Applied Engineering Letters Vol. 1, No 4, 115-121 (2016) e-ISSN: 2466-4847

AHP METHOD IN THE FUNCTION OF ADEQUATE EQUIPMENT CHOICE FOR ELV DETOXIFICATION IN SERBIA AND EU

Eleonora Desnica[1], Miroslav Vulić*[1], Milan Nikolić[1]
[1]Technical faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, Serbia

Abstract:
Both in Serbia and region and throughout Europe the increasing number of ELVs (end of life vehicle) is a significant issue. Motor vehicles are one of the greatest polluters of the Earth, starting from the production process to the end of their life cycle. Because of that, quality ELV recycling is imposing as a vital need. Besides that, ELV recycling is part of the system of sustainable techno-economic development in EU. Adequate detoxification is prerequisite for quality recycling of ELV. In the function of all mentioned, paper shows comparative techno-economic parameters of some technologies that are used for ELV detoxification in Serbia and Europe. Those parameters are used for multicriteria AHP (Analytic Hierarchy Process) method in the aim of appropriate choice of optimal technology for ELV detoxification.

ARTICLE HISTORY
Received 17 November 2016
Accepted 15 December 2016
Available online 30 December 2016

KEYWORDS
ELV, recycling, detoxification, technology, AHP method.

1. INTRODUCTION

As with other European Union countries, the Republic of Serbia automotive industry needs to improve ELV recycling rate in order to reach the minimum reuse and recovery rate required by EU directives [1].

Motor vehicles with all their components, metal part and toxic fluids which come to the ELV present important contaminants of environment. Hazardous materials with complex chemical composition come with development of science and technology. Some of those materials are not biodegradable on the natural way and their degradation last infinitely long. All this leads to the conclusion that inadequate treatment, begin from the detoxification to the dumping and placing waste are very risky and ruinous job on the environment [2-4]. Only after their safe removal from the car, it can be accessed to further recycling process to other parts of the car, which states that each centre for the recycling of cars in the country should have the right equipment for detoxification of hazardous liquids [5].

To successfully recycling process of motor vehicle precede adequate detoxication and treatment of toxic waste from vehicles [6].

2. ELV DETOXIFICATION

Without successfully completed process of detoxification there is no successfully recycling ELV process [7].

Detoxification of motor vehicles represent complete disposal of all potential toxic substances from ELV and represent unavoidable process of ELV recycling. Process of detoxification is in function of recycling ELV process, especially from aspect of satisfying the requirements of environment [8].

This equipment prevents the leakage and pollution of environment. In order to reuse the fluids the liquids it is necessary to organize separate collection and storage of various fluids, what can be achieved by using a single tank for each liquid type. Fluids are contained in the interior of the ELV, in appropriate housings, tanks or devices that is the reason why fluids are usually hard to come by. The use of specialized depollution equipment makes the process more efficient. Due to its importance we will focus on the equipment for fluid removal from an ELV stable or mobile ones. The use of professional equipment facilitates the manipulation of the

CONTACT: Miroslav Vulić, miroslav.vulic@tfzr.rs

vehicle during the depollution process that enables reduction of the negative impacts on the environment and the health of employees to a minimum [9].

3. EQUIPMENT FOR ELV DETOXIFICATION

The specialized equipment for ELV depollution process has already been available on the marked for a while. The widely known producers are Vortex [10] and SEDA [11], while the national metal processing industry and academic institutions try to design competitive equipment. This paper focuses on the proper selection of the available equipment from different aspects based on the current technological and economic situation in Serbia and the Region (figure 1 and 2) [12].

Fig. 1. SEDA Single Station drainage system

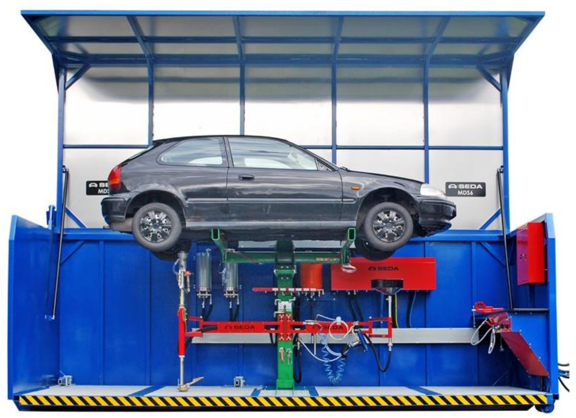

Fig. 2. SEDA mobile de-pollution of End-of-Life Vehicles

4. MULTICRITERIA DECISION ANALYSIS (MCDA)

Nowadays, there are fewer business problems concerning decision making where the choice is made on the basis of only one criterion. Complexity and multilevel characteristic of business decision making often demand multicriteria model, in other words, multicriteria basis as a starting condition for objective selection and choice of alternative solutions [13]. It is clear that the area, where strategic and other decisions are made within a company, mostly demands the application of multicriteria methods of decision making.

Multicriteria decision making (MCDM) is related to those decision making situations with a great number of conflicting criteria [14]. Ranking alternatives according to greater number of criteria simultaneously, contribute to realistic solution of these situations. Traditional optimization methods use only one criterion at decision making – by doing this, in many cases, the reality of the analysed problem is considerably reduced. However, multicriteria approach has its bad side, too; it is the need for using considerably more complex mathematical models for solving multicriteria problems. In addition, apart from the great number of different models there still isn't a completely objective and reliable method of multicriteria decision making.

The area of MCDM application is rather wide, but it is possible to deduce some common characteristics of all problem categories that can be solved in this way [15]:

- a greater number of criteria or attributes which a decision maker must create;
- conflicts among criteria – the most frequent cases considering real problems;
- incomparable measure units – as a rule, each criterion/attribute has different measure units; and,
- creating or selection. The solution of such a MCDM problem is in creation of the best activity or in selection of the best activity from the assembly of previously defined final activities.

According to the last characteristic the MCDM problems can be classified in two groups [14]:

1. Multi-attributive decision making (MADM) or multicriteria decision analysis (MCDA). This group of MCDM methods solves problems by selecting the best activity from the assembly of previously defined ones; and,
2. Multi-objectives decision making (MODM). This group of MODM methods solves problems by creating the best activities.

5. AHP METHOD

Analytic Hierarchy Process (AHP) has a wide range of using and represents one of the most using methods for decision making.

Method of analytically hierarchy processes (AHP method) is one of the most popular and most widely used MCDA methods [16]. It was developed at the beginning of the 1970s by Thomas Saaty [17]. According to [18], Saaty's works were cited in over 1000 references and there are scientific journals and conferences that have as their basic theme AHP method, its application, modifications, etc.

The method allows for the decision maker to include a subjective attitude, experience, knowledge and intuition in decision-making. AHP consider quantitative and qualitative information and combines them through decomposition complex problems in the hierarchy model. Each level of the hierarchy consists of several elements, where the elements from the same level independent of each other but comparable. The structure assumes that the elements of whatever level under the influence of level which is immediately above.

Hierarchically structured model of decision-making is generally composed from aim, criteria, a few levels sub-criteria and alternatives [19].

5.1 Applied of the AHP method for selection of proper equipment

In the aim of choice the most optimal technological alternatives (TA) for detoxification it is used AHP method (figure 3).

The selection of the equipment is done among four possible actions, namely:

1. TA 1 - Stable equipment RS.
   Facility for removing the fluid from an end of life vehicle, which represents a technical solution developed on the project TR 35033, is a fixed station for combined removal of all vehicle fluids with minimum influence on the environment [20].
2. TA 2 - Stable equipment made EU.

A modern drainage system must satisfy individual demands and fit in seamlessly with existing processes and automations. The SEDA Single Station is a fully integrated system with some of the countless advantages from the use of powerful suction pumps in combination with the certified SEDA Tank Drilling-Machine.

Customers appreciate the large, unobstructed area of operation, the endlessly field-tested, proven reliability or simply the incredible range of accessories allowing countless variation possibilities. The SEDA Single Station achieves a productivity rate of 40 cars per day (see figure 1), [11].

3. TA 3 - Mobile equipment made RS.

If stationary systems are not desirable, mobile systems are the alternative. These can be relocated depending on need and operating conditions. Mobile systems are moveable.

4. TA 4 - Mobile equipment made EU.

The SEDA MDS6 is a roll-off container in which a complete drainage system is integrated. The opened container cover functions like a roof and as rain protection. A static vehicle ramp with a capacity of up to 4 tons is installed in the container as well as catchment areas and important working aids like a workbench, tool box, etc. (see figure 2), [11].

The selection of the criteria is done among seven possible actions, namely:

K_1 - Costs of equipment [€], (demanding minimum);

K_2 - Costs of human resources per an ELV [€ / ELV], (demanding minimum);

K_3 - Energy costs [kWh / ELV], (demanding minimum);

K_4 - Reliability of equipment;

K_5 - Attainability of services and maintenance;

K_6 - Effects of equipment operation; and,

K_7 - Safety [12].

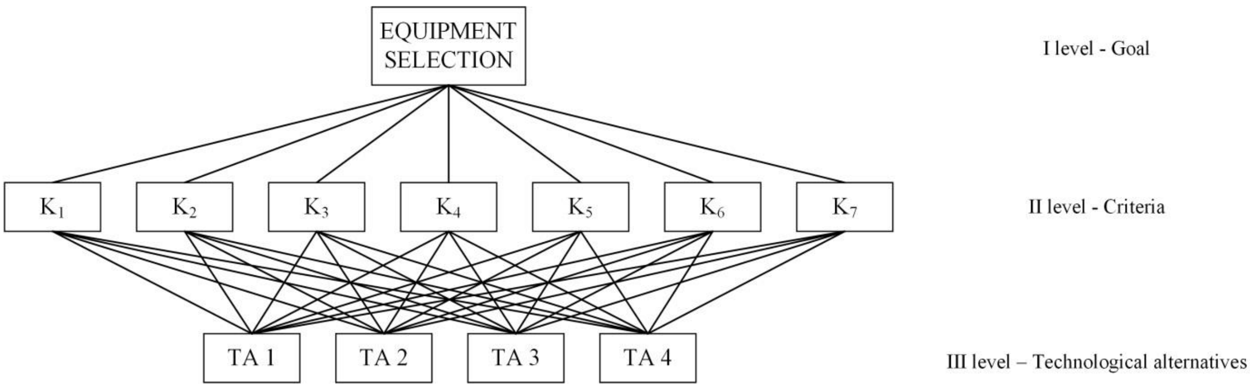

Fig. 3. Significance „tree"

Table 1. The values of criteria in relation to the technological alternatives

	K_1	K_2	K_3	K_4	K_5	K_6	K_7
TA 1	14000.00	1.20	6.20	High	Very high	Average	Very high
TA 2	39500.00	5.00	3.00	Very high	Average	High	Very high
TA 3	25000.00	3.25	9.30	Average	Very high	Very high	High
TA 4	49990.00	13.5	4.50	High	Average	Very high	High

In order of properly applying of the AHP method, researchers have determined weight coefficients elements of hierarchy based on realistic parameters from (table 1) in order to adaption calculation to method, which could be found in the tables and represent the matrix of significance relative to the aim and marked with the fields with slightly grey.

During the valuation it is used nine-point scale - Stanine score:

$$S = \left\{ \frac{1}{9}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1,2,3,4,5,6,7,8,9 \right\}$$

II level

II and III level present calculation according to available data, i.e. ranking of technological alternatives, and all in the aim of selection the most optimal technology. Calculation for II level is done in the tables 2., 3. and 4., and presents criteria which are compared with each other in relation to the aim.

Diagonal of matrix is always number 1, which present part of AHP method 7.

Table 2. The matrix of significance relative to the aim

	K_1	K_2	K_3	K_4	K_5	K_6	K_7
K_1	1	0.5	4	3	2	7	9
K_2	2	1	7	4	3	8	9
K_3	0.25	0.1429	1	0.5	0.2	2	3
K_4	0.3333	0.25	2	1	0.5	3	6
K_5	0.5	0.3333	5	2	1	5	6
K_6	0.1429	0.125	0.5	0.3333	0.2	1	2
K_7	0.1111	0.1111	0.3333	0.1667	0.1667	0.5	1
$\sum$	4.3373	2.4623	19.8333	11	7.0667	26.5	36

$K_7 \rightarrow K_6 \rightarrow K_3 \rightarrow K_4 \rightarrow K_5 \rightarrow K_1 \rightarrow K_2$

Table 3. Element column / sum column

	K_1	K_2	K_3	K_4	K_5	K_6	K_7
K_1	0.2306	0.2031	0.2019	0.2727	0.283	0.2642	0.25
K_2	0.4611	0.4061	0.3529	0.3636	0.4245	0.3019	0.25
K_3	0.0576	0.058	0.0504	0.0455	0.0283	0.0755	0.0833
K_4	0.0769	0.1015	0.1008	0.0909	0.0708	0.1132	0.1667
K_5	0.1153	0.1354	0.2521	0.1818	0.1415	0.1887	0.1667
K_6	0.033	0.0508	0.0252	0.0303	0.0823	0.0377	0.0556
K_7	0.0256	0.0451	0.0168	0.0152	0.0236	0.0189	0.0278

Table 4. Ranking of criteria

Sum of row		Average row value		Priority for II level	
K_1	1.7055	K_1	0.2436	K_2	0.3677
K_2	2.5601	K_2	0.3677	K_1	0.2436
K_3	0.3986	K_3	0.0569	K_5	0.1689
K_4	0.7208	K_4	0.103	K_4	0.103
K_5	1.1815	K_5	0.1689	K_3	0.0569
K_6	0.2609	K_6	0.0373	K_6	0.0373
K_7	0.173	K_7	0.0247	K_7	0.0247

III level

Calculation for III level is done in the tables from 5. to 25., and presents calculation to compare alternatives, each with every in relation to the criteria at the level above.

Table 5. The matrix of significance relative to the attribute K_1

K_1	TA 1	TA 2	TA 3	TA 4
TA 1	1	0.33	0.5	0.25
TA 2	3.03	1	3	0.5
TA 3	2	0.33	1	0.33
TA 4	4	2	3.03	1
$\sum$	10.03	3.66	7.53	2.08

Table 6. Element column / sum column

K_1	TA 1	TA 2	TA 3	TA 4
TA 1	0.0997	0.0902	0.0664	0.1202
TA 2	0.3021	0.2732	0.3984	0.2404
TA 3	0.1994	0.0902	0.1328	0.1587
TA 4	0.3988	0.5465	0.4024	0.4808

Table 7. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_1	
TA 1	0.3765	TA 1	0.0941	TA 4	0.4571
TA 2	1.2141	TA 2	0.3035	TA 2	0.3035
TA 3	0.5811	TA 3	0.1453	TA 3	0.1453
TA 4	1.8285	TA 4	0.4571	TA 1	0.0941

Table 8. The matrix of significance relative to the attribute K_2

K_2	TA 1	TA 2	TA 3	TA 4
TA 1	1	0.25	0.2	0.11
TA 2	4	1	0.5	0.2
TA 3	5	2	1	0.14
TA 4	9.09	5	7.14	1
$\sum$	19.09	8.25	8.84	1.45

Table 9. Element column / sum column

K_2	TA 1	TA 2	TA 3	TA 4
TA 1	0.0524	0.0303	0.0226	0.0759
TA 2	0.2095	0.1212	0.0566	0.1379
TA 3	0.2619	0.2424	0.1131	0.0966
TA 4	0.4762	0.6061	0.8077	0.6897

Table 10. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_2	
TA 1	0.1812	TA 1	0.0453	TA 4	0.6449
TA 2	0.5252	TA 2	0.1313	TA 3	0.1785
TA 3	0.714	TA 3	0.1785	TA 2	0.1313
TA 4	2.5797	TA 4	0.6449	TA 1	0.0453

Table 11. The matrix of significance relative to the attribute K_3

K_3	TA 1	TA 2	TA 3	TA 4
TA 1	1	5	0.33	3
TA 2	0.2	1	6	0.33
TA 3	3.03	0.17	1	5
TA 4	0.33	3.03	0.2	1
∑	4.56	9.2	7.53	9.33

Table 12. Element column / sum column

K_3	TA 1	TA 2	TA 3	TA 4
TA 1	0.2193	0.5435	0.0438	0.3215
TA 2	0.0439	0.1087	0.7968	0.0354
TA 3	0.6645	0.0185	0.1328	0.5359
TA 4	0.0727	0.3293	0.0266	0.1072

Table 13. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_3	
TA 1	1.1281	TA 1	0.282	TA 3	0.3379
TA 2	1.156	TA 2	0.289	TA 2	0.289
TA 3	1.3517	TA 3	0.3379	TA 1	0.282
TA 4	0.5358	TA 4	0.134	TA 4	0.134

Table 14. The matrix of significance relative to the attribute K_4

K_4	TA 1	TA 2	TA 3	TA 4
TA 1	1	0.33	3	1
TA 2	3.03	1	5	3
TA 3	0.33	0.2	1	0.33
TA 4	1	0.33	3.03	1
∑	5.34	1.86	12.03	5.33

Table 15. Element column / sum column

K_4	TA 1	TA 2	TA 3	TA 4
TA 1	0.1873	0.177	0.2494	0.1876
TA 2	0.5674	0.5376	0.4153	0.5629
TA 3	0.0618	0.1075	0.0831	0.0619
TA 4	0.1873	0.1774	0.2519	0.1876

Table 16. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_4	
TA 1	0.8013	TA 1	0.2003	TA 2	0.5208
TA 2	2.0832	TA 2	0.5208	TA 4	0.2011
TA 3	0.3143	TA 3	0.0786	TA 1	0.2003
TA 4	0.8042	TA 4	0.2011	TA 3	0.0786

Table 17. The matrix of significance relative to the attribute K_5

K_5	TA 1	TA 2	TA 3	TA 4
TA 1	1	5	1	5
TA 2	0.2	1	0.33	1
TA 3	1	3.03	1	5
TA 4	0.2	1	0.2	1
∑	2.4	10.03	2.53	12

Table 18. Element column / sum column

K_5	TA 1	TA 2	TA 3	TA 4
TA 1	0.4167	0.4985	0.3953	0.4177
TA 2	0.0833	0.0997	0.1304	0.0833
TA 3	0.4167	0.3021	0.3953	0.4177
TA 4	0.0833	0.0997	0.0791	0.0833

Table 19. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_5	
TA 1	1.7282	TA 1	0.4321	TA 1	0.4321
TA 2	0.3967	TA 2	0.0992	TA 3	0.383
TA 3	1.5318	TA 3	0.383	TA 2	0.0992
TA 4	0.3454	TA 4	0.0864	TA 4	0.0864

Table 20. The matrix of significance relative to the attribute K_6

K_6	TA 1	TA 2	TA 3	TA 4
TA 1	1	0.33	0.2	0.2
TA 2	3.03	1	0.33	0.33
TA 3	5	3.03	1	1
TA 4	5	3.03	1	1
∑	14.03	7.39	2.53	2.53

Table 21. Element column / sum column

K_6	TA 1	TA 2	TA 3	TA 4
TA 1	0.0712	0.0447	0.0791	0.0791
TA 2	0.216	0.1353	0.1304	0.1304
TA 3	0.3564	0.41	0.3953	0.3953
TA 4	0.3564	0.41	0.3953	0.3953

Table 22. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_6	
TA 1	0.2741	TA 1	0.0685	TA 3 – TA 4	0.3893
TA 2	0.3121	TA 2	0.153	TA 3 – TA 4	0.3893
TA 3	1.557	TA 3	0.3893	TA_2	0.153
TA 4	1.557	TA 4	0.3893	TA_1	0.0685

Table 23. The matrix of significance relative to the attribute K_7

K_7	TA 1	TA 2	TA 3	TA 4
TA 1	1	1	0.33	0.33
TA 2	1	1	0.33	0.33
TA 3	3.03	3.03	1	1
TA 4	3.03	3.03	1	1
∑	8.06	8.06	2.66	2.66

Table 24. Element column / sum column

K_7	TA 1	TA 2	TA 3	TA 4
TA 1	0.1241	0.1241	0.1241	0.1241
TA 2	0.1241	0.1241	0.1241	0.1241
TA 3	0.3759	0.3759	0.3759	0.3759
TA 4	0.3759	0.3759	0.3759	0.3759

Table 25. Ranking of technological alternatives

Sum of row		Average row value		Priority in relation to a criterion K_7	
TA 1	0.4964	TA 1	0.1241	TA 3 – TA 4	0.3759
TA 2	0.4964	TA 2	0.1241	TA 3 – TA 4	0.3759
TA 3	1.5036	TA 3	0.3759	TA 1 – TA 2	0.1241
TA 4	1.5036	TA 4	0.3759	TA 1 – TA 2	0.1241

Overall priority of technological alternatives in regard to aim according to the composite normalized vector is:

$$W_{TA\,1} = 0.1548$$

$$W_{TA\,2} = 0.2178$$

$W_{TA\,3} = 0.2168$

$W_{TA\,1} = 0.4152$

Which is resulting in: $W_{TA\,4} > W_{TA\,2} > W_{TA\,3} > W_{TA\,1}$.

The results show that priority should be given to TA 4, mobile equipment made EU.

6. CONCLUSION

In the aim of quality ELV detoxification which is in the function recycling process and all in the aim of environmental protection and techno-economic sustainability paper shows AHP method for selection optimal ELV equipment.

With comparing stable and mobile equipment produced in EU and RS and based on the all considered criteria which are relevant items for selection and with using AHP method it is obtained that is techno-economic the most optimal mobile equipment produced in EU. Slightly difference is between stable equipment produced in EU and mobile equipment produced in RS, while the stable equipment of domestic production is the least productive. Based on this selection, it is concluded that the price of the equipment for detoxification, as well as price of managing of equipment, the factors that should be most considered when choosing equipment.

ACKNOWLEDGEMENT

This paper is a result of the research activities conducted under the project "Sustainable development of technology and equipment for motor vehicles recycling" TR 35033, which is financed by the Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

[1] R. Farel, B. Yannou, A. Ghaffari, Y. Leroy, A cost benefit analysis of future end-of-life vehicle glazing recycling in France: A systematic approach, Resources, Conservation and Recycling, 74, 2013: 54-65.

[2] J. Milivojevic, S. Grubor, S. Kokić Arsić, Integrative and suistainable recycling of end-of-life vehicles system in serbia, 3rd National Conference about Quality of Life, 13-15 May, 2008, Kragujevac, Serbia.

[3] E. Desnica, The importance of sustainable development in engineering and education, Technical diagnostics, 13 (1), 2014: pp.13-16.

[4] M. Klarin, J. Cvijanovic, V.S. Brkić, Additional adjustment of the driver seat in accordance with the latest anthropometric measurements of drivers in Belgrade, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 215 (6), 2001: pp.709-712.

[5] M. Pavlović, S. Arsovski, S. Ćurčić, M. Milovančević, D. Tolmač, A. Tomović, Plant for ELV detoxification - prototype, Technical faculty „Mihajlo Pupin", Zrenjanin, 2013.

[6] M. Pavlović, N. Karanović, A. Đurić, Instructions for ELV detoxification in accordance with the applicable legislation of the Republic of Serbia, Part of the project „Setting up a sustainable model of recycling of motor vehicles in Banat in accordance with the new national legislation", 2011.

[7] M. Vulić, E. Desnica, A. Tomović, Analysis of new technical solution in process of detoxification ELV from environmental aspect, Machine and industrial design in mechanical engineering (KOD 2016), 9-12 May, 2016, Balaton, Hungary, pp.173-176.

[8] M. Vulić, M. Pavlović, A. Tomović, S. Stojanović, A. Đurić, Detoxification of ELV fluids in the function of quality of life, 1st International conference on Quality of Life, 9-10 June, 2016, Kragujevac, Serbia, pp.317-320.

[9] A. Tomović, M. Pavlović, M. Manojlović, M. Simić, Potentials for depollution end-of-life vehicles and their importance for environmental quality in Serbia, 2nd International Conference „Ecology of Urban Areas 2012", 15th October, Ečka, Serbia, pp.480-487.

[10] VORTEX - De-pollution & recycling equipment http://www.vortexdepollution.com/ (accessed 15.10.2016.)

[11] International company SEDA http://www.seda-international.com/en/ (accessed 18.08.2016.)

[12] M. Pavlović, S. Arsovski, M. Nikolić, D. Tadić, A. Tomović, The Technological Level of Equipment of Participants in the ELV Recycling Process in Serbia and the Region, 6th International Conference on Solid Waste Management (6th IconSWM 2016), 23-26 November, 2016, Kalkuta, India, pp.573-579.

[13] M. Radojičić, M. Žižović, Application of multi-criteria decision analysis methods in business decision making, Technical faculty, Čačak (in Serbian), 1998.

[14] M. Čupić, R. Tummala, M. Suknović, Decision making: a formal approach, Faculty of Organizational Science, Belgrade, (in Serbian), 2001.

[15] C. L. Hwang, K. Yoon, Multiple Attribute Decision Making: Methods and Applications, Springer-Verlag, New York, 1981.

[16] J. V. Vasović, M. Radojičić, M. Klarin, V. S. Brkić, Multi-criteria approach to optimization of enterprise production programme. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 225 (10), 2011: pp.1951-1963.

[17] T. L. Saaty, The Analytic Hierarchy Process, McGraw-Hill, New York, 1980.

[18] E. Triantaphyllou, Multi-Criteria Decision Making Methods: A Comparative Study, Kluwer Academic Publishers, Boston, 2000.

[19] M. Levi-Jakšić, S. Marinković, J. Obradović, Management of innovation and technological development, first ed., Faculty of Organizational Sciences, University of Belgrade, Belgrade, 2005.

[20] M. Vulić, A. Tomović, A. Pavlović, Development of technology of existing equipment for discharging brake fluid in the process detoxification of ELV, Journal of Production Engineering. 18 (2), 2015: pp.60-64.