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Heavy vehicles on the road towards the circular economy: Analysis and comparison with the automotive industry

Michael Saidani*, Bernard Yannou, Yann Leroy, François Cluzel

Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay, France

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ABSTRACT

With 270 million light vehicles and 20 million heavy-duty and off-road (HDOR) vehicles in use in the European Union, automotive and HDOR industries are two major sectors in the European economy. Each year, 12 million light vehicles plus 1 million HDOR vehicles reach their end-of-life. In a context of circular economy, following questions are of growing concern. To what extent is the circular economy achieved and implemented in the automotive and HDOR sectors? What industrial practices and regulations are prevalent and commendable in the light of the circular economy? While the end-of-life management of light vehicles – subjected to the ELV Directive 2000/53/EC – is widely studied in literature, the end-of-life stage of HDOR vehicles has been neglected for a long time from a research perspective. To fill this gap, extensive literature survey and in-depth investigations on the industrial ground are conducted. Key factors – i.e. regulations, business models and markets evolution, new and emerging technologies integration – affecting the circular economy performance of automotive and HDOR sectors are analysed. Notably, not only lessons learned from best industrial practices but also remaining challenges for a more circular economy are highlighted. Both industries are compared through the four buildings blocks of the circular economy and the four possible feedback loops defined by the Ellen MacArthur Foundation. As a result, this research contribution could lead to practical applications, for instance, in supporting industrial practitioners or policy makers to realize the opportunities and challenges of closing the loops of HDOR vehicles from different perspectives.

1. Introduction and background

Climate change, global warming, and natural resources depletion linked to anthropic root causes are no longer questioned, as highlighted in numerous Intergovernmental Panel on Climate Change reports (IPCC, 2014; IPCC, 2015). Thus, optimal designs, uses and managements of resources and systems are more than ever essential for the sake of human kind and biodiversity. Furthermore, as reported by the McKinsey Commodity Price Index (MGI, 2013), resource prices have increased significantly since the turn of the 21th century. The dependence of industries upon raw materials, such as precious or rare metals, presents highly strategic challenges for supply management. Besides the shortages and supply challenges of metals in Europe, the rise in global demand for raw materials has created extraordinary price volatility (Hagelüken et al., 2016).

For the automotive and heavy-duty and off-road (HDOR) vehicles industries, these added costs increase by several million euros from year to year (ACEA, 2015). Indeed, with 270 million light vehicles (passengers cars and light-commercial vehicles) and 20 million HDOR vehicles in use in Europe (ICCT, 2016), the automotive and HDOR sectors are two industrial giants in Europe. Their economic footprints, as well as their environmental footprints, which are still growing, are nor debatable. In fact, the turnover generated by the automotive sector represents 6.5% of the European Union (EU) gross domestic product and more that 12 million people are employed in the sector (ACEA, 2016). Being able to anticipate any shortages and to secure supply of raw materials are of the utmost importance for the manufacturers (Sievers and Tercero, 2012). Equally, the geopolitical issues around raw materials and resource efficiency are being integrated at the EU level (EC, 2010; EC, 2011 EC, 2014a; EC, 2015). Particularly, 12 million light vehicles plus 1 million heavy vehicles are taken off the roads every year in the EU, which amounts to millions of tonnes of what actually constitute valuable resources (EMF, 2013a; Weiland, 2014). As a consequence, automotive and HDOR manufacturers have a direct interest in a more sustainable management of their products, components and materials in order to say competitive in front of price rise and volatility.

To support both economic growth and sustainable resource management, the circular economy paradigm seems to be a great

* Corresponding author.
E-mail address: michael.saidani@centralesupelec.fr (M. Saidani).

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opportunity for industrial practitioners. Indeed, the promises and benefits from circular practices have been comprehensively discussed in literature (EMF, 2013b; CIRAIG, 2015; MGI, 2015; Lacy, 2015; Ghisellini et al., 2016). The circular economy is seen as a restorative solution with the potential to eliminate waste (EC, 2015a; EEA, 2015; EEA, 2016). Also, it could both secure Europe's competitiveness and ensure benefits from the three piliars of sustainable development (Banaitė, 2016 Sauvé et al., 2016; Geissdoerfer et al., 2017). Particularly, using closed-loop approaches mitigate manufacturers' dependency on virgin materials and decrease price volatility (Kiser, 2016). Yet, some industrial fields need to be boosted in their transition from a linear to a more circular economy. Companies may lack of capacity, information, indicators and targets to move to circular economy solutions (EASAC, 2016). To date, there has been so much focus on the end-of-life management of the automotive sector compared to the HDOR sector.

On the one hand, the end-of-life management and recycling issues of cars – i.e. automotive sector – have been extensively studied in literature through different perspectives in the last two decades (Tukker and Cohen, 2004; Wells and Orsato, 2005; Reuter et al., 2006; Froelich et al., 2007; Chemineau, 2011; Millet et al., 2012; Farel et al., 2013; Yi and Park, 2015; El Halabi, 2015; Despeisse et al., 2015; Simic, 2015; Idjis et al., 2017). On the other hand, the current lack of studies regarding waste minimization and end-of-life stage of HDOR vehicles seems principally due to the absence of end-of-life regulations and extended producer responsibilities. In fact, most of the research regarding HDOR vehicles are focused on the design and the use phase of such heavy equipment on wheel. This approach is justified since around 80% of the total environmental impact – throughout all life cycle – of vehicles, light or heavy, are generated during the use phase (Hill et al., 2012; Manitou Group, 2016). Current US and EU improvement road maps related to HDOR vehicles address barely the end-of-life value chain of HDOR vehicles so as to focus on the optimization of design and usage phases (ERTRAC, 2012; USDoE, 2013; Poulikakos et al., 2013). Indeed, research works are mainly focused on fuel reduction during the use phase (Walnum and Simonsen, 2015), emissions mitigation (ERTRAC, 2012), and lightweight materials integration (USDoE, 2013).

Nonetheless, the end-of-life management of HDOR vehicles is also an important research and industrial subject that is important to be tackled to identify unexploited or wasted opportunities in this sector. In addition to the willingness to fill these gaps, initial observations – based on a preliminary field diagnosis – that essentially triggered and motivated this research work related to the HDOR sector, in a context of circular economy, are the following:

- Tonnage of end-of-life HDOR vehicles represents the same order of magnitude that end-of-life vehicles (ELV) tonnage in Europe. For instance, this tonnage is around 1 million tons in France (ADEME, 2006). As such, economic, environmental and social stakes of the HDOR industry could be as important as the automotive industry and therefore constitute a significant area of work and improvement relevant for policy makers and industrial practitioners;
- Lack of regulations for the end-of-life of HDOR vehicles, contrary to ELV Directive 2000/53/EC, that leads industrial practitioners to question about the anticipation of future or upcoming regulations;

On this basis, it becomes significant to position the HDOR sector in shift towards the circular economy. As such, the aim of this paper is to provide a comprehensive overview of the situation and progress of the HDOR industry in the light of circular economy in Europe. Thus, this paper reports on existing initiatives and incentives from HDOR industry aligned with the circular economy principles. In particular, it highlights emerging approaches, such as new integrated technologies or innovative business models in their contributions and impacts in the circular economy. Also, the situation and progress of the automotive industry will be examined as a comparison point, in order to learn from best practices. Based on both in-depth literature review through different types of resources – e.g. academic papers, industrial, government and consulting reports, companies' websites – and investigations on the industrial field, keys insights and answers to the following questions will be provided throughout the paper: How far is the circular economy achieved and implemented in the automotive and HDOR sectors? What practices compatible with the circular economy already exist for these sectors? How do existing policy framework foster the move towards a more circular economy? Hereafter, these questions are studied in response to the four building blocks model of the circular economy defined by Ellen MacArthur Foundation (EMF, 2013b).

The paper is organised as follows. Section 2.1 defines the terms and boundaries of the present study. Section 2.2 describes the research methodology and investigations undertaken to provide a comprehensive view of automotive and HDOR sectors in the light of the circular economy. Section 2.3 details comparison criteria to evaluate automotive and HDOR industries with regard to the circular economy. In Section 3, several key factors affecting circular economy performance of both automotive and HDOR sectors are analysed. Relevant insights from industrial companies are also exposed. In particular, the end of Section 3 provides a significant synthesis of best practices and remaining challenges in these two sectors on their move towards an efficient and effective circular economy. Finally, Section 4 opens up relevant research perspectives for further works aiming at contributing in the shift from a linear to a more circular economy of automotive and HDOR industries.

2. Material and methods

2.1. Definitions, scope and boundaries of the study

2.1.1. Distinction between light (automotive sector) and heavy vehicles (HDOR sector)

On the one hand, the automotive sector encompasses motorised road vehicles weighing less than 3.5 tons and is therefore subjected to the ELV Directive 2000/53/EC in Europe. On the other hand, heavy-duty and off-road (HDOR) vehicles are composed of two categories, as shown in Eq. (1), namely heavy-duty vehicles (HDV) – mainly composed by trucks – and non-road mobile machinery (NRMM) – mainly composed by agriculture and construction machinery (EC and ERN, 2015). More precisely, HDV classifications are typically based upon the maximum loaded weight of the truck, typically using the gross vehicle weight rating (GVWR), and vary from geographical locations – for instance US and EU classifications are different. GVWR is defined as the maximum allowable total weight of a road vehicle or trailer that is loaded, including the weight of the vehicle. According to UK Vehicle Type Approval agency, NRMM is defined as any mobile machine, item of transportable industrial equipment that is not intended for carrying passengers or goods on the road, and installed with a combustion engine (DfT, 2016). HDV and NRMM are usually considered within the same framework in the grey literature, under the acronym HDOR, based on their similarities in terms of regulations, emissions, materials, mass, and components.

$$\text{HDOR} = \text{HDV} + \text{NRMM} \tag{1}$$

The HDOR industry includes firms that manufacture and remanufacture components or parts of off-highway equipment generally used in the construction, farming, mining, and oil and gas drilling industries. As such, HDOR equipments are much more diverse than vehicles from automotive sector. Indeed, compared to light vehicles, while the HDV sector covers all types of trucks weighing more than 3.5 tons, the NRMM sector covers a very wide variety of machinery. It comprises, for instance: construction machinery (e.g. excavators, compactors, loaders, dumpers, bulldozers, mobile cranes), agricultural and farming machinery (e.g. harvesters, cultivators). Common and specific