Basic Conceptions of Modelling of Collection Centers

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Environmental goals

Environmental goals on the national level:

to create the political-legislatively, social-culture, economic and technological environment that is subordinate to the claims of waste collection, packaging, as well as recycling

Modelling

- **On the national level - modelling of collection of recyclable products**
- **Main levels in optimization of recycle processes:**
  - **collection of discarded vehicles (*ELV – End-of-Life Vehicles*)**
  - **collection of waste of electrical and electronic equipment (*Waste Electrical and Electronic Equipment*)**
  - **paper collection (most frequently recyclable product)**

Optimization methods

- **Mostly used optimization methods:**
  - linear programming (*Linear Programming – LP*)
  - mixed integer programming (*Mixed Integer Programming – MILP*)
  - special heuristic algorithms
  - another approaches

Modelling of collection centers in Slovak Republic

- Goal:

accessibility of collection (sorting) centers for whole population in Slovak Republic for the purpose to motivate the population to collect the used products, components, packaging and redundant stocks for their dismantling and reuse.

Modelling of collection centers in Slovakia

Basic conceptions

- Two basic conceptions:
  - covering the whole population with the minimal count of service channels (*Location Set Covering Problem – LSCP*)
  - maximal covering by limited number of service channels (*Maximal Covering Location Problem – MCLP*)

Modelling of collection centers in Slovakia Population

- Slovak republic (2001)
  - 5 378 511 inhabitants
  - 2 916 communes
  - 138 cities
  - 3 021 964 inhabitants (about 56%) was living in the cities

Modelling of collection centers in Slovakia
Goal of the model

To minimize the number of residents that need to travel to collection centers.

It is evident that efficiency of collection centre depends on character of collected products (it is different in case of cars, fridges, freezers or in case of car batteries) so we considered with different variants of distances *K* that were set to 50, 40, 30, 20, 15 and 10 km.

Modelling of collection centers in Slovakia
Input data

- *n* – number of cities in Slovak Republic (138),
- **D** (*n* x *n*) – matrix of minimal distances between all cities
- *K* – maximal distance from closest collection centre,
- *Model A* – potential location of collection centers in all cities, coefficients in objective function are equal to 1 ($c_j = 1$, $j = 1, 2, ..., n$),
- *Model B* – potential location of collection centers in all cities simultaneously with requirement that the collection centre must to be located in every region city, the set of region cities – N_k, coefficients in objective function are equal to 1 ($c_j = 1$, $j = 1, 2, ..., n$), decision variables for region cities $x_j = 1, j \in N_k$,
- *Model C* – potential location of collection centers in all cities simultaneously considered the number of population so that number of population in 138 cities was $P = 3\,021\,964$ and P_j was number of population of *j*-th city, coefficients of objective function was calculated as $c_j = 1 - \frac{P_j}{P}, j = 1, 2, \ldots, n$

  so c_j represents potential number of population that travel to collection centre.

Modelling of collection centers in Slovakia
Model

$$f(x) = \sum_{j=1}^{n} x_j \to \min$$

coefficients in objective function assume the values according to considered models (the value 1 or computed weights in general)

$$\sum_{j=1}^{n} a_{ij} x_i \geq 1 \, , i = 1, 2, ..., n$$

constraints need to ensure that the distance between every city and the closest collection centre is maximal *K*

$$x_j \in \{0,1\}$$

$$a_{ij} = \begin{cases} 0, & d_{ij} > K \\ 1, & d_{ij} \leq K \end{cases} \quad i, j = 1, 2, ..., n$$

Elemets of matrix **A**, which are set to 0, if the distance between *i*-th and *j*-th cities is greater than *K*, or 1 otherwise (parameters represent distances between cities *i* a *j*)

Modelling of collection centers in Slovakia
Output data

We considered following values of *K* = 50, 40, 30, 20, 15 and 10 km for models A, B and C.

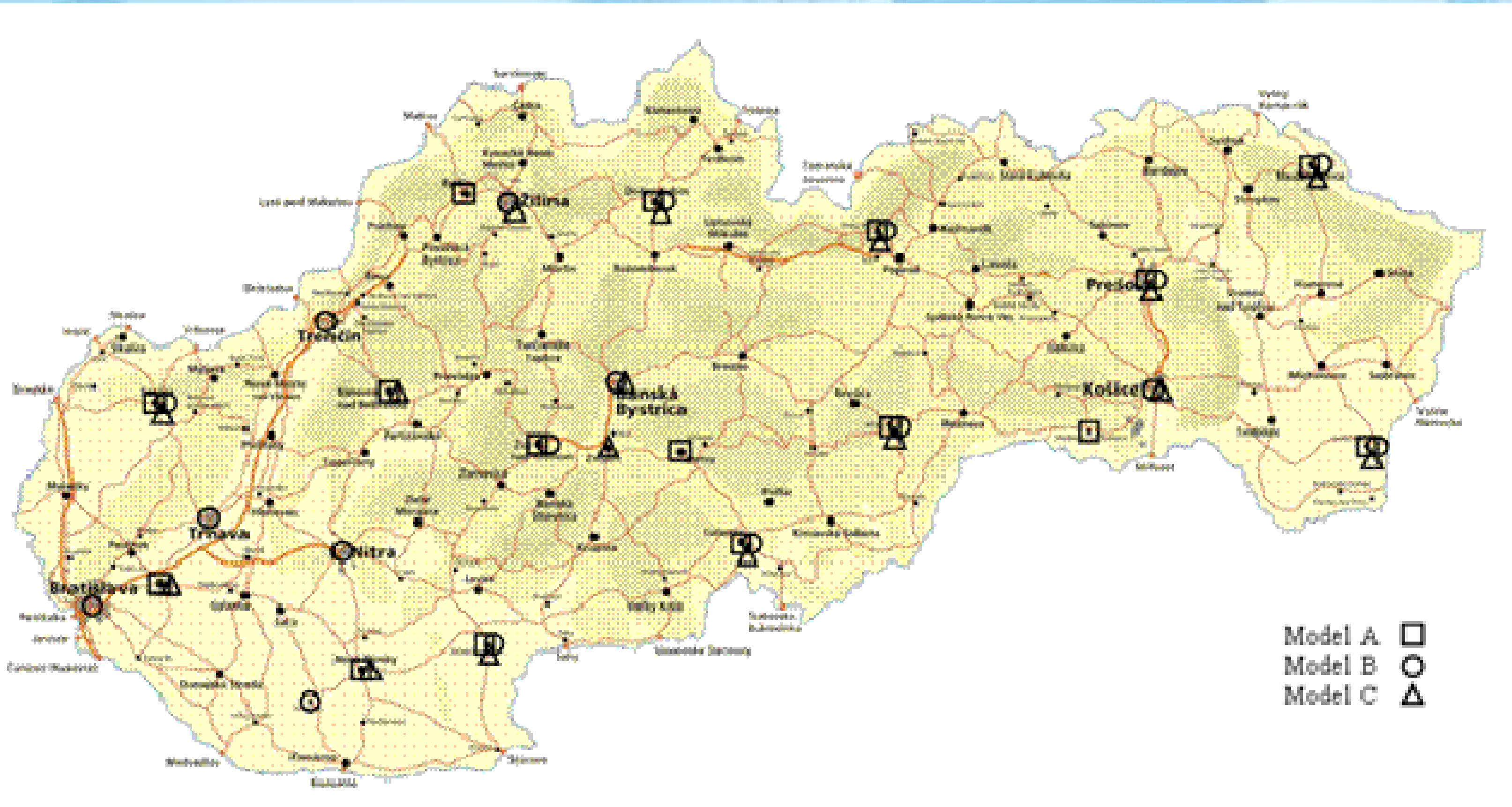
Number of collection centers	*K* = 50	*K* = 40	*K* = 30	*K* = 20	*K* = 15	*K* = 10
Model A	16	22	36	60	86	109
Model B	18	25	38	63	88	110
Model C	16	22	36	60	86	109
Intersection A, B, C	9	4	25	45	70	101
Intersection A, B	10	7	32	55	83	107
Intersection B, C	12	10	26	47	73	102
Intersection A, C	12	11	27	48	70	102

Modelling of collection centers in Slovakia
Output data

- For distance *K* = 50 the collection centers are:
- *Model A*: Bánovce nad Bebravou, Bytča, Detva, Dolný Kubín, Jelšava, Lučenec, Medzilaborce, Moldava nad Bodvou, Nové Zámky, Prešov, Senec, Senica, Veľké Kapušany, Vysoké Tatry, Želiezovce, Žiar nad Hronom
- *Model B:* Banská Bystrica, Bratislava, Dolný Kubín, Jelšava, Kolárovo, Košice, Lučenec, Medzilaborce, Nitra, Prešov, Senica, Trenčín, Trnava, Veľké Kapušany, Vysoké Tatry, Želiezovce, Žiar nad Hronom, Žilina
- *Model C:* Bánovce nad Bebravou, Banská Bystrica, Dolný Kubín, Jelšava, Košice, Lučenec, Medzilaborce, Nové Zámky, Prešov, Senec, Senica, Veľké Kapušany, Vysoké Tatry, Zvolen, Želiezovce, Žilina

Modelling of collection centers in Slovakia
Output data

- For distance K = 50 the collection centers are:



Modelling of collection centers in Slovakia
Output data

- Conclusion:
  - important factors:
    - maximal distance *K*
    - weights to corresponding city
    - the intersection between calculated sets of collection centers refers to importance of setting the weights of coefficients of objective function (by the higher value of parameter *K* the sets are significantly changed)
  - presented approach can be used as a base for efficient decision making about location of collection centers considered the special criteria as well as the given parameters of accessibility and the importance for population