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The Choice of Production Volume of the ELV Depollution Station Using the Decision-making Analysis

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Abstract *The Republic of Serbia, as a country that tends to join the European Union is obliged to harmonize its legislation acts with the ones that are implemented in the EU member states. In that manner, regulations in the area of the End-of-Life Vehicle (ELV) recycling management in the Republic of Serbia are mostly harmonized, with the relevant EU legislation acts. In order to get the full implementation of these acts the proper recycling equipment is needed to be used in the ELV recycling process, primarily in terms of removing hazardous components from ELVs. Some studies have shown that stationary ELV depollution stations are the most suitable ones for national recyclers, so they should both be analyzed from the legislative and economic sustainability aspects as well. This paper treats management strategies of production of latter stations by using engineering potentials of the national economy. To narrow down, several scenarios of production scale and market consumption needs have been proposed and examined in order to get the scale of production of the ELV depollution station with respect to national economy needs and potentials.*

Keywords: *decision-making analysis, ELV, legislation, depollution*

1. Introduction

The constant improvement of recycling industry has become one of the pillars of the modern society development. Because of its importance it is needed to create a general approach to the End-of-Life Vehicle (ELV) recycling challenges, which could lead toward the long-lasting self-sustainable recycling system [1]. It could be achieved by combining proper equipment with stable market conditions and environmental policy changes manifested through the changes in national stimulus packages and ecological taxes [1]. There are two general approaches to the ELV recycling with dismantling and shredding as dominant operations. Two types of business can originate from the dismantling process, namely: high value business parts and scrap yard business [2]. The second type is a dominating one in Serbia at the moment, while the existing shredders are out of function due to lack of collected ELVs.

The overall ELV recycling system consists of various stages, which include: administrative procedures, collection, transport, storage, depollution, dismantling and/or shredding, storage and re-fabrication of obtained parts and materials, their market placement and landfill of the waste, as it was noted in the literature [3, 4]. These steps are mostly respected in the European recycling process in order to optimize the recycling procedure, maximize recycling and reuse of materials and energy recovery with minimum negative effects on the environment [5].This is the goal which Serbia is trying to achieve. In the USA each state has its own legislation, so the ELV management is not centralized. Most of the processes are determined by the market needs. [2]. On the other side, Japan has very strict standards regarding ELV recycling and they consider the ELV recycling to be one of the priority areas in the process of waste management, with special requests for Automotive Shredder Residue (ASR) [2].

Environmental sustainability is one of the prerequisites for sustainability of one national ELV legislation system in general. Reducing the risk of hazardous situations is achieved by proper depollution process [5]. This paper is oriented mostly toward the part of this process that considers the removal of fluids from an ELV, and the production of the specialized equipment for this process. This equipment prevents hazardous situations as leakage and mixing of fluids by using a single tank for each liquid type in the drainage process. This equipment facilitates the manipulation of the vehicle during the depollution process, a vehicle is placed in the most suitable position, fluids are drained out and the vehicle is sent for further treatment. The specialized equipment for conducting the ELV depollution process has already been available on the marked (i.e. SEDA [7] and Vortex [8]), still the production of this type of stations could improve national economy which has been the main motivation for this paper.

2. Technical Background of ELV Depollution Process

There is a significant risk for the environment contamination during transport of ELV from the storage to treatment sites. The transport procedures are strictly defined, and have to be respected. On the other side, transport may significantly increase overall recycling costs, which has motivated many researchers to conduct studies in order to simulate and find optimal ELV recycling system by application of different simulation techniques [9].

The process of depollution represents the most important process for achieving the environmenntal sustainability of the ELV recycling process. Strong government measures have to be taken, especially in developing countries like Serbia, with the aim of implementing this process, because the process itself does not bring economic profit to recyclers. Otherwise, environmental risk increases rapidly, for instance, fluid leackage may cause water and soil contamination almost instantly if the drainage is conducted unprofessionaly. It is recommended that depollution activities are conducted by using the specifically designed equipment for this operation. The use of such equipment ensures that a high level of depollution (removal of over 98% of fluids contained in the ELV) can be achieved in a relatively short time-frame (up to 30 minutes per an ELV). Some alternative methods can be used, but it is necessary to achieve the same level of efficiency. Even though alternative methods are used both, the health and safety requirements must not be compromised [5]. The majority of commercially available equipment is usually operated pneumatically, [2, 7, 8] because of physical nature of fluids.

The complete depollution process of the ELVs consists of several stages: preliminary activities, removal of fluids and other items, removal or deployment of airbags [5]. Before the drainage of liquids from EKVs the operator has to conduct next preliminary activities: assess vehicle for health and safety hazards, use manufacturer guidance to obtain depollution information on the ELV, determine if ELV has airbags, remove battery, remove caps from all tanks/reservoirs, set heater control to maximum, remove wheels/tyres, remove balance weights from wheels, prepare Electric/Hybrid Vehicles for treatment [10]. The second stage is removal of all the liquids, filters, catalysts, mercury switches etc. After that, comes the removal or deployment of air bags, then an ELV is classified as a non-hazardous waste. Figure 1 shows specially designed equipment for carrying out the removal of liquids from the ELVs which can be produced by the Serbian national economy. Precisely speaking, one prototype has already been produced and tested. The choice of sustainable production range of this equipment which could satisfy national market is the topic of this paper.

The stable ELV drainage station shown in Figure 1 consists of the following subsystems: Air compressor with tank, Steel containment bund, Car girder with hydraulic power unit, Funnels, Fluid reservoirs, Pneumatic drill, Needle for outpouring the cooling liquids, Pneumatic subsystem, Subsystems for filtration of waste fuels, Hose system for waste liquids drainage. The fluid drainage procedure is strictly designed by the designers and consists of several steps described in the literature [11]. The decision-making analysis has been conducted in order to obtain the optimal number of ELV drainage stations based on the Serbian national market needs and economy possibilities. The optimal treatment time per an ELV is about 30 to 40 minutes depending on the workers' skills. This indicates that about 3600 ELVs can be treated at one station per year. Unfortunately, there are no precise data on the number of generated ELVs in Serbia per year. Some studies [12] based on the data from the Statistical Office of the Republic of Serbia state that the number of ELVs in Serbia is in the range of 100000 to 120000 ELV/year. Based on this estimation, the sufficient number of ELV drainage stations that would satisfy the market needs is up to 34.

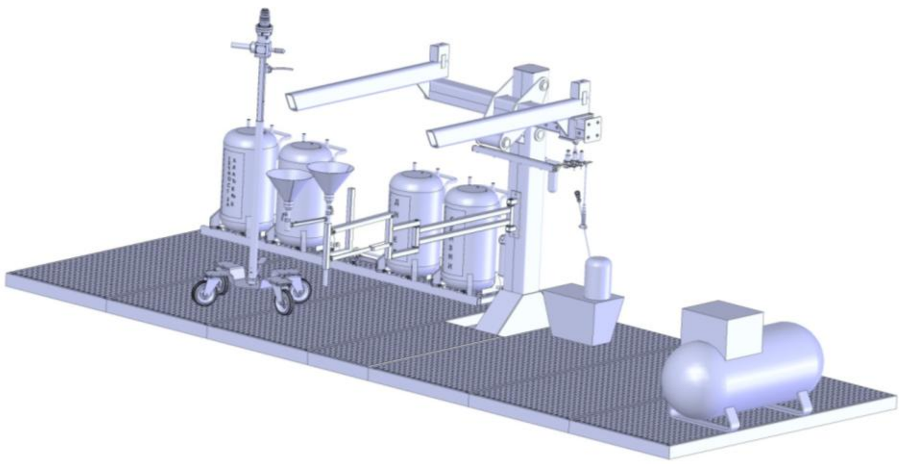

Figure 1. The equipment specially designed for carrying out the removal of fluids from the ELVs [11]

The implementation of stable drainage station increases the transport costs in the collecting process because ELVs have to be transported to the appropriate site for treatment. In the literature source [1] an analysis of using mobile vs. stationary drainage stations has been introduced. It shows that in Serbian ELV recycling system the stable stations which treat more than 3000 ELVs/year are more suitable for recyclers.

3. Decision-Making Analysis

Decision-making analysis helps in observation and definition of all available alternatives of decision-making and provides logistic framework for the choice of the best action. Thereby all influential factors are being considered and the largest number of these factors is related to risk and uncertainty. Techniques of decision-making help a decision maker to estimate the risk and uncertainty more objectively. In their estimations decision makers must rely on collected information and also on their own intuition, preferences and beliefs. The analysis of decision-making can be understood as a plan, a procedure which helps a decision maker to think, work and decide in a more systematic, organized and correct way than one would do the same without the analysis [13].

Decision-making analysis provides systematic and logically consistent procedure so that the best alternative of the available ones would be chosen. Thereby, it is consisted of systematic structuring, contiguity, determination of certainty and risks as well as the choice of the best action. In the same time, it includes practical methods for collecting relevant information for reduction of problem situation uncertainty [14].

3.1. Decision-making Analysis Without Apriori Probabilities

Decision-making analysis without apriori probabilities is related to those situations in which a decision-maker is not able to assign appropriate probabilities to certain states. Decision-making analysis without apriori probabilities is used for the choice of optimum action in the problems with more actions, most frequently in two cases:

1. When it is necessary to determine the amount of a product that should be purchased in advance for further sale;
2. When it is necessary to determine a volume of production for a certain product (in this case the actions are, in fact, possible volumes of production).

An important characteristic of this group of problems is that the number of alternatives is always equal to the number of possible states within a problem. There are several methods for the solution of these problems [13, 14]: MAXIMIN criterion, MINIMAX criterion, MAXIMAX criterion, Criterion of maximum credibility, Laplace criterion. The common theme across the methods is that a decision maker, since the probabilities of certain states appearance are not available, takes his own attitude towards the issue of decision-making. Accordingly, he first selects the method which, in great extent, determines the choice of the alternative. The following signs are in use: $\mathbf{a_i}$ -action and; $\mathbf{s_j}$-state. If in a certain problem exists **n** alternative and **m** state, then a_1, a_2, ..., a_n represent all actions, and s_1, s_2, ..., s_m represent all states of the given problem.

4. The Choice of Production Volume

A company BlockSignal [15] is planning to produce a stable station for depollution of fluids from ELVs (only one series of products is planned). The company cannot predict precisely a demand for these stations, but on the basis of previous experience it is estimated that the demand will be between 20 and 50 stations. On the grounds of the market needs and estimated number of ELVs [12] it has been estimated that 20 stations can satisfy recyclers needs when work overtime, and 50 stations should follow the increase in the number of ELVs in the future [12], still these will not work with full capacity, based on the calculation from Section 2. The company decides to analyse the following seven actions: a_1 = 20 (production of 20 stations), a_2 = 25, a_3 = 30, a_4 = 35, a_5 = 40, a_6 = 45, a_7 = 50. There are also seven states of the environment so they take the same values: s_1 = 20 (demand is 20 machines), s_2 = 25, s_3 = 30, s_4 = 35, s_5 = 40, s_6 = 45, s_7 = 50.

Production costs per unit, espected by the company interested in producing the sations are T = 17000 €, and the sale price (regular) is C = 23000 €. Clearance price varies and it depends on the market flux. The problem will be solved for four possible values of the clearance price (this price is lower than the one that company find optimal):

a) clearance price higher than costs per unit R_a = 20000 €;
b) clearance price equal to costs per unit R_b = 17000 €;
c) clearance price lower than costs per unit R_c = 14000 €;
d) clearance price lower than costs per unit R_d = 11000 €.

a) Clearance Price Higher Than Costs per Unit

Firstly, the Table of payment is made (effects) for a specific situation (Table 1). This Table shows the effects for each possible situation of a produced item (action) and for sold products as well (state). Calculation procedure is conducted as explained in the literature source [13].

Table 1. Table of payment (effects) for R_a = 20000 €

Actions	Stanja (potražnja)						
	s_1	s_2	s_3	s_4	s_5	s_6	s_7
	20	25	30	35	40	45	50
a_1 = 20	120000	120000	120000	120000	120000	120000	120000
a_2 = 25	135000	150000	150000	150000	150000	150000	150000
a_3 = 30	150000	165000	180000	180000	180000	180000	180000
a_4 = 35	165000	180000	195000	210000	210000	210000	210000
a_5 = 40	180000	195000	210000	225000	240000	240000	240000
a_6 = 45	195000	210000	225000	240000	255000	270000	285000
a_7 = 50	210000	225000	240000	255000	270000	285000	300000
max	210000	225000	240000	255000	270000	285000	300000

After forming the Table of payment (effects) the formation of the Table of complaints comes (Table 2). Complaints represent the unrealized profit which is the result of wrong choice of the action (opportunity loss).

Table 2. Table of complaints (opportunity loss) za R_a = 20000 €

Actions	State (demand)						
	s_1	s_2	s_3	s_4	s_5	s_6	s_7
	20	25	30	35	40	45	50
a_1 = 20	90000	105000	120000	135000	150000	165000	180000
a_2 = 25	75000	75000	90000	105000	120000	135000	150000
a_3 = 30	60000	60000	60000	75000	90000	105000	120000
a_4 = 35	45000	45000	45000	45000	60000	75000	90000
a_5 = 40	30000	30000	30000	30000	30000	45000	60000
a_6 = 45	15000	15000	15000	15000	15000	15000	30000
a_7 = 50	0	0	0	0	0	0	0
max	90000	105000	120000	135000	150000	165000	180000

In this case, for the choice of production volume of a stable station for depollution of vehicle fluid at the end of life cycle, two methods can be applied: MINIMAX criterion and Laplace criterion.These methods are applied because they have a balanced relation towards a risk (different from the method used by MAXIMIN criterion and MAXIMAX criterion), as well as for the fact that it is difficult to determine possible probabilities of certain states appearance (for this reason is difficult to use the method Criterion of maximum credibility).

MINIMAX criterion for R_a = 20000 €

MINIMAX criterion is also called a criterion of complaint or Savage criterion. The essence is in the following: for each alternative MAX complaint is searched in the Table of complaints and then the action with MIN complaint is chosen. Namely, the action with MINIMAX complaint is adopted (by actions). That is how this criterion has got its name. The choice of the action by MINIMAX criterion for the given case is made in the Table 3. It is obvious that by this criterion the action a_7 has to be chosen.

Table 3. Choice of the action according to MINIMAX criterion for R_a = 20000 €

Akcions	MAX complaint	Choice MIN
a_1 = 20	180000	
a_2 = 25	150000	
a_3 = 30	120000	
a_4 = 35	90000	
a_5 = 40	60000	
a_6 = 45	30000	
a_7 = 50	**0**	**a_7**

Laplace Criterion for R_a = 20000 €

A decision maker is adopting the fact that each state has the same probability of appearance. With probabilities assigned in this way it is possible to calculate the expected profit (effect) for each action and then the action with the biggest value is chosen. In other words, the action with maximum expected profit is adopted. The expected profit ($\overline{p}_i$) is calculated according to general formula [13]:

$$\overline{p}_i = \sum_{j=1}^{m} p_{ij} \cdot V(s_j).$$

Values used in latter equation are:

- $\overline{p}_i$, average expected profit of action *i for all states;*
- p_{ij}, profit of action *i* for state *j*;
- $V(s_j)$, probability of state *j* appearance.

The choice of the action by Laplace criterion for the given case is shown in the Table 4. .it is obvious that the action a_7 has to be chosen.

Table 4. Choice of the action by Laplace criterion for R_a = 20000 €

Actions	Expected profit	Choice MAX
$a_1 = 20$	120000	
$a_2 = 25$	147857	
$a_3 = 30$	173571	
$a_4 = 35$	197143	
$a_5 = 40$	218571	
$a_6 = 45$	240000	
$a_7 = 50$	**255000**	**a_7**

b) Clearance price equal to costs per unit

For the situation R_b = 17000 € only final results are showen in Table 5 and Table 6.

Table 5. Choice of the action by MINIMAX criterion for R_b = 17000 €

The best action	MAX complaints	Choce MIN
$a_7 = 50$	**0**	**a_7**

Table 6. Choice of the action by Laplace criterion for R_b = 17000 €

The best action	Expected profit	Choice MAX
$a_7 = 50$	**210000**	**a_7**

c) Clearance price lower than costs per unit (R_c = 14000 €)

For the situation R_c = 14000 € only final results are shown in Table 7 and Table 8.

Table 7. Choice of the action by MINIMAX criterion for R_c = 14000 €

The best action	MAX complaints	Choice MIN
$a_5 = 40$	**60000**	**a_5**

Table 8. Choice of the action by Laplace criterion for R_c = 14000 €

The best action	Expected profit	Choice MAX
a_5 = 40	**175714**	a_5

d) Clearance price lower than costs per unit (R_d = 11000 €)

For the situation R_d = 11000 € only final results are showen in Table 9 and Table 10.

Table 9. Choice of the action by MINIMAX criterion for R_d = 11000 €

The best action	MAX complaints	Choice MIN
a_4 = 35	**90000**	**a_4**

Table 10. Choice of the action by Laplace criterion for R_d = 11000 €

The best action	Expected profit	Choice MAX
a_4 = 35	**158571**	**a_4**

5. Results of the Analysis and Decision-making

In the case in which a clearance price is higher than costs per unit R_a = 20000 €, a producer is never at a loss so it is logical that the results point at maximum volume of production, in other words, the action a_7 = 50. Similar situation is in the case in which a clearance price is equal to costs per unit R_b = 17000 €. The first two cases are extremely favourable for producers, however, these cases are considered to be optimistic ones but they are less probable in real situations. Therefore, since we wish to be realistic and careful in analysis, other cases in which a clearance price is lower than costs per unit R_c = 14000 € i R_d = 11000 €, are observed.

For R_c = 14000 €, according to both criteria, the most favourable action is a_5, while for R_d = 11000 €, again according to both criteria, the most favourable action is a_4. Max complaint at the action a_4, in both cases, (R_c = 14000 € and R_d = 11000 €) is equal and it is 90000, while at the action a_5 in the case R_c = 14000 € max complaint is 60000, and in the case R_d = 11000 € max complaint is 120000. The sum of these pairs is always 180000, so it is not possible to choose the action with smaller sum. However, there is a bigger stability of max complaint at the action a_4 (in both cases 90000), which indicates a higher degree of complaint certainty at the action a_4.Thus, the final decision is to choose the action a_4 = 35, in other words, to produce 35 stable stations for drainage of fluid of the vehicle at the end of a life cycle. This number corresponds to the number of 34 stations introduced in Section 2.

6. Conclusion

Implementation of European regulations into national framework of the Republic of Serbia implies the respect of stricter ecology requirements in the field of recycling of ELVs. This is particularly important for the removal of hazardous materials at the beginning of the recycling process. In this sense, it is necessary to use a specialized equipment for the removal of harmful materials from the vehicles in our national industry. The equipment can be produced in the national or regional mechanical industry with the aim of further economic development.

The aim of the analysis carried out in this paper was to make a choice of the production volume of a stable station for fluid depollution from the vehicles at the end of their life cycle. We have used a decision – making analysis without apriori probabilities which is done when a decision maker cannot assign appropriate probabilities to certain states. In this case, two methods were used: MINIMAX criterion and Laplace criterion. We have observed seven production volumes and four possible values of clearance prices in comparison to predicted production price of a station for fluid depollution from motor vehicles at the end of their life cycle. On the grounds of the analysis of all results we have chosen the action a_4 = 35, in other words, optimum production volume of stable stations for fluid depollution from motor vehicles at the end of their life cycle is 35. The applied analysis was helpful in this case and the applied procedures enabled real observation of the situation and objective choice of optimum production value from financial effects' view.

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