SCIENTIFIC PAPERS
OF THE UNIVERSITY OF PARDUBICE
Series B
The Jan Perner Transport Faculty
5 (1999)

ANALYTICAL MODEL FOR RECYCLING CENTRES LOCATION

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Introduction

The ecological aspect in the field of used/damaged cars recycling is becoming increasingly important due to the rising number of old cars and useless cars, e.g. in Germany 2,6 million cars per year, in Poland 0,5 million and in the Czech Republic 0,2 million cars per year. The recycling of cars attracts, therefore, special attention and becomes one of the basic problems for the European environment, requiring a joint approach by Central/East and West European Countries.

The basic approach up to a few years ago has been to disassemble old/crash cars for in part re-utilisation in scrap yards in an unstructured, from an ecological point of view not optimal fashion and then to shred these cars. It can be seen that in the near future the laws for environmental protection in the European Community will be tightened up drastically, which will lead to considerably higher costs for the use of special garbage areas. This also increases the costs for a proper approach to dispose of cars, which may result in an increasing number of “wild” scrap yards, leading to an ecological disaster. Therefore, from the ecological point of view, dismantling of different materials from cars is necessary up to a very deep level, but from the economic point of view this has to be achieved at low costs.

It is quite obvious that these problems are common for both Central/East and West Countries. Therefore, in the scope of COPERNIKUS 1994, the R&D project Q-REC

(Technologies for High Quality Recycling of Cars) was initiated, the main objective which was to establish a new concept for the development of facilities for recycling old and damaged cars both West and Central and East European Countries. The Q-REC project is to be seen as the first step towards developing a new industrial concept for “deep” car - recycling having high quality but low cost.

Although the project has been focused on applications in the Czech Republic and Poland, the objective was to develop a general concept, which will be applicable to all CCE countries, as well as for EU countries.

In order to take into account all the relevant aspects required to establish innovative and economical solutions for car recycling the consortium consisting scientific and industrial partners from both CCE and EU countries was proposed covering all necessary technological and scientific expertise.

The proposed project was divided into several subtasks that are covered by appropriate research activities of assigned partner team related to these tasks in accordance with his experience and expertise.

One of the most important subtasks of the project is doubtless logistics and economic modelling of the recycling process. Economical effects of the car recycling process demand that the interdependencies between the market demands and the existing or future logistics structures, on one hand and the increasing quality of the recycled components and materials on the other hand have to be taken into account. In order to effective support operating of the whole network, the logistic modelling approach is used. Logistic flow modelling will include modelling of the cash flow, information and material flows (consisting of the wrecks, spare parts and second raw materials) from transport point of view. The objective is to define optimal logistics solutions in the scope of the logistics network. The goal of the logistic flow modelling is at the first time the solution of allocation and location task.

Presented model is devoted for decision making in Q-REC Logistics System. First the most important decision is setting up the number of recycling centres (RC) and their placement in geographical area. In actual state we do not include in to solution investment set up costs of recycling centres that play important role in task solution. So we presume that we know possible placement of RC as an output from Geographic Information System (GIS) and the number of RC to be located in the geographic area.

Input data

The model deals with following data inputs:

- sources of the used and crashed cars,
- road network,
- technological (economical) data,
- inputs for location model.

The network model is presented by the non-oriented graph $G = (V, X)$, where V is the set of nodes and X is the set of arcs. The nodes represent sources of used and crashed cars, wrecks storage places and potential recycling centres. The arcs represent treks of road communications.

Each node is characterised by:

- co-ordinates originated from GIS,
- name,
- identification number,
- evaluation of number of wrecks per time unit,
- recycling centre placement accuracy.

Each arc is evaluated by average cost that can be expressed by distance, time or financial units.

Model operates with following technological data:

- average weight of the wreck,
- list of secondary raw materials,
- percentage composition of raw materials of an average wreck.

Location model uses following inputs:

- list of candidates for potential recycling centres
- required number of recycling centres.

Location Model

The first phase of the algorithm is calculation of the distance matrix on the base of network. Algorithm of Floyd for symmetrical matrix was used.

In the second phase algorithm determines optimal (sub-optimal) location of prescribed number of recycling centres. This task is complex problem of discrete optimisation with large number of possible solutions. For reaching the solution in real time an iteration algorithm was used. This algorithm does not assure global optimal solution, but it enables to obtain satisfactory quality sub-optimal solution in short time.

Solution received in previous phase enables to determine attraction zones for nodes where recycling centre will be placed. Let us denote D a set of recycling centres, v_i, $v_j \in D$ two different recycling centres belonging to the set D and $A(v_i)$, $A(v_j)$ appropriate zones of attraction. In general zones of attraction are the sets of arcs and nodes. Because in our location problem are served only nodes of graph the zones of attraction will include only nodes. The zones of attraction are disjunctive no empty sets of nodes, every node belonging to one (the nearest) recycling centre zone of attraction. So we can write:

$$A(v_i) \neq \{\} \quad \text{for every } v_i \in D,$$

$$A(v_i) \cap A(v_j) = \{\} \quad \text{for every couple of } v_i, v_j \in D.$$

$\bigcup_{v_i \in D} A(v_i) = V$ that means that every node of the graph must be assigned to attraction zone.

Wrecks from each node assigned to the same recycling attraction zone are carried, dismantled and manufactured in this recycling centre according to the below mentioned wreck percentage composition of raw materials. Separated materials represent logistics flows that should be transferred to the appropriate industrial plants. The problem of optimal secondary raw materials and recycled spare parts delivery to destination plants will be solved in next period. There are several exact and heuristic methods to be used.

Implementation of Model

The model was programmed in Microsoft Excel Visual Basic 97. The correct function of the location algorithm was verified on the chosen network of the Czech Republic with 250 potential sites for recycling centre placement (see Figure 1). Evaluation of nodes was obtained by random function. We assumed average weight of the wreck 900kg. Following table includes assumed percentage compositions of raw materials of an average wreck:

Name	Percentage composition	Weight [kg]
steal	0,45	405
iron	0,12	108
light metal	0,08	72
sheet iron	0,12	108
non-ferrous	0,02	18
plastic	0,08	72
rubber	0,05	45
glass	0,04	36
liquid	0,02	18
textile	0,02	18
Sum	**1,00**	**900**

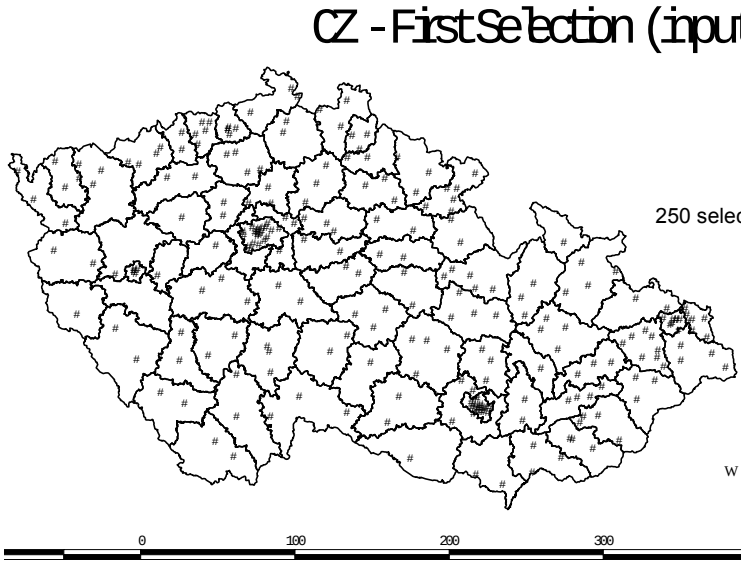

Fig. 1 *Potencial candidates for recycling centres location*

Calculation was realised for different numbers of RC from 250 nodes on computer Pentium 133 MHz. Next table shows average computing time according to the number of located RC. Figure 2 shows location of 10 recycling centres.

Number of RC	Computing time [s]
5	120
10	180
20	300
40	1 800

In the current time the maximum possible range of nodes must not exceed limit number of columns in Excel table that is 255. Program operates with squared matrices (for example distance matrix) that should be saved in form of the Excel tables. In the case of using other programming language (Pascal, C/C++ etc.) this limitation does not exist.

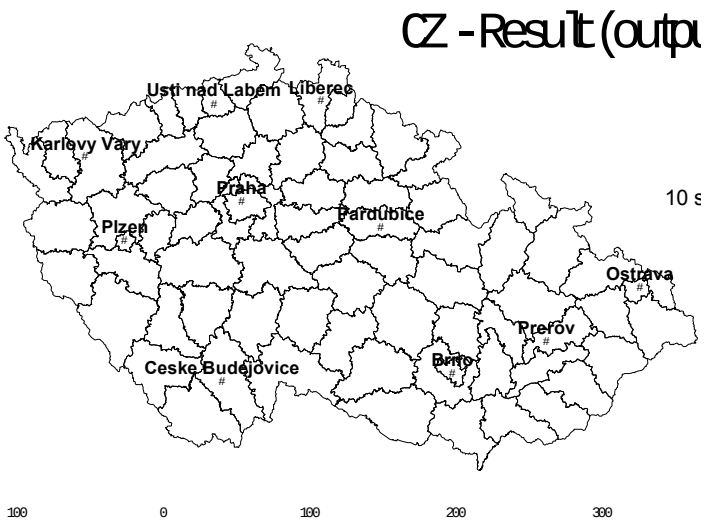

Fig 2 *Location of 10 recycling centres*

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Předloženo v březnu 2000.

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Summary

ANALYTICAL MODEL FOR RECYCLING CENTRES LOCATION

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Worn out unusable automobiles, trucks, and miscellaneous other powered vehicles become the serious problem of the Czech economy and environment. There is an effort to organise and the build recycling system for these vehicles. The article represents first results of designed analytical model that provides location of determined number of recycling centres in Czech Republic. The network of recycling system was designed by GIS means.

Zusammenfassung

ANALYTISCHES MODELL DER LOKATION DER RECYCLING-ZENTREN

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Die abgetragene und ungenützte PKW, LKW und verschiedene andere Fahrzeuge werden ein seriöses Problem für Wirtschaft und für die Umwelt der Tschechischen Republik sein. Darum gibt es die Bestrebung, ein System dem Recycling diesen Fahrzeugen zu organisieren und zu ausbauen. Der Artikel stellt die erste Ergebnisse des vorgeschlagenen analytischen Modells dar, das die Lokation der vergebenen Anzahl der Recycling-Zentren auf dem Gebiet der Tschechischen Republik gewährt. Das Netz des Recycling-Systems wurde mit der Ausnutzung der GIS-Mitteln vorgeschlagen.

Resumé

ANALYTICKÝ MODEL LOKACE RECYKLAČNÍCH STŘEDISEK

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Opotřebované a nepoužitelné osobní automobily, nákladní automobily a různá jiná vozidla se stávají vážným problémem pro hospodářství a životní prostředí České republiky. Je snaha zorganizovat a vybudovat systém recyklace těchto vozidel. Článek představuje první výsledky navrženého analytického modelu poskytujícího lokaci zadaného počtu recyklačních středisek na území České republiky. Síť systému recyklace byla navržena prostředky GIS.