Contribution of Optimal Equipment for ELV Recycling to the Sustainable Development of Serbia and the Region

M. Pavlović, D. Tadić, A. Aleksić, N. Komatina and B. H. Hosam

Abstract The "3R" (reduce, reuse and recycle) principle has been significantly employed in processing ELVs (end-of-life vehicles), particularly ELV parts and methods to promote sustainable development. Motivated by legislation such as Directive (2000/53/EC), recently, ELV problems have seriously been treated in developing countries as well. This paper analyses the impact of newly developed equipment for ELV recycling on the sustainable development of the Republic of Serbia through environmental protection, resource exploitation and socio-economic factors. Research is carried out on the national and regional level. The proposed research and analysis show the significant contribution of newly developed equipment on the sustainable development of the Republic of Serbia and the region.

Keywords Sustainable development · ELV recycling

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1 Introduction

The term sustainable development has many different meanings and therefore provokes many different responses. In broad terms, the concept of sustainable development is an attempt to combine growing concerns about a range of environmental issues with socio-economic issues (Hopwood et al. 2005). In compliance with that is proposed the classification of different trends on sustainable development, their political and policy frameworks and their attitudes towards change and means of change. The concept of sustainable development should present a socio-economic environmental system as a moving target, which is continuously evolving. Nonaka and Toyama (2005) suggest that sustainability has no clear end to it, and it requires relentless efforts to achieve it. It keeps driving the organization towards unattainable perfection. The sustainability development can be defined as a regulative function of the organization by preventing it from contending the imperfect realities. The sustainability concept includes an environmental concern, but also incorporates economic (Bagheri and Hjorth 2007) and social dimensions (Dempsey et al. 2011). It can be said that this concept strongly links environmental and socio-economic issues making an impact on the quality of life (Milivojević et al. 2011).

In 2005, the European Union adopted the Draft Declaration on Guiding Principles, which emphasizes that a sustainable development should be a key policy goal that can be achieved through the fulfilment of the following objectives: (1) environmental protection (prevention and reduction of environmental pollution and promotion of sustainable models of production and consumption in order to break the link between economic growth and environmental degradation), (2) social equity and cohesion, (3) economic prosperity (promotion of prosperities, innovative, knowledge-rich, competitive and eco-efficient economy that provides a high standard of living and total employment in the European Union) and (4) fulfilling international liabilities.

Respecting all mentioned above, it can be said that the goals of the sustainable development strategy are almost fully achieved by realizing the explained objectives. For designers of recycling equipment, very important information in designing is to what extent this equipment will contribute to sustainable development. The answer to this question is very difficult to be determined precisely. In the literature, there are no papers which treat this problem. In this paper, it is assumed that by using the regression analysis and evidence data, the amount of ELV in subsequent time periods can be predicted.

It may be considered that one of the very important tasks for managers of reverse supply chains is to select recycling equipment. Nikolić et al. (2017) suggest benchmarking analysis of the specialized pieces of equipment of the internationally known manufacturers as well as those on the national level. Evaluation criteria are current market situation and needs, as well as the unit prices. It can be said that choosing of the recycling equipment can be stated as multi-criteria optimization task (by analogy Arsovski et al. 2015; Pavlović et al. 2016).

The paper is organized in the following way: the problem statement is presented in Sect. 2, Sect. 3 presents the results of case study, and conclusion is set in Sect. 4.

2 The Proposed Approach

This research deals with the problem of determining the influence of recycling press and detoxification devices developed in the scope of activities of technological development project TR 35033 for sustainable development of the Republic of Serbia.

Using the data obtained from the Republic Statistical Bureau (http://www.stat.gov.rs/) can present the number of registered motor vehicles in the previous period. By using the regression analysis, the number of registered vehicles can be predicted in the future years. Respecting the results of the best practice from recycling domain of developed countries, it is known that minimum, maximum and average number of ELVs present 4%, 6.7% or 5.35% of total number of registered motor vehicles. With respect to all the mentioned facts, the number of ELV in considered time period is determined. For each recycling level α, $\alpha \in [0 - 1]$, the number of recycled ELV can be determined. The impact of the recycled material on sustainable development is assessed with respect to three aspects: economic, environmental protection and social that are considered from the perspective of the number of employees. The impact values are determined according to the assessment of decision-makers. In this case, the decision-makers are representatives of Ministry of Environmental Protection.

It can be assumed that one ELV, in the process of recycling, may provide 700 kg of steel. This kind of recyclate may be used as a raw material in many production companies of the metalworking sector. While selling this kind of recyclate, recycling centres generate profit which may be calculated as multiplication of obtained recyclate and unit selling prices. In this paper, the impact of treated recycling equipment on the economic aspect of sustainable development is determined as the total profit achieved through the sale of treated recyclate. In practice, the economic aspect of sustainable development should be determined by respecting many factors. The considered factor is just one of the factors that can be considered.

It is assumed that the impact of proposed recycling equipment, with respect to environmental protection, can be determined according to the estimates of decision-makers. They form their assessments on their knowledge and the results of developed countries. In this paper, evaluations of decision-makers are based on common scale measurement (Saaty 1990). Value 1 indicates that environmental protection is very low, and value 9 indicates that environmental protection has been totally achieved, respectively.

The social aspect of sustainable development can be determined by respecting many of the factors defined in the National Strategy for Sustainable Development. One of the factors is the number of employees that can be considered to be the most important factor in developing countries. In this paper, only the number of workers that should be employed in the recycling centres, which is determined in compliance with the available capacity of the considered recycling equipment, is considered.

On the basis of the obtained results, it is possible to conclude that there is a necessity of increasing the level of recycling in the Republic of Serbia. The management of each recycling centre should select recycling equipment that will be used for achieving the set objectives. The obtained results may be very useful, both for recycling

centres management and decision-makers who bring and implement a national sustainable development strategy. The proposed algorithm can be realized through the following steps:

Step 1. Collect data for number of registered vehicles in Serbia from Republic Statistical Bureau.
Step 2. Set the regression model. Determine the adequacy of the model.
Step 3. Determine the amount of ELV which may be recycled as well as the amount of motor oil for different levels of recycling.
Step 4. Assess the impact of the obtained results from Step 3 on economic, environmental and social aspects of the sustainable development if pressing machine and detoxification device constructed in the scope of technological development project TR 35033 are used.

3 Case Study in the Republic of Serbia

The proposed approach is tested on the data from the Republic of Serbia. The number of registered vehicles in the Republic of Serbia in the period from 2001 to 2014 is taken from official reports of Republic Statistical Bureau (http://www.stat.gov.rs/en-US/oblasti/saobracaj-i-telekomunikacije/registrovana-vozila) and presented in Table 1 (Step 1 of the proposed algorithm).

The change in the number of registered vehicles ($\hat{y}$) in dependency of time period (x_i) is given in compliance with the data from Table 1 (Step 2 of the proposed algorithm):

$$\hat{y}_i = 1.33804 + 0.02825 \cdot x_i$$

By applying the technique of variance analysis at the risk level of 5%, the existence of linear dependency is tested. The statistic of decision-making is

Table 1 Number of registered passenger cars in the Republic of Serbia in the period (2001–2014)

Year	Number of registered passenger cars		Number of registered passenger cars		Number of registered passenger cars
2001	1,382,396	2006	1,511,837	2011	1,677,510
2002	1,343,658	2007	1,476,642	2012	1,726,190
2003	1,388,109	2008	1,486,608	2013	1,770,162
2004	1,449,843	2009	1,637,002	2014	1,797,252
2005	1,481,498	2010	1,565,550		

$$F_0 = \frac{\sum_{i=1,\ldots,14} \left(\hat{y}_i - \overline{y}\right)}{\sum_{i=1,\ldots,14} \left(\hat{y}_i - y_i\right)/n-2} = \frac{0.1826}{0.0301/10} = 60.69.$$

The table value of Fisher's distribution is $F_{0.05,1,10} = 4.96$. As the value of statistical decision-making is greater than the value in table, it can be concluded that analysed hypothesis is true: the number of registered vehicles is linearly increased compared to the time period. The measure of scattering around the regression is determined with

$$R^2 = 1 - \frac{\sum_{i=1,\ldots,14} \left(\hat{y}_i - y_i\right)}{\sum_{i=1,\ldots,14} \left(\hat{y}_i - \overline{y}\right)} = \frac{0.0301}{0.1826} = 0.835.$$

This means that 83.5% of the points are grouped around the regression. Based on the obtained test results, it can be clearly concluded that it is quite adequate that the number of registered vehicles in the Republic of Serbia, depending on the period, is described as a linear function.

The issue of assessment of two equipment types for recycling has already been investigated in the literature (Nikolić et al. 2017). This research was applied to different equipment manufacturers with the following evaluation criteria: price, box material, box length, bale size, engine power, working pressure and weight. The weights vector is given, so that it is (0.25, 0.05, 0.125, 0.125, 0.2, 0.15, 0.1). Respecting all criteria and their weights, it can be assumed that for recycling centre in Serbia, it is optimal to purchase the equipment constructed in the scope of national technology development project TR 35033.

According to the procedure (Step 3 of the proposed algorithm), the amount of ELV, the amount of metal and the amount of motor oil, which may be obtained in the process of recycling in 2020, 2025 and 2030, are calculated, and it is presented in Figs. 1, 2 and 3. It is assumed that the level of recycling in 2020 is 15%, in 2025 it is 50%, and in 2030 it is 80%.

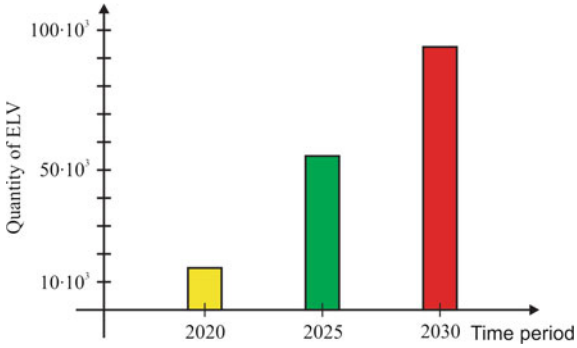

Fig. 1 Amount of ELV which can be recycled at the different levels of recycling

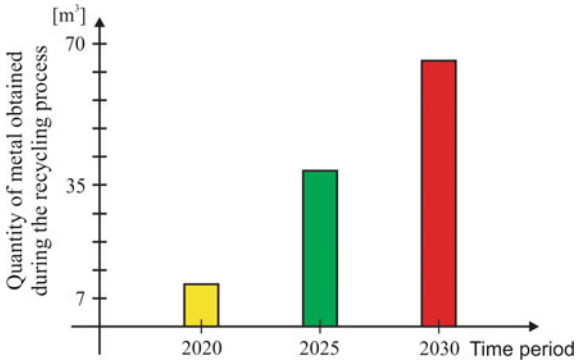

Fig. 2 Amount of metal materials that can be recycled at the different levels of recycling

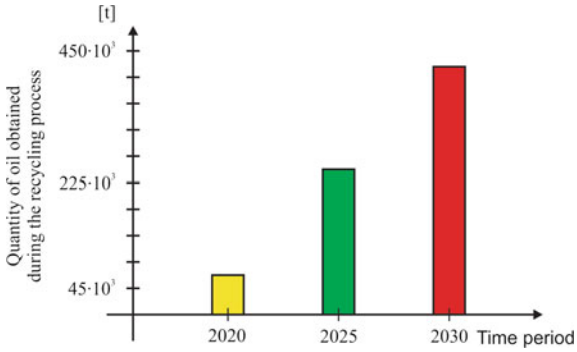

Fig. 3 Amount of motor oil that can be recycled at the different levels of recycling

In the Republic of Serbia, the unit selling price of metal materials is 0.14 €/kg, and for the motor oil it is 2 €/l. Motor oil which may be obtained in the recycling process is sold to companies that produce motor oils where certain chemicals and additives are mixed in. The operating capacity of one pressing machine is delivered in the range of 15–20 min. The operating capacity of device for detoxification is 25 min. By assuming that work is organized only in one shift, with the 242 of working days per year, the needed number of pressing machines may be calculated. By applying the calculation of proportion, the pressing machine may treat 6636.85 ELV/year. In the similar way may be calculated the volume of recycling related to detoxification device, as well as the number of workers that need to be employed for working on these devices. For different amount of ELV, the needed number of pressing machines is calculated. Taking into account that each detoxification device implies the need for engagement of two workers, the number of new employees may be calculated (Tables 2 and 3).

The impact of developed recycling equipment on various aspects of sustainable development, at different levels of recycling, is estimated and presented in Tables 2 and 3.

Table 2 Impact of ELV on sustainable development

The year	Economic aspect	Environmental protection aspect	Social aspect (the number of new employees in recycling centres)
2020	1.46 million euros	2	6
2030	5.36 million euros	5	18
2050	9.16 million euros	8	28

Table 3 Impact of motor oil as waste on sustainable development

The year	Economic aspect	Environmental protection aspect	Social aspect (the number of new employees in recycling centres)
2020	0.23 million euros	1	8
2030	0.49 million euros	4	24
2050	0.85 million euros	7	42

3.1 Discussion

If the recycling centres that exist in the Republic of Serbia use two recycling devices constructed in the scope of technological development project TR 35033 in 2020, they would achieve an income of 1.69 million euros. With increasing the level of recycling, which is one of the goals of the National Recycling Strategy, the revenue generated in recycling centres could be significantly increased. For example, in 2025, the revenue would be 5.85 million euros; in 2030, the revenue would be 10.01 million euros. It can be clearly concluded that the usage of the considered recycling equipment leads to a significant improvement in the economic aspect of sustainable development.

If the level of recycling keeps around 15%, as it is now in the Republic of Serbia, it can be concluded that almost no environmental protection has been achieved. Environmental protection is increasing with increasing the level of recycling. If the same level of recycling remains, the number of employees in recycling centres would increase for new 14 employees in 2020. If it is assumed that the required level of recycling is achieved, which is 80%, the number of employees would increase for new 70 employees.

4 Conclusion

This research deals and treats the impact of optimal equipment for ELV recycling to the sustainable development of Serbia and the region. In relation to that and taking into account the current trends in Serbia and the region, it is assumed that the current level of recycling should be enhanced. The research indicates that recycling centres

should increase their attention when the process of equipment selection for recycling is carried on. The equipment selection is a very significant task since it directly corresponds to the achievement of strategy goals.

The obtained results from the first and the second step of the proposed approach may be very from the recycling centres as well as for the other stakeholders that are implementing national strategy related to sustainable development. The main contribution of the research clearly indicates the benefits of exploitation of equipment constructed in the scope of technological development project TR 35033. The new equipment has significant impact on the sustainable development and recycling in the Republic of Serbia.

The future research should examine the impact of non-economic factors to sustainable development of the region.

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