Strategy of Location Incinerators in Slovak Republic

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Waste Management in Slovak Republic

The strategy of waste management in Slovak Republic is obliged to follow current legislation that comprises since 1993 Waste Management Program.

Waste Management Program for the years 2006 – 2010 is a basic strategic document that directs the environmental policy till the year 2010.

Because since 1.5.2004 Slovak Republic is a member of European Union, the legislation respects the legislation of European Union.

Incinerators in Slovak Republic

The basic technique of disposing of municipal waste – combustion.

The number of incinerators in Slovak Republic: 40.

Incinerators for the domestic waste in Slovak Republic – only 2 (relatively badly structured – in Bratislava and Košice).

Strategy of building the incinerators

Two basic conception were developed for solving so that problems:

- first conception is aimed for covering the whole population with minimal number of service channels – *Location Set Covering Problem – LSCP,*
- the aim of second conception is to maximize the covering of population with limited number of service channels – *Maximal Covering Location Problem – MCLP.*

Modelling of incinerators 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 incinerators in Slovakia

Goals of models

- shortest path when number of incinerators is given
- minimal distance needed to travel when number of incinerators is given
- maximal covering of population when a certain number of incinerators and also certain maximal distance are given

Modelling of incinerators in Slovakia
Input data

- n – number of cities in Slovak Republic (138),
- ***D*** *(n x n)* – minimal distance matrix (elements represent the minimal distance from city *i* to city *j*)
- K – maximal allowable distance from the closest incinerator
- p – number of incinerators
- b_j – number of inhabitants of *j*-th city
- **A** (n x n) – binary elements a_{ij} (i, j = 1, 2,...n) that represent the accessibility of incinerators from the city – producer of waste (the value 1 – *j*-th incinerator is accessible from *i*-th city in distance K, the value 0 – incinerator is not accessible in distance K)

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Variables

- y_{ij} – binary variable that represents the use of the route from *i*-th city to *j*-th incinerator (the value 1 – inhabitants of *i*-the city impart the waste to *j*-th collection centre, the value 0 – that route is not used) for *i, j* = 1, 2,...*n*,
- *z* –represents maximal distance all the incinerators from all the cities – producer of waste
- x_i – binary variable that represents if the incinerator is open (value 1) or not (value 0) in *i*-th city for *i* = 1, 2,...*n*,
- y_i – binary variable that represents accessibility of *i*-th city from some of the incinerators in distance *K* (value 1 – the city is accessible from some of the incinerators in distance *K*, value 0 - the city is not accessible) for *i* = 1, 2,...*n*.

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Model 1

- *goal – finding the minimal distance between incinerator and all the cities*

$$f(x, y, z) = z \rightarrow \min$$

$$\sum_{i=1}^{n} y_{ij} = 1, \quad j = 1, 2, \ldots n$$

$$y_{ij} - x_i \leq 0, \quad i, j = 1, 2, \ldots n$$

$$\sum_{i=1}^{n} x_i = p$$

$$\sum_{i=1}^{n} d_{ij} y_{ij} - z \leq 0, \quad j = 1, 2, \ldots n$$

$$x_i, y_{ij} \in \{0,1\}, \; i, j = 1, 2, \ldots n$$

$$z \geq 0$$

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Model 2

- *goal – finding minimal total distance needed to travel when maximal number of incinerators is given*

$$f(x,y)=\sum_{i=1}^{n}\sum_{j=1}^{n} b_j d_{ij} y_{ij} \rightarrow \min$$

$$\sum_{i=1}^{n} y_{ij} = 1, \quad j = 1, 2, \ldots n$$

$$y_{ij} - x_i \leq 0, \quad i, j = 1, 2, \ldots n$$

$$\sum_{i=1}^{n} x_i = p$$

$$x_i, y_{ij} \in \{0,1\}, \quad i, j = 1, 2, \ldots n$$

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Model 3

- *goal – to maximize the covering of inhabitants*

$$f(x,y)=\sum_{i=1}^{n} b_i y_i \rightarrow \max$$

$$\sum_{j=1}^{n} a_{ij} x_j - y_i \geq 0 \ , i = 1, 2, \ldots n$$

$$\sum_{j=1}^{n} x_j = p$$

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

$$a_{ij} = \begin{cases} 0, & d_{ij} > K \\ 1, & d_{ij} \leq K \end{cases}$$

Modelling of incinerators in Slovakia
Solving of models

- *models were solved by GAMS*
- model 1: with given parameter $p = 10$
- model 2: with given parameter $p = 10$
- model 3: with given parameters $p = 10$ *and* $K = 50$

Modelling of incinerators in Slovakia
Results

- model 1: parameter *p* = 10

- Dolný Kubín, Hanušovce nad Topľou, Ilava, Malacky, Michalovce, Nové Zámky, Rožňava, Spišská Nová Ves, Veľký Krtíš, Zvolen with maximal distance 65,5 km (Dolný Kubín – Čadca)
- total distance 71 899 602,8 km

Modelling of incinerators in Slovakia
Results

- model 2: parameter *p* = 10
- Bánovce nad Bebravou (Stará Turá, 56 km), Bratislava (Dunajská Streda, 48,5 km), Košice (Tornaľa, 98,5 km), Michalovce (Medzilaborce, 70 km), Poprad (Hnúšťa, 72,5 km), Prešov (Svidník, 57,5 km), Šurany (Štúrovo, 61,5), Trnava (Gbely, 68,5 km), Zvolen (Rimavská Sobota, 87 km), Žilina (Trstená, 99,2 km)
- after each collection center is given also the distant city from that the waste is transported as well as corresponding cost (named into brackets).
- total distance 71 899 602,8 km

Modelling of incinerators in Slovakia
Results

- model 3: parameters *p* = 10 *and K* = 50

- Bytča, Hnúšťa, Hurbanovo, Krupina, Partizánske, Ružomberok, Senec, Senica, Spišská Nová Ves, Vranov nad Topľou
- in this case 6 % of inhabitants are not covered to 50 km distance (the maximal distance is between Čierna nad Tisou and Vranov nad Topľov – 86,5 km)

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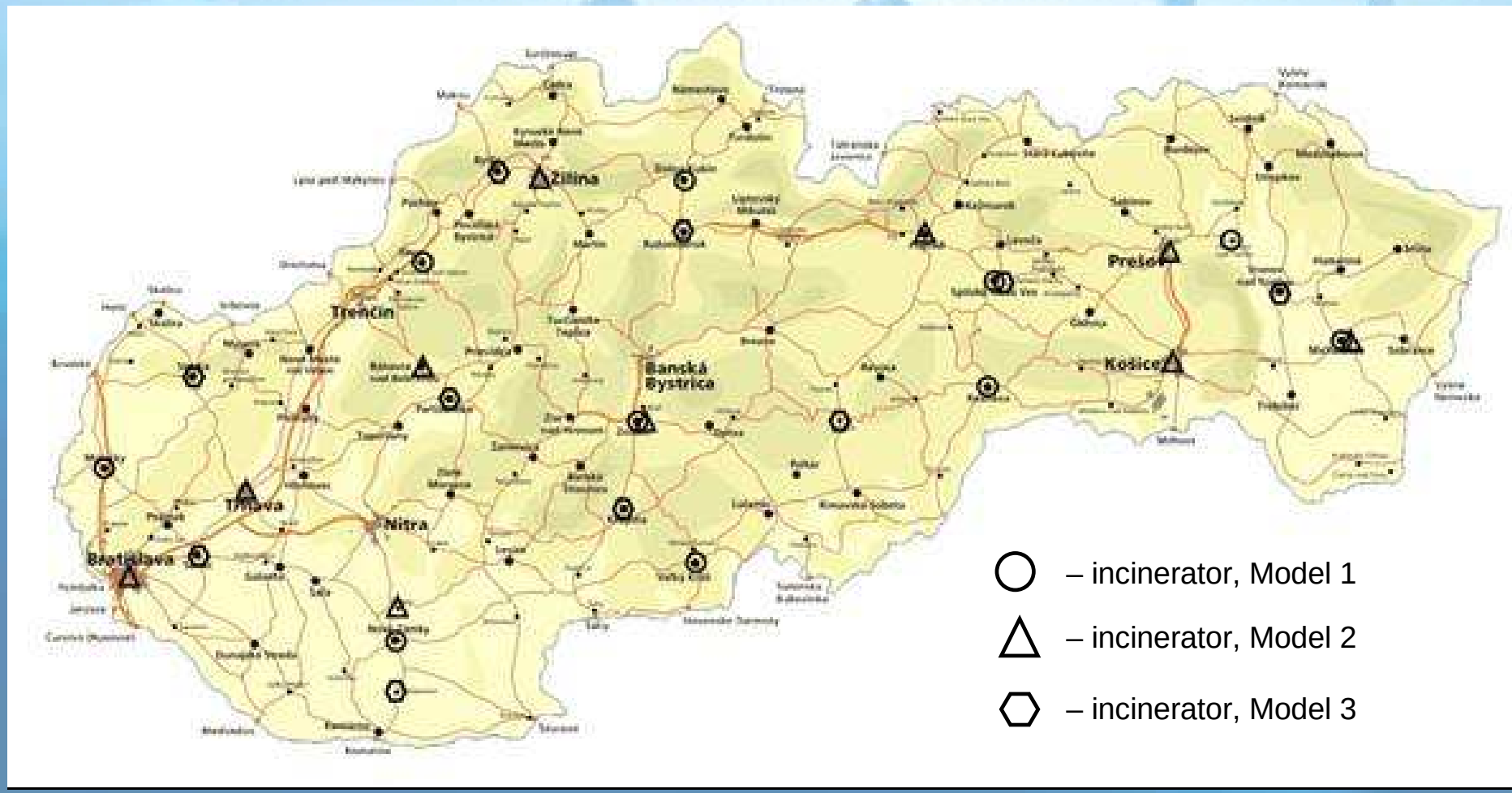
Results - Figure



Modelling of incinerators in Slovakia
Conclusion

- it is possible to formulate the strategy of incinerators placing that is based on fulfillment of a given conditions
- conditions can be modified for different levels of *p* (maximal number of incinerators) and *K* (maximal distance of the city from the closest incinerator)
- presented procedure can be a base for strategy decisions about location of incinerators in potential localities
- presented models can be used in general for different sets and problem size