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Towards a more direct policy feedback in circular economy monitoring via a societal needs perspective

Luc Alaerts[a,*], Karel Van Acker[a,b], Sandra Rousseau[b], Simon De Jaeger[b], Gustavo Moraga[c], Jo Dewulf[c], Steven De Meester[d], Steven Van Passel[e], Tine Compernolle[f], Kris Bachus[g], Karl Vrancken[h,i], Johan Eyckmans[b]

[a] Sustainability Assessments of Material Life Cycles, Department of Materials Engineering, KU Leuven, Kasteelpark Arenberg 44, 3001, Leuven, Belgium
[b] Center for Economics and Corporate Sustainability (CEDON), KU Leuven, Warmoesberg 26, 1000, Brussels, Belgium
[c] Department of Green Chemistry and Technology, Ghent University, Coupure Links 653, 9000, Gent, Belgium
[d] Department of Industrial Biological Sciences, Ghent University, Graaf Karel de Goedelaan 5, 8500, Kortrijk, Belgium
[e] Department of Engineering Management, University of Antwerp, Prinsstraat 13, 2000, Antwerp, Belgium
[f] Department of Economics, University of Antwerp, Prinsstraat 13, 2000, Antwerp, Belgium
[g] Research Group Sustainable Development, HIVA, KU Leuven, Parkstraat 47 bus 5300, 3000, Leuven, Belgium
[h] VITO - Flemish Institute for Technological Research, Boeretang 200, 2400, Mol, Belgium
[i] Department of Bio-Engineering, University of Antwerp, Groenenborgerlaan 171, 2020, Antwerp, Belgium

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ABSTRACT

The increasing focus on circular economy at the level of governments and policy requires the development of appropriate indicators to effectively monitor the progress towards the circular economy. Currently two very different types of indicator areas are under development: (i) monitoring frameworks based on macro indicators that summarize the progress at (supra)national level, and (ii) micro indicators tailored towards assessing circularity at the level of products. It is not possible to obtain sufficiently direct feedback about the impact of policy interventions by either macro or micro indicators alone. In this paper, a conceptual approach is developed that aims to bridge the gap between the micro and macro level with meso level indicators, and thus ultimately deliver more direct feedback for policymakers, via the insertion of an extra level of meso indicators in between the macro and the micro level. These indicators have been extracted from a dedicated workshop that involved policy, sector and societal stakeholders. The aim of these indicators is to report on progress towards circular economy objectives based on the fulfillment of societal needs. In this way the consumption perspective is given a central position, and the role of circular business models is acknowledged. Following the development of the concept, the next steps towards tailored, flexible and agile monitoring frameworks for circular economy at (supra)national and regional level are outlined. The paper concludes with an illustrative example of the framework applied to the mobility system.

1. Introduction

In recent years the term “circular economy” has gained momentum in the context of sustainable development and as a new focus for policy and business development. For instance circular economy can be understood to align with a number of the UN’s Sustainable Development Goals (Schroeder et al., 2018), and many action plans for circular economy and reports on the potential of circular economy for business have been published (McKinsey, 2015; European Commission, 2015; Dutch government, 2018). There is no clear boundary around the circular economy concept, as shown by the lack of a clear and unified definition (Kirchherr et al., 2017) and the use of the term ‘umbrella concept’ by a number of authors (Blomsma and Brennan, 2017; Homrich et al., 2018; Moraga et al., 2019). In essence, circular economy is about maintaining products and materials at their highest application level – coming down to the set of efforts to take care of the stocks of materials – while minimizing their environmental impact (European Commission, 2014). In the broadest sense possible, circular economy is to be seen as a societal transition, in which the circulation of materials eventually contributes to economic, environmental and societal benefits (Reichel et al., 2016). Recently, the challenge for the current economy has been to stay within a safe and just zone, with upper

* Corresponding author.
E-mail address: luc.alaerts@kuleuven.be (L. Alaerts).

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boundaries at the planetary ecosystem level and lower boundaries at the societal level (Steffen et al., 2015; Raworth, 2017). As circular economy has clear links with e.g. waste management, supply of critical materials, technological innovations, labor, water, food, buildings etc., the potential outcomes are evident in this context. For instance, the availability of particular metals may become threatening for the development of technologies that determine current standards of living (Du and Graedel, 2013; Nassar et al., 2015). Also, the role of circular economy in preventing runaway climate change has been recognized (Material Economics, 2018).

In order to make sure that the circular economy is really delivering such outcomes, guidance is clearly needed. In this respect the availability of monitoring frameworks is crucial. In their absence, there is a risk that an economy which is more circular displays a poor environmental and/or societal performance, despite a lot of well-intentioned actions and statements. The main objective of a monitoring framework is to serve governments at the (supra)national, regional or city level, in order to evaluate the impact of circular economy policy interventions and to determine the actions to be taken to steer the economy (Reichel et al., 2016). For that purpose a monitoring framework should be able to account for progress and deliver feedback to strategy and planning development. In addition, it should ideally be able to make the different actors recognize their possible roles in contributing to circular economy. Moreover, the broader effects at the level of the economy, environment and society should also be made visible.

Considering the monitoring frameworks that have already been launched at the Chinese, French, Dutch and EU levels (Geng et al., 2012; Magnier et al., 2017; Potting et al., 2018; European Commission, 2018), the question is to which extent these are already delivering on the above objectives. All frameworks hold collections of macro indicators on materials, waste and recycling, for example Direct Material Consumption (DMC), generation of municipal or other waste, recycling rates of different material flows, and derivatives of such scores. At the basis of this are datasets that are available from a long-standing previous policy focus on waste and resources. At the European level this is, for instance, evident in the previously published Waste Framework Directive, the Resource Efficiency Scoreboard and the Raw Materials Scoreboard (European Commission, 2018). These collections of macro indicators allow an assessment of a number of aspects of circularity and of the effects on a society-wide level. They will, however, fail to deliver significant information on the shorter term. Only when the circular economy has reached a sufficiently large size to affect a considerable part of the economy will the scores of these macro indicators start to allow a first reflection on the transition. Also, the underlying datasets generally used for macro indicators are sometimes updated late and infrequently, especially for the ones based on input-output data, and thus, feedback to policy will not be delivered in the period in which the circular economy is emerging and in which steering would be most desirable (Potting et al., 2018). Furthermore, these macro indicators on materials, waste and recycling often provide very aggregated data. The available monitoring frameworks also display a few indicators focusing on other aspects, but these do not compensate for this time-lag issue. For instance, in the French and the EU framework, broader aspects like employment and innovation were included (Magnier et al., 2017; European Commission, 2018) and in the Chinese framework a focus on so-called eco-industrial parks was included in order to reflect a particular important development from the perspective of an economy with a rapidly developing industrial sector (Geng et al., 2012). Two indicators in the French framework might have potential to give a more direct feedback: household spending on maintenance and repair, and car-sharing. However, the data underlying the indicator scores can be improved, as the former indicator is strongly biased by the majority of spending that is connected to common private car maintenance and the latter is only based on a basic and limited survey.

In literature several examples can be found where meso and/or micro indicators have been included in monitoring frameworks to overcome the disadvantages of macro indicators described above. In the context of circular economy, Moriguchi (2007) has pointed out that in order to measure progress towards circular economy, indicators on the performance of microeconomic contributors are needed to incorporate, for instance, companies and consumers as actors. Giljum et al. (2001) have presented a comprehensive set of indicators from the micro to the macro level with the argument that such a set allows a tailored approach towards different types of resources and hence makes it suitable for policy-oriented application. More recently, Potting et al. (2018) have described the integration of scores of micro indicators as a possible avenue towards more direct feedback for policy. In a broader context, Noss (1990) has described the added value of a monitoring framework on biodiversity consisting of four levels ranging from individual species to regional landscape as a way to link specific projects at a small scale to long-term developments at a large scale. In the domain of monitoring agrosystem health, Peterson et al. (2017) have proposed the inclusion of indicators that can report on product-based measures in order to create a more direct link between actions and environmental outcomes.

Already a lot of indicators, methods and tools have been developed to measure circularity at the micro level (Di Maio and Rem, 2015; EMF, 2015; Linder et al., 2017; Saidani et al., 2017; Niero and Kalbar, 2019). However, in none of these contributions linkages with macro indicators or a more policy-oriented application are explored. At the level of macro indicators for circular economy, efforts to connect to or include micro indicators do not appear in current research (Moriguchi, 2007; Smol et al., 2017; Mayer et al., 2018; de Wit et al., 2018; Jacobi et al., 2018; García-Barragán et al., 2019). This suggests the existence of two separate domains that focus either on macro or on micro indicators for circular economy without much initiatives to create linkages. In this paper, a conceptual approach is presented to build a connection between the macro level pertaining to countries and regions, and the micro level pertaining to products and services. In this way the development of monitoring frameworks tailored for circular economy will be enhanced by providing an avenue for more direct feedback to policy.

2. Materials and methods

First a consultation of the available literature was performed in order to screen for gaps in the current monitoring frameworks of circular economy and to discover possible solutions. In this process, different sources of knowledge were combined. Next to the academic body of literature on this topic, sources from outside academia have been extensively consulted (a large amount of conceptual work is done by non-academic actors, due to the high knowledge need (Alaerts et al., 2018)). The output of this can be retrieved in elaborated reports published e.g. by policy departments with a particular focus on monitoring and/or on circular economy, or by consultancy companies. The reports found most relevant in this consultation are listed in the references section (Magnier et al., 2017; Potting et al., 2017; de Wit et al., 2018; European Commission, 2018; Material Economics, 2018; Potting et al., 2018; Vercalsteren et al., 2018).

The process of building a concept for a circular economy monitor was initiated in a team of academic experts. They have been joined in a policy research center funded by the Flemish government with the aim to provide guidance in enabling the circular economy transition and to develop a circular economy monitor for Flanders. The experts have extensive track records in the fields of materials and resource management, environmental economics, system analysis and policy research. After an initial brainstorm session, two dedicated workshops were organized with a focus on the gaps and leads of the previous discussion and on finally converging towards a first concept for monitoring.

Next, this proposal was used as a basis to start discussions with policy stakeholders at an individual basis. More specifically, these stakeholders were 14 policy officers from the Flemish administration (the advisory council on environment, the departments on economy, science

and innovation and on environment, the waste agency and the transition team Circular Flanders) and two from the Netherlands Environmental Assessment Agency.

Eventually, after incorporating the feedback, the reworked concept was approved in a dedicated workshop with an audience of 34 policy, sector and societal stakeholders of Flanders. The aim of the workshop was to assess whether the concept was acceptable, useful and practically workable. In this workshop, a presentation of the concept for circular economy monitoring was followed by an extended plenary discussion to allow for questions and further clarifications. Then, the participants were divided into six subgroups. With the help of facilitators they were invited to reflect and discuss in three sessions of 30 min each on the stepwise practical filling up of the monitor with indicators. In the first session, the participants had to come up with suggestions of what could be the most prominent systems to fulfill societal needs and why. In the second session, the participants had to focus on one of three systems: mobility, housing or nutrition. They were invited to reflect on future trends in the specific system focusing on evolutions towards a business-as-usual scenario and an idealized circular economy scenario. The final session was dedicated to determining what should be measured to monitor the transition to circular economy in the specific system, how this could be done, where data could be obtained and what could be the products and services to focus on. The detailed output of these discussion sessions is available as supplementary information to this paper. After the workshop, the concept for circular economy monitoring was improved with the feedback and input of the stakeholders. The final result has been summarized in the current paper, and the most tangible extracts of the outputs of the discussion sessions have been used to present a tentative proposal of indicators for mobility to be used in the monitoring framework.

3. Results and discussion

In the first part of this section, the perspective of functions starting from the level of products and services will be discussed. Next, the perspective of fulfillment of societal needs as the bridge between the micro and the macro level in circular economy monitoring will be presented. Finally, an elaboration is provided of how meso indicators to monitor circular economy achievements could be developed from the perspective of fulfillment of needs with the particular example of mobility, in order to demonstrate the added value of this approach.

3.1. From a product/service perspective towards a function perspective

When dealing with the level of products and services in the context of circular economy (called the micro level in this paper), it is essential to consider that many products exist in combination with services: both terms are commonly understood as an economic good. There is a whole range of possible combinations between pure products and pure services (Tukker and Tischner, 2006). As an example, consider a product like a privately owned car with a limited service in a maintenance contract. The service of a car can alternatively be offered via a sharing platform: there is still a car involved as the product, but the service aspects are much more prominent. It is relatively straightforward how the central idea of taking care of materials and products in the circular economy can take shape at the micro level, e.g. by an adjusted design of products, a maximized utilization, or efforts to keep up performance or optimal feeding into subsequent material cycles when the End-of-Life stage has been reached (Potting et al., 2017). Overviews of options and possibilities have been published in lists of so-called R-strategies (Kirchherr et al., 2017; Reike et al., 2017; Potting et al., 2017). In the extended list published by the Netherlands Environmental Assessment Agency (Potting et al., 2017; Potting et al., 2018), all definitions of R-strategies have been phrased in terms of the functions to be fulfilled by products and services, with the explicit purpose of stimulating a sufficiently broad perspective when considering circular economy at the products and services level, in order to achieve the highest environmental benefit. In the example of a car, considering it in a circular economy context could in the first instance generate ideas on recyclability of the car components, or on circulation of second-hand cars or car parts. However, only by considering the fact that a car provides access to mobility (the function), also higher strategies will come into consideration, like the use of cars in a circular business model like car-sharing. This is an option with the potential of fulfilling the same function with less cars compared to a situation with only privately owned and used cars. In this way, less resources will be consumed and the realized benefit is larger, at least in absence of strong rebound effects.

This example also shows that by taking this broader perspective, a clear consideration of the potential of circular business models is provided, an element often overlooked in the context of circular economy monitoring (Reichel et al., 2016; Kirchherr et al., 2017). A similar broadening has recently been elaborated in a report demonstrating the potential of circular economy for climate mitigation (Material Economics, 2018). Overall, by taking the perspective of functions, a full view is provided on all the elements relevant at the products and services level: function fulfillment, product design and engineering, and production and disposal of materials (Fig. 1). In this way the effects of factors affecting these elements become fully visible. One factor is innovation: in the context of circular economy it can take place not only at the level of product design and engineering (e.g. material selection, options for repairability) but also at the level of the business model, i.e. the way products are produced or consumed in order to fulfill a function in such a way that a viable business exists. Similarly, policies in the context of circular economy can affect how products are designed, produced, treated at End-of-Life etc., but also the boundaries and

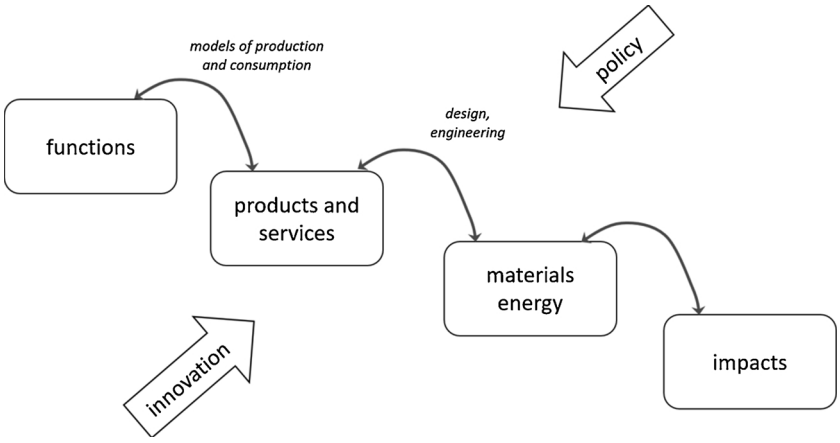

Fig. 1. The function perspective at the micro level of circular economy monitoring. Products and services are fulfilling functions, arranged via models of production and consumption. The creation and the use of products and services requires materials and energy from the production till the End-of-Life phase, and this leads to impacts. Policy measures and innovation can affect the different elements in this figure.

bottlenecks encountered when creating novel ways of doing business (Potting et al., 2017). Of course, policies and innovations based on other motivations are also important, like the effects of company decisions in other contexts or the success of marketing campaigns.

By clearly addressing functions, a gap in the coverage of current micro indicators is revealed. A recent analysis showed that among the published micro indicators in the context of circular economy there are no examples where the idea of a function has been elaborated in an indicator, although the term functions is being touched upon in a few instances (Moraga et al., 2019). This is not surprising, as when an analysis starts from a function perspective, there are several ways to fulfill a function, and multiple products, services and business models will have to be considered in parallel. This goes beyond the typical scope of micro indicators. Hence, functions can also be seen as an element to make the connection with a higher level of monitoring. Section 3.2 will present how this could take shape.

3.2. Fulfillment of societal needs: a perspective to bridge the gap between measuring circular economy at the micro and the macro level

In the literature on circular economy measurement, a meso level is occasionally addressed (Ghisellini et al., 2016; Potting et al., 2018), but this is much less well defined, in contrast to the terms macro and micro which are well known from economics. Up to now these examples of proposed intermediate level indicators should be considered as mere extensions of either the micro or the macro level that provide additional insight, but not as bridges between the macro and the micro level. For instance, in the Chinese monitoring framework, a separate part has been reserved for so-called eco-industrial parks, which is a particular element in China's development as a country with a rapidly growing industrial sector (Geng et al., 2012). The focus here is on the interaction between companies but as such this connects to the micro level. As another example, in the Dutch monitoring framework, the scores of the macro indicators have been disaggregated to five key sectors, in order to align with the sectoral agreements for the transition to circular economy made by the Dutch government (Potting et al., 2018). This kind of top-down disaggregation from the macro level is not ideal for circular economy monitoring, as the circular economy transition is expected to have a clear cross-sectoral impact and this is not adequately reflected with a disaggregation to the sector level. In a similar example of monitoring resource consumption by disaggregation from the macro level, an interesting approach was followed by displaying material consumption based on what the authors call key societal needs (de Wit et al., 2018). While providing a connection to the micro level was not in the scope of the work, the applied terminology provides an interesting lead of how a bridge between the macro and the micro level could be realized by mentioning societal needs in a context of the use of materials.

As there is a clear connection with the idea of functions fulfilled by products and services explained in Section 3.1, this fulfillment of needs concept was further elaborated into a perspective for circular economy monitoring at the meso level. The identification and ranking of needs is a scientific discipline on its own, starting with the famous pyramid of Maslow (Maslow, 1954). Some fundamental discussions in this field are on the existence of a hierarchy of needs, and on the question of whether needs are unchangeable or rather depending on time and culture (Maslow, 1954; Max-Neef, 1992). An interesting approach was found in the ideas of Max-Neef, who makes a clear division between needs and satisfaction of those needs. This satisfaction, or fulfillment, changes over time and cultures, and is empowered by economic goods. As the circular economy transition is about a reconsideration of the common ways in which products and materials are dealt with, the theory of Max-Neef suggests that fulfillment of needs by products and services is an ideal perspective to make the bridge to the macro level. Indeed, in a general way, the economy can be defined as a way to fulfill needs.

A meso level in circular economy monitoring frameworks can hence be realized using indicators that report circular economy achievements in systems that fulfill societal needs. In this way, there will be more insight at the macro level, as in order for each system to fulfill needs, different strategies will be necessary to accelerate the transition towards a more circular economy (de Wit et al., 2018). This also has implications for consumption, as the relation between economic goods, fulfillment of societal needs and the needs themselves especially pertains to the way how consumption is organized (Max-Neef, 1992). A connection can then be made to existing consumption-based data available at the macro level for circular economy monitoring. The connection to the micro level can be made by using indicators that reflect on how products and services are fulfilling needs. In this way it will be possible to see more clearly how changes in specific products and services in the long run affect the economy as a whole. In sections 3.3 and 3.4 this will be elaborated more in practice.

3.3. Using meso indicators to monitor systems fulfilling needs

A first question is how to define a suitable set of systems fulfilling needs with the purpose of circular economy monitoring. Potential sets were found in one publication on circular economy and three on sustainable consumption (de Wit et al., 2018; Hertwich, 2003; OECD, 2018; Notarnicola et al., 2017). In each of these publications a set of elements has been presented as a pragmatic way to summarize overall impacts on materials and/or environment (Table 1). These elements are considered as candidates for systems to fulfill needs serving as the background for meso indicators in circular economy monitoring.

In Table 1 the elements have been listed such that similar terms have been positioned next to each other as much as possible. In this way the striking similarities between the four retrieved lists of elements become apparent, although the motivations for the selections come from different perspectives. The most detailed motivation is the perspective of systems to fulfill societal needs introduced before (de Wit et al., 2018): the driver for the elaboration was that, depending on the system, different strategies will be needed. This points to an advantage for policy makers as some systems can be more or less directly related to policy domains, and therefore, the monitor is adaptable to local policy structures. Next in Table 1, there is the perspective of products and services delivering components of lifestyles (Hertwich, 2003), which comes close to needs and satisfiers (Max-Neef, 1992), and it illustrates

Table 1
Overview of elements found in literature used for capturing material or environmental impacts of the economy.

Reference	de Wit et al., 2018	Hertwich, 2003	OECD, 2018	Notarnicola et al., 2017
Terminology	Systems to fulfill societal needs	Life functions	Drivers for consumption	Key consumption areas
Elements	housing	housing	home	housing
	mobility	mobility	transport	mobility
	nutrition	nutrition	food	food
	consumables	clothing	goods	household goods
	services	leisure	leisure	electr(on)ic appliances
	healthcare	health		
	communication			

that a consumption perspective has been chosen. The third perspective in Table 1 aims to identify the elements to provide an extra layer of insight in the context of a low-carbon transition (OECD, 2018). This source does not mention circular economy as a term, but the link between material use and environmental impact has been explicitly mentioned in the role of extraction and production and the associated impacts. Lastly, with the basket of products indicators the idea is to obtain a composite score per consumption area on footprints (Notarnicola et al., 2017). In this way a possible set of meso indicators is constructed from the bottom-up by aggregating information from a selection of economic goods.

The many overlaps in Table 1 suggest that it should not be too difficult to agree on a preliminary set of systems to fulfill needs. For instance, the systems housing, mobility and nutrition are listed in all four sources and together they can be expected to take a substantial part of material consumption. On a global level, the share of the associated material demand has been estimated at 90% (de Wit et al., 2018). These three systems were also highly prominent in the discussions in the stakeholder workshop. With respect to the selection of additional systems, complete coverage of material use and environmental impacts is probably not feasible and should not be strived for – the question is which set of systems would allow to meet the purposes of monitoring sufficiently by capturing substantial evidence of the circular economy transition.

A monitoring framework elaborated with a distinct meso level is presented in Fig. 2. In the centre of the figure are a collection of meso indicators that represent the material and environmental realities of the fulfillment of societal needs. At the macro level, in the upper part of Fig. 2, indicators focusing on the society-wide effects and results of the circular economy could appear. The Netherlands Environmental Assessment Agency has provided valuable suggestions of existing indicators reporting on outputs and outcomes (Potting et al., 2018). As indicated before, consumption-based macro indicators are indispensable in this proposal, as the scores of the meso indicators can be directly linked to them and provide deeper insight. Clear examples are the Direct and Raw Material Consumption (RMC) and carbon footprint indicators; these could be further disaggregated in different consumption domains. At the micro level, circularity scores of products and services should be linked to indicators at the meso level. Zooming out from this part of Fig. 2 would result in Fig. 1, and thus the fulfillment of needs can be further displayed in a set of specific products and services. The other way around, it will also be clear how and when innovations and policies pertaining to circular economy will influence the material and environmental realities of fulfillment of needs. In fact, some products and services may be linked to more than one system. The aim is not to aggregate data from this level, but rather to indicate how the needs fulfillment perspective can be used to construct a set of products and services that are together relevant for the circular economy transition at the micro level.

3.4. Tentative monitoring of circular economy monitoring in the system mobility

To provide a tentative example on how this could work in practice, an elaboration of a monitor of mobility is presented in this section. First, a number of questions and proposals for answers using meso indicator scores has been provided (Table 2). This table contains the processed output of the workshop sessions that focused on mobility (see supplementary information). The choice of this system was made since the results of the respective sessions were the most tangible with respect to coming to proposals of indicators.

In order to measure the circular economy achievements in mobility, a first question is how to measure mobility. This could be done for instance by listing all kilometers traveled, in total and split per modus and/or other aspects, like persons vs. freight. It is important to take these absolute numbers as a start, in order to see evolutions in circular mobility relative to evolutions in overall mobility, otherwise there is a risk that the monitor is not picking up the benefits of circular mobility in case overall mobility increases.

In a next step, the amounts and kinds of vehicles used to deliver this mobility can be monitored. The occurrence of circular business models in mobility will become apparent via such indicators. If for instance car-sharing grows into a more common practice, the amount of vehicles is expected to decrease relatively compared to the amount of passenger kilometers. It will also be possible to monitor modal shifts, for instance, in the case that increased car-sharing leads to a decreased use of public transport (Becker et al., 2017). In this way, system dynamics will be captured to a certain extent. Some additional ways of measuring circular mobility could be delivered by monitoring the degree of occupation of cars, or alternatively the mileage of cars at End-of-Life, as the expectation is that car-sharing will in the longer run stimulate an increase of this (Material Economics, 2018). With respect to freight transport, the amount of empty space in trucks could be monitored.

Then, indicators should be developed that go into more detail on the materials needed for the production, use and End-of-Life phases. In connection to this, the environmental impacts should also be

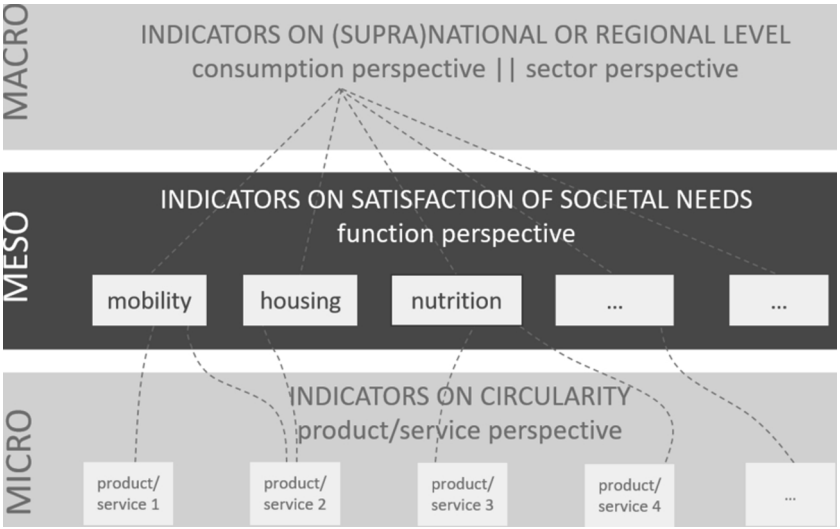

Fig. 2. Proposed outline of an intermediate level to appear in a circular economy monitor in order to provide the bridge between the micro and the macro level, illustrated with dashed lines.

Table 2
Leads for meso indicator development for mobility as a system to fulfill needs.

Questions and proposals for monitoring	Possible indicators or data
How does the need fulfillment evolve?	
- total distances traveled	number of passenger kilometers per year, in total, and split per modus
How is the fulfillment delivered by materials?	
- stocks of all kinds of vehicles	numbers of vehicles in use (per passenger km)
- use intensity of vehicles	average kilometers reached at End-of-Life
- use efficiency of vehicles	degree of occupation, filling ratios
- End-of-Life cars leaking from the stock	amount and kind of recycling
- materials used in production of vehicles	tonnes of metals, plastics in cars
- materials used in the use of vehicles	replacement of tires and oil during maintenance
- End-of-Life: recyclability of materials	theoretical ability to recycle or reuse components
- energy consumption	tonnes of fuels sold
Which environmental impacts are caused?	
- production of vehicle materials	process data
- use of vehicles	numbers of cars per fuel type, per EURO norm; CO_2, NO_x, particulate matter (in passenger km)
- End-of-Life of vehicles	process data

monitored. An important part of this connects to fuel consumption. Impacts could be monitored for instance by monitoring engine types in the current stock-in-use of vehicles (if data allow this, down to the level of environmental performance, e.g. indicated by engine norms), by the exhaust gases produced and/or by the amounts of fuel consumed. With respect to production and End-of-Life, more detailed process data will be required. This part of the monitor will be especially useful to reflect the roles played and the efforts delivered by business actors producing the products and services.

It will not be feasible to provide an exhaustive monitoring for all kinds of transportation means down to the level of materials, effects and impacts. As explained above, a direct bottom-up aggregation from the micro level is not strived for. The idea is to focus on one or a few representative products and services that carry a relatively large share of the material demands, effects and impacts per system to be monitored more closely. Here it will be possible to make the link with data typically obtained via micro indicators monitoring circularity on a product and service level. With additional systems to fulfill needs to be included in circular economy monitoring, eventually a representative set of products and services should be composed at the micro level. It will, itself, display a set of scores on materials and impacts, and via the links with one or more systems, the eventual materialization of the transition towards circular economy will be made visible.

With this approach, it is clear that disaggregation will be necessary to avoid errors. The modal split is one example, and this has been included in Table 2 already to some extent. Other disaggregations could be based on demand category (commuting, leisure, shopping etc.) or on the subject of mobility (people vs. freight). Also, a number of forces that may work in opposite directions become apparent, e.g. the balance between lifetime extension and environmental performance (keeping current cars with a lower environmental performance in use longer, at the expense of slowing down the introduction of cars with a better performance), or between material and energy efficiency (recyclable vs. lightweight materials). Another issue is the scope of the monitor: the perspective of the needs fulfillment perspective is consumption-based, but for instance, looking to a typical European country, a lot of exhaust from traffic comes from foreign-based vehicles. Also, with respect to End-of-Life, there can be different options inside or outside the territory, e.g. exporting to countries where recycling by hand can be organized in cheap, efficient but not necessarily desirable ways (with respect to safety, health and environment) vs. local shredding and recovering of the materials to the extent that the obtained quality allows – which is another example of opposite forces. Furthermore, spillovers between systems will occur, for instance decreased mobility due to increased teleworking will increase materials and impacts related to energy consumption (Nakanishi, 2015). While the monitor should not provide solutions to these kinds of issues, it is important that the scores are shown that allow the assessment of such issues.

In order to assess the feasibility of this approach, a search was performed in the mobility data openly available at the level of Flanders via websites of the respective administrations and sector organizations (see supplementary information). Next, a set of preliminary indicators was created from these data (Fig. 3). Because the most extensive data were retrieved on private and company cars, the displayed indicators only focus on these vehicles for now.

In the upper part of Fig. 3, two lead meso indicators are featuring: the total amount of person-kilometers driven in Flanders by car, and the stock of cars owned in Flanders, shown per year. Overall, the amount of person-kilometers is fluctuating around 60 billion kilometers, without a clear trend. The car stock has been steadily increasing, with ca. 250 000 additional cars in 2016 compared to 2010. In the middle of Fig. 3, two meso indicators further illustrate the use efficiency of cars. The average amount of kilometers yearly driven per car is between 13,250 and 13500 kilometers. These numbers have been obtained by dividing the total amount of car-kilometers by the total amount of cars. Next, the average amount of persons per car was calculated by dividing the amount of person-kilometers by the amount of car-kilometers, resulting in scores between 1.29 and 1.38. Any trends are difficult to discern due to the low amounts of data points. At the bottom of Fig. 3, data about End-of-Life cars are presented. The total amount of cars recycled in official centres was ca. 85,000 in 2010 and decreased to around 60,000 in more recent years. The percentage of materials reused and recycled in these centres has increased from 88 to 93 mass percent over this period. Summarizing this first illustration of how the monitor could work, the general impression is that while the personal mobility need was relatively constant over the past few years, this need was delivered by increasing amounts of cars that were not used more intensively and in which not more persons are traveling. Moreover, the local recycling of End-of-Life cars decreased, but the applied technologies clearly gained in efficiency. Overall, the observations in these tentative and preliminary set of indicators do not suggest a more general trend towards more circular economy in mobility, except for the aspect of application of recycling technologies.

Comparing this for instance with the scores of typical macro indicators obtained from input-output data on transport (for instance DMC, RMC or carbon footprint disaggregated for the consumption domain mobility), it becomes clear how a more direct policy feedback is obtained here: the data presented in Fig. 3 are available yearly, and updates are published much sooner after closing of the year compared to input-output data. With respect to the further development of this monitor, a number of points of attention have to be revealed. In order to have a more complete and more nuanced view, more and more detailed data will be needed. A first step is to check with the administrations and federations themselves, as they probably have more data available than

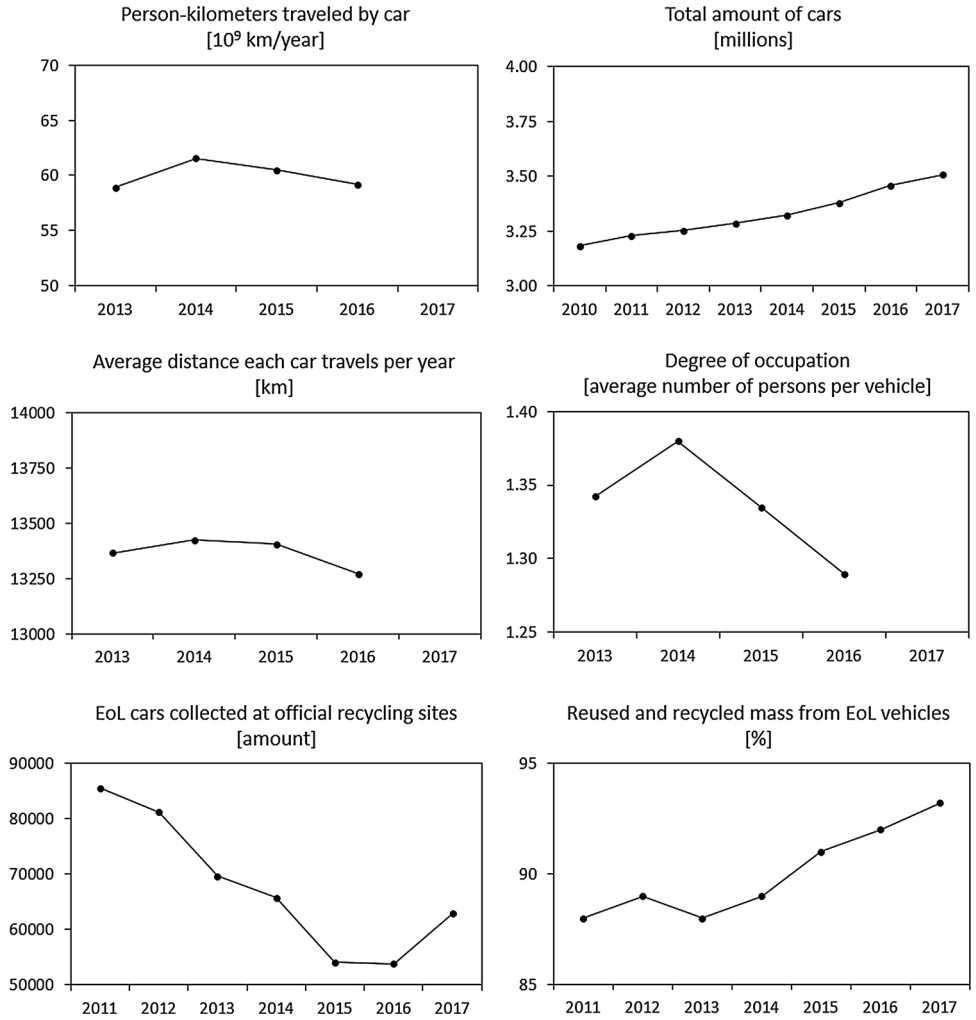

Fig. 3. Preliminary indicator scores to monitor circular economy in the system mobility in Flanders between 2010 and 2017 (EoL = End-of-Life; raw data available as supplementary information).

those appearing in online reports. For instance, to monitor the use efficiency of cars, the better measurement would be the mileage of cars reached at End-of-Life. Such data are typically recorded in the obligatory inspections and registrations and could perhaps become accessible for the monitor with additional efforts. With respect to the collection of End-of-Life vehicles, data on export should be further added in order to give a more comprehensive view. The data on car recycling efficiency in Fig. 3 directly show the added value of making the link to the micro level as these data are the aggregated outputs of the recycling processes of companies. By including more micro data, technology and market innovations and policy interventions, operating at smaller scales, can be captured. This could be delivered for instance by scores on car-sharing, recyclability of materials used in cars and environmental scores of the production processes – providing a direct feedback on the initial phase of the circular economy transition. This would be especially relevant in the context of the emergence of electrical vehicles. Collaborations with production companies will be indispensable for having accurate data. Besides, the link with environmental impacts could next be provided by additional data pertaining to the use phase (types of cars, fuel efficiency, exhaust data) and the production and the End-of-Life phases (process data). Finally, in order to better understand the accuracies and sensitivities in these data, a careful investigation into the sources and methodologies that have been used to compile the data needs to be carried out. All of the above aspects will have to be considered in the future development of the monitor.

4. Conclusion

Up to present, there seem to be two different and unconnected ways of circular economy monitoring. Monitoring at (supra)national or regional level seems to be restricted to macro indicators only, and micro indicators are providing scores on products throughout their life cycle. In this paper an approach has been proposed to improve the current ways of monitoring of circular economy. It is based on the introduction of meso indicators measuring circular economy achievements and effects at the level of fulfillment of societal needs. This proposal has been based on leads found in the literature on circular economy and on sustainability. It has been approved by a diverse set of academic experts, policy makers and stakeholders. The main advantage of including such meso indicators in the monitoring at (supra)national or regional level is the more direct feedback received. The exemplary elaboration for mobility as a system to fulfill societal needs demonstrates how indicators can capture circular economy in overall mobility, vehicles, associated materials and impacts. In this way, the impact of policies and innovations in the context of the circular economy transition will be directly visible in the monitor, and in addition, the way the initial changes at the product and service level affect the economy at a broader level will be clear. Moreover, data updates will be much faster compared to current macro level monitoring based on input-output data. In this respect the two major implications for policy makers are providing them with a tool that allows a more direct policy feedback and therefore the ability to steer policy, and guidelines to further develop what is

needed for evidence-based policy making in terms of data. Additionally, the needs fulfillment approach brings to the front the consumption perspective in the circular economy transition, appropriately reflecting its cross-sectoral nature, and explicitly addresses the role of circular business models. These two indispensable aspects for circular economy monitoring have up to now not been appearing in monitoring frameworks.

The idea to develop meso indicators based on systems to fulfill societal needs is expected to foster current initiatives at the level of countries, regions and cities on circular economy monitoring, as there is to a certain extent alignment between these systems and policy domains. As such this way of monitoring highlights the effects of different strategies in the circular economy transition. Upon the elaboration of such a monitoring framework with indicators, further creation and management of data will be crucial in order to continue to tailor and adapt the monitor. The needs fulfillment perspective allows the necessary freedom and flexibility to incorporate new data in a way that the resulting information on the progress towards circular economy will be appropriately displayed. An example of an aspect to be included when data will be available is the quality of the stocks of materials in use.

Finally, the connection between the developed framework and the more general sustainability strategies that are running today is clearly there. If the circular economy transition will be successful, then it will lead to a lower material use and environmental impact via a more efficient use of materials and products, and the monitor will reflect this. But with respect to sustainability, the overall challenge of living well within planetary and societal boundaries is so stringent that it cannot be ignored. While it may be ambitious to cover these more absolute boundaries centrally in a circular economy monitor, indicators that show the absolute amounts of material consumption and the impacts caused by the current way of living prepare the way for a comparison with the planetary boundaries, which are ultimately measured in absolute terms. In this way circular economy is to be seen as a set of strategies allowing smoother fulfillment of needs with lower amounts of materials being consumed, and lower impacts. In this sense the presented proposal is future-oriented, in contrast to monitoring frameworks featuring relative indicators that neglect to take into account such profound impacts on planet and society and that are therefore not appropriate as a compass for desirable societal evolutions.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at https://doi.org/10.1016/j.resconrec.2019.06.004.

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