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MULTICRITERIA ANALYSIS OF OPTIMAL SOLID WASTE MANAGEMENT SYSTEM-CASE STUDY OF KRAGUJEVAC (SERBIA)

Abstract: *Local government is most responsible for solid waste management in the city. The realization of this complex task requires appropriate organizational capacity and cooperation between many stakeholders in the public as well as in private sectors. Determination of the morphological composition of municipal solid waste is necessary in order to achieve successful development strategies and concepts for sustainable waste management. In this paper, for the city of Kragujevac (Serbia), on the basis of current data on the waste composition and quantity, simulations of eight different scenarios of waste management system were performed. For comparative analysis of relevant environmental, economic and energy parameters for selected scenarios of waste management, DSS software package (Decision Support Software) was used. According to obtained results, some recommendations for optimal system of municipal waste management in the city of Kragujevac were made.*
Keywords: *Municipal solid waste, Decision Support Software, Scenario, Multicriteria analysis, Waste composition*

1. INTRODUCTION

Humans are the only species that create waste. Due to increasing amounts of waste created as well as its environmental impacts, solid waste is one of the most important ecological problem of the modern world.

Determination of the morphological composition of the waste is the key of successful municipal solid waste management. It is necessary for municipal and industry stakeholders involved in the process of waste management at the municipal (city) level to the successful development of a strategy for sustainable waste management, as well as for re-use and waste disposal.

As it is expected, there can be found many researches aimed at finding the optimal technology for waste management in terms of minimizing negative impacts on the environment, improving the energy efficiency and cost-effective, and economically viable solutions. In line with this objective, efficient and reliable methods for quantifying the influence of applied technology, as an essential tool in the decision making process and the selection of the optimal environmental, energy and economic scenarious were developed.

According to [1], the main drivers for development in the field of solid waste management are:

- Public Health – Sanitary Revolution,
- Environment protection,
- Limited amount of natural resources and economical value of waste,
- Climate change,
- Information and public participation (awareness and concern).

The combination of these drivers, as ecological, energetics and economic factors, has a very complex influence on development MSW management.

In the 1980s, researchers started to take into account certain direct and indirect economic and environmental benefits in the process of analyzing of solid waste management. During this period, systematic analysis of applied techniques contribute to the development of long-term plans for management of municipal solid waste, taking into account the full range of costs and benefits, with or without environmental restrictions. During the nineties, there is progress in analysis optimization. In this developing phase, analysis could support the decisions related to the operation of short-term and long-term waste management including various socio-economic and environmental objectives and specific constraints in terms of a minimum level of sustainability [2].

With the development of LCA (Life Cycle Assessment) method, the possibilities in terms of optimal selection and application of the most appropriate management techniques were significantly expanded [3].

At the beginning of 21th century, all studies concerning improvement of MSW management, necessarily contains economic aspects (process costs and the profit from converting waste to energy or through the process of recycling, composting, etc..), energy balance (inventory of energy consumed in the process as well as the possibility of obtaining energy from waste) and environmental benefits and impacts. Certainly such a complex approach, which incorporates an adequate response to the demands of the five previously mentioned drivers of the waste management system, resulting in finding all the better, more efficient (in economic, energy and environmental terms) and sustainable waste management options.

2. MUNICIPAL SOLID WASTE MANAGEMENT IN THE CITY OF KRAGUJEVAC (SERBIA)

The city of Kragujevac is situated in the middle of Republic of Serbia. It is regional, administrative, economic, industrial, cultural, educational and health center of the region. It is situated on the banks of the river Lepenica. According to official results of the 2011 census, the city has a population of 150,835 inhabitants, while administrative area has a population of 179,417, and it is the fourth biggest city in the Republic of Serbia. The city area covers an area of 835 square kilometers.

Waste management in the city of Kragujevac is based on landfilling. Beside the separation at source of some recyclable waste, all the collected mixed waste go directly to city landfill. The landfill has been in operation since 1966. It is 3 kilometers from the city center and the nearest village is located about one kilometer. Landfill covers an area of 15 hectares, and the average height of the deposited waste reaches 15 meters.

Since landfill is used for almost half a century and taking into account the amount of waste disposed, its proximity to the city and some suburbs, as well as the limited area that it can occupy, it can be concluded that the landfill in Jovanovac is one of the biggest environmental problems of the city of Kragujevac. Landfill capacity is almost completely filled, and it is predicted that it can be relatively safe to use it within a maximum of two years.

Table 1 - Waste composition

Composition of MSW in Kragujevac	
Type	**(%)**
Organics	31.43
Garden	11.29
Paper and cardboard (Packaging)	13.04
Paper (Other)	8.07
Wood (Packaging)	1.05
Wood (Other)	0.62
Glass (Packaging)	3.02
Glass (Other)	2.02
Metals (Packaging)	1.77
Metals (Other)	1.06
Plastics (Packaging)	13.23
Plastics (Other)	3.68
Other	9.72
Σ	100

For waste management system planning is necessary to know the composition and quantity of solid waste. The amount of waste collected is measured at scale, which is installed at the landfill. Each truck is measured before landfilling the waste. Methodology used to determine the composition of municipal solid waste generated in the city of Kragujevac was developed by Jovicic et al., [4] and it is implemented in the act of the Government of the Republic of Serbia - Waste Management Strategy of the Republic of Serbia for the period 2010 – 2019. Mentioned methodology was developed based on experience and similar methodology applied in the EU. According to this methodology, which involves determining the morphological composition of waste in three different seasons and three zones of the city, composition of the waste that is used in this paper was obtained. The composition of MSW in the city of Kragujevac addapted to DSS software is shown in Table 1.

3. ALTERNATIVE SCENARIOS OF MUNICIPAL SOLID WASTE MANAGEMENT

A waste quantity per capita in the city of Kragujevac, based on measurements, is 0.75 kg per day. Anticipated annual growth rate of waste production is 1.5% and, in accordance with that total waste generation in the 2020th year is 56158 tons. Biodegradable municipal waste share is 65.5%, and packaging waste share is 32.11% in total waste amount.

As part of this research, eigth alternative scenarios of municipal solid waste management was formed. These scenarious are presented in Table 2. For each of the scenarios different set of treatment options for biological, packaging and residual waste was made. In six of eigth scenarios the construction of a single plant for the treatment of residual waste was predict. In the last two scenarios there was two predicted plants. Biowaste tretment is provided in composting plants (in five scenarios) and anaerobic digestion (in three scenarios). Packaging waste, in all eight scenarios, is treated in material recovery facilities (MRF). For each scenario, MBT facility is provided, while in the last two biodrying was includid. Four scenarios include final disposal of residual waste, while other four scenarious include waste to energy.

Table 2 - Eight scenarios of solid waste management in Kragujevac used in DSS

BIOWASTE		PACKAGING WASTE	RESIDUAL WASTE				
Capacity (tn)		Capacity (tn)	Capacity (tn)				
11 995		14 239	28 286				
	Biowaste	Packaging waste	Technology for Facility 1	% for Facility 1	Technology for Facility 2	% for Facility 2	RDF/SRF treatment
1.	Composting	MRF	MBT-Composting-Recyclables	100		0	Landfilling
2.	Composting	MRF	MBT-Composting-RDF	100		0	Landfilling
3.	Composting	MRF	MBT-AD-Recyclables	100		0	Landfilling
4.	Composting	MRF	MBT-AD-RDF	100		0	Landfilling
5.	AD	MRF	MBT-Composting-Recyclables	100		0	Waste to Energy
6.	AD	MRF	MBT-AD-RDF	100		0	Waste to Energy
7.	Composting	MRF	MBT-Composting-Recyclables	80	Biodrying	20	Waste to Energy
8.	AD	MRF	MBT-AD-Recyclables	80	Biodrying	20	Waste to Energy

4. RESULTS AND DISCUSSION

By using DSS (Decision Support Software) tools package simulation of the eight scenarios for solid waste management for the city of Kragujevac was performed. Table 3 presents the results obtained for eleven selected parameters.

Table 3 - The values of selected parameters for the eight created scenarios (highlithed cells are four best values of certain parameters)

*	SCENARIO							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
P1	9060275	9060275	14660903	14660903	11723165	17323793	9015017	16158410
P2	2321270	2321270	3311280	3311280	2681120	3671130	2349556	3501414
P3	1673547	1757757	2993557	2949587	2062065	3357681	1812170	2968227
P4	32898	10269	27241	27241	32898	27241	30069	25544
P5	-109651	-107042	-110526	-107918	-19896	-22351	-116514	-22226
P6	-23	-17	-27	-21	-26	-23	-15	-7
P7	410	495	153	238	-640	-1445	-468	-930
P8	1307	1307	2297	2297	2147	3137	1165	2797
P9	2533	3099	3099	3664	2713	3844	2986	3618
P10	0	0	3394	3394	2687	6081	0	5402
P11	-2533	-3099	296	-270	-26	2237	-2986	1784

* (P1 - Capital expenditure (euro), P2 - Annual operation&maintenance cost (euro), P3 - Total operational cost (euro), P4 - Land requirement (m^2), P5 - GHG (tn eq./a), P6 - Emission to air (tn SO2 eq./a), P7 - Conventional fuel savings (toe/a), P8 - Water consupmption (m^3/a), P9 - Energy consumption (MWh), P10 - Energy production (MWh), P11 - Energy balance (MWh))

On the basis of 29 criteria grouped into five groups (environmental, technical, economic, social and criteria that evaluate compliance with relevant regulations and legislation for waste management sector) and assigning weigh coefficients, the qualitative ranking of the selected scenarios was made.

According to previous multicriteria analise scenario No. 5 was the best in total ranking for selected parameters, while first scenario had slightly weaker results. The worst ecological, economic and energy characteristics were calculated for fourth and sixth scenario.

All results are obtained by the accepting default values of weigth coefficients, given in DSS.

As already mentioned before, table 3 shows eleven selected parameters for each of eight scenarious, while four best values for each scenarious are highlighted in order to visualise frequency of best results per scenario.

Economic parameters are shown in Figure 1. These parameters include Capital costs, annual operation and maintenance costs as well as total operational costs.

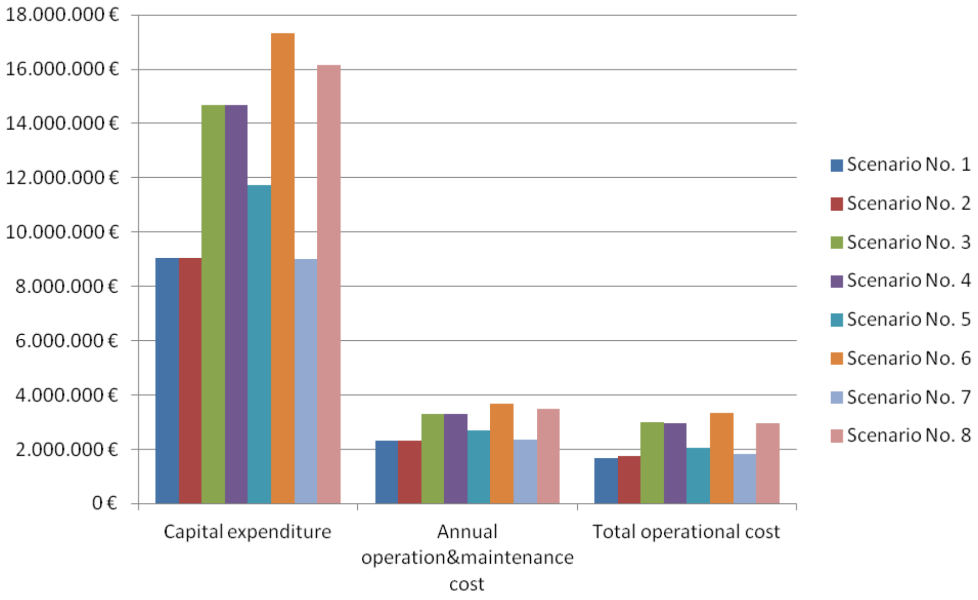


Figure 1 – Economic parameters

Figure 2 presents GHG emissions per scenario as most important ecological parameter, in comparation to present system for solid waste management (less is better).

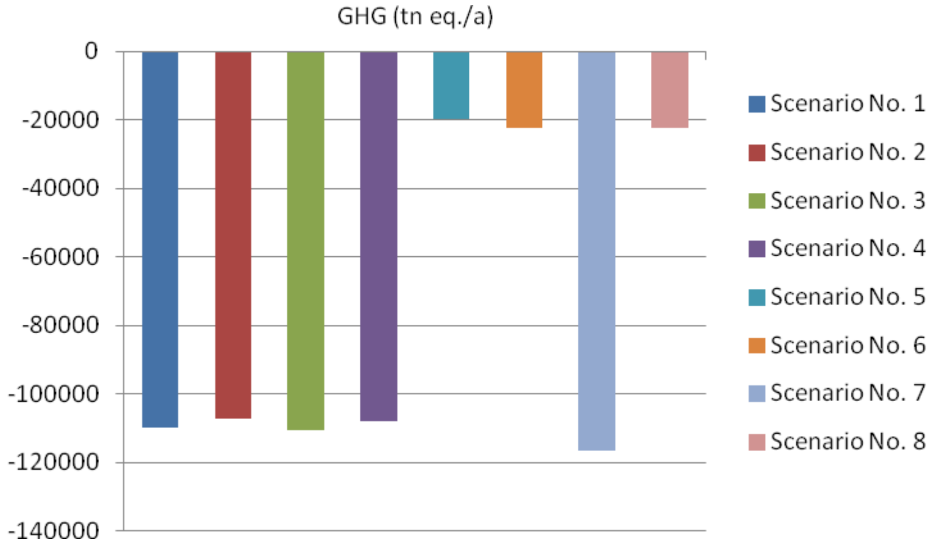


Figure 2 – Ecological parameters

Energetic parameters are shown in Figure 3.

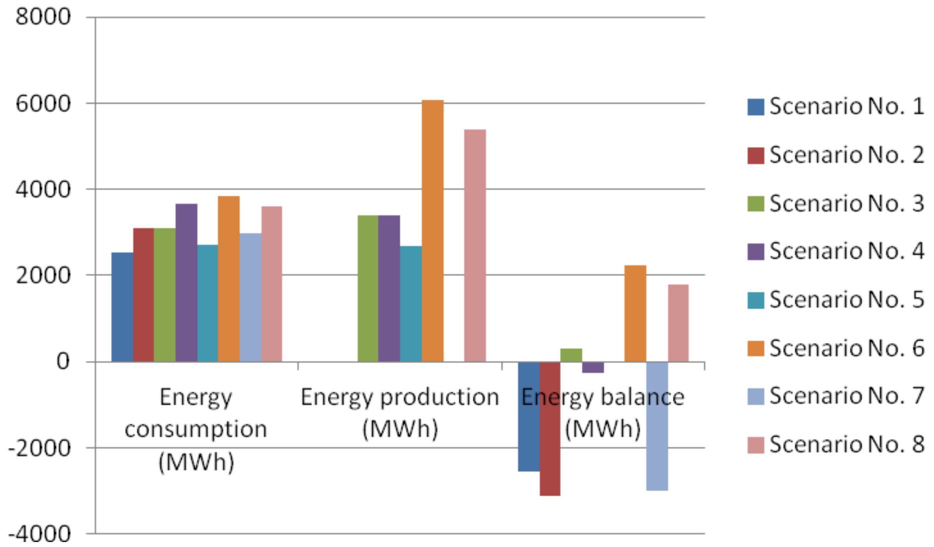
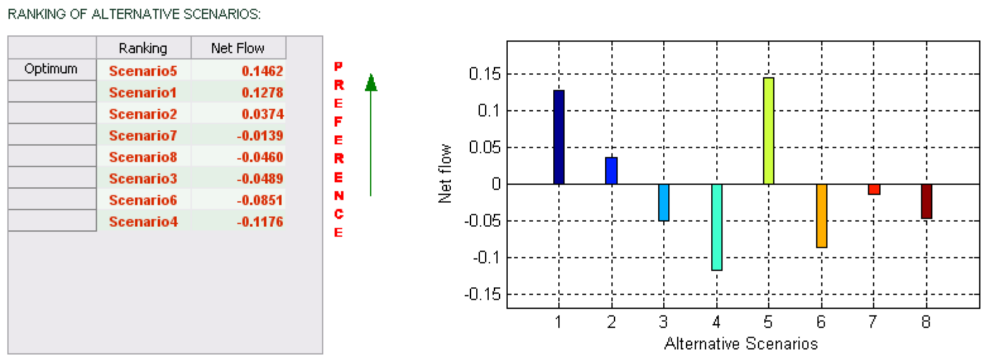


Figure 3 – Energetic parameters

Ranking of alternative scenarios are shown at Figure 4. On the left side of the figure overall ranking is shown. The right side of figure shows Net flow for each scenario.



RANKING OF ALTERNATIVE SCENARIOS:

	Ranking	Net Flow
Optimum	Scenario5	0.1462
	Scenario1	0.1278
	Scenario2	0.0374
	Scenario7	-0.0139
	Scenario8	-0.0460
	Scenario3	-0.0489
	Scenario6	-0.0851
	Scenario4	-0.1176

Figure 4 – Ranking of alternative scenarious

5. CONCLUSION

Within the next few years solid waste management in the City of Kragujevac must be reformed in order to achieve serious and sustainable system. The present system is unsustainable, especially in the environmental, energy, as well as in economic matter. Also, all activities must comply with the relevant regulations and standards. During the analyze presented in this paper, from eight scenarios considered municipal solid waste management, the optimal scenario for the city of Kragujevac, according to DSS is scenario No. 5. This scenario include anaerobic digestion plant for biowaste, material recovery facility for packaging waste, and treatment of collected mixed waste in MBT facility (composting and recycling), while the rest of waste is transferred to energy. Also, scenario No. 1, which is by characteristics close to optimal scenario, include composting for biowaste, treatment in MRF for packaging waste and composting, recycling and final disposal of mixed waste. By varying the priorities (economic, environmental, and energy) similar analysis can be made, which may bring some other optimal solution.

REFERENCES:

[1] Wilson, D.C., "Development drivers for waste management", *Waste Management & Research* 25 (3) (2007) 198-207.

[2] Chang, N.B., Wang, S.F., "Solid waste management system analysis by multi-objective mixed integer programming model" *Journal of Environmental Management* 48 (1996) 17-43.

[3] Banar, M., Cokaygil, Z., Ozkan, A., "Life cycle assessment of solid waste management options for Eskisehir, Turkey" *Waste Management* 29 (2009) 54-62.

[4] Jovičić, N., Vujić, G., Milovanović, D., Jovičić, G., Despotović, M., Batinić, B., Stanisavljević, N., Ubavin, D., Gvozdenac, B., Bošković, G., *The methodology for determining the morphological composition of municipal waste,* The technical solution, 2009.