Modeling Aspects of Reverse Logistics

Ivan Brezina – Zuzana Čičková – Juraj Pekár

Department of Operations Research and Econometrics
Faculty of Business Informatics
University of Economics - Bratislava

Reverse Logistics

(Entsorgungslogistik)

- Collection, sorting, dismantling and treatment of the used products, components, secondary products, excess inventory and packaging with aim to achieve their reuse or material revaluating in such way that is environmentally friendly and also economic attractive. (Škapa, R.)

- Decision making about a range in which the goods are reused depends on proportion of recovery costs to disposal costs. Recycling costs include besides remanufacturing costs also logistic costs (collection, sorting, storage and transport), against them there are disposal cost as waste dump, composting or landfill. (Stehlík, A.)

Reverse Logistics

- The process of planning, implementing and controlling backwards flows of raw materials, in process inventory, packaging and finishing goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal.

  (European Working Group on RL REVLOG)

- Seminars Reverse Logistics Association (based 07/2002)

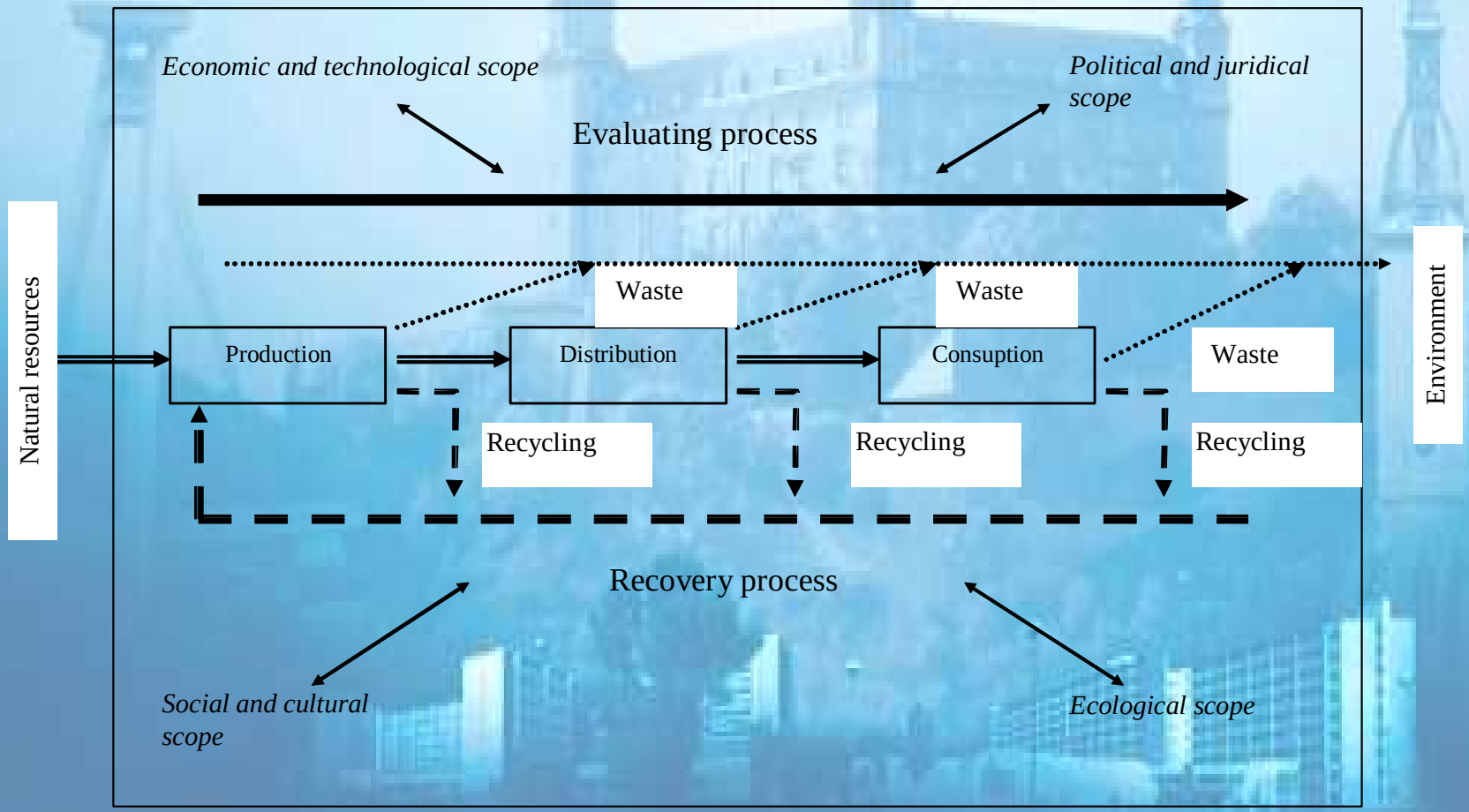
  (http://www.reverselogisticstrends.com)

  Mar 05, 2008 - Los Angeles

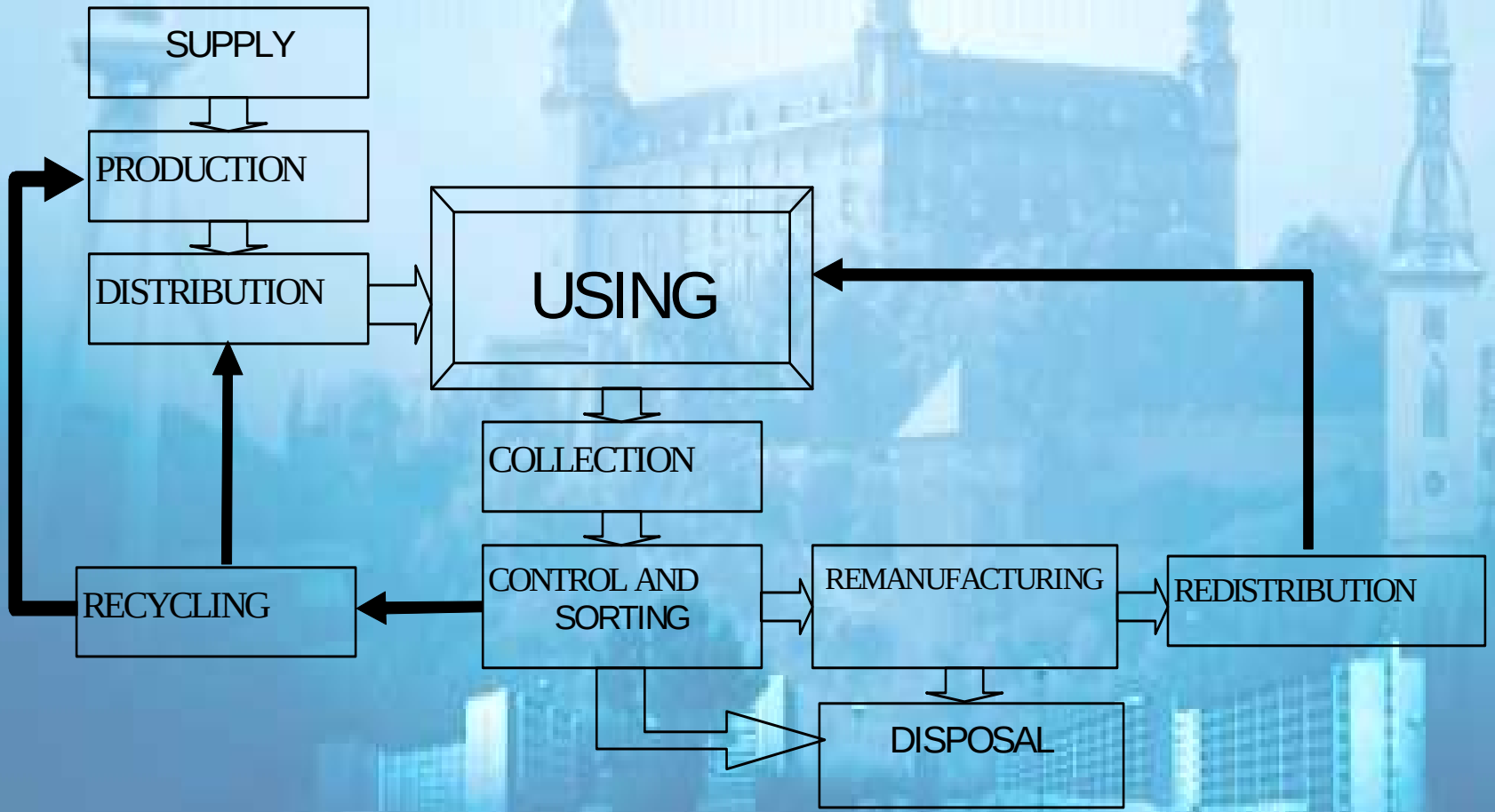
  Apr 16, 2008 - Hong Kong

  May 07, 2008 - Chicago

Material flows of reverse logistics



Processes of reverse logistics



Modeling of reverse logistic processes

- general models,
- prognostic models,
- production and control models,
- storage models.

In general, those models can be connected with localization models of factories, storages, landfills etc.

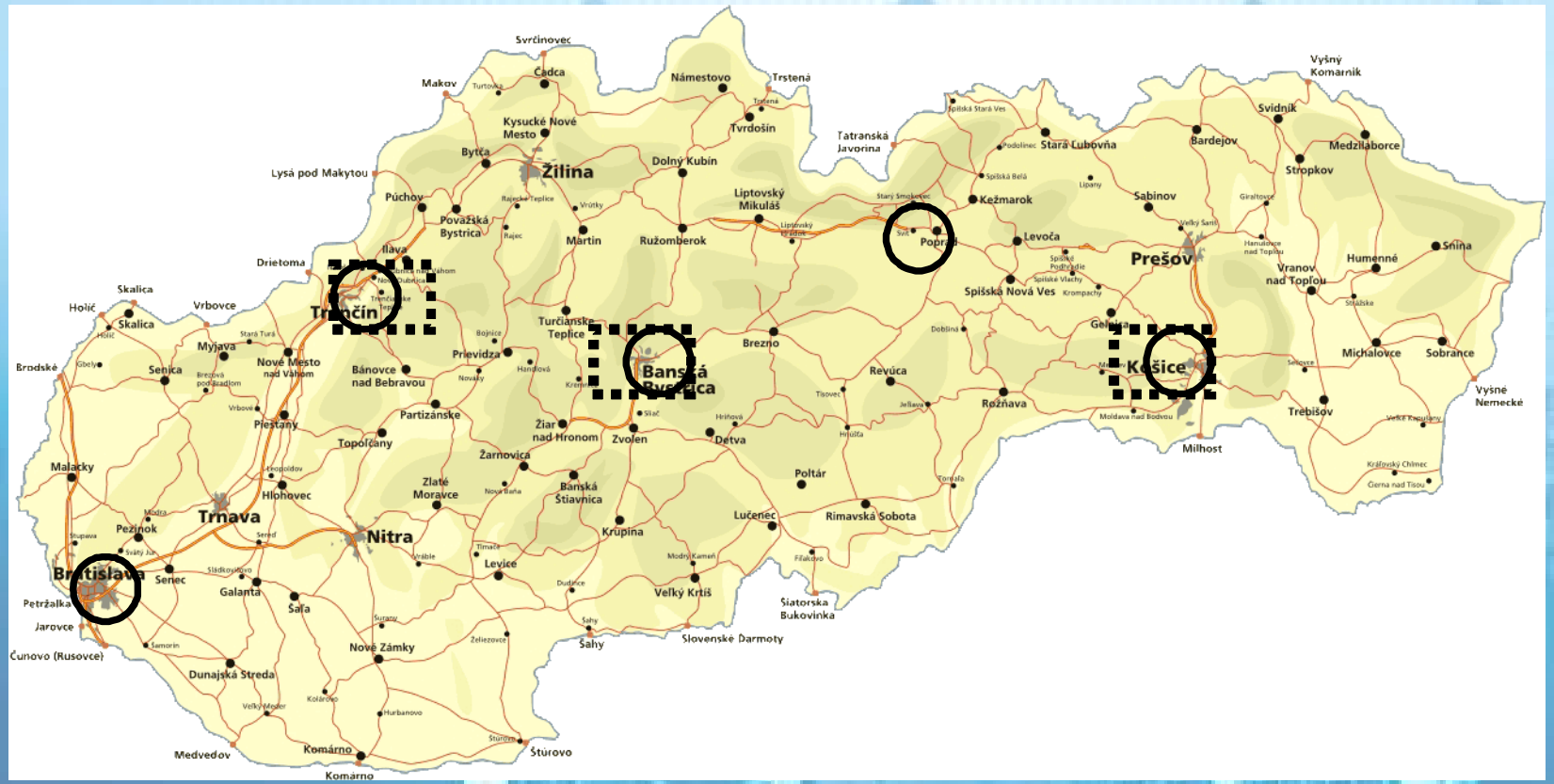
Model of paper recycling in Slovakia

- Theoretical base :
  - Recovery Network Model (RNM) - Fleischmann 2001
  - Investment–Allocation Problem - Bloemhof-Ruwaard 1996
- Aim : to minimize total investment and operating costs with respect to market conditions of acquiring and reuse and also technical and economical limits
- Mixed integer linear programming model (MILP)

Model of paper recycling in Slovakia

- Model:
- Existing customer localities in Slovakia: Bratislava (BA), Trenčín (TN), Banská Bystrica (BB), Poprad (PP) and Košice (KE)
- Possible localities for depots and collection centers are customer localities.
- As candidate places for central facility were chosen Trenčín (TN), Banská Bystrica (BB) and Poprad (PP).
- The goal - a decision about location of central facility for paper recycling, and also depots and centers for paper collection.

Model of paper recycling in Slovakia



- customer localities, centers for paper collection, depots

-potential facilities

Input data *- Variables*

- X^f_{ijk} *- demand of k–th customer supplied from i–th facility and j–th depot*
- X^r_{klj} *- part of returns of k–th customer through l–th collection center to i–th production facility*
- U_k *- non–satisfied demand of k–th customer*
- W_k *- non–collected part of returns of k–th customer*
- Y^p_i *- indicates, if the i–th production facility is opened or not*
- Y^s_j *- indicates, if the j–th depot is opened or not*
- Y^r_l *- indicates, if the l–th collection center is opened or not*

Input data - *Costs*

- c^f_{ijk} - forward flows: unit costs to satisfy customer demand from *i*–th production facility and *j*–th depot, including production, distribution and manipulate costs
- c^r_{kli} - reverse flows: unit variable costs of returns from *k*–th customer through *l*–th collection center to *i*–th production facility , including transactional and manipulate costs minus savings of production costs in *i*–th production facility
- c^r_{kl0} - unit variable cost of non–collected part of returns, including collecting, distribution and manipulate costs from from *k*–th customer to *l*–th collection center
- c^u_k - penalty costs for non–satisfied demand of *k*–th customer
- c^w_k - penalty costs for non–realized returns of *k*–th customer
- f^p_i - fixed costs for opening *i*–th production facility
- f^s_j - fixed costs for opening *j*–th depot
- f^r_l - fixed costs for opening *l*–th collection center

Input data *- Parameters*

- d_k - demand of *k*–th customer on reuse market
- r_k - returns of *k*–th customer on acquiring market
- γ - minimal part of non–collected returns

Parameters of the model

- *173 variables*
  - *13 binary variables*
  - *160 continuous variables*
- *153 constraints*

Model

$$\min f\left(Y_i^p, Y_j^s, Y_l^r, X_{ijk}^f, X_{kli}^r, U_k, W_k\right) = \sum_{i=1}^{3} f_i^p Y_i^p + \sum_{j=1}^{5} f_j^s Y_j^s + \sum_{l=1}^{5} f_l^r Y_l^r +$$

$$+ \sum_{i=1}^{3}\sum_{j=1}^{5}\sum_{k=1}^{5} c_{ijk}^f d_k X_{ijk}^f + \sum_{k=1}^{5}\sum_{l=1}^{5}\sum_{i=0}^{3} c_{kli}^r r_k X_{kli}^r + \sum_{k=1}^{5} c_k^u d_k U_k + \sum_{k=1}^{5} c_k^w r_k W_k$$

$$\sum_{i=1}^{3}\sum_{j=1}^{5} X_{ijk}^f + U_k = 1 \qquad k = 1,2,\ldots,5 \qquad (1)$$

$$\sum_{l=1}^{5}\left(\sum_{i=1}^{3} X_{kli}^r + X_{kl0}^r\right) + W_k = 1 \qquad k = 1,2,\ldots,5 \qquad (2)$$

$$\gamma\sum_{i=0}^{3} X_{kli}^r - \sum_{j=1}^{5}\sum_{k=1}^{5} d_k X_{ijk}^f \le 0 \qquad k = 1,2,\ldots,5, l = 1,2,\ldots,5, j = 1,2,3 \qquad (3)$$

$$\sum_{k=1}^{5}\sum_{l=1}^{5} r_k X_{kli}^r - \sum_{j=1}^{5}\sum_{k=1}^{5} d_k X_{ijk}^f \le 0 \qquad i = 1,2,3 \qquad (4)$$

$$\sum_{j=1}^{5} X_{ijk}^f - Y_i^p \le 0 \qquad i = 1,2,3, k = 1,2,\ldots,5 \qquad (5)$$

$$\sum_{i=1}^{3} X_{ijk}^f - Y_j^s \le 0 \qquad j = 1,2,\ldots,5, k = 1,2,\ldots,5 \qquad (6)$$

$$\sum_{i=0}^{3} X_{kli}^r - Y_l^r \le 0 \qquad k = 1,2,\ldots,5, l = 1,2,\ldots,5 \qquad (7)$$

$$Y_i^p, Y_j^s, Y_l^r \in \{0,1\} \qquad i = 1,2,3, j = 1,2,\ldots,5, l = 1,2,\ldots,5 \qquad (8)$$

$$X_{ijk}^f, X_{kli}^r, U_k, W_k \in \langle 0,1 \rangle \qquad i = 1,2,3, k = 1,2,\ldots,5, l = 1,2,\ldots,5 \qquad (9)$$

Output data

- *facility – Banská Bystrica*
- *depots – Banská Bystrica, Bratislava*
- *collection centers– Bratislava, Košice, Banská Bystrica (also for Trenčín and Poprad)*
- *customers - Bratislava, Košice, Banská Bystrica, Trenčín, Poprad*

Output data – material flows