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SYSTEM SUPPORTING LOCATION OF SERVICE WORKS - CASE STUDY

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ABSTRACT

Purpose: The purpose of this work was to propose a new approach to assess the influence of decision variables on the running costs of networks providing services, taking recycling networks as an example. The authors have analyzed the importance of these variables and the trends in these changes.
Design / methodology / approach: A computer system supporting decisions about the location of ELVs recycling network facilities, which indicates globally optimum locations of all facilities, was applied. An analysis of output variables sensitivity: location and cost of recycling on decision variables changes, i.e. the ELVs stream, and cost components connected with recycling was performed. The results of the analysis were presented in the form of graphs showing the relation between the cost of recycling generated by the network in the period of one year and the changes in the cost of transport, storage and dismantling of ELVs as well as the transport of dismantled parts and materials.
Findings: The approached proposed by the authors allows to reject insignificant decision variables (it simplifies decision-making) and identifies the values which have the greatest impact (shortens decision-making for alternative data variants).
Practical implications: The proposed approach allows to specify the values of decision variables, and provides information required for the evaluation of profitability of the recycling network.
Originality / value**:** The proposed approach allows to assess the relationship between the cost of recycling and decision variables at a general level - the territory being analyzed in the period of one year, and at a detailed level - the cost of recycling one vehicle.

Keywords: system supporting location, case study, vehicle recycling, sensitivity analysis

INTRODUCTION

The location problem has been known for a long time, and it is discussed while planning networks of a certain kind of facilities (objects). When designing a network, we wish to select the locations of the objects that belong to the network so as to optimize the function that characterizes the location of all the objects that make up the network. Due to the huge variety of networks, the solution to the problem is sought in each case individually. The development of IT techniques created new possibilities concerning the optimization of the location of objects in the spatial structure of the system being designed or managed. There are various models and methods of optimization, including linear programming and sophisticated heuristics, depending on the complexity of the problem.

Recently, there have been published a lot of work concerning the location problem, e.g. location of product distribution centres with respect to selected parameters of the process, most frequently minimization of the distance. There were developed models taking into account a different number of products (multi-product) (Nozick and Turnquist, 2001) and different methods of distribution (Nonås and Jörnsten, 2007) and (Weiwei Gong *et al*. 2007). (Daskin *et al*., 2002) and (Zuo-Jun *et al*., 2007) formulated this problem in the form of a nonlinear integer programming model and used Lagrangian relaxations. Various tools were used to solve the model depending on the degree of the model complexity (Shu *et al*., 2005) - Column Generation Method. (Ek Peng Chew *et al.*, 2002) used genetic algorithms to solve the problem of location and took into consideration the cost of the distribution process and the quantity of stocks. Given random changes of distribution process parameters, the quantity of stocks may be assessed using computer simulation, (Miranda and Garrido, 2006) and Monte Carlo methods, (Kwilosz, 2011).

The above research do not analyze the influence of individual decision variables in the model on the assessment indexes of the networks designed. Such analysis might simplify the structure of the network model as well as shorten the time required to assess solutions. A similar idea regarding improvement of simulation research was proposed in transport problem by KwangSup Shin *at al.*, 2012. The paper proposes a simulation method using genetic algorithms for the optimal location of objects of the network, with a limited site selection. Here, the location is understood as a spatial organization of objects of the network in the topographical sites to choose from, within the specified industrial/administrative area (country/macroregion). In order to assess the importance of selected decision variables, sensitivity analysis was applied to study their influence on the cost of recycling.

FORMULATION OF THE OPTIMIZATION TASK

Appropriate location of the objects of recycling network in Poland, conforming to general criteria of providing services (including both local and European Union regulations), should facilitate the development of this kind of business activity. The optimization problem regarding the studied case is complex and includes:

- linear and non-linear problems,
- problems not defined formally,
- huge spaces of possible solutions,

- operating on sets of possible solutions and not on values of individual decision variables,
- no model solutions,
- seeking a global optimum for systemic selection of the location of objects in a network, instead of the optimum location of a single object in a network.

With regard to the above, seeking an optimum solution by means of non-classical methods seemed justified. Recycling is an environment friendly and cost-effective way of end-of-life vehicle (ELVs) utilization. The authors assumed 3-level organization of a recycling network. The network consists of the following objects: vehicle collection points, dismantling stations and processing facilities. The cost of recycling depends on the cost of transport of vehicles, parts and materials between the facilities (objects) of the system. Therefore, the location of each object should be correlated with the locations of other objects of the network.

The general form of the objective function and the optimization criterion for the presented case has the following form:

$$K_{rec} = f\left(K_s, K_m, K_d, K_c\right) \rightarrow \min \qquad (1)$$

and individual costs depend on the following variables:

$$K_s(k_s, Q_j, a(\mathrm{i},\mathrm{j})),\; K_m(k_s, \sum_{j=1}^{N} Q_j),\; K_d(k_d, \sum_{j=1}^{N} Q_j),\; K_c(k_c, S_k, a(j,l))$$

$N \geq J \geq 1,\ L \geq 1$

where:

i=1,…,N - number of vehicle collection points,

j=1, …, J - number of vehicle dismantling stations,

l=1, …, L - number of processing facilities,

K_s, k_s – the total cost and the unit cost of transport ELVs, PLN/year, PLN/t km,

K_c, k_c - the total cost and the unit cost of transport of parts and materials, PLN/year, /t km

K_d, k_d - the total cost and the unit cost of dismantling, PLN/year, PLN/psc.

K_m, k_m – the total cost and the unit cost of storage, PLN/year, PLN/psc.

Q_i - stream of vehicles transported from vehicle collection point VCP_i to dismantling station

DS_j, psc./day

S_k – stream of materials and parts transported to processing facility PF_k, t/day

a(i,j), **a**(j,l), – matrices of transport distances, km.

Consequently, the optimization task involves the determination of the cost of recycling depending on the stream of vehicles Q_j, and such locations $\mathbf{a}(i,j)_{min}$ and $\mathbf{a}(j,l)_{min}$ of facilities in the region that the total cost of transport which also depends on Q_j is minimized. A computer system supporting selection of the location was developed for this purpose, (Gołębiewski, 2011). The principle of operation of the system supporting the selection of the location of vehicle dismantling stations is presented in Fig. 1.

"Take in Figure (No.1)"

The system has the following output variables: daily stream of vehicles, number and location of vehicle collection points (determined by the criteria adopted for the selected region), number and location of processing facilities and cost components connected with recycling. The location and number of dismantling stations are determined using genetic algorithms, to minimize the cost of recycling.

RESULTS OF SIMULATIONS AND DISCUSSION

The following parameters of the optimization task were identified in the analyzed case study: $J \leq 37$, $k_m(Q_j>30)=2.50$ [PLN/psc.] ; $k_d=205+334\exp(-0.124Q_j)$, PLN/psc.; $k_s=1.62$ [PLN/tkm]; $k_c= 2.21$ [PLN/tkm]; distances $\mathbf{a}(i,j)$ and $\mathbf{a}(j,l)$ were determined based on the current maps of the region.

The results of simulated locationns of dismantling stations for selected input variables were presented graphically: on the maps of the province and in the form of graphs. The diagram in fig.2. presents the system of simulation experiments; the symbol w_p denotes a coefficient change of the unit the cost components.

"Take in Figure (No.2)"

Comparative analysis was based on the cost of recycling calculated for the maximum stream of vehicles directed to all recycling stations in the Mazovia province and other parameters identified for this area, $K_{rec}=f(Qmax, PF_{pd}, k_S, k_d, k_m, k_c)$.

The obtained values of K_{rec} for the identified data that constitute the basic set of data in the conducted research, were presented in fig. 3. The result K_{rec} considered the best, due to the value of the adaptation function, was obtained after 71 iterations - generations. Stations are located in seventeen ($J = 17$) district towns.

"Take in Figure (No.3)"

The sensitivity (Tarnowski and Kiczkowiak, 2006) of the developed system was analyzed by studying the influence of percentage changes (w_p) of the objective function components, i.e. cost connected with the following: transport of vehicles K_S, transport of parts and materials K_C, dismantling K_d and storage K_m on percentage changes of the total cost of recycling.
The analysis of sensitivity presented in fig. 4, 5, 6 significantly depends on the cost connected with transporting parts and materials and the cost of dismantling, whereas the cost connected with transport and storage of vehicles are less significant.

"Take in Figure (No.4)"

"Take in Figure (No.5)"

"Take in Figure (No.6)"

Changes in the cost connected with transport of parts and materials have the greatest influence on the cost of recycling, which is a consequence of long distances between stations and processing facilities.

The influence of changing the location of processing facilities on the location of dismantling stations - DS was also studied. The basic variant, presented in Fig.7.A. and in Fig.7.B., assumes that materials and parts are transported to processing facilities located south of the area being analyzed.

"Take in Figure (No.7)"

Fig.7. shows the consequences of locating these facilities north of the Mazovia province. DS located in the same places on maps A and B in Fig.7. are marked by the symbol ●.

CONCLUSIONS

The results of the sensitivity analysis, shown in figs. 4,5 and 6, provided both the information that is easy and difficult to anticipate a priori. The cost of transport of parts and materials have the greatest impact on the cost of recycling, which can be attributed to considerably long distances between dismantling stations and processing facilities. The cost of dismantling ELVs also has a considerable influence on the total cost of recycling, while the costs of storage and vehicle transportation are negligible due to small number of stored vehicles and short distances between collection points and dismantling facilities. Given the specified constraints of the case being analyzed, the global cost of connected with the recycling network operation considerably depend on the number of dismantled vehicles. A percentage change in the cost of recycling depending on the cost components depends to a little extent on the demand for the services being analyzed, provided that the objects of the recycling network have the optimum locations in the given area. Similarly, if the objects of the recycling network have optimum locations, the average cost of recycling one vehicle do not depend on the demand for this type of services, which, in case of conducting this type of activity, has a considerable importance in assessing its profitability.

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