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Network Design for the Dismantling Centers of the End-of-Life Vehicles Under Uncertainties: A Case Study

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This paper addresses the issues involved in the design of the ELV dismantling centres locations network. The problem to be considered is one of ELV waste management problems. Its solution is of the utmost importance for ELV waste management problem, as it influences the choice and efficiency of ELV waste management strategies. It is realistically posed that the choice of locations depends on multiple, rather conflicting criteria. The uncertain criteria values are described by linguistic expressions modelled by fuzzy numbers. The values of the first three criteria are modelled by discrete fuzzy numbers, whereas the values of other considered criteria are modelled by triangular fuzzy numbers. These criteria also have a different relative importance. In this paper, the criteria importance is given by the pairwise comparison matrix and weight vector is calculated by applying the eigenvector approach. A new multi-criteria fuzzy model based on Pareto analysis is developed and applied. The developed model is illustrated with examples containing the real world data collected in Serbia.

Dizajn mreže centara za rasklapanje vozila na kraju životnog ciklusa: studija slučaja

Izvornoznanstveni članak

Ovaj rad adresiran je na problem dizajniranja mreže lokacija na kojima se vrši demontaža ELV. Razmatrani problem je jedan od problema upravljanja otpadom. Njegovo rješenje je od najveće važnosti za ELV menadžment problem jer utječe na izbor i efikasnost strategija za upravljanje ELV otpadom. Realno je pretpostaviti da izbor lokacija zavisi od više kriterija koji su u konfliktu. Neizvjesne vrijednosti su opisane pomoću lingvističkih iskaza koji su modelirani fazi brojevima. Vrijednosti prva tri kriterija su modelirana pomoću diskretnih fazi brojeva, dok vrijednosti ostalih kriterija su modelirani pomoću trokutastih fazi brojeva. Kriteriji imaju različite relativne važnosti. U ovom radu, relativne važnosti kriterijuma su zadane preko matrice parova poređenja relativnog odnosa važnosti kriterija i vektor težina je izračunat pomoću metode sopstvenog vektora. Nov razvijeni više-kriterijumski fazi model je zasnovan na Pareto analizi. Razvijeni model je ilustriran primjerom u kojem egzistiraju realni podaci koji su prikupljeni u Srbiji.

1. Introduction

In the past decade, recycling of End-of Life Vehicles (ELV) has arisen as a very important issue for car-manufactures worldwide, and the improvement of ELV recycling processes has become one of their most important tasks. Moreover, problem of ELV recycling is not exclusively faced by industrialized countries. According to (Togawa, 2006), the implementation of strict product-oriented legislation (Life-Cycle- Assessment standard is associated with car-industry) will sooner or later become of dominant interest in developing countries.

In industrial countries with developed recycling industry, networks of dismantling and recycling centres are developed and they are supposed to have an optimal configuration. Such a situation has posed the problem of determining optimal waste management strategies, as well as optimal waste reduction strategies.The treated problem has become of special importance for developing conutries, such as Serbia where ELV recycling process is in its infancy. The importance of the considered problem can be illustrated with the fact that dismantling centers network design determines in a high degree that whole process of ELV recycling, influencing thus, in the first place, its efficiency.

It is mentioned, that selection of locations for recycling of waste is not a strainghtforward task. Many aspects, such as environmental features, social impact assessment, cost considerations, etc. must be accounnted for in order to point to an adequate management of recycling processes. In the literature, there are not many papers which offer knownledge-based systems used in both waste management and process of determining locations for recycling different types of waste.

It is realistic to suppose that the choice of location can be stated as multi-criteria optimization task. The optimum network configuration of dismantling centres can be found by applying some developed multi-criteria desision making systems, and knownledge-based systems. Primitive version of these multi-criteria appraches suppose that all data relevant for the problem of location selection are crisp (Cruz-Rivera and Ertel, 2009, Captivo and Clìmaco, 2008, Erkut, *et al*, 2008).

Numerous papers treat the problem of selecting waste locations. In Hokkanen & Salminen (1996) athe problem of choice of a waste treatment facility location is considered. Bian and Yu (2006) propose the problem of location analysis of reverse logistics to be a complex multi-criteria decision making problem. The optimal rank of possible locations (various countries in the Asia Pacific region where international electrical manufacturers operate) is given by applying the analytic hierarchy process. In Barlishen (1996) a developed knownledge-based system for optimal recycling and incineration programs planning is presented. By applying a developed knownledge-based system several cost and operations parameters must be provided in order to minimize costs of different recycling schemes. Fiorucci *et al*. (2003) developed decision support system which allows to plan the optimal number of landfills and treatment plants, and to determine the optimal quantities and the charactesistics of the refuse that has to be sent to treatment plants, to landfills and to recycling. The optimal solution is brought about from the condition of objective function minimum (recycling, transportation and maintenance costs).

Situations are changing rapidly or are uncertain and values of many parameters present in the considered problem are difficult or impossible to quantify. As uncertainty is an important factor in waste management problems, many researchers applied fuzzy set theory for modelling of uncertainties. Fuzzy set theory can provide a valuable tool to cope with three major problematic areas of waste management: imprecision, randomness and ambiguity. Fuzzy logic enables us to emulate the human reasoning process and make decision based on vague or imprecise data (Kaur and Chakrabortyb, 2007). It has been shown that fuzzy approaches to treating uncertainties in real-world applications have numerous advantages as follows: (a) they are conceptually easy to understand, (b) they can capture most nonlinear relations in problems of arbitrary complexity, (c) they are based on a natural language, (d) they can be built based on the expertise and (e) they could be combined with conventional methods and techniques for dealing and reasoning with uncertain data (Türkşen, and Fazel Zarandi, 1999).

Modified multi-criteria techniques and fuzzy decision support systems are used to solve waste management problem, offering thus solution to the most prominent part of waste management, i.e. determining an optimal configuration of the network of locations for dismantling, repairing and recycling under different types and sources of uncertainty and inaccuracy.

Kannan *et al*. (2008) offer an effective and efficient multi-criteria decision-making model for selecting the collecting centre location in the reverse logistics supply chain model (RLSCM). The rank of locations (in this paper those are locations in the southern part of India where manufacturing industry is situated) are given by applying both primitive and fuzzy analytic hierarchy processes. The proposed model helps the manufacturing industry select the collecting centre location effectively for RLSCM. Koo *et al* (1991) developed a multi-objective waste management model. They considered the following criteria: economic efficiency, environmental risk (social and political factors), equity and administrative ease. The appropriate alternative for the siting of long life public sector facility are determined by utilizing fuzzy set theory. Alves *et al* (2009) give a fuzzy multi-criteria decision support system to determine the location of a landfill site. Considered problem is a very complex one and the optimal solution is found with respect to numerious different criteria, simultaneously. The values criteria can be crisp or uncertain. The uncertainties are described by triangular and trapezoid fuzzy numbers. Fuzzy decision approach is used in order to integrate qualitative and quantitative information from decision processes.

Classification of different items is most often used in inventory management problems, though it should be noted that the classification problem exists in all management problems. In the context of ELV dismantling location problem, a decision maker is to choose the location of the utmost importance for ELV recycling industry development. In practice, classification method based on Pareto analysis is of the most general application. In the primitive version of this method, the classification of considered items is performed according to one crisp criterion, which certainly does not satisfy the need of a real classification problem. There is a number of papers presenting different modified versions of this classification method.

Up-to-date literature offers papers describing ABC with uncertain data (Puente *et al*. 2002, Tadić & Stanojević, 2005, and Tadić *et al.* 2007). In Puente *et al* (2002), management values, unit prices and demand are described by triangular fuzzy numbers. In Tadić and Stanojević, (2005) the criteria values are described by fuzzy numbers with a different shape of membership functions. These criteria have different relative importance. Classification criterion is presented with the analytical function which depends on all considered criteria with respect to their relative importance. The importance of treated items is gained in the process of fuzzy number comparison. In Tadić, *et al* (2007) it is assumed that the values of imprecise optimization criteria and their relative weights are described by discrete fuzzy numbers. Ching-Wu *et al*. (2002) offer a new fuzzy inventory control approach, which can handle variables with either nominal or non-nominal attribute, incoporate manager's experience, make judgements on inventory classification, and can be implemented easly. The developed model can also be easily modified and applied to classification of the items characteristic of not only inventory control problems.

This paper is organized in the following way: Section 2 gives description of modelling of uncertainties present in models. A new fuzzy model for the selection of the best locations for ELV dismantling with respect to numerious criteria, simultaneously, is based on Pareto analysis and described in Section 3. Finally, Section 4 offers an illustrative example with real data collected in Serbia.

2. Modelling of uncertainties

In this Section, modelling of uncertainties that exist in the developed ABC classification model is described.

2.1. The relative importance criteria

The set of criteria representing the base for evaluation of each possible location for ELV dismantling centers is defined. The number and types of these criteria depend on judgments of the decision makers.

The relative importance of each of the considered criteria is different and not dependent on the location. It is also supposed to be unchangeable during the considered period of time. In general, the relative importance can be assigned in various ways. It is well known that managers get the most accurate estimates by comparing the relative importance of one criterion to the relative importance of another one.

In this paper, pairwise comparison matrix of relative importance of the considered criteria is constructed. The elements of this matrix are defined in the following way: importance of the criterion k to criterion $k^{'}, w_{kk^{'}}, k, k^{'} = 1,..,K; k \neq k^{'}$. In order to estimate the relative importance of the considered criteria, decision makers use statistical data, experience of other countries, legal procedures etc. These values are estimated with reference to the Satty measurement scale (Satty, 1990), which is defined for the set of real numbers with the interval [1-9]. Value 1 denotes that both criteria k and $k^{'}$ are of the equal importance, whereas value 9 denotes that criterion k is of extreme importance in comparison to criterion $k^{'}$, $k, k^{'} = 1,..,K; k \neq k^{'}$.

There are a lot of approaches for the estimation of the weights of criteria, w_k, k=1,..., K from a pairwise comparison matrix. In this paper, the eigenvector approach proposed by Satty (Satty, 1977) is used. According to many researchers, the eigenvector approach represents a theoretically and practically proved method for weights estimation. In order to get a unique solution, it is necessary that pairwise comparion matrix be consistent, and the consistency index, C.I. can be C.I.≤0.1.

2.2. Modelling of uncertain criteria values

It is supposed that values of all criteria underlying the evaluation of possible locations for dismantling centres cannot be precisely determined. In this paper, a new approach to modelling of the uncertain criteria values of possible locations of ELV dismantling centers which is based on real data obtained in practice is proposed. Eight linguistic expressions are used to describe criteria values: *very low value*, *low value*, *fairly low value, fairly medium value, medium value, fairly high value, high value, very high value* . The number of linguistic expressions and their meanings are determined in consultation with the decision makers. These expressions are modeled by triangular fuzzy numbers (Zimmermann, 1996) defined in the interval [0,1], where 0 denotes the lowest value i.e., there is no criteria values and 1 denotes the highest criteria values. The membership functions given in Figure 1 are defined as follows:

very low value	(x;0,0,0.1)
low value	(x;0.05,0.1,0.15)
fairly low value	(x;0.12,0.18,0.2)
fairly medium value	(x;0.18,0.22,0.28)
medium value	(x;0.26,0.33,0.4)
fairly high value	(x;0.4,0.55,0.7)
high value	(x;0.5,0.7,0.9)
very high value	(x;0.9,1,1)

3. A new fuzzy model

Determining an optimal dismantling centers network is one of the critical tasks of ELV management and it is present in the whole ELV management problem, which finally influences the realisation of two basic tasks of ELV management.

In this paper, the estimation of relative importance of considered criteria is made by the decision maker, and it is presented by a matrix of pairwise comparison. The values of weights of considered criteria, w_k, k=1,..., K are calculated by applying the eigenvector approach and they are described by ordinal numbers.

In order to associate each uncertain criteria values of each dismantling center of ELV with the appropriate linguistic expression, the actual criteria value is normalized i.e., mapped into the interval [0,1] using a normalization procedure. First, the maximum criterion value of all possible dismantling centers, v^{max}, is determined using the evidence data. Then, criterion value k, k=1,..., K' of dismantling center i, v_i, i=1,..., I is divided by v^{max} in order to map the value into the interval [0,1]. The linguistic expression is selected from the 5 expressions defined in Section 2 in such a way that normalized criterion value $\frac{v_i}{v^{max}}$ belongs to the support of the corresponding membership function. Support of a fuzzy set is a crisp interval with all the elements of the fuzzy set which have nonzero membership degrees. In practice, it is possible that a criterion value can be characterized by two linguistic expressions because the supports of their membership functions overlap. In this case, the criterion value is described by the linguistic expression for which the value attains the higher value of the corresponding membership function. In this way, value of each considered criterion is described by a triangular fuzzy number $\tilde{v}_i = (x; l_i, m_i, u_i)$, with the lower and upper bounds l_i, u_i and a modal valuel$_i$ m_i respectively.

The values of rest considered criteria can not calculated according to evidence data. Then, determining of criteria values are based on judgements of experts.

The weighted normalized criteria values, $\tilde{d}_{ik}, i = 1,..,I; k - 1,..,K$ are calculated. The value of classificatin criterion for each possible location i, $\tilde{F}_i$ i=1,..,I is calculated with respect to all considered criteria, simultaneously, taking into account their relative weights. The representative scalar of fuzzy number $\tilde{F}_i$ is given by using defuzzification procedure. The relative value of classification criterion for location i, f_i, i=1,..,I is determined by deviding F_i by sum of all F_i, i=1,..,I.

Ranking of the possible locations is performed according to values f_i, i=1,..,I. Rank number 1 is given to the location with the highest value f_i, and the end position is given to the location with the lowest value f_i, i=1,..,I. For each possible location i, i=1,,..,I a cummulative value of classification criterion, ef_i, is calculated.

According to rules of Pareto analysis, the most important locations for the decision maker are those resulting from the condition that cumulative value of classification criterion, $ef_i \approx 0,8$. The remaining 15% of ef_i correspond to the locations having "medium importance" for decison makers. The other treated locations are of the least importance for the decision maker.

3.1 Algorithm for ranking and selction of the best location

The algorithm outlined below describes in a more formal way the problem of location selection for ELV dismantling. The algorithm can be divided into the following steps:

Step 1. Generate a [KxK] pairwise comparison matrix of the relative importance of treated criteria. By applying eigenvector approach, weights of criteria is calculated.

Step2. Calculate the weighted normalized criteria values:

$$\tilde{d}_{ik} = w_k \cdot \tilde{v}_{ik}\text{ , k=1,..,K, i=1,..,I.} \quad (1)$$

Step 3. Calculate the criterion classification value for each possible location for dismantling centre, F_i, and the relative value of F_i, f_i:

$$\tilde{F}_i = \sum_{k=1}^{K} \tilde{d}_{ik}, \quad (2)$$

$$F_i = \text{difuzz } \tilde{F}_i, \text{ and } f_i = \frac{F_i}{\sum_{i=1}^{I} F_i} \quad (3)$$

Step 4. Let us rank the possible locations in such a way that rank number 1 belongs to the dismantling centre location with the highest value f_i, and the end position is given to the location with the lowest value f_i. After that, a cumulative value of classification criteria for each possible location, ef_i, is calculated and locations are divided in groups.

4. Case study

Decision maker define a number of possible locations where ELV dismantling centres should be built. Generally, a decision maker can be a government, local autorities, vehicle users, and other interested parties, e.g. entrepreneurs. In this paper, the decision maker is the Government of Serbia whose aim is to form the inicial network of ELV dismantling centres. In this paper, our attention is focused on the 34 possible locations where one or more disamantling centers in Serbia can be built. A set of possible locations where ELV dismantling centres can be built is defined according to: (1) the data on quantity, type and degree of recyclablity for each region in Serbia, which were gained as the outcome of the project: "" funded by the two corresponding ministries of the Government of Serbia and (2) the distance between each two possible locations is about 50 km (such a distance enables transportation costs to be as low as possible, based on the experience of ELV recycling processes in Bavaria).

They are indexed from i=1, to i=34.

i=1, Aranđelovac	i=10, Kruševac	i=19, Priboj	i=28, Trstenik
i=2, Beograd	i=11, Leskovac	i=20, Paraćin	i=29, Užice
i=3, Bor	i=12, Loznica	I=21, Prokuplje	i=30, Valjevo
i=4, Čačak	i=13, Niš	i=22, Ruma	i=31, Vranje
i=5, Gornji Milanovac	i=14, Novi Pazar	i=23, Smederevo	i=32, Vršac
i=6, Jagodina	i=15, Novi Sad	i=24, Sombor	i=33, Zaječar
i=7, Kikinda	i=16, Pančevo	i=25, Sremska Mitrovica	i=34, Zrenjanin
i=8, Kragujevac	i=17, Pirot	i=26, Subotica	
i=9, Kraljevo	i=18, Požarevac	i=27, Šabac	

According to the decision makers' opinion there are seven important criteria for evaluating locations where ELV dismantling centres should be built. In this paper, the decision maker, i.e. the Government of Serbia defined criteria based on the experience of the countries with a developed ELV recycling system. They are indexed from k=1 to k=7: k=1, economical level of the region where a dismantling centre is located, in monetary unit, k=2, income per vehicle in dismantling centre, in monetary unit, k=3, number of ELV in the area of each possible dismantling centre per year, in monetary unit, k=4, technology level of dismantling equipment, k=5, recyclability level of ELV, k=6, local support (expressed in local taxes benefit, financial support, knownledge communication, etc.), and k=7, punishment policy.

Table 1. Input data

Tablica 1. Ulazni podatci

	k=1	k=2	k=3	k=4	k=5	k=6	k=7
i=1	high value / velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	medium value / osrednja vrijednost
i=2	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	high value / velika vrijednost	very high value / veoma velika vrijednost	high value / velika vrijednost
i=3	medium value / osrednja vrijednost	fairly medium value / prilično osrednja vrijednost	low value / mala vrijednost	medium value / osrednja vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly medium value / prilično osrednja vrijednost
i=4	high value / velika vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	fairly medium value / prilično osrednja vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost
i=5	high value / velika vrijednost	medium value / srednja vrijednost	low value / mala vrijednost	medium value / osrednja vrijednost	fairly medium value / prilično osrednja vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost
i=6	very high value / veoma velika vrijednost	fairly low value / prilično mala vrijednost	fairly high value / prilično velika vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	high value / velika vrijednost	low value / mala vrijednost
i=7	high value / velika vrijednost	low value / mala vrijednost	medium value / srednja vrijednost	high value / velika vrijednost	high value / velika vrijednost	fairly high value / prilično velika vrijednost	fairly medium value / prilično osrednja veličina
i=8	fairly medium value / prilično osrednja vrijednost	high value / velika vrijednost	fairly medium value / prilično osrednja vrijednost	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost
i=9	medium value / osrednja vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost
i=10	fairly low value / prilično mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost

i=11	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	low value / mala vrijednost
i=12	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	medium value / osrednja vrijednost
i=13	high value / velika vrijednost	high value / velika vrijednost	very high value / veoma velika vrijednost	high value / velika vrijednost	fairly high value / prilično velika vrijednost	fairly medium value / prilično osrednja vrijednost	fairly high value / prilično velika vrijednost
i=14	fairly medium value / prilično osrednja vrijednost	very low value / veoma mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	medium value / osrednja vrijednost	very low value / veoma mala vrijednost
i=15	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	high value / velika vrijednost	fairly low value / prilično mala vrijednost	high value / velika vrijednost	high value / velika vrijednost
i=16	high value / velika vrijednost	low value / mala vrijednost	high value / velika vrijednost	medium value / osrednja vrijednost	low value / mala vrijednost	fairly low value / prilično mala vrijednost	high value / velika vrijednost
i=17	low value / mala vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	fairly low value / prilično mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost
i=18	high value / velika vrijednost	low value / mala vrijednost	fairly medium value / prilična osrednja vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	medium value / osrednja vrijednost	low value / mala vrijednost
i=19	low value / mala vrijednost	fairly low value / prilično mala vrijednost	low value / mala vrijednost	very high value / veoma velika vrijednost	very high value / veoma velika vrijednost	low value / mala vrijednost	low value / mala vrijednost
i=20	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost
i=21	low value / mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost
i=22	high value / velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	fairly high value / prilično velika vrijednost
i=23	high value / velika vrijednost	low value / mala vrijednost	fairly high value	fairly low value / prilično mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	medium value / osrednja vrijednost
i=24	high value / velika vrijednost	medium value / osrednja vrijednost	fairly low value	very high value / veoma velika vrijednost	high value / velika vrijednost	high value / velika vrijednost	fairly high value / prilično velika vrijednost
i=25	very high value / veoma velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	medium value / osrednja vrijednost	high value / velika vrijednost
i=26	very high value / veoma velika vrijednost	low value / mala vrijednost	high value / velika vrijednost	fairly high value / prilično velika vrijednost	low value / mala srijedna	high value / velika vrijednost	high value / velika vrijednost
i=27	high value / velika vrijednost	low value / mala vrijednost	medium value / osrednja vrijednost	medium value / osrednja vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	medium value / osrednja vrijednost
i=28	low value / mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost
i=29	medium value / osrednja vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost

i=30	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost
i=31	fairly low value / prilično mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	low value / mala vrijednost	low value / mala vrijednost
i=32	high value / velika vrijednost	fairly high value / prilično velika vrijednost	low value / mala vrijednost	very low value / veoma mala vrijednost	very low value / veoma mala vrijednost	medium value / osrednja vrijednost	high value / velika vrijednost
i=33	medium value / osrednja vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost	low value / mala vrijednost
i=34	high value / velika vrijednost	medium value / osrednja vrijednost	low value / mala vrijednost	high value / velika vrijednost	medium value / osrednja vrijednost	medium value / osrednja vrijednost	medium value / osrednja vrijednost

The pairwise comparison matrix of relative importance of considered criteria is:

$$\begin{bmatrix} - & 1/7 & 1/5 & 1/3 & 1/3 & 2 & 2 \\ & - & 3 & 5 & 5 & 9 & 9 \\ & & - & 3 & 3 & 5 & 5 \\ & & & - & 1 & 3 & 3 \\ & & & & - & 3 & 3 \\ & & & & & - & 1 \\ & & & & & & 1 \end{bmatrix}, \quad \text{C.I.}=0.024$$

The weights vector is

$$w = \begin{bmatrix} 0.052 & 0.442 & 0.225 & 0.104 & 0.104 & 0.036 & 0.036 \end{bmatrix}$$

Using the procedure described in Step 2 and Step 3, transformed values of criteria are calculated and presented in Table 2.

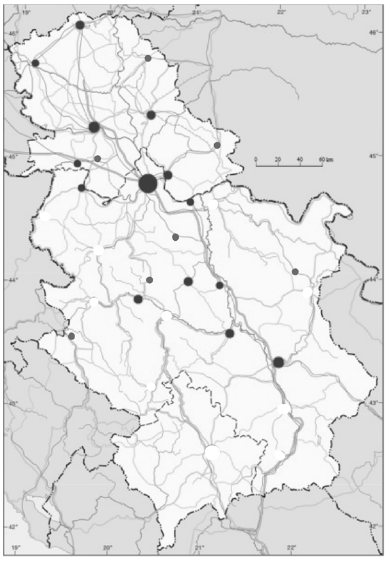

Figure 1. The optimal configuration of network for the dismantling centers of the ELV

Slika 1. Optimalna struktura mreže centara za rasklapanje ELV

Table 2. Classification criterion value for all possible locations

Tablica 2. Vrijednost kriterija klasifikacije za sve moguće lokacije

	$\tilde{F}_i$	f_i		$\tilde{F}_i$	f_i
i=1	(0.11731, 0.18618, 0.25505)	0.019918	i=18	(0.10496, 0.15598, 0.2219)	0.016687
i=2	(0.8431, 0.957, 0.985)	0.102382	i=19	(0.25769, 0.32246, 0.34875)	0.034498
i=3	(0.14485, 0.19314, 0.25099)	0.020663	i=20	(0.06635, 0.1197, 0.17665)	0.012806
i=4	(0.17822, 0.26103, 0.34592)	0.027926	i=21	(0.0026, 0.0052, 0.1025)	0.000556
i=5	(0.21413, 0.28536, 0.35867)	0.030528	i=22	(0.09855, 0.1635, 0.22845)	0.017492
i=6	(0.25644, 0.35171, 0.4241)	0.037627	i=23	(0.17954, 0.26515, 0.38404)	0.028366
i=7	(0.23148, 0.32817, 0.42558)	0.035108	i=24	(0.34592, 0.4456, 0.5238)	0.04756
i=8	(0.47426, 0.60174, 0.71396)	0.064376	i=25	(0.15431, 0.22338, 0.28725)	0.023898
i=9	(0.09727, 0.15866, 0.22005)	0.016974	i=26	(0.2642, 0.3717, 0.474)	0.039765
i=10	(0.12639, 0.19766, 0.26685)	0.021146	i=27	(0.1626, 0.23125, 0.2999)	0.02474
i=11	(0.04295, 0.0859, 0.14285)	0.00919	i=28	(0.0026, 0.0052, 0.1025)	0.000556
i=12	(0.05051, 0.09418, 0.15185)	0.010076	i=29	(0.09727, 0.15866, 0.22005)	0.016974
i=13	(0.56398, 0.72852, 0.87128)	0.077939	i=30	(0.10455, 0.1701, 0.23565)	0.018198
i=14	(0.11392, 0.15747, 0.26026)	0.016847	i=31	(0.04839, 0.09366, 0.14309)	0.01002
i=15	(0.74758, 0.86092, 0.8982)	0.092103	i=32	(0.24141, 0.33908, 0.45755)	0.036276
i=16	(0.21516, 0.3145, 0.4124)	0.033646	i=33	(0.06087, 0.11186, 0.16285)	0.011967
i=17	(0.03718, 0.06812, 0.135)	0.007288	i=34	(0.24993, 0.33564, 0.42135)	0.035908

Table 3. Classification of the possible locations over considered time period and measures of belief that locations belong to class A
Tablica 3. Klasifikacija mogućih lokacija u razmatranom vremenskom periodu i mjere vjerovanja da lokacije pripadaju klasi A

	ef_i	The considerated time period / Razmatrani vremenski period		ef_i	The considerated time period / Razmatrani vremenski period	The measures of belief that locations belong to class A / Mjere vjerovanja da lokacije pripadaju klasi A
i=2	0,102382	A	i=3	0,814455	B	0.9649
i=15	0,194485	A	i=1	0,834373	B	0.9180
i=13	0,272424	A	i=30	0,852571	B	0.7492
i=8	0,3368	A	i=22	0,870063	B	0.7060
i=24	0,38436	A	i=9, i=29	0,904011	B	0.7691
i=26	0,424125	A	i=14, i=18	0,937705	B	0.3918
i=6	0,461752	A	i=20	0,950511	B	
i=32	0,498028	A	i=33	0,962478	C	
i=34	0,533936	A	i=12	0,972554	C	
i=7	0,569044	A	i=31	0,982574	C	
i=19	0,603542	A	i=11	0,991764	C	
i=16	0,637188	A	i=17	0,999052	C	
i=5	0,667716	A	i=21, i=28	1	C	
i=23	0,696082	A				
i=4	0,724008	A				
i=27	0,748748	A				
i=25	0,772646	A				
i=10	0,793792	A				

Applying the developed model based on Pareto analysis, the following result is obtained concerning the classification of possible locations where ELV dismantling centres should be built: out of 34 considered locations, 18 are of the first priority for the decision maker (Table 3, and Figure 1). Appropriate to determine measures of belief that these locations may belong also to class A in the time period in which they are initially classified into class B. The measure of belief that a location may belong to class A is calculated using the procedure in (Bass nad Kwakernaak, 1977, Dubois and Prade, 1979).

According to the statistical data, at the end of 2009 in Serbia, there were 180,000 different types of vehicles at the end of life cycle, of different age and recyclability level, which needed to be recycled. The same statistics shows that 120,000 vehicles become disused yearly. Approximately 74% of all ELV found in Serbia are concentrated around the chosen locations.

Based on the data specific to the initial ELV dismantling centres network, the decision maker defines the educational strategy, employs workforce in the dismantling centre and plans their permanent training. The dismantling centre activities should abide to certain standards, the most important being ISO 9000 standard - quality management, ISO 14000 standard - environment management, Occupational Health and Safety (OHSAS) standard - health and work safety management, and ISO 22628 standard - regulating the ELV recyclability.

Network design for the ELV dismantling centres is an input for the construction of: (1) ELV collecting networks; ELV collecting centres can share the same location with dismantling centres, or a collecting network can be designed in such a way that ELV can be taken from one collecting location to one or more desmantling centres, (2) networks for repairing spare parts, compositions and mechanisms (e.g. in FIAT, one engine out of ten is repaired and placed at the spare parts market) and (3) recycling centres networks, which is the base of the recycling industry development.

5. Conclusion

The experience of developed countries all over the world points out the neccessity of developing recycling industry and integrating it with other industries with the aim of maintaining the market competitiveness. This effect is reaching developing countries, and Serbia will be affected sooner or latter. Also, the demand for ELV waste management has a growing trend, which means that Serbia, having a car industry, should react promply and undertake all neccessary actions that would enable the development of ELV recyling processes. Unfortunately, however, there is not a defined network of ELV dismantling centres in Serbia, which would be an input datum for defining ELV waste management strategies which, among other, increase the national economy sustainability.

It can be concluded that determining the network design of ELV dimantling centres depends on many different criteria, such as: economic group criteia, social group criteria, environmental group crietria, etc., which are very often in conflict. The considered criteria have a different relative importance and values criteria can be crisp or uncertain. The proposed model based on modified Pareto analysis enables the choice of the best locations for ELV dismanling cenetres under different uncertainties and vagueness, with respect to all criteria, simultaneously, taking account of its relative importance.

It is shown that fuzzy sets are suitable for modelling of the uncertain input data in the considered ELV waste management problem that are subjectively estimated. The developed fuzzy models are flexible: (1) they include and operate with both precise and imprecise specific data, (2) all the changes, as the changes in the number of criteria or its relative importance, or number of possible locations and membership functions shape of fuzzy numbers can be easily incorporated into the model, and (3) fuzzy model could be modified for solving different waste management problems.

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