be considered effective. The theory of the desired outcome outlines the approach, so the points of improvement sought by the response. It defines what such improvement would look like in practice.

The final, third thread refers to the theory about what kinds of laws and policies could help in producing the desired results. Articulating the theories in environmental policymaking allows for a critical examination of a regulatory response in light of existing scientific evidence. While framing is implicit in all policy interventions, the articulation of the values and preferences in the framing is not always clear. We see this risk as inherent in particular while using a circular economy or PSS strategy.

Existing literature on PSS policies often only engages with the third part of the theory, that on the regulatory intervention itself. Circular economy strategies do not necessarily critically engage with the issues of the problem definition or the desired outcome. The use of intervention theories, however, allows for a systematic life-cycle-based consideration of the problem definition and the regulatory objectives of the intervening instruments.

By making the underlying assumptions, differences in priorities, and gaps within regulatory interventions more visible, we help articulate a framing that can better capture the nuances in the complex environmental problems of transportation. This, in turn, helps define the appropriate goals for the necessary regulatory interventions. Conversely, our case study on car sharing helps advance critical reflections on using the circular economy, and PSSs, as a framing in policy discussions such as the EU's Sustainable Products Initiative.

C. Intervention Theories in Analyzing Policies on PSSs

There are various ways that laws and policies can support sustainable PSSs. Because PSSs are not inherently sustainable, regulation can integrate mechanisms to ensure environmental sustainability in the production and service systems of suppliers.[38] Regulation can also help in the diffusion of sustainable PSSs by overcoming different cor-

32. Arnold Tukker et al., *Product-Services and Sustainability*, *in* New Business for Old Europe: Product-Service Development, Competitiveness, and Sustainability 7 (Arnold Tukker & Ursula Tischner eds., Routledge 1st ed. 2006); Material Economics, The Circular Economy—A Powerful Force for Climate Mitigation: Transformative Innovation for Prosperous and Low-Carbon Industry 6 (2018), https://materialeconomics.com/publications/the-circular-economy.
33. Kjaer et al., *supra* note 23.
34. Eva Heiskanen & Mikko Jalas, *Can Services Lead to Radical Eco-Efficiency Improvements? A Review of the Debate and Evidence*, 10 Corp. Soc. Resp. & Env't Mgmt. 186, 191 (2003).
35. Kjaer et al., *supra* note 23; Tukker, *supra* note 7. *See* Michael Martin et al., *Environmental Assessment of a Product-Service System for Renting Electric-Powered Tools*, 281 J. Cleaner Prod. art. 125245 (2021); Carlos Pablo Sigüenza et al., *Circular Business Models of Washing Machines in the Netherlands: Material and Climate Change Implications Toward 2050*, 26 Sustainable Prod. & Consumption 1084 (2021).
36. Shaheen et al., *supra* note 31, at 9.
37. Janet A. Weiss, *From Research to Social Improvement: Understanding Theories of Intervention*, 29 Nonprofit & Voluntary Sector Q. 81 (2000).
38. Oksana Mont & Thomas Lindhqvist, *The Role of Public Policy in Advancement of Product Service Systems*, 11 J. Cleaner Prod. 905 (2003).

porate, regulatory, and market barriers to mainstreaming PSS solutions.[39]

In innovation policy literature, these policies can be categorized as either supply-push, demand-pull, or systemic, based on their objectives.[40] Regulations can overcome information barriers[41] and consumers' general tendency to purchase traditional products and services[42] and preference for material ownership. There are discussions on how regulations could take into account rebound effects and negative unintended consequences.[43]

An important question on regulating PSSs is whether instruments should target PSSs specifically and directly, or whether broad measures should be used instead.[44] Oksana Mont and Thomas Lindhqvist caution against developing specific measures that directly target PSSs if there is uncertainty on whether such type of PSS is an environmentally preferable option.[45] According to these authors, regulatory instruments could target lowering the environmental life-cycle impacts more generally (e.g., by introducing extended producer responsibility obligations, efficiency obligations, or strict requirements regarding the use and disposal of products). This approach would help ensure technological neutrality and a level playing field among competing solutions.

Yet, from a sectoral perspective, there is an increasing recognition of the need for more specific instruments. At the local level, where governments are more familiar with the actual regulatory context, actions directly targeting PSS solutions tend to have a significant influence.[46] Considering the diverging views, we analyzed the prospects of different laws and policies to support PSSs from both PSS-specific and more general perspectives.

II. Regulating Car Sharing as an Environmentally Sustainable Circular Economy Strategy

Car sharing is increasingly considered in strategic documents to make transport sustainable, although the environmental focus and benefits of car sharing in these documents vary. At the EU level, the European Strategy for Low-Emission Mobility highlighted the role of regions and cities in delivering sustainable transport modes, including car sharing and carpooling (where passengers and drivers with the same origin and destination share the ride, whether formally or informally[47]) schemes as a way of reducing air pollution and congestion in cities.

City strategy documents see car sharing as a solution for decongestion by reducing cars and freeing public space (e.g., Bremen Car-Sharing Action Plan),[48] but also as part of a strategy to meet emission reduction targets (e.g., Carbon-Neutral Helsinki's 2035 Action Plan).[49] Car sharing is also sometimes communicated as part of the hierarchy for sustainable transport or as part of sustainable urban transit planning.[50] However, although car sharing is also a circular economy strategy to achieve resource efficiency, this aspect remains largely underexplored.

A. *The Problem Definition—Resource-Related Environmental Impacts of Transportation*

The first step in our interventionist theoretical framework on car sharing is the definition of the problem: what kinds of environmental problems would car sharing solve as a PSS that operationalizes a circular economy strategy? Foremost, this step entails clarifying and identifying the environmental impacts that are to be addressed. Second, the different components that cause these environmental impacts, and thus affect the environmental sustainability of transportation, need to be well understood: the vehicle, fuel, and infrastructure (i.e., parking spaces, charging facilities, lanes). Also, the operational aspects and the (shifts in) traveling mode and traveling behavior affect these impacts.[51] Depending on the environmental impacts that are identified as the problem that needs to be solved, these causal elements are of more or less relevance.

1. What Environmental Problems Would Car Sharing Solve?

Transportation has always been an important and challenging field of environmental regulation. The understanding

39. Diego Honorato Clemente et al., *Product-Service Systems (PSS) and Public Policies: Lessons From the Literature*, 73 Procedia CIRP 284 (2018); Andrius Plepys et al., *European Policy Approaches to Promote Servicizing*, 97 J. Cleaner Prod. 117, 119 (2015).
40. Fabrizio Ceschin & Carlo Vezzoli, *The Role of Public Policy in Stimulating Radical Environmental Impact Reduction in the Automotive Sector: The Need to Focus on Product-Service System Innovation*, 10 Int'l J. Auto. Tech. & Mgmt. 321 (2010).
41. Henning Wilts & Meghan O'Brien, *A Policy Mix for Resource Efficiency in the EU: Key Instruments, Challenges, and Research Needs*, 155 Ecological Econ. 59 (2019).
42. Leonidas Milios, *Advancing to a Circular Economy: Three Essential Ingredients for a Comprehensive Policy Mix*, 13 Sustainability Sci. 861 (2018).
43. *See* Nihan Akyelken et al., *The Importance of Institutions and Policy Settings for Car-Sharing—Evidence From the UK, Israel, Sweden, and Finland*, 18 EJTIR 340 (2018).
44. Plepys et al., *supra* note 39.
45. Mont & Lindhqvist, *supra* note 38.
46. Plepys et al., *supra* note 39.
47. Shaheen et al., *supra* note 31, at 9.
48. Car-Sharing Action Plan for Bremen, Resolution for the Meeting of the Committee for Construction and Transport on 17.09.2009 and for the Meeting of the Committee for Environment and Energy on 24.09.2009 (2009), https://relaunch.mobilpunkt-bremen.de/app/uploads/2020/05/Bremen_-Car-Sharing-Action-Plan_English.pdf.
49. City of Helsinki, The Carbon-Neutral Helsinki 2035 Action Plan 49 (2018), https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/HNH-2035/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf.
50. Wulf-Holger Arndt et al., Integration of Shared Mobility Approaches in Sustainable Urban Mobility Planning 22-23 (2019), https://www.eltis.org/sites/default/files/integration_of_shared_mobility_approaches_in_sustainable_urban_mobility_pl.pdf.
51. Levon Amatuni et al., *Does Car-Sharing Reduce Greenhouse Gas Emissions? Assessing the Modal Shift and Lifetime Rebound Effects From a Life Cycle Perspective*, 266 J. Cleaner Prod. art. 121869 (2020); Donna Chen & Kara M. Kockelman, *Carsharing's Life-Cycle Impacts on Energy Use and Greenhouse Gas Emissions*, 47 Transp. Rsch. Part D: Transp. & Env't 276 (2016).

of the essential environmental problems in transportation has evolved and widened in response to new scientific evidence linking the sector to negative environmental phenomena.[52] The evolution has also reflected a shift from local to transboundary environmental problems. Earliest concerns focused on predominantly parochial issues such as the impacts of transportation on local noise, and context-specific problems such as local urban air quality.[53]

In the late 1960s and 1970s, wider environmental concerns such as atmospheric pollution began to take a stronger hold in the discussions. Regulation started to turn toward the broader impacts of transport on the urban environment and on human health, such as lead content in fuel and particulate matter causing carcinogenetic effects.[54] In the late 1970s and 1980s, mounting concerns over the deleterious effects of acid rain, which have negative impacts on animal and plant life, highlighted automobiles as important contributing factors for sulfur dioxide (SO_2) and nitrogen oxide (NO_x).[55]

Around the same time, the role of (air-conditioned) vehicles in the releases of chlorofluorocarbons (CFCs), which lead to the depletion of the ozone layer, was also brought to light.[56] In the beginning of the 1990s, the Intergovernmental Panel on Climate Change brought to global attention the problem of "greenhouse effects."[57] This led to a close scrutiny of transport's role in global warming as a major source of GHG emissions.

The problem of biodiversity loss has recently regained attention as a priority environmental problem, highlighted by its interrelationship with climate change. Transportation impacts biodiversity through transport-related pollutants that cause eutrophication and acidification.[58] The conversion of land to build road infrastructure, in turn, affects landscape fragmentation, which obstructs the movement of animals as well as degrades habitats and ecosystems.[59] These biodiversity-related issues are thus also likely to figure increasingly in the definition of the environmental impacts of transportation.

The plurality of the identified environmental problems makes it difficult to achieve consensus on what constitutes "sustainable" transportation.[60] Life-cycle analyses on the impacts of vehicles strive to capture the diversity of the environmental (and other) impacts of the governed products. Still, this breadth of knowledge is only one aspect of the problem definition in the interventionist-theoretical sense of the term. A life-cycle assessment does not respond to the more political question about how to prioritize these environmental problems. The resources to address them are limited, and the efforts thus, to some extent, contradictory. The problems are also interrelated. As Henrik Gudmundsson has observed, it matters how "sustainable" transportation is conceptualized in a particular system because this influences the problem definition.[61]

Given the far-reaching implications of climate change, GHG emissions remain by far the most prominent problem definition of current transportation policies. This is understandable: in Europe, for example, the transport sector is responsible for one-quarter of total GHG emissions,[62] of which approximately 70% come from road transport,[63] with emissions from passenger cars accounting for 12% of the total EU emissions.[64] Unlike other sectors in the EU, this sector has not experienced a decline in GHG emissions since the 1990s. Thus, transportation policies tend to be framed against the problem of climate change (i.e., how to reduce GHG emissions in the sector).

The current surge of attention on the circular economy thus takes place within a climate-centric context. Yet, also in transportation, considerations of resource efficiency are not new in themselves.[65] Eco-efficiency is another sustainability concept that puts emphasis on resource use. We next explore what kinds of environmental problems would be addressed by a circular economy framing in transportation, in particular how the circular economy framing interacts with the objective of reducing GHG emissions in the sector. Indeed, as will be seen, it is often neglected how important circular economy strategies are in climate mitigation. Other environmental problems must not be overlooked, either.

52. Kenneth Button & Werner Rothengatter, *Global Environmental Degradation: The Role of Transport*, *in* Transport, the Environment, and Sustainable Development 19, 21 (David Banister & Kenneth Button eds., Routledge 1st ed. 1993).
53. *Id*. at 20.
54. *Id*. at 20-21; *Commission Green Paper on the Impact of Transport on the Environment: A Community Strategy for "Sustainable Mobility,"* COM (92) 46 final (Feb. 20, 1992).
55. David L. Greene & Michael Wegener, *Sustainable Transport*, 5 J. Transp. Geography 177, 179 (1997); J.G. Irwin & M.L. Williams, *Acid Rain: Chemistry and Transport*, 50 Env't Pollution 29, 50 (1988).
56. David Banister & Kenneth Button, *Environmental Policy and Transport: An Overview*, *in* Transport, the Environment, and Sustainable Development 4 (David Banister & Kenneth Button eds., Routledge 1st ed. 1993).
57. Button & Rothengatter, *supra* note 52, at 19.
58. European Commission, Handbook on the External Costs of Transport: Version 2019 (2020), https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1.
59. Ana Benítez-López et al., *The Impacts of Roads and Other Infrastructure on Mammal and Bird Populations: A Meta-Analysis*, 143 Biological Conservation 1307 (2010); Victoria J. Bennett, *Effects of Road Density and Pattern on the Conservation of Species and Biodiversity*, 2 Current Landscape Ecology Reps. 1 (2017).
60. Berger et al., *supra* note 10; Henrik Gudmundsson, *Making Concepts Matter: Sustainable Mobility and Indicator Systems in Transport Policy*, 55 Int'l Soc. Sci. J. 199 (2003); Henrik Gudmundsson & Mattias Höjer, *Sustainable Development Principles and Their Implications for Transport*, 19 Ecological Econ. 269 (1996).
61. Gudmundsson, *supra* note 60.
62. *Commission Communication to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, a European Strategy for Low-Emission Mobility*, COM (2016) 501 final (July 20, 2016).
63. European Environment Agency, *Greenhouse Gas Emissions From Transport in Europe*, https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport (last visited Sept. 22, 2022).
64. European Commission, *CO_2 Emission Performance Standards for Cars and Vans*, https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en (last visited Sept. 22, 2022).
65. Gudmundsson, *supra* note 60, at 203.

2. Contribution of a Circular Economy Perspective

The transportation sector utilizes a significant amount of resources. The production of vehicles and transport infrastructure account for 20% to 40% of the consumption of materials such as aggregates, cement, steel, and aluminum.[66] Transport infrastructure, primarily roads, accounts for up to 30% of land in Organisation for Economic Co-operation and Development (OECD) urban areas.[67]

The number of vehicles has been steadily increasing, and global sales are predicted to more than double between 2015 and 2050, from 85 million units to more than 200 million.[68] In fast-developing countries like China, the increase is even more dramatic. As of 2015, more than 90% of automobiles were powered by fossil fuels, with low emission vehicles (LEVs) constituting the minority. However, this trend is expected to reverse by 2050.[69] This is important, because the shifts toward more advanced vehicle technologies increase the material intensity for certain components of passenger vehicles.[70]

Overall, given the material intensity of the sector, there is growing interest in assessing and governing transportation also from the viewpoint of circular economy strategies. However, there is a lot of ambiguity regarding the precise environmental problems that a circular economy framing would and should address. The ambiguities are enhanced by economic considerations.

One of the earlier notions of a "circular economy" can be traced to the concept of a spaceship economy, which described the environmental problem in terms of the limited capacity of nature in a linear economy to supply resources and assimilate waste.[71] From this perspective, resource use in itself is a problem when done at a rate that leads to a depletion of resources essential for human and environmental health. Further, even though there is still sufficient material stocks to meet global demand, the renewal rate of renewable materials is limited and the production of nonrenewable materials is likely to become expensive over time.[72]

Yet, the ambiguity of environmental objectives of the circular economy manifests itself already here, in the lack of consensus on defining and measuring the environmental impacts of resource use. Most life-cycle assessment studies use "abiotic resource depletion" as an impact category.[73] The use of this impact category in defining the problem is problematic,[74] however, as it straddles economic, environmental, and other considerations. "Abiotic depletion potential" is often expressed in terms of the available reserves vis-à-vis their extraction rate, yet this type of scarcity reflects usually economic concerns rather than the impacts on the environment.[75] It is not so much that the resources are completely exhausted, as it is that their increasingly difficult extraction becomes economically prohibitive.

Another way of assessing the resource use implications of automobile and infrastructure production is by looking at the amount of land disturbed by the mining activities that are attributable to the primary or raw material resource extraction.[76] Besides the land disturbance, this perspective also brings to fore the impact of resource extraction on the surrounding environment, including the direct and indirect changes in land use as well as pollution. GHG emissions are obviously essential, but the refocus on biodiversity is also noteworthy. These other impacts are often addressed only indirectly in the circular economy literature.[77] Other methods for assessing the environmental impact of resource use exist, emphasizing different aspects of the problem.[78]

The precise environmental problem definition of a circular economy strategy on transportation thus requires considerable attention. The assessment entails addressing the vagueness of "resource depletion," the various environmental impacts caused by the resource extraction and transformation processes for their end use, as well as the issue of eliminating or minimizing waste. Still, even that is not quite sufficient. It is also important to highlight the several synergies and trade offs between these impacts as caused by the various elements of the sector. They are here conceptualized as a part of the problem definition, albeit they could also be considered from the viewpoint of desired outcome, the second layer of intervention theories.

☐ *Comprehensiveness debacle: Synergies and trade offs of environmental impacts*. Recent discussions have highlighted the significant potential of material efficiency strategies in reducing GHG emissions in transportation during the production phase of vehicles and infrastructure.[79] This expands

66. Berger et al., *supra* note 10, at 305.
67. OECD, Decoupling the Environmental Impacts of Transport From Economic Growth 49 (2006), https://www.oecd-ilibrary.org/environment/decoupling-the-environmental-impacts-of-transport-from-economic-growth_9789264027138-en.
68. Shoki Kosai et al., *Natural Resource Use of Gasoline, Hybrid, Electric, and Fuel Cell Vehicles Considering Land Disturbances*, 166 Res. Conservation & Recycling 1 (2021).
69. *Id*.
70. Iulia Dolganova et al., *A Review of Life Cycle Assessment Studies of Electric Vehicles With a Focus on Resource Use*, 9 Resources 32 (2020); Nikolas Hill et al., Determining the Environmental Impacts of Conventional and Alternatively Fuelled Vehicles Through LCA: Final Report 155 (2020), https://op.europa.eu/en/publication-detail/-/publication/1f494180-bc0e-11ea-811c-01aa75ed71a1.
71. Blomsma & Brennan, *supra* note 21, at 608; Kenneth Boulding, *The Economics of the Coming Spaceship Earth*, *in* Environmental Quality in a Growing Economy (Henry Jarrett ed., RFF Press 1966); Martin Geissdoerfer et al., *The Circular Economy—A New Sustainability Paradigm?*, 143 J. Cleaner Prod. 757, 759 (2017).
72. Julian M. Allwood et al., *Material Efficiency: A White Paper*, 55 Res. Conservation & Recycling 362, 363-65 (2011).
73. Hill et al., *supra* note 70, at 281.
74. Lauran van Oers & Jeroen Guinée, *The Abiotic Depletion Potential: Background, Updates, and Future*, 5(1) Resources 1 (2016).
75. Hill et al., *supra* note 70, at 281.
76. Kosai et al., *supra* note 68.
77. Geissdoerfer et al., *supra* note 71, at 765.
78. Berger et al., *supra* note 10; Dolganova et al., *supra* note 70; Thomas Sonderegger et al., *Mineral Resources in Life Cycle Impact Assessment—Part I: A Critical Review of Existing Methods*, 25 Int'l J. Life Cycle Assessment 784 (2020).
79. International Resource Panel, Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future 11-12 (2020), https://wedocs.unep.org/bitstream/handle/

the focus of climate mitigation strategies beyond the fuel component of transport. The GHG-relevant material efficiency strategies target the amount of resources contained in the vehicles. They importantly expand also from the qualities of the physical product to how intensively the vehicles, and hence the resources that they contain, are used.[80]

Material efficiency strategies that promote sufficiency are especially important in addressing increasing transportation demands, which have so far negated the impacts of ever-tightening fuel efficiency regulations. Besides reducing GHG emissions, the decreased mining of primary materials for vehicle production and road infrastructure contributes also to mitigating pollution, ecological degradation, and biodiversity loss.

The problem of GHG emissions and those of material scarcity (or land disturbance) are not always mutually inclusive, however, and can have several trade offs. LEVs,[81] in particular EVs, tend to entail higher mineral or metal use than vehicles with internal combustion engines associated with power train and battery production.[82] Shoki Kosai et al. have also found that there is an inverse relationship between the scale of land disturbances resulting from mining activities of primary resources used in "total material requirement" (TMR) and carbon dioxide (CO_2) emissions from internal combustion engine vehicles (ICEVs) and EVs.[83] The life-cycle TMR of ICEVs are lowest, while those of EVs are the highest. Conversely, the life-cycle CO_2 emissions of EVs are the lowest and those of gasoline vehicles the highest.

The model of Kosai et al. did not, however, consider the possibility of using recycled metals, which is an important aspect of circular economy strategies. Moreover, EVs tend to have higher impacts than power train technologies using fossil fuels in terms of toxicity when considering materials used in the manufacturing stage.[84] Meanwhile, using lighter materials in the vehicle composition, such as by shifting from steel to aluminum, increases the materials-related emissions while reducing the overall life-cycle emissions due to increased fuel efficiency.[85] Also, lighter advanced materials that increase fuel efficiency can pose technical problems for recycling and face economic barriers.[86]

□ *Holistic yet accurate approach to a problem definition.* There thus is a range of environmental impacts and trade offs that a circular economy strategy on transportation needs to consider as a problem definition. The starting point for assessing the impacts is to specify the focus of a circular economy on resource efficiency. Resource efficiency, in turn, needs to be understood from a life-cycle perspective, so that the analysis of impacts reaches beyond the sustainability of the resources themselves. Moreover, a problem definition of a circular economy strategy that focuses only on one environmental aspect—resource efficiency—would still lead to gaps and create trade offs and other unintended negative consequences with other environmental qualities. The problems thus need to be assessed holistically and with precision, allowing for the setting of an order of priority for addressing them.

We demonstrate in this Article the approach and its implications for PSSs as the societally desired outcome in circular transportation. To reach a sufficient level of detail, we focus our analysis on resource efficiency and its interactions with GHG emissions in transportation, thus excluding the other important environmental problems.

The steps of defining the problem and the outcome guide the development of regulatory interventions that are appropriate under the increasing demand for transport and pressures on the environment and on the use of urban space. The debate in framing "environmentally sustainable transport" is precisely about the scope of environmental problems to be included, and how these different environmental objectives are to be reconciled.

B. *The Societally Desired Outcome—Defining Car Sharing*

On the basis of the problem definition, the theory of intervention entails formulating the preferable social outcome, as well as defining the social actors that can produce the desired outcome.[87] The desirable outcome should allow for targeting the attention on a manageable set of factors that address the defined problems.[88] The theory of desired outcome should set the objectives clearly, allow for the consideration of alternatives, and include a systematic analysis of these alternatives against the defined problems.[89] Further, the desired outcome entails a solution to create synergies, and to reconcile the potential trade offs, among the objectives.

In this Article, we focus our analysis of the desired outcomes within the specific context of car sharing. This section thus assesses whether and how exactly car sharing as a PSS-based circular economy strategy addresses the defined environmental problems to produce the desired environmental outcomes. The analysis also determines which actors would have a role in realizing these outcomes.

Our analysis above highlighted the importance of defining the problem that a circular economy strategy would

20.500.11822/34351/RECCR.pdf; Stefan Pauliuk et al., *Global Scenarios of Resource and Emission Savings From Material Efficiency in Residential Buildings and Cars*, 12 Nature Commc'ns art. 5097 (2021); Paul Wolfram et al., *Material Efficiency and Climate Change Mitigation of Passenger Vehicles*, 25 J. Indus. Ecology 494 (2021).

80. International Resource Panel, *supra* note 79, at 49-60; Wolfram et al., *supra* note 79.
81. LEVs include EVs, hybrid EVs, and fuel cell vehicles.
82. Dolganova et al., *supra* note 70.
83. Kosai et al., *supra* note 68.
84. Hill et al., *supra* note 70, at 197.
85. International Resource Panel, *supra* note 79, at 4, 54.
86. *Id.* at 101; Géraldine Oliveux et al., *Current Status of Recycling of Fibre Reinforced Polymers: Review of Technologies, Reuse, and Resulting Properties*, 72 Progress Materials Sci. 61 (2015); Bárbara Rodrigues et al., *Resource Efficiency for UK Cars From 1960 to 2015: From Stocks and Flows to Service Provision*, 41 Env't Dev. 1, 11 (2022).
87. Weiss, *supra* note 37, at 85.
88. Janet A. Weiss, *The Powers of Problem Definition: The Case of Government Paperwork*, 22 Pol'y Sci. 97, 117 (1989).
89. *Id.*

seek to address in a holistic manner, so that it is not limited merely to the depletion of natural resources. Car sharing would also need to contribute to addressing those important environmental problems that are directly and even indirectly related to resource use. For considerations of space, we limit the analysis in this Article in this latter respect to climate change. We thus proceed to analyze in turn the relevant factors and actors, within the context of car sharing, in reducing resource use and GHG emissions.

1. Reducing Resource Use Through Car Sharing

From the perspective of reducing resource use, car sharing as an access-based PSS can have two major types of material efficiency benefits. First, it has the potential to lower virgin material demand through the intensified use of vehicles.[90] Car sharing makes it possible to meet transportation needs while using fewer passenger vehicles, which can help reduce the need to manufacture cars over time. This could also translate to lower demand for parking space and result in reduction of the associated materials.[91] Second, car sharing can facilitate the use of materially efficient vehicles. The availability of lighter and smaller vehicles can help replace bigger and less material-efficient private vehicles.[92]

☐ *Reduced material stock through increased utility*. By sharing cars, each individual or household does not need to purchase a vehicle of his or her own. Shared cars are used more intensively than private cars. If car sharing thus replaces private car ownership rather than complements it with a second vehicle, car sharing can reduce the overall number of vehicles produced. Many studies have reported that car sharing is indeed able to displace private ownership of vehicles.[93]

It is common for policies on car sharing to aim at replacing privately owned cars, albeit often in a nonbinding manner. However, the environmental benefit of reducing overall vehicle stock is not only dependent on the extent to which car sharing is able to displace private ownership. It depends also on the replacement rate of the shared vehicles.[94] Car-sharing fleets are likely to be replaced considerably more often than average private cars, because of their use intensity.[95] Car-sharing providers typically replace their cars every two to three years due to faster wear and tear.[96] Consequently, reducing the vehicle miles traveled (VMT) of shared cars may contribute to lowering the car manufacturing rates.

Determining the optimal moment of replacing the car is difficult, because it requires considering the trade offs between the saved resources and effects on other environmental impacts, in particular on the GHG emissions. This consideration focuses on the material extraction required for manufacturing a new car, on the one hand, and the higher GHG emissions during the use of an older, less efficient model, on the other.[97] Yet, car-sharing providers rarely choose the moment of replacing vehicles in their fleet on such environmental grounds. Many providers of free-floating car-sharing services are owned by car manufacturers[98] or rental companies.[99] Their overall strategic objective may be, in fact, to *increase* the sales of cars. After their replacement in a car-sharing fleet, the shared cars are usually sold to other users.

The service providers may also enter the car-sharing business for strategic reasons, for example to promote their new vehicle fleet and to gain direct access to consumer insights.[100] Then again, the value of sensitizing and introducing consumers to new models may be particularly important to affect paradigmatic change, if the sensitization supports a move to hybrid vehicles and EVs. Car sharing shows here how the environmental and economic aspects of circular economy strategies are interwoven.

Hence, while car sharing may influence private ownership, it is not evident that car sharing actually reduces overall car production over time.[101] The above discussion highlights that in terms of promoting material efficiency, the desirable outcome of car sharing should not just be on replacing private ownership, but on the ultimate impact of slowing down the manufacturing rates of vehicles over time. These observations are relevant also in terms of the actors contributing to the desired outcome. Besides influencing end-users to shift to shared transport, it is also important to address the role of car-sharing providers in slowing the production rates of vehicles (e.g., by investing in durable highly efficient vehicles and having the fleet professionally maintained).[102]

90. *See* Material Economics, *supra* note 32, at 130.
91. *See* Chen & Kockelman, *supra* note 51.
92. Hans Nijland & Jordy van Meerkerk, *Mobility and Environmental Impacts of Car Sharing in the Netherlands*, 23 Env't Innovation & Societal Transitions 84 (2017).
93. *See* Elliot Martin & Susan Shaheen, Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities (2016), http://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf; Michiko Namazu & Hadi Dowlatabadi, *Vehicle Ownership Reduction: A Comparison of One-Way and Two-Way Carsharing Systems*, 64 Transp. Pol'y 38 (2018).
94. Levon Amatuni et al., *Does Car-Sharing Reduce Greenhouse Gas Emissions? Assessing the Modal Shift and Lifetime Rebound Effects From a Life Cycle Perspective*, 266 J. Cleaner Prod. art. 121869 (2020); Chen & Kockelman, *supra* note 51.
95. Oksana Mont, *Institutionalisation of Sustainable Consumption Patterns Based on Shared Use*, 50 Ecological Econ. 135 (2004).
96. *Id.* at 142.
97. *See* Rens Meijkamp, *Changing Consumer Behaviour Through Eco-Efficient Services: An Empirical Study of Car Sharing in the Netherlands*, 7 Bus. Strategy & Env't 234, 242 (1998).
98. Anu Tuominen et al., *Facilitating Practices for Sustainable Car Sharing Policies—An Integrated Approach Utilizing User Data, Urban Form Variables, and Mobility Patterns*, 2 Transp. Rsch. Interdisc. Persps. art. 100055 (2019).
99. Shaheen et al., *supra* note 30.
100. Monitor Deloitte, Car Sharing in Europe: Business Models, National Variations, and Upcoming Disruptions (2017), https://www2.deloitte.com/de/de/pages/consumer-industrial-products/articles/car-sharing-in-europe.html.
101. Aaron Kolleck, *Does Car-Sharing Reduce Car Ownership? Empirical Evidence From Germany*, 13 Sustainability 7384 (2021). *But see* Peter Schmidt, *The Effect of Car Sharing on Car Sales*, 71 Int'l J. Indus. Org. art. 102622 (2020).
102. Material Economics, *supra* note 32, at 28-29.

☐ *Reduced material intensity of vehicles*. Another way that car sharing can improve resource efficiency in transportation is by reducing the material intensity of the vehicles and their components, for example by downsizing.[103] In terms of downsizing, this can be accomplished if car sharing provides access to smaller trip-appropriate sized vehicles to replace bigger and less material-efficient private vehicles.[104] However, this should not hinder the possibility of increasing passenger occupancy to increase resource efficiency. Allowing more passengers to use and occupy a vehicle could lead to smaller demand for cars.

2. Reducing Transportation-Sector Emissions Through Car Sharing

While contributing to the core objective of reducing material use of vehicles, car sharing needs to be assessed from the viewpoint of the problem of GHG emissions. Resource use-related objectives should not only avoid trade offs with higher GHG emissions, but preferably contribute to decreasing the emissions.

☐ *Lowered VMT*. One of the ways by which car sharing can reduce GHG emissions is that it leads to an overall reduction in VMT. A reduction in the overall distances traveled by cars depends on whether users of car sharing are driving fewer miles than they would have by a private car or when fewer vehicle trips are being made because of shared trips. In fact, if car sharing is used as an additional rather than as a replacement for private car use, car sharing may result in increased VMT and thus higher emissions. Besides decreasing the car fleet, the shift to car sharing can also induce behavioral change. It can influence the distances traveled and shift users to other less carbon-intensive modes of transport.[105] Many studies have estimated the effects of adopting car sharing to the overall distances traveled by car with varied results.[106]

Understanding the impact of car sharing in reducing VMT is relevant because its influence on emissions savings can be greater than those attributed to vehicle manufacture and maintenance directly.[107] Donna Chen and Kara Kockelman have found that the adoption of car sharing (in a dense urban neighborhood and with good access to public transit, with relatively short distances traveled) can result in up to 51% reductions of transport-related life-cycle GHG emissions among individual car-sharing users.[108] Chen and Kockelman attributed the reductions to fewer trips (avoided travel) and the shift to non-auto modes of travel. The greatest reductions were then followed by the emission savings due to decreased parking infrastructure demand. Meanwhile, the emissions savings attributed to vehicle manufacture and maintenance had a relatively smaller impact.

Levon Amatuni et al. had a much lower estimate of the GHG emissions reduction resulting from the adoption of car sharing.[109] They estimated a reduction of between 3% to 18% in overall life-cycle GHG emissions in a study of three cities, when taking into account, inter alia, the effect of the intensity of vehicle use as a result of car sharing on a vehicle's lifetime. Nevertheless, the authors also found that behavioral change had the most significant impact in the total emissions. This resulted from a reduction in overall private driving after becoming members of car-sharing services. Thus, to contribute to the GHG aspects of the defined problem, car sharing should also reduce overall vehicle trips.

☐ *Increased operational efficiency*. Besides decreasing the amount of trips, car sharing can facilitate the users' access to LEVs or highly fuel-efficient vehicles.[110] The cost, and thus the threshold to subscribe to an LEV car fleet, is usually much lower than that of procuring the LEV for oneself. The intensified utilization and replacement rates can also facilitate shifts to more fuel-efficient technologies in the cars being used.[111]

Shifting toward EVs to increase fuel efficiency may, however, lead to increased demand for certain materials, particularly those used in battery manufacturing,[112] and also affect the resource intensity of the overall supply chain.[113] Thus, car sharing has a double effect: by promoting LEVs, it increases the demand for certain materials, yet decreases such demand compared to a similar shift in privately owned vehicles. It is thus also from the viewpoint of operational efficiency important to consider the various trade offs in resource use and GHG emissions while shifting to EVs via car sharing.

☐ *Multimodal transport*. A point where the preferred outcomes of reductions in VMT and increased operational efficiency merge is multimodal transport. There are namely many ways to transit, which multimodal transport systems strive to combine in environmentally (and otherwise) optimal ways. The VMT and the operational efficiency of car sharing are influenced by their integration with even more sustainable modes of transport, like public transit, walking,

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103. Wolfram et al., *supra* note 79.
104. Material Economics, *supra* note 32, at 129.
105. Amatuni et al., *supra* note 94; Chen & Kockelman, *supra* note 51.
106. Elliot Martin & Susan Shaheen, *The Impact of Carsharing on Public Transit and Non-Motorized Travel: An Exploration of North American Carsharing Survey Data*, 4 Energies 2094 (2011); Martin & Shaheen, *supra* note 93; Nijland & van Meerkerk, *supra* note 92.
107. Amatuni et al., *supra* note 94; Chen & Kockelman, *supra* note 51.
108. Chen & Kockelman, *supra* note 51.
109. Amatuni et al., *supra* note 94.
110. Material Economics, *supra* note 32, at 6, 129; Michiko Namazu et al., *Is Carsharing for Everyone? Understanding the Diffusion of Carsharing Services*, 63 Transp. Pol'y 189, 189 (2018).
111. Meijkamp, *supra* note 97, at 242.
112. Dolganova et al., *supra* note 70; European Environment Agency, Electric Vehicles From Life Cycle and Circular Economy Perspectives (2018), https://www.eea.europa.eu/publications/electric-vehicles-from-life-cycle.
113. Dolganova et al., *supra* note 70; Burak Sen et al., *Material Footprint of Electric Vehicles: A Multiregional Life Cycle Assessment*, 209 J. Cleaner Prod. 1033 (2019).

or biking.[114] In other words, car sharing can be beneficial, for example as the first- or last-mile solution to reach the nearest point of public transit, and if it does not lead to more miles being driven by car.[115]

3. Governing Interdependencies Between Climate and Material Efficiency Objectives

Overall, the benefits of improving material efficiency through less vehicle production can, in terms of climate impacts, be negated if the impacts from fuel use are not equally considered. Access to smaller and lighter vehicles through car sharing would also contribute to fuel efficiency. At the same time, increased utility impacts the lifetime of vehicles, so it is important to optimize from an environmental perspective the rate at which car-sharing vehicles are replaced. This would have a positive impact on improving material efficiency.

Thus, in case the total annual driving demand stays similar and without increasing vehicle occupancy, merely switching from private ownership to car-sharing schemes limits the *nonoperational* (e.g., manufacturing, infrastructure) GHG reductions. Finally, the operational advantages without changes in driving demand, on the other hand, would depend on the design and power train technologies of the vehicles used (e.g., the car-sharing fleet consisting of (more) LEVs, or of more lightweight or smaller and trip-appropriate vehicles, which contribute to fuel efficiency) and increased occupancy.[116] In turn, using more expensive, lighter, and advanced materials creates incentives for their recovery and reuse, which contributes to material efficiency.[117]

C. Regulatory Interventions—Supporting Car Sharing to Address the Defined Problems

The final, third step in our analytical framework of intervention theories assesses the points and means of regulatory interventions in supporting the societally desired outcomes as discussed above.

We proceed in the same order as we analyzed the desired outcomes, moving from decreasing car production to emissions reductions. Our examples are not meant to be an exhaustive account of all possible points and means of intervention to ensure that car sharing produces the desired environmental outcomes. The goal, rather, is to showcase a selection of the most prominent regulatory responses, and to analyze them against the theory of intervention. The analysis makes explicit some of the essential underlying assumptions and highlights to what extent these assumptions are supported by existing evidence.

114. International Transport Forum, Good to Go? Assessing the Environmental Performance of New Mobility 63 (2020), https://www.itf-oecd.org/sites/default/files/docs/environmental-performance-new-mobility.pdf.
115. International Resource Panel, *supra* note 79.
116. Material Economics, *supra* note 32.
117. *Id*. at 129.

1. Interventions to Reduce Overall Car Production Through Increased Utility

Interventions to govern the overall car production can focus on reductions in the demand for travel, or on the demand for private cars to meet transportation needs, or a mix of these objectives. In this section, we focus on interventions that impact overall car production from the material efficiency strategy of increasing vehicle utility.

☐ *Reducing car dependency through land use and transportation planning*. The issue of travel demand needs to be addressed in multiple areas of law from urban and spatial planning to the broader organization of the economy. So far, economic and population growth; the way societies organize areas of work, leisure, and rest; as well as consumer values and preferences have translated into increased demand for goods and a higher number of people who desire and can afford to travel. The International Transport Forum projects a growing demand for transport, with passenger transport increasing up to threefold by 2050.

Land use patterns remain a significant factor in driving the demand for urban transportation.[118] Thus, strategies to reduce unnecessary trips and car dependency need to be integrated into land use and transportation planning. In the urban context, this means planning that ensures residents have access to services without a need for motorized travel. It also means plans that promote access to more sustainable modes of transport. This leads to focusing car sharing as a solution to situations where car-based transport cannot be reduced (e.g., because of spatio-temporal considerations) and where service gaps exist in public transit.[119]

Increasing accessibility to car sharing only in strategic areas is a means of reducing individual car ownership overall. Experiments in Umeå, Sweden, provide early evidence that incorporating car sharing in building developments can facilitate use. The incentives to reduce parking are not limited to car-sharing programs, but also include other more sustainable transportation options, such as discounted train tickets.[120] A similar incentive is being used in Helsinki, Finland, where the city is exchanging real estate developers' parking space requirements for their long-term commitments to facilitate car-sharing services for residents.[121]

☐ *Removing existing incentives on private car ownership*. An important point of intervention to support PSSs while reducing overall car production is to remove existing financial incentives attached to private car ownership. These in-

118. International Transport Forum, ITF Transport Outlook 2021 (2021), https://www.oecd-ilibrary.org/content/publication/16826a30-en.
119. *See* Akyelken et al., *supra* note 43, at 351; Rodrigues et al., *supra* note 86, at 11.
120. Nancy Bocken et al., *Emergence of Carsharing Business Models and Sustainability Impacts in Swedish Cities*, 12 Sustainability 1594 (2020); Caroline Mattsson, Mobility Management and Land-Use Planning in Sweden (2015), https://www.eltis.org/discover/case-studies/mobility-management-and-land-use-planning-sweden.
121. Tuominen et al., *supra* note 98.

centives include company cars.[122] In a 2014 OECD study, it was estimated that most EU countries undertax the company car benefit.[123] The report posited that undertaxation of the capital component of vehicles can affect employee decisions to retain the company car as an additional vehicle, while a neutral tax treatment could encourage households to reduce the number of vehicles owned. Incentives on individual consumers' purchases of EVs, in turn, have the unintended negative consequence of more cars being bought instead of individuals using public transit.

A point of intervention could thus involve requiring employers that already provide employees with company car benefits to replace this with an alternative, equivalent benefit in the form of a transit budget. The transit budget can be used for various sustainable transport options, such as bike sharing, public transit, and car sharing, but exclude less sustainable options such as ride-hailing and taxis. Legislation to this effect has been implemented recently in Belgium.[124] In this regard, subscriptions to "mobility as a service" (MaaS), which incorporates car sharing as an alternative to company car benefits, could be piloted. To ensure positive environmental effects, the measure could require that to qualify for the transit budget, the car-sharing services need to be certified as complying with strict environmental standards on emissions and/or the use of EVs in the fleet.

Further, the optimal pricing for such subscriptions needs to be carefully evaluated to avoid overconsumption of the alternative modes of transit.[125] The latter would lead to perverse results such as the crowding of public transit, inducing a modal shift back to private car use. Increased vehicle trips due to the facility of car sharing is another rebound effect to monitor. The examples highlight the importance of focusing on the desired outcome instead of merely the intermediate objective of removing incentives.

☐ *Replacing private car ownership through use charges*. Factors that influence decisionmaking in owning cars vis-à-vis using other transport modes include costs associated with car ownership, such as fuel duties and parking costs. The purpose of these types of interventions is to induce a modal shift away from vehicles and a reduction in vehicle use.[126] Use charges impact the decision to purchase a car. At the same time, these interventions indirectly incentivize increased vehicle occupancy.

In urban contexts with well-developed public transportation, expensive parking space creates an incentive to reduce car ownership. Meanwhile, the viability of car sharing depends on the accessibility and availability of parking for car-sharing vehicles.[127] Thus, parking regulations could be designed so as to have the dual purpose of supporting car sharing while deterring private users from owning cars.[128] However, it is again important that the intervention does not reduce the costs of car sharing to the extent that it becomes more attractive than even greener modes of transport, such as walking, biking, and public transportation.

☐ *Directly incentivizing increased vehicle occupancy*. Different regulatory interventions are possible to encourage increased passenger capacity in transportation. They include setting minimum occupancy standards and creating preferences, such as curb access rules, or creating preferential lanes for high-occupancy vehicles (HOVs). The efficacy of such rules in motivating increased ridership is context-specific. For example, use of HOV lanes is likely to increase ridesharing in areas where there are recurrent congestion problems.[129] Whether rules promoting higher occupancy actually result in reducing vehicle ownership is not yet well studied.[130]

2. Interventions to Reduce the Emissions of Car Use

Although resource use is the principal problem that PSSs as a circular economy strategy strive to address, it is also important to consider this objective from the viewpoint of GHG emissions to promote environmental sustainability. In this regard, it is essential not only to minimize vehicle ownership, but also to reduce the operational GHG emissions in passenger transport. The increase in transportation-related emissions despite the many technological developments in terms of power train technologies and vehicle design is symptomatic that the "root causes" of influencing the demand for travel are not adequately addressed by existing regulatory interventions. Thus, regulatory interventions to support car sharing as a PSS-based circular economy strategy in transportation must catalyze and not contradict actions that target the root cause of increasing travel demand.

122. Akyelken et al., *supra* note 43.
123. Michelle Harding, *Personal Tax Treatment of Company Cars and Commuting Expenses: Estimating the Fiscal and Environmental Costs* 70 (OECD, Taxation Working Papers No. 20, 2014), https://www.oecd-ilibrary.org/content/paper/5jz14cg1s7vl-en.
124. Deloitte, The Mobility Budget: A Second Alternative for the Company Car (2019), https://www2.deloitte.com/be/en/pages/tax/articles/The-Mobility-Budget.html.
125. Daniel Hörcher & Daniel J. Graham, *MaaS Economics: Should We Fight Car Ownership With Subscriptions to Alternative Modes?*, 22 Econ. Transp. art. 100167 (2020).
126. *See* Stephen Potter, *Purchase, Circulation, and Fuel Taxation*, *in* The Implementation and Effectiveness of Transport Demand Management Measures: An International Perspective 13, 14 (Stephen Ison & Tom Rye eds., Routledge 2008).
127. Akyelken et al., *supra* note 43.
128. Joschka Bischoff & Kai Nagel, Impact Assessment of Dedicated Free-Floating Carsharing Parking, Paper Presented at the Fifth Institute of Electrical and Electronics Engineers (IEEE) International Conference on Models and Technologies for Intelligent Transportation Systems 6 (2017).
129. Stephen Schijns & P. Eng, *High Occupancy Vehicle Lanes—Worldwide Lessons for European Practitioners*, *in* Urban Transport XII: Urban Transport and the Environment in the 21st Century (WIT Transactions on the Built Environment) 188 (C.A. Brebbia & V. Dolezel eds., WIT Press 2006).
130. Most evaluations of HOV lanes focus on their effectiveness in reducing vehicle use or congestion, but not vehicle ownership. *See* Jaimyoung Kwon & Pravin Varaiya, *Effectiveness of California's High Occupancy Vehicle (HOV) System*, 16 Transp. Rsch. Part C: Emerging Techs. 98 (2008); Schijns & Eng, *supra* note 129.

☐ *Disincentivizing car use to lower VMT*. One way to intervene to lower VMT is by increasing the cost of driving. Car sharing is thought to influence travel behavior toward lower VMT by emphasizing variable driving costs, such as per hour and/or mileage charges.[131] The advance planning needed to use car-sharing vehicles is also a driver in reducing VMT.[132] As illustrated by a study in Flanders, Belgium, the use of subsidies to further lower the costs of car sharing may need to be limited to avoid the negative effect of increasing miles traveled. Car sharing needs to be cost efficient, but not cheaper than using public transit.[133] A delicate balance needs to be struck with regulation that affects the overall price of fuel (e.g., fuel duties, and hence the duration and frequency of vehicle trips), vehicle occupancy, and the uptake of fuel-efficient vehicles in car-sharing fleets.

Interventions that aim to make car use difficult through financial disincentives (e.g., congestion charges) can also be considered, albeit with caution, in the mix of instruments on PSSs. Making car use difficult in areas where no suitable alternatives exist may only serve to increase transportation costs, but not decrease travel demand. Hence, the context matters in whether driving costs can influence travel options and travel demand. There is mixed evidence on the effectiveness of regulatory interventions on the matter,[134] which necessitates that the regulatory experiments be closely monitored.

☐ *Facilitating multimodal transport through car sharing*. Another point of intervention regarding emissions is the cross-over between car sharing and public transportation. As noted, car sharing must not replace public transportation, because public transportation is usually more effective in reducing the emissions per VMT per passenger. Car sharing can facilitate more sustainable transport by increasing commuters' convenience and filling in accessibility gaps in multimodal transportation left by public transit.[135] It is also important to note that these interventions aim to satisfy travel demand more efficiently, but they do not address travel demand per se.

A far-reaching multimodal transport policy is the MaaS concept, which is operational in Helsinki, for example. In MaaS, the fares and information on different types of transportation, including car sharing, are merged. However, car sharing needs to be integrated into public transportation also physically. Transportation hubs are an important example: they are spaces of physical co-location for public transportation and car sharing, creating nodes that enable car sharing as the first- and last-mile solutions.[136]

Transportation hubs are generally situated on major public transit corridors in cities and large towns.[137] Bremen, Germany, a pioneer in developing transportation hubs and other measures supporting the use of car sharing, has reported an increase in the use of public transit by linking it to car sharing.[138] There are also some indications that rules on the type of permitted car sharing—whether station-based or free-floating—is a point of intervention, because they affect the conduciveness of the service in facilitating multimodal transportation.[139]

☐ *Incentivizing increased number of passengers*. The benefits of increasing the number of passengers that use or occupy a single vehicle are not limited to a smaller demand for cars, which contributes to material efficiency as discussed above. Increasing occupancy through rules on curb access and preferential lanes also reduces the miles driven, reducing tank-to-wheel GHG emissions. Increased occupancy addresses the need to use multiple vehicles to make the same trip, but does not avoid the need to use a vehicle in the first place. In short, regulatory interventions targeting occupancy address vehicle demand, but not car-based travel demand.[140]

☐ *Interventions to address operational efficiency*. A further point of intervention in considering GHG emissions in car sharing is the operational efficiency of vehicles. The use of low or zero emission technologies in car-sharing fleets improves their emission performance. There are different ways of regulating the use of clean technologies among car-sharing providers. One approach is to mandate the use of EVs as a precondition to providing car-sharing services. In Milan, Italy, only EVs are allowed in car-sharing fleets by 2024.[141] Because the Milanese approach offers no flexibility for car-sharing providers, it creates a significant potential to reduce GHG emissions, although it may impact their economic viability in areas where car sharing is still a nascent market.

Another way to intervene is to tie economic incentives, such as access to parking, to the use of clean technologies in car sharing. The availability and allocation of parking space is considered crucial for the viability of car-sharing

131. Chen & Kockelman, *supra* note 51; Shaheen et al., *supra* note 31, at 178, 281.
132. *Id.*
133. Raïsa Carmen et al., CE Center Circular Economy Policy Research Center, Car-Sharing in Flanders 1 (2019), https://ce-center.vlaanderen-circulair.be/en/publications/publication/9-car-sharing-in-flanders.
134. *See* Ella Graham-Rowe et al., *Can We Reduce Car Use and, if So, How? A Review of Available Evidence*, 45 Transp. Rsch. Part A: Pol'y & Prac. 401 (2011); Roger L. Mackett, *Reducing Car Use in Urban Cities*, *in* Sustainable Transport for Chinese Cities 225 (Roger L. Mackett et al. eds., Emerald Group Publishing 2012); Alin Semenescu et al., *30 Years of Soft Interventions to Reduce Car Use—A Systematic Review and Meta-Analysis*, 85 Transp. Rsch. Part D: Transp. & Env't art. 102397 (2020).
135. *See* Montserrat Miramontes et al., *Impacts of a Multimodal Mobility Service on Travel Behavior and Preferences: User Insights From Munich's First Mobility Station*, 44 Transportation 1325 (2017); Shaheen et al., *supra* note 31, at 22-23.
136. Haheen et al., *supra* note 31, at 138.
137. CoMoUK, Mobility Hubs Guidance (2019), https://uploads-ssl.webflow.com/6102564995f71c83fba14d54/618d29b3d06c81de72c38fdc_CoMoUK%20Mobility%20hub%20guidance%20_Oct%202019.pdf.
138. Hannes Schreier et al., Team Red, Analysis of the Impacts of Car-Sharing in Bremen, Germany (2018), https://northsearegion.eu/media/5724/analysis-of-the-impact-of-car-sharing-in-bremen-2018_team-red_final-report_english_compressed.pdf.
139. *Id.*; Shaheen et al., *supra* note 31; Tuominen et al., *supra* note 98.
140. *See Reducing Car Dependency Through Land Use and Transport Planning* subsection in Section II.C.1.
141. Agenzia Mobilitá Ambiente Territorio, *Piano Urbano della Mobilità Sostenibile*, https://www.amat-mi.it/it/progetti/piano-urbano-mobilita-sostenibile/ (last visited Sept. 22, 2022).

operations.[142] Hence, parking regulations can be used to motivate the use of clean technologies. In Bremen, car-sharing vehicles benefit from parking space, but only if they fulfill an environmental standard. Compliance can be demonstrated by obtaining a certification from the German Blue Angel eco-labeling scheme.[143] The technical criteria under the eco-label include limit values for NO_x and particulate emissions, as well as a minimum quota for EVs in the operator's fleet.[144]

More broadly speaking, CO_2 or other emission-based vehicle purchase and circulation taxes (i.e., annual registration) serve to stimulate the uptake of fuel-efficient vehicles.[145] One-time registration fees based on the CO_2 performance (grams/kilometer), such as those implemented in Norway, promote the use of fuel-efficient and lighter vehicles.[146] While these measures are effective in influencing the choice of vehicle technology, they do not necessarily lower travel demand. LEVs tend to have high capital costs but low running costs. Shifting to LEVs can thus have the perverse effect of promoting car use and dependency. While such an effect can be beneficial for the climate in the short to medium term, it nevertheless negatively impacts resource use. Thus, it is important that vehicle and circulation taxes are complemented with measures that manage travel demand and vehicle use.

3. The Regulatory Interventions in a Broader Context

The appropriateness of specific interventions to support car sharing as a societally preferred outcome depends on the practical and regulatory context in which they are applied. The above interventions to reduce emissions assume, for example, that the switch to LEVs is economically viable to the providers of car-sharing services, that parking incentives sufficiently offset the cost of purchasing more expensive but highly fuel-efficient vehicles, that authorities are able to enforce the relevant regulations, or that consumers are comfortable using vehicles that are more modern and used in slightly different ways.

The choice of the appropriate interventions for a specific transportation context thus expands into intricate multi-criteria analyses. While an important part of the third step of the intervention theoretical approach, they fall outside the scope of our present analysis. Indeed, the intervention theoretical framework needs to be seen as a part of the policy cycle more broadly speaking. The impact of regulatory interventions in supporting the societally beneficial outcomes, and consequently in solving the defined environmental problems, deserves careful analysis. The circular economy strategy of car sharing will need to be refined based on the evolutions observed along each of the three steps of the intervention theory.

III. Conclusion

The circular economy has gone mainstream as a normative framing in the transition toward a more sustainable society. Laws that are framed as promoting a "circular economy" may, however, fall short of defining in adequate detail what their precise environmental objectives are. Indeed, "a 'circular economy' is not the ultimate objective of any law or policy, but an intermediate means of achieving environmental objectives"[147] (as well as other benefits).

In this Article, we used classic intervention theory to clarify the discussion on "circular economy policies." We used intervention theories to showcase how, first, the ultimate environmental problems addressed by circular economy regulation need to be defined in adequate detail. Next, the problem definition is used to determine the societally preferred outcomes that are pursued with a circular economy strategy. In our example, the parameters under which car sharing as an access-based PSS is to be promoted need to be determined in sufficient detail against the environmental problem definition. On that basis, it is then possible to choose the most effective regulatory interventions to support reaching the outcomes.

Our analysis of car sharing showed how, in the first step, the problem definition, a circular economy approach adds the resource efficiency angle to the many earlier environmental problem definitions on transportation, such as congestion, air pollution, and GHG emissions. Resource efficiency in the narrow sense means that less virgin natural resources are used, which is an environmental benefit. Still, this problem definition of a circular economy approach must not be limited to avoiding the depletion of natural resources. The extraction of natural resources causes many environmental impacts, in particular GHG emissions and a loss of biodiversity. These impacts are often significant and need to be quantified and included in the problem definition of circular economy approaches.

However, the inclusion of these impacts in the problem definition is also not sufficient. Decisions on resource use have impacts across the entire life cycle. These impacts may be larger, in terms of, for example, GHG emissions, than those that concern the extraction phase. Thus, impacts across the full life cycle constitute the problem definition. By carefully considering resource use alongside GHG emissions and other life cycle-based environmental impacts of transportation, it is possible to identify the full range of impacts in the problem definition of a circular economy

142. Akyelken et al., *supra* note 43.
143. Bremen Senate Department for Environment, Construction, and Transport, Sustainable Urban Mobility Plan: Bremen 2025, at 35 (2014) (Ger.), https://www.bauumwelt.bremen.de/mobilitaet/veroeffentlichungen-98244.
144. Blue Angel, Car Sharing: Basic Award Criteria (2018), https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20100-201801-en-Criteria-V4.pdf.
145. Werner Antweiler & Sumeet Gulati, Frugal Cars or Frugal Drivers? How Carbon and Fuel Taxes Influence the Choice and Use of Cars (2016), http://www.ssrn.com/abstract=2778868; Potter, *supra* note 126.
146. Shiyu Yan & Gunnar S. Eskeland, *Greening the Vehicle Fleet: Norway's CO_2-Differentiated Registration Tax*, 91 J. Env't Econ. & Mgmt. 247 (2018).
147. Online Interview with Reid Lifset, Research Scholar, Yale School of the Environment (Dec. 4, 2020).

strategy—and to make explicit the important trade offs between them.

As for the second step of intervention theory, the determination of societally desired outcomes of car sharing, when correctly defined and implemented, addresses the identified problems. To be more specific, we found the societally desirable outcomes of car sharing to be to increase the utility and to reduce the material intensity of vehicles. Beyond targeting resource use, car sharing also enables reduced pollution and GHG emissions by lowering the VMT, by increasing the operational efficiency of vehicles, and by facilitating multimodal transport. Thus, a range of environmental impacts and the trade offs between them are considered. The exact type of car sharing thus represents the policymakers' careful value judgments in prioritizing the different desired environmental outcomes, considering context-specific factors of transportation.

The pathway to these societally desired outcomes can then, as the third step in applying the theory, be governed by targeted regulatory interventions. The interventions usually entail a combination of instruments to address all the different aspects of the problem definition for a societally desirable outcome. In car sharing, this means regulations that circumscribe the use of car sharing to address travel and vehicle demand and the environmental impacts of both the vehicles and fuel component. Interventions that promote such synergies and help in avoiding and solving environmental trade offs should be pursued as a matter of priority. Circular economy policy interventions that achieve this—for example, integrating car sharing in land use planning and zoning regulations—provide a viable alternative to not owning vehicles.

Other interventions include incentives to limit private cars and increase occupancy in vehicles, such as priority lanes and parking. While these rules support resource efficiency, they also promote GHG emission reductions. Regulating the use of car sharing illustrates the importance of being attentive to multiple environmental impacts. This includes promoting car sharing as part of multimodal transport structures that include even more resource-efficient and climate-friendly modes such as walking, biking, and public transit. Rebound effects, such as increased travel due to greater accessibility of car-sharing options, can be addressed with regulatory interventions that increase in general the cost of using cars (e.g., fuel duties and road charges).

In contexts where car-based travel is the most feasible mode of traveling, regulatory interventions can help in reducing the impacts of the car-sharing fleet by requiring the use of smaller vehicles and low-emission technologies. Finally, the societally desired outcomes tend to involve prioritizing certain environmental outcomes over others. As these priorities will likely evolve, it is important to design the regulatory interventions in transportation in ways that avoid path dependencies, are technologically neutral, and allow for corrective measures and novel solutions.

Circular economy strategies can create societal value. Our three-step intervention theory approach on the PSS of car sharing demonstrates that a circular economy is not the ultimate objective in itself. A circular economy is a means to environmental sustainability. It must adopt a detailed yet broad definition of the targeted environmental problems. Lawmakers are then able to exercise their judgment on the desired societal outcomes on the basis of a proper analysis of the trade offs among the various environmental impacts. Consequently, a flexible mix of regulatory interventions can be developed to support the specified environmentally sustainable circular economy strategy.