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PavementLCM

6.1 LCM and Circular Economy: New challenges and Approaches, and

6.2 European NRAs and Circular Economy

6.3 Circular models to favor the uptake of green asphalts

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Authors of the deliverables 6.1 and 6.2:

Konstantinos Mantalovas, University of Palermo, Italy

Tony Parry, University of Nottingham

Elisabeth Keijzer, TNO, The Netherlands

Davide Lo Presti, University of Nottingham, University of Palermo

Gaetano Di Mino, University of Palermo

Author of the deliverable 6.3:

Konstantinos Mantalovas, University of Palermo, Italy

Deliverables 6.1 and 6.2, Author Contributions: Conceptualization, D.L.P., K.M., G.D.M., Methodology, K.M.; Validation, K.M.; Formal Analysis, K.M.; Investigation, K.M.; Data Curation, K.M.; Writing—Original Draft Preparation, K.M., Writing—Review and Editing, K.M., G.D.M., D.L.P., E.K., T.P.; Visualization, K.M.; Supervision, T.P., D.L.P. and G.D.M.; Project administration, D.L.P. and G.D.M.; Funding acquisition, D.L.P. and G.D.M.

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Executive Summary

The pavement engineering industry, having realised the significance of the impacts that imposes to the environment through the production, construction and management of their products and assets, has been driven towards transitioning to a more sustainable and circular way of operating. In other words, mostly sustainability and less frequently circularity indicators are being incorporating into the lifecycle management tools of different National Road Authorities (NRAs). However, not all of them seem to be adequately familiar with the aforementioned concepts. This is why the specific deliverable is trying to fortify the transition of the NRAs to a more circular way of doing business.

In ***Chapter 1***, the necessity of shifting towards circular economic models in the road engineering sector is being stated, along with the main questions that are addressed later on in the document; “Is there a plan of NRAs to implement the principles of Circular Economy (CE)?”; “What has been done so far to progress towards the execution of this plan?”; “How do NRAs implement then and communicate their implementation of CE and its principles?”

In ***Chapter 2***, the origins of the Circular Economy are thoroughly analysed by presenting the state-of-the-art on what actually Circular Economy is; and continuing by researching the meaning of CE in the context of transportation infrastructures and more specifically asphalt pavements, where 3 main directly applicable to the asphalt pavements principles of CE are defined. Some real-life practices and representative attempts towards CE in the asphalt paving industry are also presented.

Chapter 3 is focusing on the review of all the different documents that have been published by regional/national authorities within the “European Circular Economy Stakeholder Platform” (https://circulareconomy.europa.eu/platform/en/strategies?page=1). From the review of the latter, it could be deduced that there are no specific guidelines or even recommendations on how to implement circular economic principles tailored for the sector of road engineering; although generalised mentions about transportation infrastructures and asphalt recycling were detected within very few of the aforementioned published roadmaps towards CE, NRAs should invest in pushing towards the realisation of such guidelines.

Questionnaires covering the topic of CE, its principles, the level of its implementation and the limitations and challenges faced were distributed to 11 different NRAs. The results are summarised and tabulated, and findings are analysed in ***Chapter 4***. All the NRAs contacted are aware of the concept of CE and have at least minimum knowledge about what it is that it represents and seem to be familiar with the most commonly known and easily applicable principles of the CE. The most commonly applied practices that indicate the implementation of some of the CE principles are the removal of restrictions on asphalt recycling and the service life of the asphalt pavements extension, usually by means of preventive maintenance. It is

worth mentioning that although the concept of CE is not totally new as analysed in the introduction and hence, some of its characteristics have already been practiced for years by National Road Authorities. Aspects such as recycling, resource efficiency and utilization of waste materials in foundation layers are not new topics and have been implemented by NRAs for years now. Indeed, these practices that have been adopted for a long time now are in line with the principles of CE and yet some of the NRAs do not project them as "supporting the CE". In other words, although some NRAs might have stated that no specific principles of the CE are being implemented, they still recycle and trying to use their resources efficiently while extending the service life of their assets. This turns out to be a matter of definitions. Some country might do nothing about sustainability or CE but do have legislation or targets for using waste in foundations and are thus, although they do not use the word itself, practicing CE. The challenges of implementing CE practices that the NRAs stated exist, are the inadequate technical and mechanical performance of recycled materials, technological, economic, and administrative limitations and the difficulty laying rules/legislations to support this effort. Finally, an online search has been undertaken within the official websites of the investigated NRAs, in order for different plans/roadmaps/route maps communicating CE to be identified. The search was undertaken in both English and the local language of each NRA.. However, so far most of the NRAs seem not to have invested in the communication of CE principles. Only 4 out of 10 have uploaded in their websites communicative material relevant to CE, while the rest are focusing in sustainability or nothing of the two researched keywords at all.

In ***Chapter 5***, the knowledge gaps existing in NRAs were identified and the areas of knowledge development that NRAs should be focusing on are presented. In addition, two significantly relevant documents published by the European Commission are analysed and circular practices that could help the NRAs to transit to a more sustainable and circular way of operating are presented. In other words, it is presented in the NRAs what has already been done and it is there for them to follow; and finally, a step further is being made towards the circularity of NRAs by the development of the "Map of Circular Recommendations". Circular procurement, supply chain management, end of life strategies, applicable innovations and technical feasibility are the major knowledge gaps of the NRAs. The aforementioned map thus, could potentially help NRAs to make decisions and operate in a more circular and sustainable way, by fulfilling the principles of circular economy.

In ***Chapter 6****,* a brief introduction is presented. The definitions and functions of business models, sustainable business models, and circular business models are provided. Some insights are provided on how these aspects can be of use for the NRAs and their efforts towards more circular and sustainable overall operational patterns. The different aspects of a business model are explained and thus, NRAs can adjust their strategies, ambitions,

expectations, and operating regimes in order for a more circular road and pavement engineering sector.

In ***Chapter 7***, the concepts of public procurement, green public procurement, sustainable public procurement, and circular public procurement are presented and discussed. Moreover, aspects and the situation of the road engineering sector regarding its relationship and accomplishments in terms of circular economy are presented and analysed. It was deduced that not a lot of effort has been put through by NRAs towards implementing the propositions of the European Commission for green and circular public procurement, and even circular economy in general. To get a more spherical and deeper understanding of the situation, a questionnaire relevant to operation and managerial aspects of the NRAs in regard to the circular economy was sent to the collaborating NRAs and after receiving replies just from four of them, the results were gathered, tabulated, and analysed. It became obvious that they have not invested enough resources and time to the understanding of circular business models and circular public procurement and for this reason an attempt was made for the proposition of several recommendations that could potentially help the NRAs and involved stakeholders to move towards the highly desirable “circular and sustainable business logic”.

In ***Chapter 8,*** a general discussion and final conclusions are presented. Wrapping up, it can be concluded than only a few NRAs have taken under consideration the potential benefits of CE in asphalt pavements, Thus, it can be said that in general, national road authorities so far have not invested into producing roadmaps/guidelines towards the implementation and communication of CE. This could be due to lack of budget, lack of experts in CE within the national road authorities and due to the uncertainty of the successful implementation of CE. This also incorporates the lack of well-structured and comprehensive circular business models and incentives for the stakeholders associated with the market of asphalt pavements.

Another aspect is that NRAs also do not efficiently communicate their CE plans or their implementation of CE, if any. An online search was conducted within the websites of the NRAs, both in English and in their local languages, and the outcome was that only 4 out of 10 NRAs are actually communicating issues relevant to CE. Others focus only on sustainability while the rest do not seem to be communicating nothing relevant to CE at all. Moreover, having contacted several national road authorities it seems that all the NRAs are familiar with the concept of CE. In addition, most of them are also familiar with most of the principles it represents, but their majority is not implementing them. Most of the NRAs replied that are prioritizing the designing of the waste out of their products and that they attempt to prolong the life of their assets by conducting preventive maintenance. Some of the NRAs stated that they are not implementing such circular practices, but however, they do recycle, they do implement preventive maintenance regimes and they do sometimes utilize waste materials as

resources within the asphalt pavements that they construct and manage. This proves that all of the NRAs that have filled the questionnaire with one or another way implement practices that are aligned with the principles of CE, without though advertising it as so. This could lead to the conclusion that more people with specialization in CE should be operating within the NRAs providing more accuracy, insights and knowledge in terms of CE implementation. In addition, NRAs could follow the green procurement criteria published by the EU and are relevant to road construction, use and maintenance.

Also, relevant and applicable to road pavements, documents published by the European Commission were presented in order to inform NRAs that many recommendations have already been published that could strengthen their attempt to become more circular by adopting the suggested principles. Another aspect that NRAs should consider is the technical report published again by the European Commission and is about the CE principles in buildings design. It is not something that addresses the circular challenges directly into the sector of road engineering but a lot of the principles in this report that have been presented in this deliverable could be immediately applicable to the road engineering sector and could help NRAs to become more circular. It could be said that more and more NRAs should allocate percentages of their budgets towards the development of circularity metrics and roadmaps/strategies towards the implementation of CE and the assessment of the levels of this implementation. This could help to monitor and evaluate the progress that is being made and develop a feasible and spherical framework of how they should actually be implementing CE in asphalt pavements in the best way possible, following the recommendations for knowledge development and the “Map of Circular Recommendations” presented in this deliverable.

Concluding, in order to help interested and involved stakeholders for a more circular approach in their businesses, organisations/institutions, the following recommendations can be drawn.

- Examination of the reasons behind the potential adoption of circular procurement schemes within an organization and the acquisition of a clear picture of what circularity means to different organizations.
- Collaboration and discussion with internal stakeholders in order to align interests, involve and inform internal stakeholders.
- Transformation of the tendering procedures in such procedures that can reflect the pragmatic and realistic targets of the project. If collaboration is key e.g., then it has to be clarified and transparently communicated. [The European Commission’s tendering principles offer a clear framework for both commercial organizations and tendering authorities.]

- Development and implementation of a circular selection and award framework.
- Financial incentives can be introduced through circular revenue models in order for the desired circular performance to be achieved.
- Use of circularity metrics and KPIs to obtain the required or desirable performance before during and after the tender procedure.
- Robust and transparent collaboration between clients and contractors for effective contract management and optimisation.

1 Introduction

The debate of future availability of natural resources is lately once again in the centre of attention. Tremendous amounts of natural, non-renewable resources are being exploited in order for the needs of industries to be fulfilled. This leads to severe environmental, social and of course economic impacts that disturb the desirable equilibrium between what is that the three pillars of sustainability represent, as firstly proposed by E. Barbier in 1987 [1], [2]. According to the Roadmap to a Resource Efficiency Europe (RERM) , better construction and use of built infrastructure could help achieving significant resource savings: it could influence 42% of our final energy consumption and about 35% of our total GHG emissions, 50% of the extracted materials, and it could save up to 30% of water in some regions, when it comes to the construction industry [3], [4]. Admittedly, since transportation infrastructures -and road pavements in particular- consist one of the largest parts of built infrastructures, their contribution to the energy and water consumption, the extraction of virgin materials and the emission of GHGs is significantly elevated. A promising concept that has lately re-emerged and pledges to improve the situation and/or completely release the pressures on the environment, society and economy is the concept of Circular Economy. It could thus potentially provide an answer to the increasing demands because it actually aims to transform the function of resources in an economy [5]–[9]. In this perspective, the objective of this report is to present the findings of an attempt to answer two questions revolving around the Circular Economy and National Road Authorities (NRAs).

- Is there a plan of NRAs to implement the principles of Circular Economy?
- What has been done so far to progress towards the execution of this plan?

In order to do so, firstly the state-of-the-art of CE is analysed. Secondly, the roadmaps towards CE that have been published through the European CE Stakeholder Platform are reviewed. Finally, questionnaires including questions about CE and its level of implementation of National Road Authorities (NRAs) were produced and distributed to eleven different NRAs across Europe and one in the USA, and their inputs are thoroughly analysed. Conclusions, discussion and recommendations for knowledge development and circular practices can also be found on the last chapters of the report. Hence, it becomes obvious that part of the deliverable 6.2 of the work package 6 entitled “D6.2: European NRAs and Circular economy (03/2020 – M18)” - A review of the different approaches that NRAs currently use to implement and communicate circular economy principles, is also partially being developed and presented in this deliverable itself. However, it will be finalised within 6 months as planned in the project management timeline and delivered in combination with the current deliverable.

2 What is Circular Economy: State-of-the-art

One of the first publications that successfully managed to raise awareness about the issue of overloading earth's natural sinks and overexploiting non-regenerative resources, was the report of Meadows et al. (1972), "The Limits to growth", for the Club of Rome. The broader public was confronted with the thought that only limited growth is possible on a finite planet with finite resources [10]. The proposed model of Meadows and colleagues studied the intertwined interactions between pollution, population, non-renewable resources, food and industrial output. According to their scenario, the system "failure" occurs due to pollution, even though -supposedly- society would have been able to effectively manage to conserve non-renewable resources [10]. However, B. Lomborg, questioned the objectivity and accuracy of the Meadows model, arguing that the human ingenuity and the strength of innovations were not taken under consideration in the described model [11]. A philosophy or concept that encompasses in its' core innovation and innovative business models as well, is the Circular Economy. It is a concept that made its first appearance as a proactive policy goal for numerous businesses and in political agendas in the late 1970s, mainly due to climate change and the acute concern of rising resource prices, raised by R. Carson and K. Boulding [12]–[16]. The Circular Economic concept encompasses the principles of multiple schools of thought, such as "industrial ecology and symbiosis", "performance economy", "biomimicry", "cradle to cradle", "blue economy", "regenerative design", "cleaner production", and "natural capitalism" [17], [18]. Although there is not a consensual and definitive definition of CE, one of the most widely accepted definitions is that of the Ellen MacArthur Foundation (EMF): "economy that is restorative and regenerative by design, and which aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" [19]. Two different types of products can be identified; products that after their lifecycle can either return into the technical cycle (durables), or into the biological cycle (consumables) [17]. This definition is based on three principles [9], [20]:

- **Design out waste and pollution:** This includes the detection and exclusion of the negative externalities of economic activities, which can cause damage to human health and ecosystems, by minimizing the emission of toxic substances, greenhouse gases, and eliminating water, air, and land pollution.
- **Keep products, components, and materials at their highest value and in use:** Adapting the design process to support the reuse, the remanufacturing, and the recycling of components and materials, biological or technical, in order to keep them in circulation within the same or another product system. In circular systems, it is possible to maximize the use and the value of various components that have been

designed in such a way by cascading them into different applications or product systems [20].

- **Regenerate natural systems:** CE is able to support the flow of nutrients or technical materials within the same system, generating ideal conditions for regeneration, and thus, the enhancement of natural capital [20], [21].

Moreover, following this definition, Ellen MacArthur foundation supports the norm of thinking in systems and cascades. This comes as a natural continuity of the second aforementioned principle. Adopting a systemic thinking and a cascade approach, end-products, components and even materials can be repurposed, reutilised, recycled or have their service life extended while keeping their highest values. Another aspect that consists a core pillar of circular economy, is the utilization of renewable resources for the operation of production systems [19]–[22]. Moreover, the concept of CE has as an end target of providing a “marketable set of products and services capable of jointly fulfilling a user’s needs” and not just end products to be solely sold to consumers [23], [24]. That would mean that retailers and manufacturers can maintain the ownership of their products and become their “service providers” [21], [25]. This is something that would be sensible, and it would be significantly beneficial if implemented to asphalt pavements and their holistic life-cycle management. The manufacturer of the road would also have to manage their asset in addition to just constructing it [12]. Figure 1 summarises the main schools of thought that have contributed into shaping the philosophy of CE as known today.

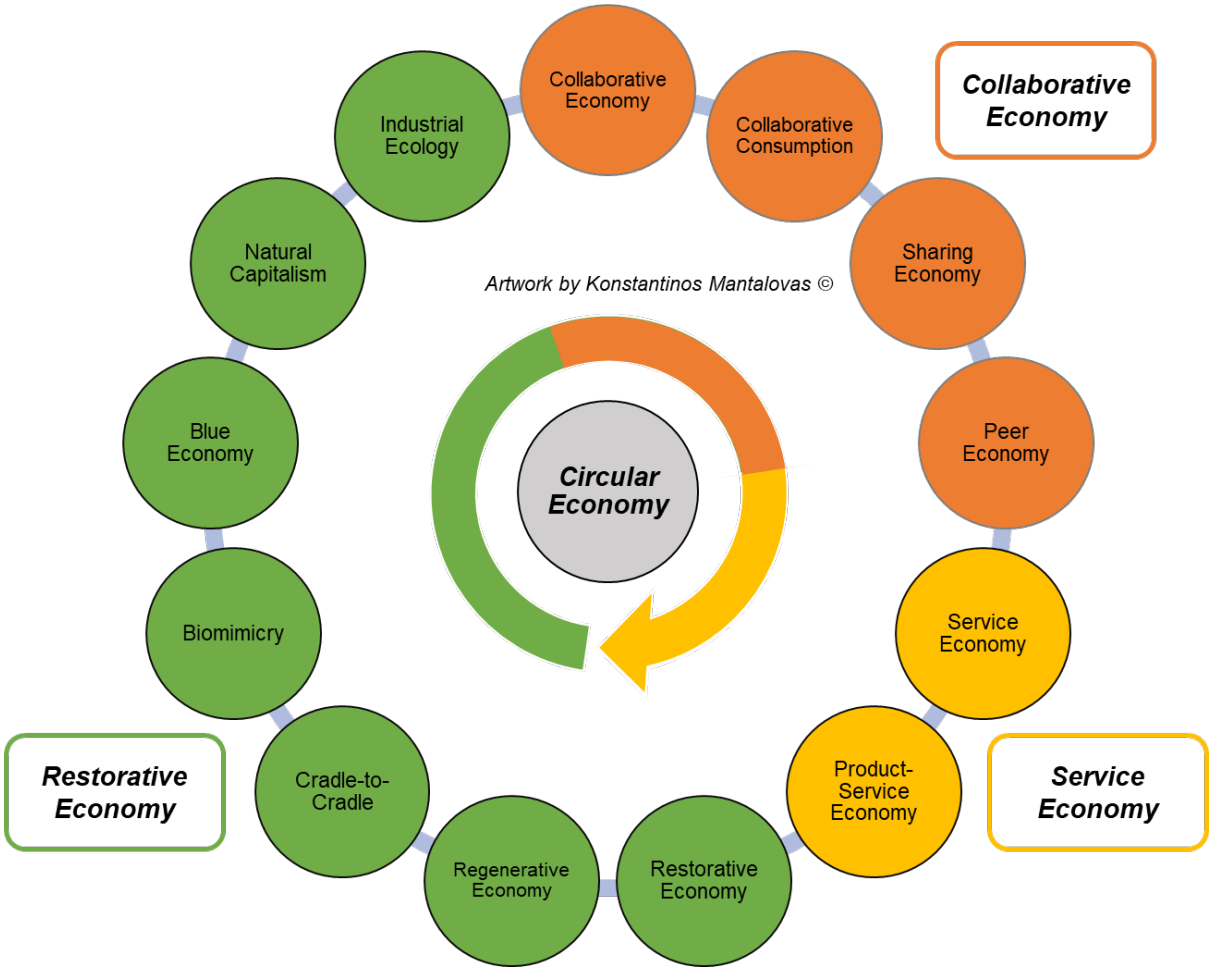

***Figure 1**. Schools of thought and economic approached forming the philosophy of CE*

Collaborative economy is a type of economy that has been decentralized and contains networks of individuals and communities instead of institutions. Th is type of economy aims to change the way of current production, consumption, finance and education [9], [26]. Different expressions that could describe this type of economy is “sharing economy/ peer economy” or even “collaborative consumption”. In the context of this type of economies, inventors and investors are brought together in order to compile the full procedure of sharing, selecting, producing and distributing new products. Moreover, the utilization of products through redistribution or shared access is a representative paradigm of this type of economies. Thus, the three main aspects of a collaborative economy can be described as:

1. A shift of power away from institutions towards networks of individual actors, 2.
2. Main drivers are technological innovation, shifting values, economic realities and environmental pressure and
3. Innovative and efficient product utilization [9], [19], [26].

Circular economy is a type of economy that integrates principles and approaches originating from all the different type of philosophies/approaches seen in Figure 1. Some of

these proposals date back to 1970 and the constant evolution of different, but with a similar end goal, approaches have been developed since. CE was firstly mentioned in 1990 by Pearce and Turner who also modelled it [27]. After that, various researchers and economic approaches have helped CE to shape its principles and values as they are known today. In particular in Figure 2, the aforementioned schools of thought are being allocated to the three principles of CE defined for the asphalt pavements.

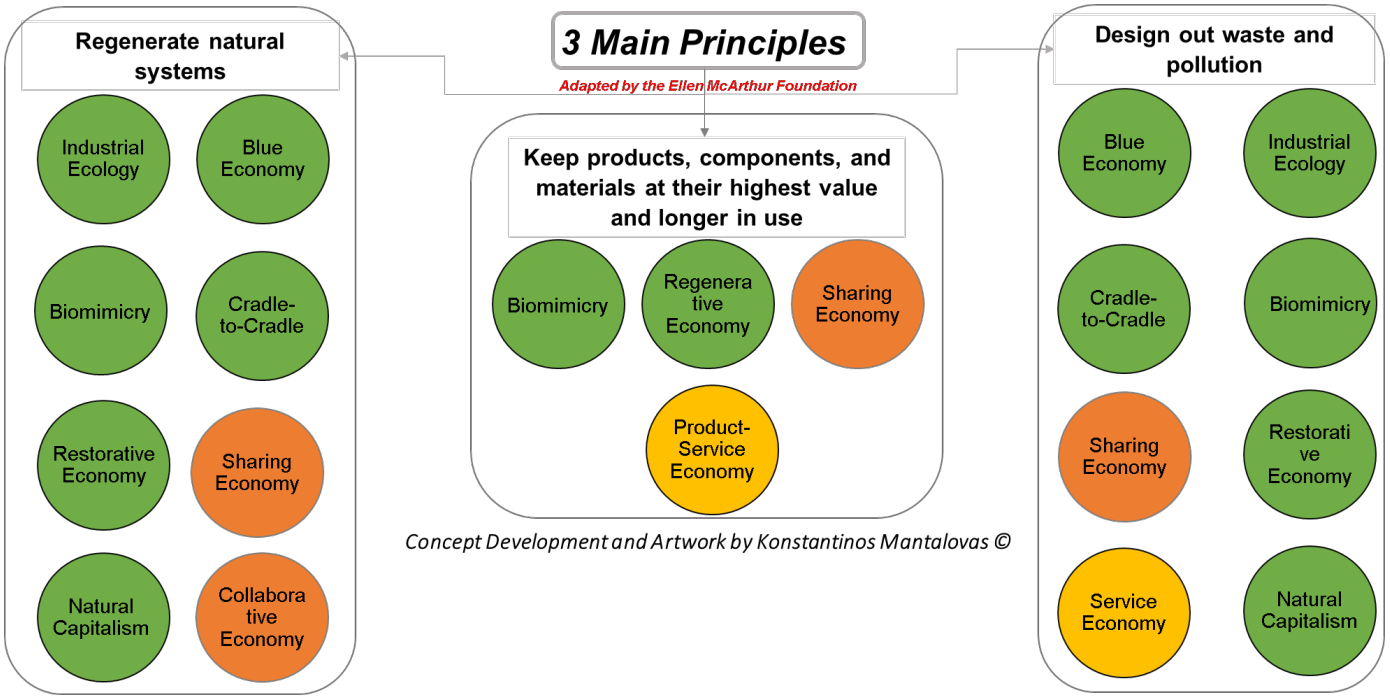

***Figure 2**. Schools of thoughts within the CE and how they can be allocated in help of defining the 3 main principles of CE*

Restorative Economy or "regenerative economy" represents the need for a new type of relationship to be created between the industrial systems and the ecosystems. This type of economy should be able to successfully and efficiently copy the natural mechanisms/practices of nature in order to restore the natural environment instead of degrading it. Products in the context of this economy should be accordingly designed so as to be able to be reused as material inputs to another system's lifecycle or to be easily deconstructed and reused or maintained with an ultimate goal of increasing biodiversity and not the opposite [9], [28]. Other similar approaches that have also been inspired by nature are: "cradle to cradle", "biomimicry", "blue economy", "industrial ecology" and "natural capitalism" [29]–[38]. The circular economy contains aspects of all three alternative economic models mentioned above. However, the concept distinguishes itself by focusing on the circularity of resources and the avoidance of waste.

Service economy supports the transition of procurement patterns from product purchasing to service purchasing. The consumer becomes a user, who pays for using a specific product instead of owning it. The term refers to an economic model where the importance is placed on services and the majority of jobs are in service activities. By changing this economic pattern, the service provider not only has an incentive to cut down the resource expenditure but also to reduce the energy consumption in the production process [9], [38].

2.1 Benefits of a circular economic approach

The currently increasing demands for raw materials, the dependence on other countries, the increasing population and energy demand, and the impact on the planet consist the most crucial factors that lead to the belief that shifting towards such an economy can have great advantages. They are not just limited in environmental gains, but instead, the adoption of CE seems able to deliver economic benefits as well [9]. According to Su et al. 2013 [39] and Geng et al. 2012 [40] adoption of CE can lead to improved competitiveness of enterprises, more efficient use of materials and energy, increased competitive advantage and revenues from “waste” sales, and reduced environmental penalties. Preston (2012) and Park et al. (2010) state that implementation of CE can lead to more direct relationships with the consumers through collaborative consumption, while reducing the cost through the usage of recycled materials, the utilization of centralized waste management plans and the resale of used products, projecting a more positive corporate image [9], [41], [42]. Sinkin et al. (2008) identified the benefits of CE as reduced costs through less waste inefficiencies and pollution and increased profits and firm value. Kienbaum Management Consulting (2014) [43] published a report identifying the contribution of CE implementation as reduced costs through less waste inefficiencies and pollution, reduced material and energy costs and competitive advantage. Additional income streams from selling of refurbished products, reduced labour costs, enhanced customer value and differentiation are the most important benefits of CE according to Accenture (2014) [44]. Finally, through multiple publications of the Ellen MacArthur foundation the tremendous benefits of a transition to a CE in Europe are described as annual net material cost savings up to USD 630 billion in the European economy; reduced labour and energy costs, and costs for carbon emissions, along with improved customer interaction and dependency on resource prices. Finally, reduced product complexity and simpler lifecycles with reduced warranty risks and improved product design could be achieved [19], [21], [22]. It becomes thus apparent that the transition to CE is essential and stakeholders along with governmental bodies should aim towards the support and acceleration of this transition.

2.2 Circular Economy in Transportation Infrastructure

How can though circular economy principles be applied to take full advantage of such intelligent assets and help them contribute to wider smart city solutions? A large part of the answer lies in letting a highly networked transport system behave more like an ecosystem than a mechanism, relying less on top down control and more on local rules in an environment with rich feedback between vehicles and the infrastructure on which they rely. This could be achieved by “keeping the traffic and the information flowing”, “smart pricing and investing”, and “re-circulating the energy”. While digital technologies are transforming vehicles and how we interact with them, they are also reshaping city transport infrastructure. Smart infrastructure technologies, collectively known as intelligent transportation systems (ITS), are being embedded in traffic lights, car parks, toll-booths, roads and bridges, making them increasingly able to communicate with each other and with the vehicles that use them. Together these innovations offer the prospect of a transport infrastructure system that suffers less congestion, is safer, and can be maintained predictively. However, this would not be a direct implementation of the three pre-defined principles of circular economy themselves in terms of material use, but instead a circular way of managing information and energy systems in order to satisfy a circular economic model aiming for more sustainable transportation infrastructure. Finally, it is worth mentioning that no specific and/or detailed guidelines are in place towards the transition to such integrated and intelligent systems.

2.3 Circular Economy in asphalt pavements

So far the most common practices that various national road authorities are implementing and are in line with the principles of circular economy are the recycling of reclaimed asphalt, the extension of the service life of their assets (preventive maintenance), the utilization of wastes in asphalt pavements, the attempt of increasing the allowed percentage of recycled materials inside the asphalt mixtures and partially the prioritization of regenerative energy sources. Sometimes however, these practices are actually implemented by the national road authorities not because they serve the principles of circular economy and are beneficial in terms of sustainability, but just because they are economically profitable and by the rule of thumb are considered as best practices. Again, nothing has been published in terms of asphalt pavements when it comes to legislative guidelines towards more circular pavements. This has not stopped though some individual stakeholders moving towards this direction. KRATON for example has moved forward by producing SYLVAROADTM RP1000; it is an additive derived from Crude Tall Oil (CTO), a renewable raw material, characterized as a by-product of the paper industry and developed by. It is able to increase the levels of RA incorporated into the asphalt mixtures while avoiding significant environmental burdens [12], [45]. Another

noteworthy attempt towards more circular products has been made by Tarpaper Recycling, along with Super Asfalt, which have proposed the production of REC100. It is a mobile asphalt plant that ensures 100% utilization of the resources in roofing felt and asphalt waste, in order to produce asphalt mixtures incorporating 100% recycled resources. Unfortunately, though, the effort of the pavement engineering industry towards more circular and sustainable products can merely be characterized as adequate. More attempts thus should be made towards this direction.

3 Current situation: Analysis of the Roadmaps produced by national/regional authorities towards Circular Economy

Policies that encourage the implementation of the principles of CE have already been introduced in some cases. The European Commission following the increasing pressures on natural resources launched the European Resource Efficiency Platform (EREP) in 2012 [46]. The target was actually to move towards a harmonized and controlled transition from linear economic patterns to circular ones. As described in the published manifesto the desirable adopted approach would be a transition towards a resource efficient and ultimately restorative circular economy. After the foundation of the aforementioned platform, which is composed by practitioners and politicians, guidelines have been publicly provided, in order for the implementation of “circular economy(-friendly)” approaches and frameworks to be widely adopted and finally implemented [3], [46]. Moreover, the United Kingdom acting as a pioneer in this context was the first European country to publish standards about the implementation of CE in 2017 [17]. France followed with the development of voluntary standards called XP X30, published by ANFOR in 2018. The title is “Circular economy - Circular economy project management system - Requirements and guidelines –“ and the standards propose a common understanding grid, laying out the terms, principles, and practices relevant to CE. The development of the aforementioned standards led to the creation of a technical committee within the International Organization for Standardization (ISO TC 323) which is working on enriching and developing international standards for the field of circular economy. The proposed deliverables will apply to any organization or group of organizations wishing to implement circular economy projects, such as commercial organizations, public services and not-for-profit organizations. Specifications relevant to already covered and standardized aspects such as eco-design, life cycle assessment, environmental management and sustainable procurement will not be included in the standards. Moreover, in July 2019, Platform CB’23 from the Netherlands has published a framework for circular construction, focusing on the building works. The requirements for a uniform measurement method of

circularity are emphasized and a circularity quantifying approach is proposed accordingly [47]. Finally, the European Union understanding the necessity of CE had officially adopted an action plan in 2015 to help accelerate Europe's transition towards a circular economy, boost global competitiveness, promote sustainable economic growth and generate new jobs and in 2019 the Circular Economy Action Plan has been fully completed [48]. However, when it comes to transport infrastructures and asphalt pavements specifically, it becomes difficult to encompass and conceptualize all these principles in their life cycles. Indeed, there is a plethora of roadmaps towards circular economy that have been published attempting to pave the way towards achieving circularity in national levels but not a lot of effort has been made to specifically address the sector of road engineering. In Table 1, all the national plans and/or roadmaps published online through the European CE Stakeholder Platform can be found, along with the unique roadmap related directly with national road authorities.

Table 1. *National plans and/or roadmaps published online through the European CE Stakeholder Platform (https://circulareconomy.europa.eu/platform/en/strategies?page=1)*

A. The Danube goes Circular - Transnational Strategy to Accelerate Transition Towards a Circular Economy in the Danube Region (ENGLISH)	Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovak Republic, Slovenia, Ukraine, Moldova, Serbia, Montenegro, Bosnia and Herzegovina
B. Circular Flanders kick-off statement (ENGLISH)	Belgium
C. Regional plan for the circular economy, Brussels Capital Region (DUTCH, FRENCH)	Belgium
D. Leading the cycle - Finnish road map to a circular economy 2016–2025 (ENGLISH)	Finland
E. 50 Measures for a 100% Circular Economy (ENGLISH)	France
F. German Resource Efficiency Programme II (ENGLISH)	Germany
G. National Action Plan on Circular Economy (ENGLISH)	Greece
H. Towards a Model of Circular Economy for Italy - Overview and Strategic Framework (ENGLISH)	Italy
I. Luxembourg's National Waste and Resource Management Plan (FRENCH)	Luxemburg
J. Leading the transition: a circular economy action plan for Portugal (ENGLISH)	Portugal

K. Strategy for the Transition to the Circular Economy in the Municipality of Maribor (ENGLISH)	Slovenia
L. Roadmap towards the Circular Economy in Slovenia (ENGLISH)	Slovenia
M. Extremadura 2030 (SPANISH)	Spain
N. Strategy of the government of Catalonia: Promoting green and circular economy in Catalonia (SPANISH/CATALAN)	Spain
O. Circular the Hague: transition to a sustainable economy (DUTCH)	The Netherlands
P. A Circular Economy in the Netherlands by 2050 (ENGLISH)	The Netherlands
Q. Kernmethode voor het meten van circulariteit in de bouw (DUTCH)	The Netherlands
R. Making Things Last: a circular economy for Scotland (ENGLISH)	United Kingdom
S. London's Circular Economy Route Map (ENGLISH)	United Kingdom
T. Circular Economy Approach and Routemap* (ENGLISH)	United Kingdom

**It is worth mentioning that the only National Road Authority that has published a publicly available roadmap towards circular economy is Highways England in collaboration with AECOM and ATKINS.*

A: The Danube goes Circular - Transnational Strategy to Accelerate Transition Towards a Circular Economy in the Danube Region [49]. It is a strategic document prepared on the basis of studies, reports and analyses made by national and/or European organisations, with the purpose of setting the objectives to improve the framework conditions and policy instruments for eco-innovation and the transition to a circular economy [49]. The reference period is from 2019 until 2030 and the target groups that the document is aiming towards are National, regional and local public authorities, business support organisations, higher education and research organisations, private and public business entities [49]. In this strategic document a framework methodology for measuring circular performance of Danube region is explained. Few of the selected indicators refer to the quantification of the percentage of materials that have been reused (such as Circular material use (CMU) rate) and the framework can be linked to the built environment indeed, but not directly to road pavements. Furthermore, the key challenges were identified with regard to the transition of the Danube Region towards a circular economy are identified and strategic objectives and sets of recommendations are proposed, stressing the need for new circular business models [49].

B: Circular Flanders kick-off statement [50]. This kick-off statement was published by Vlaanderen Circulair and refers to the Flanders region. The document emphasizes the need for transition from a linear economy to a circular economy, outlining the benefits that the latter can provide. Their transition action plan is analysed, and it is based on three main principles: circular purchasing, circular cities and circular business. It is worth mentioning that the pillar of circular cities also includes built environment and thus transportation infrastructures, but without any further details relevant to road pavements [50].

D: Leading the cycle - Finnish road map to a circular economy 2016–2025 [51]. Published by SITRA in 2016, this roadmap covers the strategic action plan of Finland towards a circular economy from 2016 to 2025. Emphasis is given to the fact that for an actual transition to circular economy, systematic change is needed. The action plan is described and analysed and the circular economy targets for the economy, the society and the environment are defined. Moreover, the roadmap separates the actions needed into five main sectors: food systems, forest-based loops, technical loops, transportation and logistics, and common actions. Practices to implement CE within the built environment and transportation infrastructures are explained and promoted, without specific reference to road pavements [51].

E: 50 Measures for a 100% Circular Economy [52]. The roadmap was published by the French Ministry for an Ecological and Solidary Transition and Ministry for the Economy and Finance in 2018. It analyses the reasons behind the need for transition to a circular economy and provide the objectives of the published framework. The roadmap is divided in four major action areas (better production, better consumption, better management of wastes and mobilization of all the actors). Detailed description of the hey objectives of each are is being provided along with the key measures and the targeted audience. The roadmap includes the built environment and infrastructures, without direct mention to road pavements. However a plethora of the measures can be directly implemented to the latter [52].

F: German Resource Efficiency Programme II, Programme for the sustainable use and conservation of natural resources [53]. It is the second resource efficiency published by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The first one was published in 2012 paving the road for resource efficiency from 2012 to 2015. However, the second resource efficiency program of Germany refers to energy efficiency as well. It emphasizes and describes the inclusion and interaction of other resources such as water, soil, air, living organisms, land and resources as food and feedstuff. Analytic indicators are presented in the document along with the desirable targets and the action areas under focus. It is worth mentioning that the specific resource efficiency Programme takes under consideration the built environment, the transportation infrastructures and there are targeted mentions directly to asphalt recycling and re-circulation [53].

G: National Action Plan on Circular Economy [54]. The Greek national action plan on Circular Economy was published in the end of 2018 and analyses the compatibility of CE with the recently adopted development plan. In the document the policy axes to achieve a CE are described along with the main strategies and goals to be followed in the future. Finally, the operational and governance action plan with its regulatory and legislative reforms is presented. The specific action plan also refers to urban development and the built environment setting targets relevant to the construction sector, without being specific about road pavements though. It is worth mentioning that in 2017 the Greek government adopted a set of laws relevant to waste management and materials efficiency that supports in a legislative way the implementation of CE principles [54], [55].

H: Towards a Model of Circular Economy for Italy - Overview and Strategic Framework [56]. The Italian roadmap towards circular economy was published in 2017 by the "Ministero dell'Ambiente e della Tutela del Territorio e del Mare and the "Ministero dello Sviluppo Economico". It describes the current situation in Europe and specifically in Italy while stressing that for an effective transition to CE, the companies, the consumers and also the fiscal and economic instruments have to walk towards the same direction. In order for this transition to be ensured, indicators measuring circularity are analysed along with emphasis given in the importance of the traceability of the resources and the production chains and the promotion of sustainable production and consumption models. The roadmap includes recommendations for the construction sector, but nothing specifically addressed to transportation infrastructures and/or road pavements.

J: Leading the transition: a circular economy action plan for Portugal [57]. It is an action plan published in 2017 that presents a constitute proposal for action towards the implementation of CE. Within the published action plan the importance of a CE is emphasized and the approach of achieving a CE is analyzed. The aim is to introduce CE principles in three levels: macro, meso and micro. It is worth mentioning that according to the action plan, guidelines for the most important and environmentally relevant sectors will be developed and detailed goals and complementary indicators will be present, monitoring the progress. Guidelines will be developed also specifically for the built infrastructures and roads, covered by the complementary indicators [57].

K: Strategy for the Transition to the Circular Economy in the Municipality of Maribor [58]. This strategy is in reality the analysis of an innovative models as a system for managing all the resources available in the Municipality of Maribor and the wider urban area. The purpose of the Strategy is cross-sectoral cooperation in handling, processing, re-use and development of resources, which deals with the circular economy in Maribor in seven selected sectors. The model and its' horizontal and vertical deployment are analysed and there are strategic measures referring to build environment and transportation infrastructure. However,

no indicators for measuring the expected circularity are being developed but mentions exist about the importance of improved energy and resource efficiency in each analysed sector [58].

L: Roadmap towards the Circular Economy in Slovenia [59]. This roadmap was published in 2018 and it is a part of Slovenia's strategic development priorities. It emphasizes that the transition to CE is not a trend but a civilizational necessity instead. It defines and analyses the circular triangle, which is based on Circular Culture (citizens as the core), Circular Change (public sector as the core) and Circular Economy (companies as the core). Moreover, all the areas in which the transition should be prioritized are recognized and the potentials occurring due to CE within these areas are analysed. One of the strategic areas is "mobility"; within this area transportation infrastructures are included, and recommendations are given towards more circular practices. However, no direct mention exists about road pavements specifically [59].

P: A Circular Economy in the Netherlands by 2050 [60]. It is more in reality a government-wide programme for the transition of the Netherlands to a CE, published in 2016. In the document the promising prospects of the implementation of CE are analysed along with the necessity for the transition towards such an economy. Moreover, the economic opportunities of reusing materials are described and the vision along with the goals of the programmed are mentioned. Generic and specific policies for change for each sector and/or value chain are provided and an attempt towards fostering legislations and removing obstacles is made. In the document the prioritized sectors of biomass and food, plastics, the manufacturing industry, consumer good and construction sector, are explained along with the action plan for each one of them. It is worth mentioning that within the construction sector, asphalt pavements and the reuse and/or the recycling of asphalt are mentioned and promoted, supported by best practices paradigms and finally the anticipated strategic goals [60].

Q: Kernmethode voor het meten van circulariteit in de bouw [47]. It is worth mentioning that the specific document was not found in the European CE Stakeholder Platform, but instead was published by Platform CB'23. It was reviewed due to the fact that it consists one of the most analytic and comprehensive approaches towards the implementation of CE within the construction sector holistically; meaning that every time of built infrastructure could benefit by following the proposed approach and methodology. It focuses on the material aspects of circularity in an attempt to promote the integral sustainability that The Netherlands is already pursuing as already declared in "A CE in the Netherlands by 2050" [60]. It is focusing in the built environment, referring thus to the transportation infrastructure as well. To do so, within this report, it is described how to develop "passports for construction" that represent a digital representation of a construction work and it depends on the life phase of the work itself and the value that than can be created with this data. Life Cycle Assessment is coupled with the creation of a passport and the metrics of alternative passports are compared. Moreover,

an approach to quantify the circularity of construction works is defined and direct mentions exist about transportation infrastructures and asphalt based material [47].

R: Making Things Last: a circular economy for Scotland [61]. It was published in 2016 by the Scottish government and it is a strategy that sets Scotland's priorities for moving towards a more circular economy. It builds on Scotland's progress in the zero waste and resource efficiency agendas. In the document the environmental, economic and societal benefits emerging through the implementation of CE are analysed. Moreover, it is explained that in order for the transition to CE to be achieved priority should be given to the following aspects: waste prevention, design, reuse, repair, remanufacture, recycling, producer responsibility for reuse and recycling, recovering value from biological resources, energy recovery, and landfilling. In addition, the built environment along with the construction sector and transportation infrastructures are mentioned but without focus on road pavements. Finally, targets are being set and metrics such as waste reduction, recycling rates and re-use rates are set as indicators [61].

S: London's Circular Economy Route Map [62]. The London waste and recycling board published this route map in 2017. It is a route map attempting to accelerate the growth and development of CE across London, whilst setting out an ambitious plan of action. Sectors such as food, textiles, electrical, plastics and built environment are analysed and recommendations along with an action plan for each are provided. Focus is given to the built environment and the buildings sector and then transportation infrastructure indeed, without specific mentions of asphalt roads [62].

T: Circular Economy Approach and Route map* [63]. This route map is the only one published by a national road authority. It was published in 2016 by Highways England in collaboration with AECOM and ATKINS. Its' objectives are described as: the development of a corporate circular economy strategy within the context of the Highways England Sustainable Development strategy; the definition of what circularity means for Highways England; the shift towards a fully optimised resource use on Highways England's projects and operations and to deliver a plan to embed a culture of resource efficiency across the organisation and Highways England's supply chain. It is separated in 4 core components: governance, procurement, monitoring and reporting, tools and guidance. Resource efficiency, utilisation of waste and minimisation of resources exploitation are the cores of the proposed actions of this report. It is worth mentioning that direct mention to transportation infrastructures in general and to asphalt pavements in specific can be found, stating that the wastes originating from the life cycle management of roads should be exploited with utmost efficiency. Finally, some case studies are presented, indicating the usefulness of this roadmap and the implementation of CE. However, specific indicators and metrics have not been developed for the quantification of the circularity, but instead key performance-based indicators are mentioned.

3.1 Circular Economy roadmaps: Analysis and discussion of the reviewed documents

Reviewing the documents collected from the European Circular Economy Stakeholder Platform, it becomes obvious that the principles of CE within the transportation sector are not well established yet. It is worth mentioning that only one of the reviewed documents has officially been published by a national road authority i.e. Highways England, while the rest of them have been published by governmental bodies, ministries, companies and/or groups and platforms formed to promote circular thinking. Not all of them however are analytical and comprehensive delivering a specific set of strategic actions and indicators, metrics or desirable targets to be reached. Some of the most detailed publications are providing specified action plans for each sector to be followed and targets that need to be fulfilled under specific timetables in order for the transition to a CE to be actually realised. The most common points that can be found in the documents are initiatives such as more effective waste management and minimisation, utilisation of waste as resources to parallel industries, minimisation of CO2 emissions under predefined time horizon and resource and energy efficiency. When it comes to pavements however not specific mentions can be found in the documents apart from the ones published by the Highways England (United Kingdom), the Dutch government and Platform CB'23 (The Netherlands) and the Portuguese government (Portugal). There are examples of CE implementation that entails the promotion of asphalt recycling, the attempt to surpass legislations that restrict the massive recycling of asphalt, the common effort towards constructing and managing longer-lasting pavements and the plan towards the utilisation of renewable energy sources for the production, construction and maintenance of asphalt pavements. To sum up, it can be said that in general national road authorities so far have not invested into producing roadmaps towards the implementation of CE. As it is going to be analysed in the following chapter, this is happening due to lack of budget, lack of experts in CE within the national road authorities and due to the uncertainty of the successful implementation of CE, which also incorporates the lack of well-structured and comprehensive circular business models and incentives for the stakeholders associated with the market of asphalt pavements.

4 Current Situation: The perspective of the National Road Authorities

4.1 Tabulated results of the questionnaires

Questionnaires have been sent to a number of national road authorities in an attempt to gather knowledge in matters relevant to circular economy and the level of its implementation by them. The countries and their corresponding national road authorities, along with the replies in the questionnaires that have been sent, can be seen in Table 2. In addition, the complete section of the questionnaire that is relevant to the CE and analysed in this deliverable can be found in Appendix A.

Table 2. *Summarized results of the replies relevant to CE, provided for the questionnaire by the contacted national road authorities*

COUNTRY	**Lithuania**	**Norway**	**Slovenia**	**Sweden**	**Netherlands**
Awareness about CE	**YES**	**YES**	**YES**	**YES**	**YES**
Principles of CE that the NRA is familiar with	Design out/minimize waste	Design out/minimize waste	Design out/minimize waste	Efficient use of existing and renewable resources where material flows are recirculated.	Design out/minimize waste
	Use waste as resource	Preserve and extend what is already made	Use waste as resource		Use waste as a resource
					Prioritize regenerative resources
				Use waste as resource	Preserve and extend what is already made
Implemented CE principles	-	-	Use waste as resource	Preserve and extend what is already made	Use waste as a resource
					Preserve and extend what is already made
CE practices	Testing materials from waste in trial sections to find out their potential use and limitations in road structures. Evaluation during design phase to maximize their second use and minimize waste	-	Recycling and reusing of asphalt	Removing restrictions on asphalt recycling.	Incorporation of recycled material in asphalt mixtures (foundation layers as well as pavement layers), periodic maintenance to repair aged spots of the pavement and preventive maintenance with the use of rejuvenators

Challenges of implementing CE practices	In some cases, there are technology limitations. A limiting factor is that LRA is administration body, and its rights are regulated very strictly	-	-	Difficult to avoid downgrading.	The durability of recycled materials or bio-based is a challenge. Shorter durability is undesirable as it will cause cost, environmental impact and nuisance for the road user. As it takes too long to find out in practice what durability performance is achieved, other test methods are needed
CE indicators/metrics	**NO**	**NO**	**-**	**NO**	**NO**
	-	-	-	-	-
Challenges of developing indicators/metrics	No clear rules	-	-	-	-
Existing Roadmap towards CE	**NO**	**NO**	-	**-**	**YES**
Publicly available	-	-	-	-	https://platformcb23.nl/leidraden (referring to Construction works)
Challenges of developing a Roadmap towards CE	There are no incentives for a roadmap development.	-	-	-	-
COUNTRY	**Austria**	**Belgium**	**Denmark**	**Germany**	**United Kingdom**
Awareness about CE	**YES**	**YES**	**YES**	**YES**	**YES**
Principles of CE that the NRA is familiar with	Design out/minimize waste	-	Preserve and extend what is already made	Design out/minimize waste	Design out/minimize waste
	Use waste as resource			Use waste as resource	Use waste as resource
	Prioritize regenerative resources			-	Preserve and extend what is already made
	Preserve and extend what is already made				
Implemented CE principles	Design out/minimize waste	-	Preserve and extend what is already made	Use waste as resource	Design out/minimise waste
	Use waste as resource				Use waste as resource
	Prioritize regenerative resources				Preserve and extend what is already made (limited degree through preventive maintenance)

CE practices	Specifications in guidelines and internal planning manuals	Lifetime Enhancing Maintenance (incipient)	Preserve the road condition to extend the life-time using proper maintenance strategies.	Circular economy is largely based on waste legislation (Kreislaufwirtschaftsgesetz national law of EU directive 2008/98/EG)	Preventive maintenance Use waste as resource
Challenges of implementing CE practices	Reasons for non-implementation is when a certain lifetime or required requirements cannot be achieved.	-	-	-	-
CE indicators/metrics	**YES**	**NO**	**NO**	**YES**	**NO**
	End of Life recycling input rate	-	-	Quota of reuse of RAP in hot mix asphalt. (87 % in 2016)	-
	Resource Efficiency				
Challenges of developing indicators/metrics	-	-	The problem is the budget	-	This would be led by others within Highways England, rather than the Pavements Team specifically.
Existing Roadmap towards CE	**YES* (Sustainability Strategy)**	**YES*** (Not published by an NRA)	**NO**	**NO**	**YES**
Publicly available	https://www.asfinag.at/media/3077/asfinag-nachhaltigkeitsbericht_2017.pdf	https://vlaanderen-circulair.be/en	-	-	https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/specialist-information/knowledge-compendium/Circular+Economy+-+Approach+and+Routemap.pdf
Challenges of developing a Roadmap towards CE	-	-	The change in policy and lack of common point of view which does allow to combine efforts	The incentive for reuse is industry driven.	The above is not specific to pavements – interpretation of what the circular economy means specifically for road pavements would be useful

4.2 Analysis of the questionnaire findings

Following Table 2, it can be seen that all the NRAs contacted are aware of the concept of CE and have at least minimum knowledge about what it is that it represents. All the NRAs seem to be familiar with the most commonly known and easily applicable principles of the CE, apart from the NRA that represents Belgium. Austria's and the Netherlands' NRAs seem to be the most informed in terms of CE knowledge, exhibiting the higher number of CE principles that they are familiar with. Among all the NRAs to which the questionnaire was sent, the most commonly known principles of CE are:

- Design out/minimize waste
- Use waste as resource
- Preserve and extend what is already made (usually translated as "preventive maintenance")

When the NRAs were asked about which principles of the CE are implementing, Belgium, Norway and Lithuania replied that none of them is currently being implemented. However, among the remaining NRAs the most common answers that were received in terms of implemented CE principles are:

- Preserve and extend what is already made
- Design out/minimize waste

In the question about which are the applied practices that indicate the implementation of some of the CE principles, Austria's NRA replied with specifications in guidelines and internal planning manuals, similarly to Germany's NRA which is following the waste legislation (Kreislaufwirtschaftsgesetz national law of EU directive 2008/98/EG), Belgium's, United Kingdom's and Denmark's NRAs stated that are preserving the road condition and extending its service life. Lithuania is trying to test waste materials in trial sections in order to promote the use of waste as a resource, while Slovenia and Slovakia are marching towards removing restrictions on asphalt recycling and keep recycling and reusing asphalt. Finally, the Netherlands are incorporating recycled materials in asphalt mixtures and extensively perform periodic preventive maintenance to extend the lifecycle of the asphalt pavements. Thus, the most commonly applied practices that indicate the implementation of some of the aforementioned principles are:

- Removing restrictions on asphalt recycling
- Extending the service life of the asphalt pavements, usually by preventive maintenance
- Testing waste materials for potential utilization as resources on asphalt pavements

In this point it is worth mentioning that although the concept of CE is not totally new as analysed in the introduction and hence, some of its characteristics have already been practiced for years by National Road Authorities. Aspects such as recycling, resource efficiency and utilization of waste materials in foundation layers are not new topics and have been

implemented by NRAs for years now. Indeed, these practices that have been adopted for a long time now are in line with the principles of CE and yet some of the NRAs do not project them as “supporting the CE”. In other words, although some NRAs might have stated that no specific principles of the CE are being implemented, they still recycle and trying to use their resources efficiently while extending the service life of their assets. This turns out to be a matter of definitions. Some country might do nothing about sustainability or CE but do have legislation or targets for using waste in foundations and are thus, although they do not use the word itself, practicing CE. Moving on, the challenges of implementing CE practices that the NRAs stated exist are the inadequate technical and mechanical performance of recycled materials, technological and administrative limitations and the difficulty laying upon the downgrading of recyclable materials. When it comes to CE indicators and/or metrics, only the NRAs of Austria and Germany are implementing some of them. In detail, Austria’s NRA is utilizing the end of life recycling input, while Germany’s the quota of reuse of Reclaimed asphalt pavement in the production of hot mix asphalt.

The rest of the NRAs state that the challenges encountered towards developing or implementing circularity metrics are the budget restrictions along with the lack of clear rules/legislations to support this effort. Finally, the only NRA that has officially published a roadmap or a strategy towards the implementation of CE is the one of United Kingdom’s. However, Austria’s NRA is following the national sustainability strategy, Belgium’s has adopted the circular roadmap published by the “Circular Flanders”, and the Netherlands’ is following the guidelines towards circularity, recently published by Platform B23. The challenges of doing so as well, that most of the remaining NRAs are encountering are the changes in policy and lack of common points of view which does allow to combine efforts, the lack of incentives and the fact that the existing incentives foe the reuse of asphalt is mostly industry driven.

4.3 CE communication of National Road Authorities

In order to identify the ways that different NRAs utilise in order to communicate CE, an online search has been undertaken The search has been conducted online in English and in the local languages of the NRAs. The websites of the listed NARs in Table 3. have been visited and in their “search” function, the words “circular economy” and “sustainability were searched. The results of the search have been tabulated in Table 3.

Table 3. *Ways that NRAs are implementing and communicating CE*

National Road Authority per Country	***CE Implementation Plan and communication***
Austria [ASFiNAG]	Sustainability strategies and reports / nothing related to CE
Belgium [Agency for roads and traffic / Wallonia General Direction for roads and traffic]	Sustainability related research and reporting / nothing related to CE
Denmark [Danish Road Directorate - Vejdirektoratet]	Environmental Assessment reports, Sustainability related research and reporting / nothing related to CE
Germany [Federal Ministry of Transport, Building and Urban Development - Bundesministerium für Verkehr und digitale Infrastruktur]	Climate Action Program 2030 / CE related: preservation of resources, maximization of resource efficiency, resource cycle management/bioeconomy
United Kingdom [Highways England, Transport Scotland, Welsh Government, Roads Service	Circular Economy Approach and Route map
Lithuania [Lithuanian Road Administration and family of road engineers]	Nothing related to CE
Norway [Norwegian Public Roads Administration -NPRA]	Sustainability related research and reporting / nothing related to CE
Slovenia [Slovenian Roads & Infrastructure Agency]	Conferences organized, JRC collaborations for circular economy implementation / Slovenian development days to promote CE
Sweden [Swedish Transport Administration-Trafikverket]	Sustainability related research and reporting / nothing related to CE
Netherlands [Rijkswaterstaat, State advisors for urban development & infrastructure]	Circular Public Procurement / Resource Efficient business models / National Waste management Plan

As can be observed, only 4 out of 10 investigated NRAs are attempting to communicate the ways that CE principles are projected through their operational patterns. The only NRA that has published an “Approach and Route Map” towards circular economy is the Highways England. In which future visions and plans that are aligned with the implementation of CE are described. Moreover, Germany’s NRA seems to be in a similar path since it has developed a plan called Climate Action Program 2030, which contributes towards the implementation of more circular and sustainable practices. In addition to that, practices relevant to the preservation of resources, maximization of resource efficiency, resource cycle management and bio economy are strongly supported and communicated. It can be seen however that the majority of the investigated NRAs is publishing sustainability reports and communicating their plans in terms of sustainability, but CE is still not a matter that seems to be under their attention. There is still thus, a significant opportunity for knowledge development in the field of road engineering agencies and on the topic of CE.

5 Suggestions and recommendations for strategies towards the implementation of CE principles and knowledge development

5.1 Green Public Procurement for road design, construction and maintenance [64]

The European commission has invested into CE and sustainability in every sector. For the pavement engineering and road construction and maintenance sectors, a technical report has been published in 2016, detailing the practices that NRAs and involved stakeholders should be implementing for more sustainable and circular approaches. Moreover, a set of criteria has been developed, that can help stakeholders act immediately even without having a deep knowledge of CE and sustainability. EU commission has identified some of the most impactful stages and aspects of a road's lifecycle that when modified accordingly can be significantly beneficial for the environment and the economy, based on the principles of green procurement and CE. The stages/aspects identified are:

- **Pavement vehicle interaction (Mean Profile Depth [MPD], [International Roughness Index [IRI]:** higher fuel consumption has been detected with higher values of these two indicators and thus, lowest possible and acceptable values are suggested.
- **Resource efficient construction:** Since it has been found that by increasing the resource efficiency during the construction and maintenance phases, can lead to decreased environmental impacts, the EU commission is suggesting the implementation of Life cycle assessment for every stage of the road construction and maintenance phases, along with increased attention to the embodied impacts of the transportation distances of the materials.
- **Recycled content:** Materials that able to be recycled within a closed loop perspective seem to be crucially beneficial for the environment. In this regard, it is suggested that high percentages of materials are recycled into the asphalt pavements while, however, complying with the performance requirements for the road pavement. It is highlighted that the transportation distance of the recycled materials should be assessed in order not to end up transporting materials to be recycled in such distances that in the end will impact the environment in a higher degree.
- **Materials transportation:** Significant focus is being given to the total transportation of the materials wither they are virgin are recycled. Transport distance can impose a significant environmental burden when an environmental assessment has not been undertaken. It is suggested that NRAs should adopt an indicator that is able to express the CO2eq per tonne of transported materials and thus can optimise the location of

the plants and quarries in order to minimise the environmental impacts originating from the energy consumption during the transportation of the materials.

- **Excavated materials, soil and wastes management:** It is highly recommended that excavated materials such as soils and wastes that are not labelled as hazardous are reused on site. Moreover, it is proposed that tracking of the waste production is undertaken and recorded.
- **Water and habitat conservation**: Road drainage systems must comply with minimum technical requirements in order to adequately drain both stormwater from the road surface and sub-surface water from groundwater flows that may impact on the sub-base. Moreover, it is suggested that SUDS [Sustainable Urban Drainage Systems] are promoted and utilized in the asphalt pavements, while the addition of drainage components assisting the removal of sediment and solid particles is supported.
- **Noise:** Although both low-noise road surfaces and noise barriers contribute positively to the reduction of noise levels in targeted areas, whether one type of approach or the other, or a combination of both is the optimum solution, will depend very much upon. It is thus suggested, that noise emissions are monitored during the construction, use and maintenance phases and desirable thresholds should be set [ISO/DIS 11819-2]. Namely:
    - 87 dB(A) at 50 kph, and/or
    - 92 dB(A) at 70 kph, and/or
    - 95 dB(A) at 90 kph.
- **Congestion:** In order for extra potential environmental impacts due to congestion, fuel usage and lack planning to be avoided, traffic mitigation plans are suggested to be developed, not only during the construction stage of and asphalt road but also during its use and maintenance.
- **Maintenance and rehabilitation strategies:** The design team or the Design and Build tenderer or the Design Build and Operate tenderer shall include a Maintenance & Rehabilitation Plan, that follows all the aforementioned suggestions, in the detailed design. For each section of road specifically characterised by specific construction methods, materials, environmental conditions, meteorological conditions and use, the M&R Plan shall, as a minimum:
    - Include routine, preventive and rehabilitation actions;
    - Optimise the cost-benefit ratio of the maintenance works;
    - Declare the environmental performance of any routine, preventive and rehabilitation action/strategy
    - Include the cost, expected intervals between maintenance activities, the Traffic Congestion Mitigation Plan and the Demolition Waste Management Plan for each action.

All the aforementioned suggestions and recommendations relevant to different stages and/or aspects of the construction, use and maintenance of a road can be seen summarised in Figure 3.

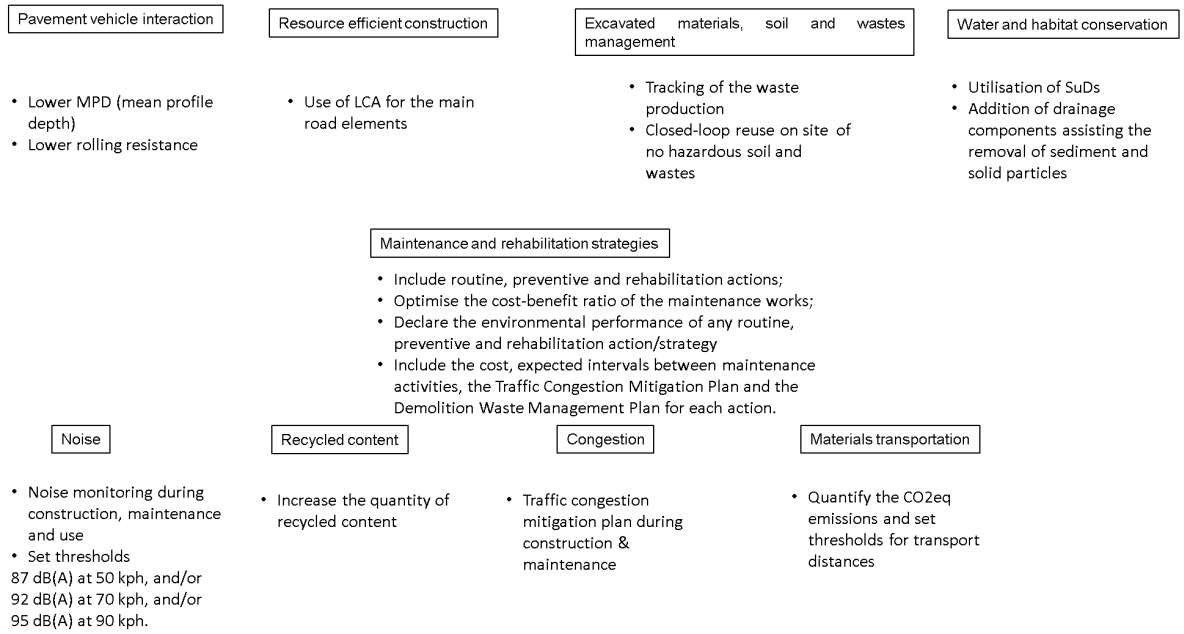

***Figure 3**. Suggestions and criteria to be fulfilled for the construction, use and maintenance of a road for a more sustainable and circular approach according to the European commission [64]*

5.2 "Circular Economy: Principles for Buildings Design" [65]

Moreover, the European Commission has also published a document entitled "Circular Economy: Principles for Buildings Design" [65] and details the general principles that should be implemented if a more circular approach is to be adopted in the building sector. The document is specifically focused on buildings, but the main defined principles are presented here due to the fact that a lot of similarities exist between buildings and roads.

- **Design principles of circular economy and sustainable buildings are applicable to all actors along the value chain.**
- **Sustainable choices must consider total life cycle costs, financial and non-financial return on investments.**
- **Viable business models must exist or be developed for each economic operator in the supply or value chain.**
- **Principles need to be applied considering proportionality - benefits should outweigh the costs.**
- **Better knowledge is needed about construction techniques to facilitate deconstruction and to enhance durability and adaptability of a building.**

- **Durability of buildings depends on better design, improved performance of construction products and information sharing.**
- **Prevent premature building demolishment by developing a new design culture.**
- **Design products and systems so that they can be easily reused, repaired, recycled or recovered.**

As aforementioned these principles are referring to buildings, but the majority of them can easily and immediately be transferred into the road sector and.

5.3 Targeted knowledge development of NRAs

Having identified the most commonly accepted definition of the CE, it shall thus mean that it would be time to attempt and translate it in the context of asphalt pavements. As mentioned in chapter 2, the three main principles of the CE are:

- *Design out waste and pollution*
- *Keep products, components, and materials at their highest value and in use*
- *Regenerate natural systems*

And hence, practical recommendations for the NRAs would have to be focusing on translating actions and approaches into an eligible hodgepodge of measurable outputs towards the implementation of the aforementioned principles. Moreover, challenges related to the transition of the road engineering industry have been presented in chapter 3 and 4. The combination of these pieces of information while keeping the sustainability assessment of asphalt pavements in mind are inevitably leading towards identifying areas of knowledge that if developed, could lead to a better understanding of CE and a more informed implementation of its principles in the context of asphalt pavements. The areas for knowledge development that have been identified by the author and could potentially improve the understanding and the implementation of circular economy by the NRAs are presented in Table 4, along with the pre-defined principles of CE that they fulfil. However, in this point it is worth mentioning that apart from working towards the implementation of CE and the sustainability of asphalt pavements its important for the various NRAs to also find more attractive and innovative ways of communicating their status in terms of circularity, since appropriate communication of an organisation's business patterns combined with the knowledge of the CE "jargon" can play an essential role towards the implementation and dissemination of CE practices.

***Table 4**. Areas proposed to the NRAs for knowledge development*

Knowledge Development Areas	***CE principles***
Alternative energy sources	[1], [3]
Technical feasibility	[1], [2], [3]
Increased yield	[1], [3]
Circular procurement	[1], [2], [3]
End of life strategies	[1]
Lifecycle extension	[1], [2]
Circularity + Environmental metrics	[1]
Supply chain management	[2]
Material flows	[1], [2], [3]
Waste Management	[1], [3]
Sustainable Development Goals	[1], [2], [3]
Supply chain management	[1], [3]
Innovation	[1], [2], [3]
Where: [1] Design out waste and pollution; [2] Keep products, components, and materials at their highest value and in use; [3] Regenerate natural systems	

In a more analytic perspective and considering that NRAs can usually be in collaboration with different stakeholders relevant to the production of asphalt mixtures and the maintenance of asphalt pavements, Figure 4 attempts to illustrate how different stakeholders and different lifecycle stages of asphalt pavements can be influenced by the proposed knowledge development areas. In other words, assuming that most NRAs represent the area of a "Cluster", it can be seen that even if by themselves develop the knowledge in the suggested areas, for a holistic life cycle approach, various other stakeholders will have to be a committed part of the equation -as well- in order to collectively progress towards a systemic regional circular economy. This is why it is worth reiterating that communication, transparent supply chains and stakeholders' engagement are key components towards a CE.

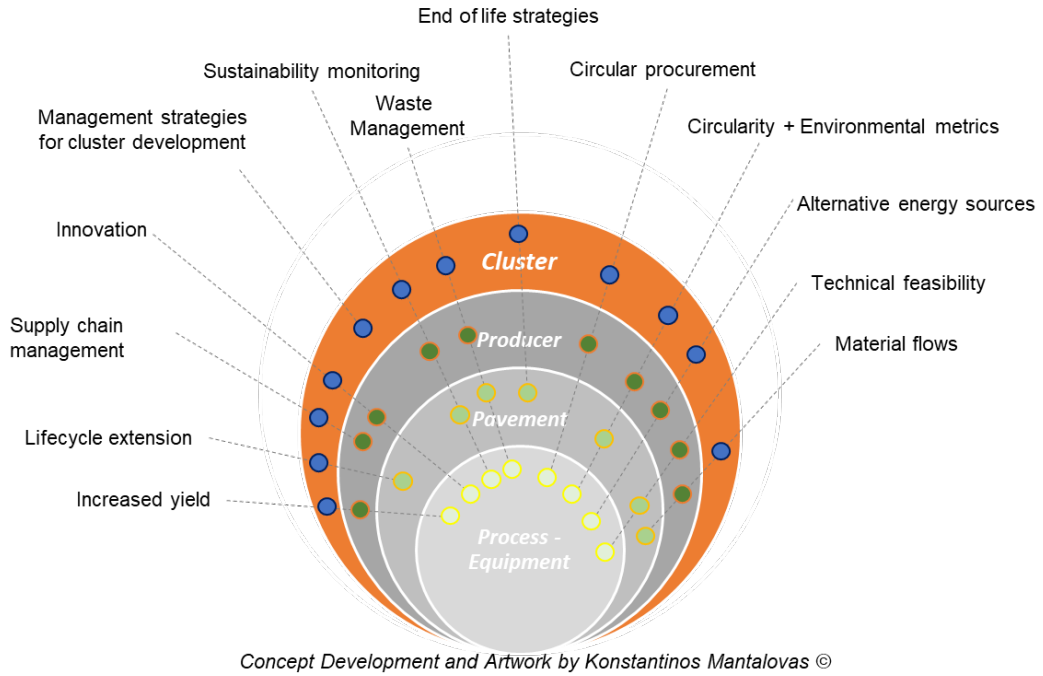

Figure 4. *Stakeholders and areas in need of knowledge development mapping*

5.4 Map of Circular recommendations & practices

Now, after the identification of the potentially most relevant areas of knowledge development, a map of recommendations is also presented in this chapter. It is not the ultimate goal of the deliverable, but it can be utilised by the NRAs in order to proceed to actions/practices that could fulfil the three pre-defined circular economy principles. The purpose of this maps is to allow NRAs to detect their internal opportunities that could be exploited towards the transition to a more circular way of operating. As mentioned above, the three principles of the CE that can be projected in the context of asphalt pavements are presented in green colour within Figure 5. It is worth mentioning though, that for an organisation or an NRA in this case the first 4 steps that can in a way be considered as prerequisites are the stakeholder's engagement, the transparent and safe communication with the supply chain, the corporal social responsibility reporting and finally the push towards regional, circular procurement policies. The map starts with the 3 principles of CE defined (green boxes). Further on, the blue boxes represent some of the practices that can assist on fulfilling the CE principle that are related to. After that, the grey boxes are different alternative processes -that do not recant each other- which can be implemented and lead towards increased circularity. Hence, some of the most immediately applicable recommendations that can be given to NRAs towards the implementation of CE are:

- Establish compulsory and regulated end of life strategies
- Optimise pavement design standards towards thinner layers

- Optimise preventive maintenance strategies by implementing a holistic sustainable pavement management system
- Use material flows and material passports to track the life cycles of materials
- Use of biomaterials as main paving materials through reusing and recycling
- Maximise the use of Reclaimed asphalt and increase the reuse of secondary materials. Shifting towards use of lower percentages of virgin materials should be established as the norm and thus;
- Target setting towards the exploitation of all the available Reclaimed Asphalt
- Replacement of diesel with biodiesel or other available cleaner energy sources
- Use of renewable energy sources
- Change utilisation patters [sharing models, product as service]
- Minimise the construction of new road networks by optimising the layouts of existing ones

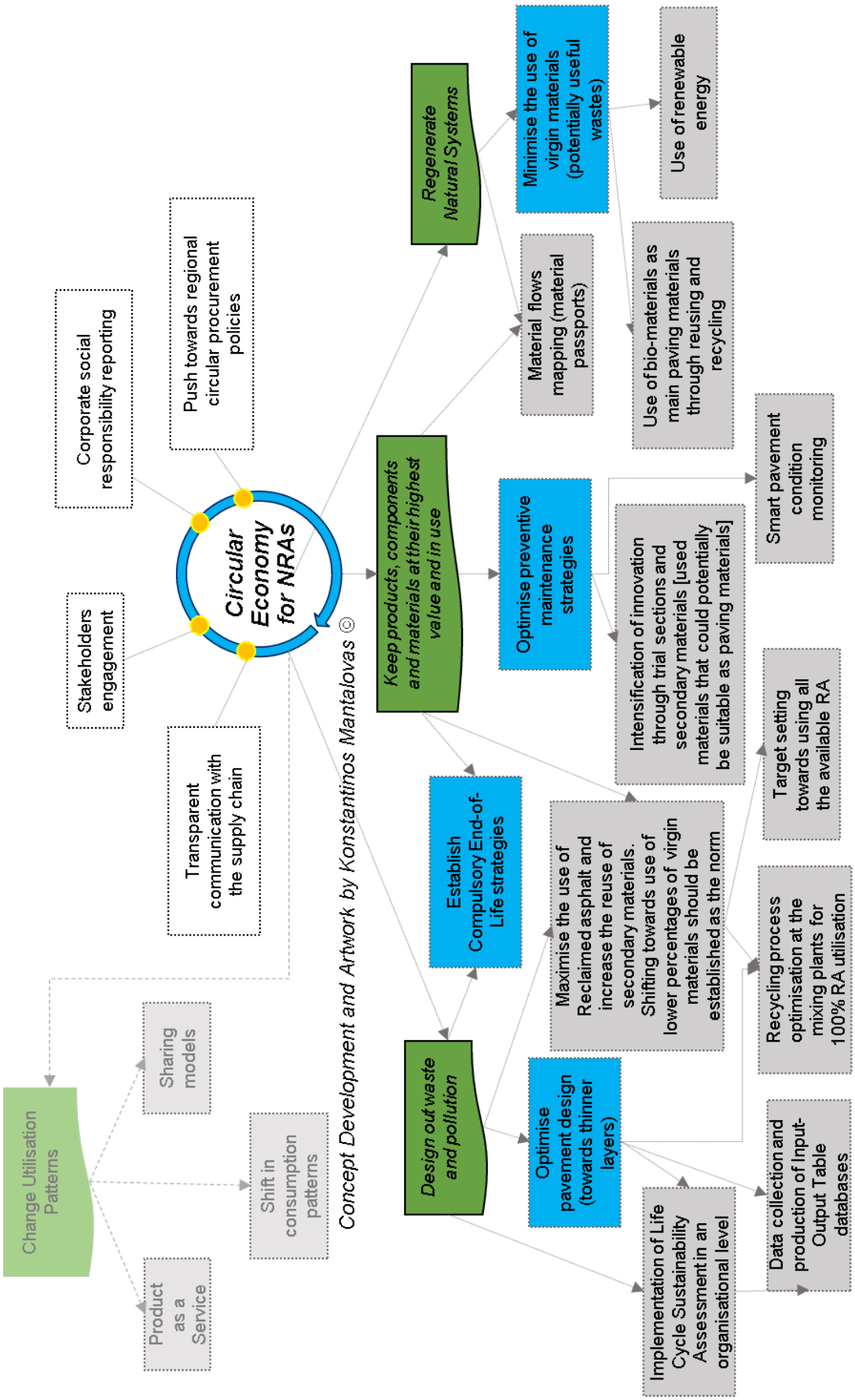

***Figure 5**. Circular Map of recommendations for the implementation of CE by NRAs*

6 Business models logic under the umbrella of CE

6.1 Business models

Emerging from the dotcom era, the concept of business models (BM) has lately drawn the attention of not just researchers but also of industrial stakeholders, practitioners and governments as well. The reason why the concept has gotten increasing interest can be a result from the fact that researchers, as well as practitioners, seeks to find the correlation between companies' competitive advantage and its business model [66]. Although recent interest on the subject, there is no consensus of a definition for the concept. In Figure 1, the most noteworthy definitions of BM are exhibited.

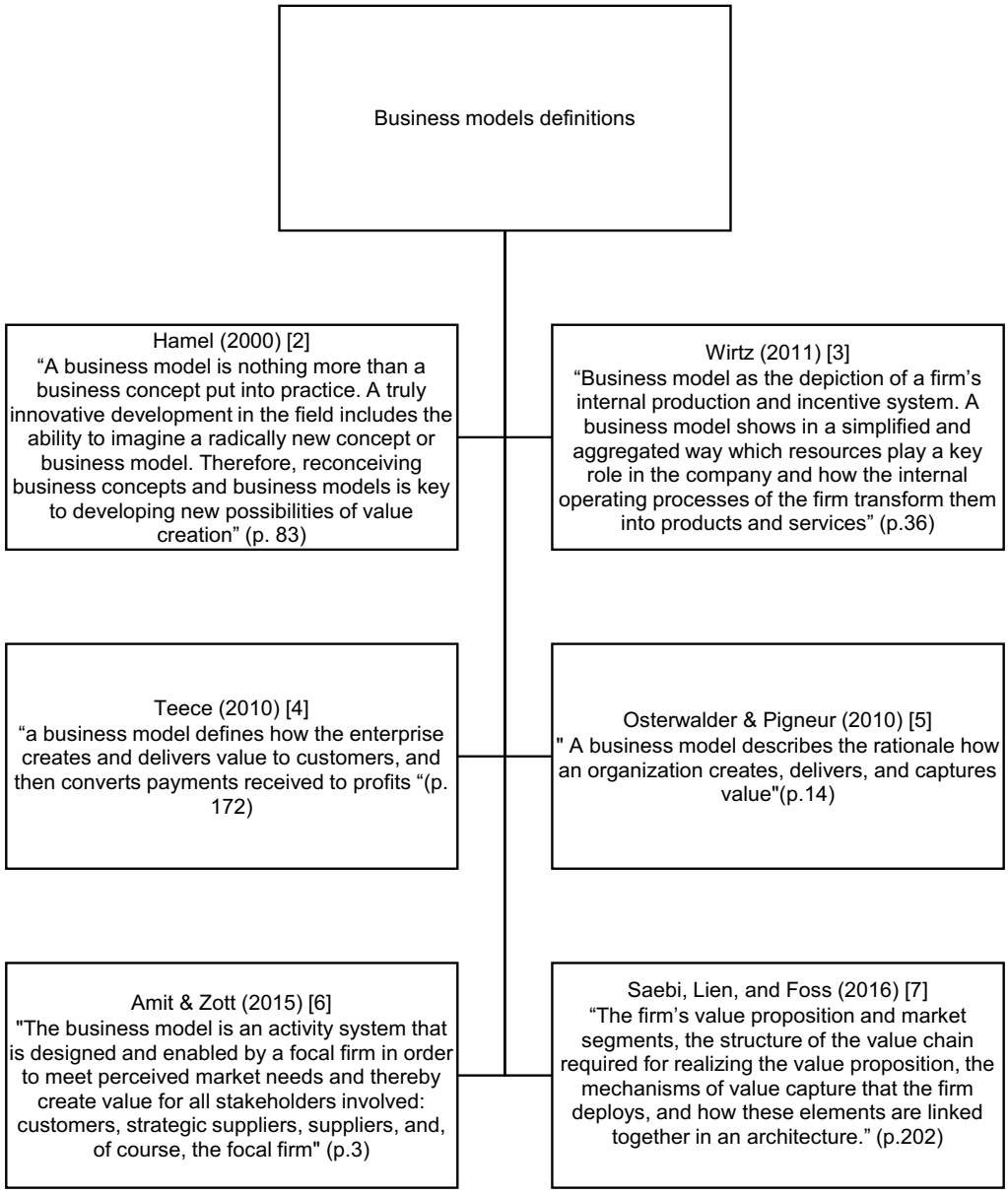

Figure 6. *BM definitions according to various researchers/scholars/publications [66]–[73]*

As can be seen from Figure 1, the definitions that circulate about BM are various but nonetheless relatively consistent. Timely research also tends to include in the definition and/or in the description of BM also the perspective of the potentially involved stakeholders for a more spherical approach to be adopted. Apart from differences, common denominators for BMs tend to be a systemic approach that answers how an organization does business and how it delivers value from a set of activities [66]–[69]. Since the definitions vary, there is neither a consensus structure of elements. However, as Johnson et al. [70] describe four main building blocks in all business models tend to appear: Key resources, key activities, Customer value proposition and Profit formula . Business models are often depicted as a map of how certain elements should be designed and their interactions. One of the most widely used definition/description of a BM is the one provided by Osterwalder & Pigneur, where a BM is seen as a clearly structured hodgepodge of aspects and activities [68], [71].

6.2 The Business Model Canvas

The Business Model Canvas (BMC) is a concept that makes it possible to describe and analyse a BM and has diligently been used by scholars and practitioners [68], [72]. It is a strategic tool that maps out a company's structure, processes, and systems. It consists of nine different building blocks: customer segments, value proposition, channels, customer relationships, key resources, key activities, key partners, cost structure and revenue streams, shown in figure 3. The nine blocks are described separately below according to Osterwalder & Pigneur [68], [72].

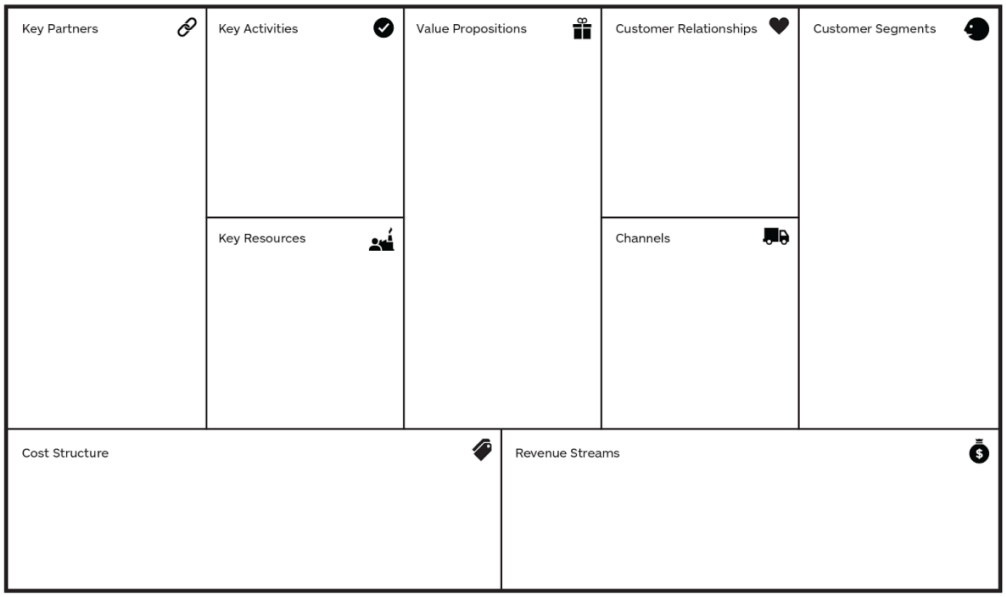

Figure 7. *The Business Model Canvas (after Joyce & Paquin, and Osterwalder)* [68], [72]

Customer segments

Since unavoidably customers are the key parameter of every company's Bm, a level of segmentation can be deemed necessary for a wider spectrum of clients to be included within the company's market capacity. There is macro and micro segmentation. Micro segmentation refers to the location, organisation structure, and geo-location, while the micro segmentation that usually follows the former, is opting to single out, in a more pragmatic approach, the most probable clients [68], [73]. One or multiple and more analytic segments can be identified, and an appropriate BM should be able to cover as much segments as possible, thus, a higher and more diverse market coverage can be achieved. A few examples could be niche markets, diversified markets, mass market and multi-sided platform [68], [71]–[73].

Value proposition

The combination of services and products that creates value for the customer segments is called value proposition. The preference of a customer over one or another company -and thus BM- can be based upon the company's value proposition. A specific company can have multiple value propositions that correspond to different market segments. Usually, the trend that is exhibited is that mass customization and customer co-creation is more important to be involved in the value proposition. Important factors that can appeal to customer problems are design, price, cost reduction, risk reduction and comfort [68], [71], [72].

Channels

To deliver a value proposition to the right market segment, company channels are important. Communication, distribution, and sales are the channels that companies use to interact with customers, and these definitely are the key factors for customer satisfaction. Not only is it important how someone reaches the customers, but it is also important to do it through the channels they more likely desire to be reached through. Effective channels can be used in multiple market segments. Channels can be direct, such as online sales, or indirect channels through retail stores [68], [71].

Customer relationship

Companies must determine what type of relationship they want to establish with each se/group of customers. Depending on the purpose of the relationship, it can be personal, automated, or mixed. The motivation for establishing a relationship may be to attract new customers, retain them, or increase sales. For the new market, the most important thing is to attract new customers, while in a well-established market the most important thing is to maintain and increase sales. The customer relationship directly affects the customer experience [68], [71], [72].

Key resources

In order to create and deliver a value proposition, all business models require critical resources. Different companies need different key resources. Key resources can be owned, leased or purchased from partners, and are classified as: material, human, intangible and financial [68], [71], [72].

Key activities

Success in business requires significant action. Critical activities are necessary to relate to the value proposition, create value, penetrate the market, maintain good relationships, and generate higher returns. The production problem-solving platform is a diverse category of main activities [68], [71], [72].

Key partnerships

Many companies have collaborated to optimize BM, reduce risk, and secure resources. The corporate network of suppliers and other partners is an important part of the partnership. Partnerships can be alliances with non-competitors, “stay close to the enemy” partnerships, collaborations with others to create new companies, or “strengthen buyer-seller” partnerships. An essential aspect here is to identify and secure the key resources someone needs to dominate the market and thus, their competitors [68], [71], [72].

Cost structure

The company's most important costs should be included in the cost structure. The cost structure relies on the profit-making blocks. If a company knows the cost structure, they know how much money they will take to run a profitable business. There are two evaluation aspects of the cost structure. Cost centre and value centre. Most companies fall into two classes and seek to provide higher value to their customers while reducing costs. [68], [71], [72].

Revenue streams

Customers in each department are essential to providing a source of revenue for the company and keeping the business running. Customer segments are willing to pay in other ways. This is the key to understanding and increasing the flow of revenue. There are several ways to generate revenue and adapting to different segments is a big advantage. Revenue flow can be generated via selling assets and creating them using usage fees, such as monthly subscription fees, product rentals, etc., depending on how much the customer uses the product. Each revenue source can have a different pricing strategy. Fixed prices or dynamic prices can both be detected in various BM and revenue streams [68], [71], [72].

6.3 Sustainability in Business Models

The value of sustainable development for the company is increasing with the continuous increase of resource expenditures in the corporate social responsibility reporting program, research has started to solve the problem of innovation of the sustainable development-oriented business model. The organization is expected to set higher standards to address economic and social inequality, financial crises, environmental incidents, resource shortages, energy demand, and technological developments involved in its business model [71], [72]. These challenges can be seen as risks and opportunities for organizations to promote innovation oriented towards sustainable development [71], [74]–[76]. The “triple bottom line” encourages organizations to consider their society and the environment in addition to their financial bottom line and has made great contributions to incorporating sustainability into the business in recent years [71], [72], [77].

For an organization to succeed, it is important to creatively innovate ecologically efficient and ecologically efficient innovations, focusing on maximizing the use of natural, financial, and social resources and integrating them into BM. As described by various scholars, [71], [74], [75], [78], [79] sustainability-oriented innovation must transcend the boundaries of incremental change but expand within the organization and the wider stakeholder environment. For many years, companies have viewed sustainability from an inaccurate perspective, and as a result have rarely significantly reduced the total use of energy and resources [71], [72].

Joyce & Paquin expanded the original business model canvas (BMC) into a new practical tool that integrates social, economic, and environmental issues into a more comprehensive view of the organization's BM, called the triple layered business model canvas (TLBMC) [72]. Similarly, the model proposed by Osterwalder & Pigneur, is an easy to use and practical tool because it allows you to visualize and develop business models creatively [68]. In addition, it provides a way to communicate innovation and sustainable business model changes to different audiences, thereby supporting the transition from incremental innovation to more integrated and systematic sustainability-oriented innovation (Joyce & Paquin 2016). The distinctive feature of the concept is that it uses the stakeholder management perspective and life cycle analysis in the newly created environmental and social canvas to adjust and conceptualize different types of value creation within the business model perspective. (Joyce & Paquin 2016).

The environment layer is shown in Figure 3. It is based on the Life Cycle Assessment (LCA) of environmental impact, which is a formal method of evaluating the environmental impact of a product or service throughout its lifecycle. As mentioned by FORA, the combination of LCA with business innovation can create and support competitive business, product, and service innovations, which have different environmental enhancement characteristics than

traditional business innovations [71], [80].

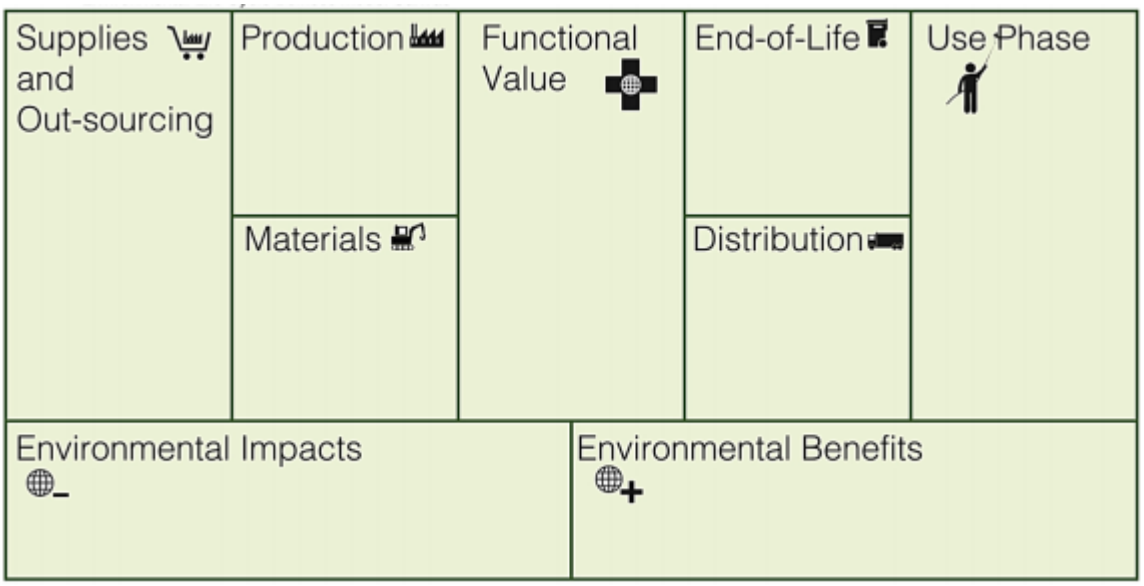

***Figure 8**. Environmental layer of the business model (after Joyce & Paquin)* [72]

6.4 Circular strategies in Business models

In order to improve the resource efficiency of society and/or individual sectors, the concept of circular economy has become a widely considered tool. This concept is a paradigm, which promotes the redesign of the current linear economic system with a linear flow of resources, moving to a closed/open-loop system and maintaining the environmental and economic value of the products/services over time. The reduction of waste generation and the extraction of raw materials is a potential result of a circular economy, which generates environmental benefits [71], [81], [82]. Most BMs are designed to adapt to linear systems where negative environmental externalities are not included in resource prices. To formulate a recycling strategy, the logic of value creation that adds economic value must be reconsidered [81]–[85]. As Nußholz describes, by using the CE strategy to rethink the three dimensions of value in Figure 3, the value creation logic of the company can be changed.

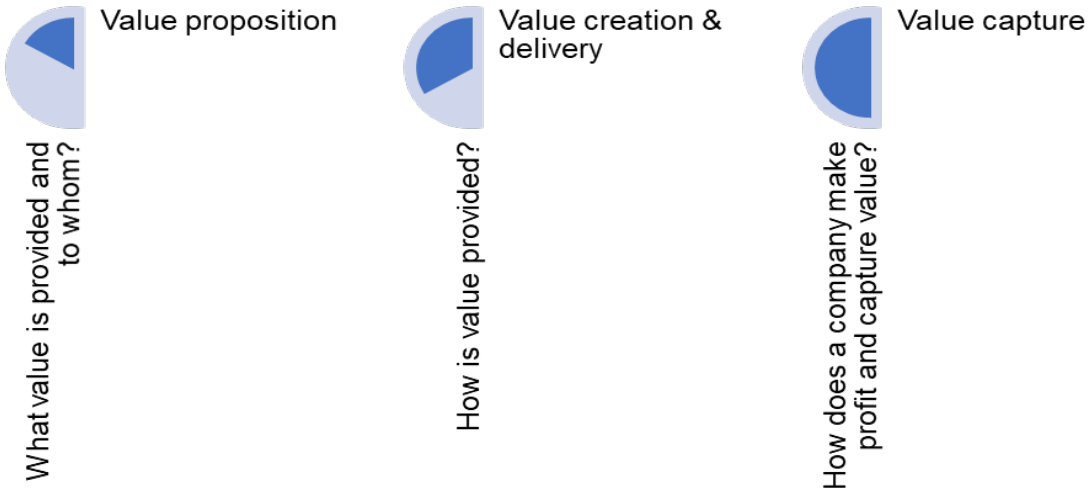

***Figure 9**. Value dimensions of a BM* [68], [71], [86]

The value proposition can be used after an appropriate adjustment to offer a more circular product or service, and even a material flow under an open/closed loop approach. This in turn can attract clients/customers that are environmentally aware. This kind of potential customers can be attracted and thus establish a stable costumer relationship with a company that supports the return of products, through buy back schemes or product service contracts [71], [86], [87].

The value creation and delivery with embedded circular strategies can focus on a series of BMC points. Strategically selecting the key activities for implementing the established company policy is essential, while taking under consideration concepts such as resource efficiency and resource recovery. Moreover, the acquisition of key resources is of significant importance as well as the identification of key partners that can be the suppliers of secondary materials or service providers. Through appropriate channels the key partners are able to motivate and support the return and reuse of goods and secondary materials. Innovation here is of strategic importance since policy barriers can be removed and the extension of the expected service life of a product or a component can be achieved, creating closed/open loop patterns that strengthen the implementation of circular economy [71], [86].

The value capture focuses on the elements that can add additional revenue sources, non-monetary benefits or cost reduction associated with circular economy efficiency strategies and value preservation [71]. More streams of revenue can originate through the capitalization of markets regarding secondary materials/products, which can add value to a company via reselling, repairing, and redistributing. The case can also include the generation of profit through the sales of long-life products at a higher price, from selling access to a product, or providing maintenance services. Changes in cost structure can come from substituting higher

priced primary production with secondary production or avoiding costs in end-of-life disposal [71], [86], [88].

However, a significant amount of companies follow operational patterns that correspond to actions such as substitution of primary material input with secondary production, extended useful life of products, and material recycling [71]. The operational approaches are strongly corelated with the waste hierarchy framework, which in turn is not necessarily implemented in an optimal way. This is where Nußholz mentions that the choice of resource strategy should be guided by environmental impact assessments like life cycle assessments. Sometimes product and material flows are only closed within larger value chain networks and a companies' circular BMs may be a contribution that enables circular strategy and coordinates BM innovation in the network. Finally, actors, independent of value chain position, should strive towards taking responsibility to close material loops and when end-of-life is reached, make sure that resource efficiency is achieved [71], [81], [89].

7 Public Procurement

7.1 Green Public Procurement (GPP) & Sustainable Public Procurement (SPP)

Transitioning towards a functional circular economy regime it has been argued that a systematic and multilevel change is required. This change includes technological innovation, new BM and stakeholders collaboration [89]–[92]. During the achievement of the extension of service lives, and the transformation of wastes into resources, it is of high importance to firstly understand and explore the possibilities and the potential of the opportunities that arise for new business models, digitalization, and a regulative framework, what is considered useless waste and what is considered a raw material. It is true that CE can provide a collaborative platform for various business models through which value creation, delivery, and capture are predominantly based on a circular pattern [68], [83], [93]–[96].

These models apart from delivering an economic value proposition, also, support a more sustainable way of proposing value for all the involved stakeholders [97], [98]. New value networks and stakeholder collaboration are emphasized as essential in developing circular business models [30], [33], as they cannot be based solely on smarter product design, but also on the development of related support services and recycling infrastructure [99]. Leasing, hiring, and product sharing, rather than direct ownership, are examples of such changes. Future business models may be vastly different from earlier forms, necessitating a shift in consumer behaviour [90], [100]. Public procurement, which accounts for an average of 14% of

the European Union's (EU) GDP each year [94], is increasingly recognized as providing considerable opportunity to support the transition of goods and services. This can may be of help towards the incorporation of environmental criteria within all the phases of the life cycle of a product, while ensuring the consideration of the externalities of the environmental degradation. In order to achieve the desirable social and environmental objectives of a resource efficient society, Green Public Procurement (GPP) and Sustainable Public Procurement (SPP) are considered two of the most potent market-based tools that can provide tremendous support towards doing so [101]–[105]. When SPP is to be implemented, the corresponding responsible purchasing agency takes into consideration all three pillars of sustainable development (environment, society, economy). When it comes to GPP the weight is being given predominantly to the environmental aspects of the purchase [94], [104]. GPP is "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured" [106].

7.2 Circular Public Procurement (CPP)

Hence, it becomes obvious that when the objective is to promote the goals of sustainable development and sustainable public or not procurement, GPP is of significant importance. Usually, certain pre-established environmental criteria must be fulfilled during the tender call for a product, process, or infrastructure in general. In addition, the EU's common GPP criteria and GPP criteria at national level have been developed for several product groups, which could help procuring units to buy products with higher circular status [90]. It could therefore be said that circular elements are already being realized to some extent in these product groups through the existing mechanisms of sustainable and green public procurement. However, there is no evidence on how well these SPP and GPP criteria actually capture the circular elements [90].

The use of pre-set criteria relevant to the environmental aspects in the process of public procurement does not necessarily offers a transformation towards more sustainable and circular patterns. It is still under debate to what extent GPP/SPP policies can provide the desirable magnitude of sustainability implications [90], [107]–[111]. Therefore, specific areas of interest in the CE literature are closed-loop supply and value chains, circular business models, and circular product design (Geissdoerfer et al., 2017). Although the production phase, use phase, and end of use are key areas in the circular procurement process, the design phase can also play a key role, which means that procurement can influence design choices. At the end of service life (EoL), components are suitable for repair, refurbishment, or reuse (Philips 2016). This provides opportunities for public contractors to help select

components and determine material requirements and supply chain transparency. According to the common understanding, circular public procurement (CPP) refers to the possibility of contractors to promote the general principles of CE, according to this principle, through slowing down, shutting down, and minimizing resource input and waste, emissions and energy leakage in the system. And narrow the material and energy loop [90], [112], [113]. From a buyer's point of view, this means promoting the six "Rs", namely reuse, recycling, repair, refurbishment, remanufacturing and recycling, while stimulating and creating are beneficial to the CE transaction [114] .In circular procurement, the buyer must ensure that the products are further processed after use, that they are repairable and that [90], [113] they can be divided into sub-components and / or materials and reused at the end of their life cycle [90], [115]. The highest expectations involve circular public purchases aimed at achieving zero waste and no negative effects on production, resulting in products or their elements that are completely compostable or reusable, eliminating toxic materials and using renewable energy for production. This means that in the supply chain, waste can increasingly be seen as a valuable raw material, so waste prevention and recycling will provide bidders with a competitive advantage. Several initiatives and pilot projects have been implemented in circular public procurement.

For example, in Denmark, the Sustainable Procurement Forum and the GPP Association [90], [116] are working hard to use the country’s public procurement as a facilitator of the European Community. In addition, pilot cases of circular acquisitions have been carried out in the textile, computer, office furniture, catering and construction sectors [90], [117]. The British and Dutch governments are also actively participating in the introduction of the concept of circular public procurement at the EU level and have initiated cases and pilot procurement plans in this field [60], [90]. Although the term circular public procurement has been used in general discussions to indicate the possibility of public procurement to green the value chain and capture value creation, there is no standard definition or description of the concept in the literature, and there is no such thing as many public acquisitions Evidence of fulfilment of these expectations.

7.3 Circular economy in the road engineering sector

Policies that encourage the implementation of the principles of CE have already been introduced in some cases. The European Commission, responding to the increasing pressures on natural resources launched the European Resource Efficiency Platform (EREP) in 2012, with a manifesto and policy recommendations that were adopted in Brussels on the 17th of December 2012. The European Resource Efficiency Platform called on business, labour and civil society leaders to support resource efficiency and the move to a circular economy [46]. The target was to move towards a harmonized and controlled transition from linear economic

patterns to circular ones. As described in the published manifesto, the desirable approach would be a transition towards a resource efficient and ultimately restorative CE. After the foundation of the aforementioned platform, which is composed of practitioners and politicians, guidelines have been publicly provided, in order for the implementation of “circular economy(-friendly)” approaches and frameworks to be widely adopted and finally implemented [3], [46]. The United Kingdom acting as a pioneer in this context was the first European country to publish standards about the implementation of CE in 2017 [118]. France followed with the development of voluntary standards called XP X30, published by the French Association for Standardization (ANFOR) in 2018 [78]. The title is “Circular economy—Circular economy project management system—Requirements and guidelines” and the standards propose a common understanding grid, laying out the terms, principles, and practices relevant to CE.

The development of these standards led to the creation of a technical committee within the International Organization for Standardization (ISO TC 323) which is working on enriching and developing international standards in the CE field. The proposed deliverables will apply to any organization or group of organizations wishing to implement CE projects, such as commercial organizations, public services, and not-for-profit organizations. Specifications relevant to already covered and standardized aspects such as eco-design, life cycle assessment, environmental management and sustainable procurement will not be included in the standards. Moreover, in July 2019, Platform CB’23 from The Netherlands published a framework for circular construction, focusing on building works. The requirements for a uniform measurement method of circularity are emphasized and an approach for quantifying circularity is proposed [61]. Finally, the European Union, understanding the necessity for CE, had officially adopted an action plan in 2015 to help accelerate Europe’s transition towards a CE, boost global competitiveness, promote sustainable economic growth and generate new jobs and in 2019 the Circular Economy Action Plan was completed [48]. The European Commission has invested in CE and sustainability in every sector. For the pavement engineering, and road construction and maintenance sectors, a technical report was published in 2016 [64], detailing the practices that NRAs and involved stakeholders should be implementing for more sustainable and circular approaches.

Moreover, a set of criteria has been developed, that can help stakeholders act immediately even without having a deep knowledge of CE and sustainability. The EU commission has identified some of the most impactful stages and aspects of a road’s lifecycle that when modified accordingly can be significantly beneficial for the environment and the economy, based on the principles of green procurement and CE. The most relevant stages/aspects identified that can be immediately applicable for increased circular performances are:

- Resource efficient construction.
- Recycled content: high percentages of materials are recycled into asphalt pavements, while complying with the performance requirements for the road pavement.
- Excavated materials, soil, and wastes management: excavated materials, soils and wastes that are not hazardous can be reused on site.
- Water and habitat conservation: road drainage systems must adequately drain both stormwater from the road surface and sub-surface water from groundwater flows. Moreover, it is suggested that Sustainable Drainage Systems (SUDS) are promoted to re-use the drained water.
- Maintenance and rehabilitation strategies: a Maintenance & Rehabilitation Plan, that considers all the suggestions, should be developed during detailed design.

The European Commission has also published a document entitled “Circular Economy: Principles for Buildings Design” [65] that details the general principles that should be implemented if a more circular approach is to be adopted in the building sector. The document is specifically focused on buildings, but the main principles are presented here because of the similarities that exist between buildings and roads.

- Better knowledge is needed about construction techniques to facilitate deconstruction and to enhance durability and adaptability of built assets.
- Durability depends on better design, improved performance of construction products and information sharing.
- Prevent premature asset demolition by developing a new design culture.
- Design products and systems so that they can be easily reused, repaired, recycled, or recovered.

While these principles refer to buildings, they can easily and immediately be applied to other built assets such as road pavements, thus assisting the road engineering industry as well. The road engineering industry, by taking under consideration the recommendations/suggestions, could potentially improve its environmental performance and sustainability levels while increasing its circularity. Green, Sustainable, Circular Procurement

However, direct directives, legislations, or standards do not exist for the circular procurement when it comes to the road engineering sector. There are mentions in the aforementioned reports of the European Commission about the reuse or recycling of asphalt for the minimisation of waste and resource extraction; reduction of the transportation distances of materials and the use of smart and innovative technologies for the production of asphalt

mixtures, construction and management of asphalt pavements. Now, when it comes to the aspect of procurement in combination with the circular economy, no details can be found in the literature or standards. For this reason, within the PavementLCM project a questionnaire was structured and sent to the involved NRAs in order for a better understanding to be acquired. The full questionnaire can be found in Appendix B.

7.3.1 Questionnaires to National Road Authorities

In order to identify procurement schemes, policies, economic models, and business models a questionnaire was sent to NRAs that are in partnership with the funding body of the project (CEDR). They were contacted by email and the questionnaire was sent electronically and filled through a Google platform. However, the survey was structured in a manner which was able to provide a qualitative analysis through the questions, which are relevant to the circular procurement and business models and were also included to the questionnaire for a more spherical overview. The data and results presented include all the NRAs that have filled in the questionnaire. It was filled openly by up to 2 persons working within the corresponding NRAs in positions closely related to sustainability and/or sustainability development and assessment. The questionnaire was filled by only the 4 NRAs given below.

- Austria (ASFiNAG)
- Denmark (Danish Road Directorate—Vejdirektoratet)
- Norway (Norwegian Public Roads Administration—NPRA)
- Netherlands (Rijkswaterstaat, State advisors for urban development & infrastructure)

The questionnaire can be found in Appendix B.

7.3.1.1 Results/Outcomes of the questionnaire

After having received back the replies of the NRAs that participated in the survey their answers were tabulated and the final answers can be seen below in Table 1. It is important to underline that from the at least 9 NRAs that were contacted only 4 replied to the questionnaire.

Table 5. *Presentation of the replies given by the 4 participating NRAs*

QUESTIONS	REPLIES PER COUNTRIES' NRAs			
	Netherlands	Denmark	Austria	Norway
Could you please briefly describe the way that your National Road Authority proceeds with procurements ?	We have an EPD (i.e. MKI) requirement in the RWS specifications as reference value. In addition for some contracts we use MEAT (most economic attractive tender) to stimulate lower EPD values.	As per current practice, the DRD procures through tendering processes where criteria must be met. Evaluations are based on price. However, the DRD, and indeed the rest of Denmark, are in the midst of implementing an LCA-model which, at a later point, will enable environmental and climate-based criteria to acts as an evaluation parameter too.	CO2 equivalent analyses tool which prefers ecological products	The Norwegian Road Authority is organized in divisions. Procurements of large investment contracts is in a separate division. Procurements for maintenance and small investment contracts is in a separate division. Procurements related to consultancy for planning processes is in a division called Transport and society.
Is there a specific procurement scheme that has been developed following the business logic of Circular Economy? If yes, please provide the business logic behind it and the reasons for its implementation. If no, what is the reason?	The MKI method includes some rules for circularity incl. module D. It is not perfect, but still a first step.	This is conducted through tendering processes with specifications as per the contract contents More will and can follow within 6-12months.	this tool assesses different asphalts with regard to CO2 emissions. (with the same life cycle and load)	Lowest price has been the most used criteria in evaluating procurement in most contracts up to now although it has been other criteria also – like quality and willingness and competence to reduce negative effects on nature and climate due to building. In the new procurement strategy for maintenance makes a change by claiming that all new procurements must make demand on reporting on emissions of CO2 and reducing them. The procurement strategy also opens for contracts that last longer (maintenance) and to try out new procurement methods in order to encourage innovation. The intention is to both improve quality and reduce environmental footprint, within a cost-efficient approach.
What is the procedure to create bids for potential road asset construction and/or management ?	in some cases MEAT	Not yet as described here. It will follow.	In addition to costs, the CO2 emissions (qualitative) are taken into account for the award	-
Do the practices take under consideration principles that comply to Circular Economy and/or Sustainability? If yes, please provide the principles and the ideology behind their development. If	yes, see above (MEAT on MKI)	LCC, or CE, will be joined in the sense that the new LCA-model will enable better or full illumination of emissions and reduction potentials. From there, economy and monetizing of initiatives can be adjoined to reveal what initiatives are most efficient, seen from an	Not only the economic components (such as durability and stability) but also ecological components (noise reduction and CO2 reduction)	-

no, what is the reason?		economic point of view.		
Is there a macro-economic model in place for the implementation of Circular Economy in your National Road Authority's practices? If yes, is it available publicly and could you provide it? If no, what is the reason?	Not really macro economic model. However, we use the McKinsey cost curve method to rank the innovations. I.e. low cost high effective innovations are implemented first. This is not yet available.	Not yet as described here. It will follow.	Not yet	Not really. In early stages of the planning process there is an economic model that do socio-economic analysis. It is called EFFECT. The model takes in estimated emissions on an overall level. Most of nature related topics are not considered in the economic model
Are there policies or legislations dictating the implementation of Circular Economy in your business approach? If yes, is it available publicly and could you provide it? If no, what is the reason?	yes, policy of Ministry of infrastructure. See https://www.rijksoverheid.nl/documenten/rapporten/2020/06/15/bijlage-1-strategie-naarklimaatneutrale-en-circulaire-rijksinfraprojecten to download the document in Dutch	Dictating, no, not in this context.	the current objective of ASFINAG is to operate the ASFINAG systems with self-generated green energy (tunnels, ...)	In the spring of 2021, we will get a National strategy for circular economy. The National Road Authority has contributed to the content of this. By now the factual basis is available in Norwegian. When the strategy is published it will also be available to share (and in English).

During the selection process of the contractors and partners for the construction management of road assets, do any of these aspects are taken under consideration? - Supply chain management - Corporate social responsibility - Environmental management. If yes, in which manner? If no, what is the reason?	We require a CO2prestatieladder certificate. see https://www.rijkswaterstaat.nl/zakelijk/zakendoen-metrijkswaterstaat/inkoopbeleid/duurzaam-inkopen/co2-prestatieladder	Not yet. However, this will follow before too long. Again, perhaps 6-12months	There are award criteria (quality, social, ecological)	Yes, for example: It is required to deliver EPD on the most important raw materials and products in our procurements. We require reports on how much fuel and what kind of fuel on new contracts to be able to deliver a greenhouse gas account. The national road authority has incorporated our corporate social responsibility in the five top goals for the organization. These goals are communicated, and we are encouraged to look to these goals in almost everything we do, both in planning, building and maintenance. In new procurement it is required that the contractor need a ISO 14001 certification or to deliver according to the demands that is set by ISO 14001. In larger new contracts the contractor is also required to have a certification in Ceequal or a similar system. For a long time, the contractors, both for construction projects and maintenance, have been required to register natural qualities and deliver plans for how to protect these during the contract period. There are many themes that have been taken care of in these plans. It is the reduction on greenhouse gas emissions that is new in the systems that now are about to be implemented.

- ***Could you please briefly describe the way that your National Road Authority proceeds with procurements?***

Here we can see that the NRA of the Netherlands is using EPDs in order to support a more sustainable way for procuring, similarly to the NRA of Austria that uses a carbon foot printing tool to prioritize ecological products. The Danish NRA is for now using only cost-based criteria but and environmental decision-making approach based on Life cycle assessment is under development.

- ***Is there a specific procurement scheme that has been developed following the business logic of Circular Economy? If yes, please provide the business logic behind it and the reasons for its implementation. If no, what is the reason?***

The NRA of Netherlands is doing a first step towards circular economy by trying to include “Module D” in its procuring schemes, while the NRAs of Austria and Denmark do not seem to be progressing towards circular procurement. The NRA of Norway as well,

is using CO2 calculators and cost analysis while supporting innovation and increased quality and thus durability of the procured assets.

- ***What is the procedure to create bids for potential road asset construction and/or management?***

The NRAs of Norway and Denmark were not able to describe the requested process while in the Netherlands the most economically attractive tender is taken under consideration in some cases. Again, in Austria cost and carbon foot printing are used for the creation of bids.

- ***Do the practices take under consideration principles that comply to Circular Economy and/or Sustainability? If yes, please provide the principles and the ideology behind their development. If no, what is the reason?***

ASFiNAG takes under consideration the durability of alternative assets, the cost, and their carbon footprint, while Rijkswaterstaat again uses the most economically attractive tender and EPDs. Finally, the Danish NRA is focusing on the economic aspect of the process using life cycle costing subsequently followed by life cycle assessment.

- ***Is there a macro-economic model in place for the implementation of Circular Economy in your National Road Authority's practices? If yes, is it available publicly and could you provide it? If no, what is the reason?***

When NRAs were asked about macro-economic models the replies started projecting the immaturity of the sector in terms of advancement regarding circular economy and economic models. The NRA of the Netherlands is using the McKinsey cost curve to reward highly innovative and low-cost solutions, while the rest of the NRAs replied that no effort has been made in this regard.

- ***Are there policies or legislations dictating the implementation of Circular Economy in your business approach? If yes, is it available publicly and could you provide it? If no, what is the reason?***

Again, the Netherlands seem to be a pioneer in this regard, since the Ministry of Infrastructure has already established a policy relevant to circular economy available so far only in Dutch. Following, the NRA of Norway is working on the development of a national strategy towards a circular economy in the sector and it will be published in English and available soon.

- ***During the selection process of the contractors and partners for the construction management of road assets, do any of these aspects are taken***

under consideration? - Supply chain management - Corporate social responsibility - Environmental management. If yes, in which manner? If no, what is the reason?

Again, the use of a CO_2 calculation is used to cover aspects such as supply chain management, corporate social responsibility and overall environmental management in the Netherlands that rewards the least environmentally impactful proposals. Similarly, with the NRA of Austria where award criteria are based on quality, social, and ecological aspects. Here the most concise answer seems to be the one of the Norwegian NRA. They use EPDs for the environmental aspect of management and they robustly take under consideration the social aspects of their operation, under the umbrella of corporate social responsibility, by having five strategic goals to which they have to comply. Moreover, in larger contracts tools like CEEQUAL are used to cover all aspects of sustainability implications.

8 Discussion and Conclusions

Within the perspective of a road engineering industry, based upon the principles of sustainability and circular economy, the approaches in constructing and managing asphalt pavements play a key role. Lately, NRAs are directly or indirectly being pushed towards implementing more sustainable and circular operational patterns, this is achieved either by complying to existing legislations, or via trying to promote a more sustainable way of doing business out of environmental, social or mostly economic concerns. Moreover, the necessity for the NRAs to shift towards a more sustainable and circular way of operating has been analysed. As seen in Chapter 1, CE is not something new, but the natural evolution of concepts that attempt to lead humanity into achieving a more sustainable living and development within the boundaries of the planet earth.

In order to identify the ways that the investigated NRAs are implementing and communicating CE and its principles an online search was conducted on the official websites of the NRAs, relevant to documents or initiatives undertaken to promote CE. As it can be seen from the analysis, the majority of the NRAs is not currently communicating any CE related advances or implementation actions. Moreover, analysing the results obtained from the questionnaires sent to the NRAs, it seems that all the NRAs are familiar with the concept of CE and most of them are also familiar with most of the principles it represents, but their majority is not implementing them thoroughly. Most of the NRAs replied that are:

- ***prioritizing the "designing out" of the waste of their products*** and that they
- ***attempt to prolong the life of their assets by conducting preventive***

maintenance.

Some of the NRAs stated that they are not implementing such circular practices, but however, they do recycle, they do implement preventive maintenance regimes and they do sometimes utilize waste materials as resources within the asphalt pavements that they construct and manage. This proves that all of the NRAs that have filled the questionnaire with one or another way, do implement practices that are aligned with the principles of CE. This could lead to the conclusion that more people with specialization in CE should be operating within the NRAs providing higher accuracy, more insights and knowledge in terms of CE implementation.

Recommendations and best practices that would be able to provide NRAs a more sustainable and circular operating angle have been presented in chapter 4. The most immediate actions that NRAs could undertake in order to move towards this direction are:

- The rethinking of their designs, minimising the use of materials and improving the durability of the asphalt pavements
- The utilisation of end of life materials such as biomaterials, reclaimed asphalt and by products in general that are considered wastes.
- The utilisation of life-cycle based techniques at both design and management of their assets, quantifying the potential environmental impacts and thus proceeding with the most preferable options
- The investment in research and development of alternative, more environmentally friendly construction methods
- Design products and systems so that they can be easily reused, repaired, recycled or recovered.
- Communication and transparent relations with the whole value and supply chain
- Development of circular business models that will benefit both the NRAs and the stakeholders along with the users
- The utilization of material flow mapping, along with the utilization of soil and wastes during the construction and maintenance phases as useful materials
- Development of methodised end of life strategies, focusing on the possibility of closed loop approaches and/or upcycling.

Finally, more and more NRAs should allocate percentages of their budgets towards the development of circularity metrics and roadmaps/strategies towards the implementation of CE and the assessment of the levels of this implementation. This could help to monitor and evaluate the progress that is being made and finally develop a feasible and spherical framework of how they should actually be implementing CE in asphalt pavements in the best way possible. This way could be complimented by following the

recommendations for knowledge development and the "Map of Circular Recommendations" deployed in previous chapters, in order for a Sustainable & Circular Life Cycle Management approach to be achieved. The implementation of CE is not a simple and instant process. Hence, in order for circularity to be achieved within an organisation or an authority in this case, knowledge development has to occur in different layers of stakeholders divisions and not just the organisational territory itself. Furthermore, the aforementioned map provides recommendations on a strategic level that are able to satisfy the 3 principles of CE as defined in Chapter 2. Further in-detail structured processes are identified that when implemented, either individually or in combination, address the CE principles.

Moreover, having tabulated the answers provided by the participating NRAs it becomes obvious that there is a conceptual misunderstanding of NRAs when it comes to the business/procurement aspect of circular economy. Most of the replies of all the asked questions were referring to life cycle assessment and EPDs or CO_2 foot printing. In reality, when it comes to circular economy and procurement schemes that can comply with it the situation is much more complicated. Thus, NRAs should allocate higher budget percentages towards becoming more familiar with circular economy, circular business models and green procurement. Moreover, the collaboration with economists or economic analysts could be of great help for the NRAs in order for them to formulate a procuring and operating scheme that can fulfil their circular ambitions. In order to address this, business models with multiple layers (environment, society, economy) have to be utilized. A combination of Top-down and bottom-up approaches must be implemented for the management and optimization of the supply chains and a strong collaboration and transparent communication has to be established with all the involved stakeholders.

Yes, life cycle assessment can assess the environmental impacts of potential projects and contracts; but this is just one small piece of the pie. If we consider that circular economy mainly pushes for:

- Designing out waste and pollution;
- keeping products, components, and materials at their highest value and in use;
- regenerating natural systems,

then environmental assessment is, indeed, of significant importance but does not seem the most capable tool do be implemented for the realisation of the aforementioned principles. It can definitely help towards these targets, but it cannot stand alone as a panacea. It must be used as a support tool with the aforementioned. Moreover, environmental metrics must be merged or accompanied by circularity metrics. The supply management must be on the focal

point along with alternative energy sources, innovation -and even better, BM innovation-, circular procurement and very importantly waste management. This is because an integral part of the CPP is the life extension of products, the assurance of their reusability and recyclability in the most environmentally friendly way, product design adaptation, radical technological or ideological/methodological innovation along with, the transparency of the supply chain management and finally the "green" supply management. The focus can be on the product or service being improved, a new product being developed in circular terms, a procurement process based on a product-service system or another circular business model, or circular ecosystems, in which many stakeholders cooperate, locally provided resources are circulated, and regional networks are developed. Although these approaches can be overlapping in the sense that they may include some of the same features, procurement of new circular products and development of circular ecosystems seem to support the idea of innovative public procurement and public procurement of innovation whereas procurement of improved products and services can be carried out by adding existing GPP criteria to tendering processes. To help interested and involved stakeholders for a more circular approach in their businesses, organisations/institutions, the following recommendations can be drawn.

- Examination of the reasons behind the potential adoption of circular procurement schemes within an organization and the acquisition of a clear picture of what circularity means to different organizations.
- Collaboration and discussion with internal stakeholders in order to align interests, involve and inform internal stakeholders.
- Transformation of the tendering procedures in such procedures that can reflect the pragmatic and realistic targets of the project. If collaboration is key e.g., then it has to be clarified and transparently communicated. [The European Commission's tendering principles offer a clear framework for both commercial organizations and tendering authorities.]
- Development and implementation of a circular selection and award framework.
- Financial incentives can be introduced through circular revenue models in order for the desired circular performance to be achieved.
- Use of circularity metrics and KPIs to obtain the required or desirable performance before during and after the tender procedure.
- Robust and transparent collaboration between clients and contractors for effective contract management and optimisation.

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Appendix A [QUESTIONNAIRE]

Questionnaire about Circular Economy

SECTION 0. INTRODUCTION

What is Sustainability Assessment of Civil Engineering Works?

"Combination of the assessments of **environmental performance, social performance and economic performance** taking into account the technical requirements and functional requirements of a civil engineering work or an assembled system (part of works), expressed at the civil engineering works level." – **EN 15643-5:2017**

What is PavementLCM Project?

Road pavements are complex and dynamic systems which need to be properly managed during their whole life cycle to ensure they deliver their function to society. From this point of view, Life Cycle Assessment (LCA), Life cycle costing (LCC) and life cycle approached looking at social aspects are becoming popular techniques aimed at helping the different stakeholders in the process. However, the lack of a standard framework to perform Life Cycle Management (LCM) of road infrastructures means decisions are very much dependent on the analyst's work and assumptions, which can lead to considerable differences amongst methodologies and finally results cannot be comparable from one case to another. This is not least the case for assumptions concerning the durability of new materials, which is a necessary part of any life cycle analysis. However, discrepancies are still present within National Road Authorities (NRAs) but even amongst researchers and it is in the interest of every stakeholder that a harmonised framework and clear user-friendly guidelines are created to allow LCM analyses to be made with confidence.

PavementLCM is a 2-year international project which will be carried out by a multi sectoral consortium to deliver a complete package to allow NRAs to carry out harmonised LCM exercises for Green Asphalt, as well as providing training and user-friendly guidelines to support their widespread use. The specific objectives of PavementLCM are:

- To create a general LCM framework with templates and case studies to carry out harmonised sustainability assessments of both asphalt mixtures and road pavements and to transfer the knowledge with a training tailored to NRAs.
- To create the Pavement LCM lookup tool as a user-friendly tool to help members of NRAs to find most appropriate datasets, methodologies and results of previous LCM studies for a specific situation.
- To produce datasets of sustainability data and durability data of identified Green Asphalts for selected case studies, based on existing sustainability datasets and novel durability testing.
- To provide NRAs with a methodology and recommendations for coping with uncertainty of datasets of LCM exercises, both inputs and results, as well as roadmaps towards data harmonization at EU level.
- To produce guidelines and recommendations towards using LCM results within a multicriteria sustainability assessment (complying with CWA 17089 and EN15804).

SECTION 6. CIRCULAR ECONOMY

Are you familiar with the concept of Circular Economy and its principles?

Yes	No

If yes, which principles of Circular Economy are you familiar with? (tick as many as needed)

Design out/minimise waste

Use waste as resource (recycle, reuse)

Prioritize regenerative resources

Preserve and extend what is already made

Other, please specify:

Which of those principles have already been introduced within established pavement life cycle management practices?

Design out/minimise waste

Use waste as resource (recycle, reuse)

Prioritize regenerative resources

Preserve and extend what is already made

Other, please specify:

Which practices are you using to implement those principles for Circular Economy?

If these principles are currently not implemented into practices, which reasons/challenges are impeding it? Is there a future strategy to implement them?

Are there any current metrics/indicators to assess the level of circularity of these practices and/or the pavement management process?

Yes	No

If yes, which are these metrics/indicators?

- Product Material Circularity Index (MCIP) [Ellen MacArthur foundation (EMF)]
- Company Material Circularity Index (MCIC) [Ellen MacArthur foundation (EMF)]
- End of Life recycling input rate [Available in the EU's Raw Material Scoreboard and in EC Monitoring framework for the CE (under development)]
- Resource Efficiency [EU Resource Efficiency scoreboard (EURES)]

Other, please specify:

If no, which reasons/challenges are impeding their development? Is there a future strategy to define them?

Has a “Roadmap” towards Circular Economy been produced/published, to achieve more sustainable and circular management of asphalt pavements?

Yes	No

If yes, could you please provide us with a copy or link to find it

If not, which are the current challenges, posing as obstacles towards the production of such a roadmap? Is there a future strategy to produce one?

Appendix B [QUESTIONNAIRE]

Questionnaire about Circular Economy: WP6 questionnaire on Circular models to favour the uptake of green asphalts.

WP6 is working on the implementation and communication of circular economy (CE) principles in asphalt and pavement construction. To develop and review the best practices linked to the CE is important to obtain some information on the state-of-the-art in different countries and the consequent application in NRAs policies.

1. Could you please briefly describe the way that your National Road Authority proceeds with procurements?

2. Is there a specific procurement scheme that has been developed following the business logic of Circular Economy? If yes, please provide the business logic behind it and the reasons for its implementation. If no, what is the reason?

3. What is the procedure to create bids for potential road asset construction and/or management?

4. Do the practices take under consideration principles that comply to Circular Economy and/or Sustainability? If yes, please provide the principles and the ideology behind their development. If no, what is the reason?

5. Is there a macro-economic model in place for the implementation of Circular Economy in your National Road Authority's practices? If yes, is it available publicly and could you provide it? If no, what is the reason?

6. Are there policies or legislations dictating the implementation of Circular Economy in your business approach? If yes, is it available publicly and could you provide it? If no, what is the reason?

7. During the selection process of the contractors and partners for the construction management of road assets, do any of these aspects are taken under consideration? - Supply chain management - Corporate social responsibility - Environmental management. If yes, in which manner? If no, what is the reason?