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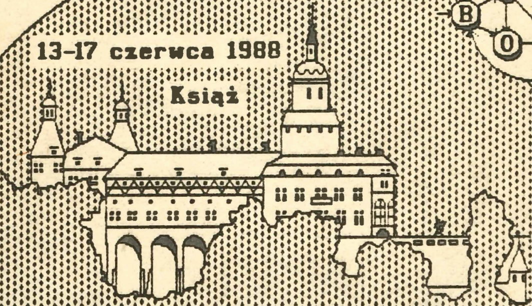

1. Krajowa Konferencja Badań Operacyjnych i Systemowych

Tom 1

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INSTYTUT BADAŃ SYSTEMOWYCH POLSKIEJ AKADEMII NAUK

POLSKIE TOWARZYSTWO BADAŃ OPERACYJNYCH I SYSTEMOWYCH

TOM 1

OPTYMALIZACJA METODY I ZASTOSOWANIA

I KRAJOWA KONFERENCJA

BADAŃ OPERACYJNYCH i SYSTEMOWYCH

Książ, 13 - 17 czerwca 1988

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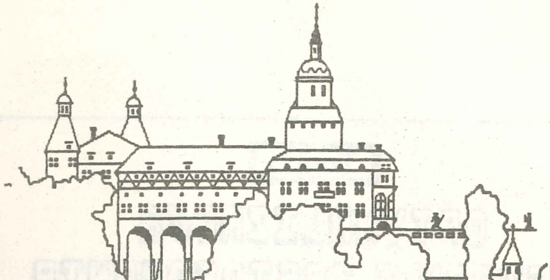

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3. Optymalizacja w transporcie

3.5

I Krajowa Konferencja
Badań Operacyjnych i Systemowych
Książ, 13 - 17 czerwca 1988r.

THE ANALYSIS OF LIQUID MILK SUPPLY TO URBAN AGGLOMERATION BY BICRITERION LINEAR TRANSPORTATION MODEL WITH THE MPSX/370 PACKAGE

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Abstract

In the paper we formulate a bicriterion linear transportation model to analyse the raw milk supply for an urban agglomeration. The model has been verified for Warsaw. To solve the bicriterion model the lexicographic as well as the parametric methods were used. The model can be considered as an element of a Multicriterial Decision Support System of raw milk supply for Warsaw.

1. Introduction

The rapid growth of the urban population as well as the nutrition value of milk have caused a fast increase in the milk production and consumption. In 1984 the consumption of liquid milk in Polish big cities was on the level of 1.2 milliard litres, that is 46 percent of total amount of liquid milk produced in Poland. The amount of the collected raw milk around large agglomerations lags behind the increase in the consumption of liquid milk in big cities. Warsaw was the best example of this problem. In 1984, the modelled system of milk supply to Warsaw consisted of four stages. The system covered 38 regional milk cooperatives in 9 districts of Poland, which supplied about 210 million litres of raw milk to four city milk plants in Warsaw. The raw milk was transported each day from more than 63 thousand suppliers through almost 18000 permanent milk reception stations. 50 percent of that amount was delivered from the Warsaw District. The expansion of the milk transfer area to supply Warsaw resulted in an increase of the transportation radius as well as in higher transportartion costs.

The forecast of the Central Union of Dairy Cooperatives determines that in 1990 raw milk collected around Warsaw will cover 20.7 percent of total amount of milk consumption. Till the 2 000, the gap between supply and demand for the raw milk will be much deeper. It also have an influence on the energy consumption, because the dairy industry is one of the most energy intensive industries between food industries in Poland.

The aim of the paper is to show the possibilities of the liquid milk supply to Warsaw by the optimization methods. This analysis have been achieved by a bicriterion linear transportation model. To predict the future possible transfer area of supplying Warsaw for 1990 we have made ex-post analysis for the period of 1984-1986. The model was solved by lexicographic as well as by parametric methods. The bicriterion analysis was performed with MPSX/370 package, which is regarded as a standard commercial tool to solve linear programming problems.

2. The statement of the model

The model of the milk marketing system for urban agglomeration is presented on Fig. 1. One of the main functions of this system is transportation of goods from the producers to the final customers. This transportation process consists of the following homogenous three parts /see: [2]/:

1. the collection of milk as a raw material or semiproducts to the milk processing plants,
2. the transportation of milk as a raw material or semiproducts between milk processing plants and city milk plants,
3. the distribution of liquid milk or liquid and solid milk products from the city milk plants to the retailing customers.

Elements of total physical milk marketing system for Warsaw

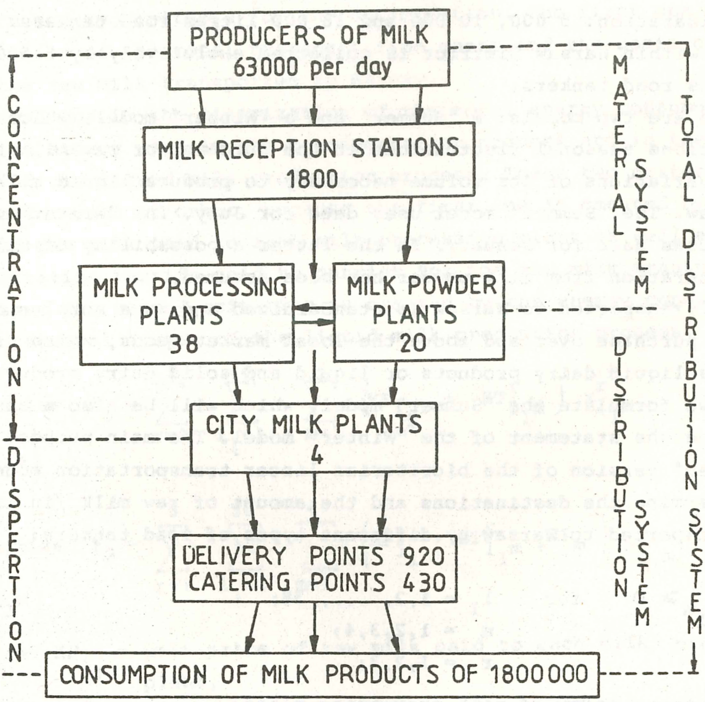
PRODUCERS OF MILK
63000 per day
MILK RECEPTION STATIONS
1800
MILK PROCESSING PLANTS
38
MILK POWDER PLANTS
20
CITY MILK PLANTS
4
DELIVERY POINTS 920
CATERING POINTS 430
CONSUMPTION OF MILK PRODUCTS OF 1800000
CONCENTRATION
DISPERTION
MATERIAL SYSTEM
DISTRIBUTION SYSTEM
TOTAL DISTRIBUTION SYSTEM

Fig.1.

The analysis of the liquid milk supply to Warsaw concerns inter-plant transportation process. To formulate a bicriterion linear transportation model of this process we have to accept the following assumptions:

- regions supplying milk reception stations as well as supplying milk processing plants are stable, therefore collection process of raw milk is out of our optimization process /see: [1] /,
- the distribution of final dairy products is analysed separately by Vehicle Routing and Scheduling Models, so it is out of our optimization process /see: [6]/,
- three kinds of means of transportation separately are taken into considaration: 5 000, 10 000 and 18 000 litres road tankers. Raw milk within Warsaw District is collected exclusively by 5 000 litres road tankers,
- there are two models: a "Summer" and a "Winter" model, which describes seasonal fluctuations in the purchase of raw milk and the variations of its volume necessary to produce liquid milk in Warsaw. The "Summer" model uses data for July. The "Winter" model uses data for January. In the latter a possibility of milk regeneration from milk powder has been assumed,
- milk transported to Warsaw is standardized and is a surplus of milk purchase over and above the local market needs, which provides liquid dairy products or liquid and solid dairy products.

First we formulate the "Summer" model, which will be also a basis to develope the statement of the "Winter" model. The main purpose of the "Summer" version of the bicriterion linear transportation model is to determine the destinations and the amount of raw milk /in litres/ transported to Warsaw by different types of road tankers:

$$x^{r}_{l_1 m} \geq 0 \quad \text{for} \quad l_1 = 1,2, \ldots, 38; \quad m = 1,2,3,4; \quad r = 1,2,3; \qquad /1/$$

where: l_1 - index of milk processing plant;
m - index of city milk plant in Warsaw;
r - index of type of road tankers.

Total amount of raw milk transported from each milk processing plant to all city milk plants in Warsaw cannot be greatrer than the raw milk surplus a_{l_1} over the l_1 local market needs.

$$\sum_{r=1}^{3} \sum_{m=1}^{4} x^{r}_{l_1 m} \leqslant a_{l_1} \quad \text{for } l_1 = 1,2,\ldots,38; \qquad /2/$$

where: a_{l_1} - difference between the raw milk supply and the demand of the local market.

Similarly, the total amount of raw milk transported from several milk processing plants to each city milk plant in Warsaw is equal to its demand b_m of milk needed to produce the liquid milk.

$$\sum_{r=1}^{3} \sum_{l_1=1}^{38} x^{r}_{l_1 m} = b \quad \text{for } M = 1,2,3,4; \qquad /3/$$

There are two criteria for the optimization. The first one is the minimization of the total transportation costs and the costs of purchase of the raw milk transported to Warsaw.

The second one is the minimization of the total energy consumption including energy used in the transportation process and in the several stages of the liquid milk production process. These two criteria are independent each of other, because the first one is created by unit price of raw milk paid to each milk processing plant as well as by the transportation tarrifs paid to carrier for the raw milk transported to Warsaw. The second criterion is created by the energy consumption used in several stages of the liquid milk production process.

$$\underset{\left\{x^{r}_{l_1 m}\right\}}{\text{minimize}} \; f_1 = \sum_{r=1}^{3} \sum_{l_1=1}^{38} \sum_{m=1}^{4} \left(KF_{l_1} + KT^{r}_{l_1 m}\right) x^{r}_{l_1 m} \qquad /4/$$

$$\underset{\left\{x^{r}_{l_1 m}\right\}}{\text{minimize}} \; f_2 = \sum_{r=1}^{3} \sum_{l_1=1}^{38} \sum_{m=1}^{4} \left(EF_{l_1} + ET^{r}_{l_1 m} + EF_m\right) x^{r}_{l_1 m} \qquad /5/$$

where: KF_{l_1} - unit price of raw milk paid to each milk processing plant,

$KT^{r}_{l_1 m}$ - unit transportation cost of raw milk transported between milk processing plant l_1 and city milk plant m in Warsaw by r kind of road tankers,

EF_{l_1}, EF_m - energy consumption on the several stages of unit liquid milk production,

$ET^{r}_{l_1 m}$ - energy consumption of raw milk unit transported between milk processing plant l_1 and city milk plant m in Warsaw by r kind of road tankers.

The equations /1/-/5/ describe the "Summer" model of liquid milk supply to Warsaw. The "Winter" model is constructed on the basis of the "Summer" model /1/-/5/. The main purpose of the "Winter" version of the bicriterion linear transportation model is to determine the destinations and the amount of raw milk as well as a raw milk to produce the milk powder for the liquid milk regeneration in Warsaw:

$$x^r_{l_1 m} \geq 0, \quad y_{l_2 m} \geq 0 \quad \text{for } l_1 = 1,2,\ldots,38; \; m = 1,2,3,4; \; r = 1,2,3; \; l_2 = 1,2,\ldots,20; \qquad /1a/$$

where: y_{l_2} - amount of raw milk to produce milk powder for liquid milk regeneration in m city milk plant in Warsaw transported by 5 ton vehicles.

Total amount of raw milk to produce the milk-powder for the liquid milk regeneration in all city milk plants in Warsaw is equaled to the raw milk surplus over the local market needs /see: /2a//.

$$\sum_{m=1}^{4} y_{l_2 m} \leq a_{l_2} \qquad \text{for } l_2 = 1,2,\ldots,20; \qquad /2a/$$

where: a_{l_2} - storing capacity of milk-powder plant of raw milk.

Similarly, the total amount of raw milk as well as the amount of raw milk to produce the milk-powder for the liquid milk regeneration in each city milk plant m in Warsaw is equal to its demand. The demand of liquid milk b_m is given in litres:

$$\sum_{l_1=1}^{38} \sum_{r=1}^{3} x^r_{l_1 m} + \sum_{l_2=1}^{20} y_{l_2 m} = b_m \qquad \text{for } m = 1,2,3,4; \qquad /3a/$$

The "Winter" model fulfills the following two criteria of optimization:

$$\underset{\left\{x^r_{l_1 m}, y_{l_2 m}\right\}}{\text{minimize}} \; f_1 = \sum_{r=1}^{3} \sum_{l_1=1}^{38} \sum_{m=1}^{4} \left(KF_{l_1} + KT^r_{l_1 m}\right) x^r_{l_1 m} + \sum_{l_2=1}^{20} \sum_{m=1}^{4} \left(KF_{l_2} + KT_{l_2 m} + \overline{KF}_m\right) y_{l_2 m} \qquad /4a/$$

$$\underset{\left\{x^{r}_{1_1m},\ y_{1_2m}\right\}}{\text{minimize}} \sum_{r=1}^{3}\sum_{1_1=1}^{38}\sum_{m=1}^{4}\left(EF_{1_1} + ET_{1_1m} + EF_m\right) x^{r}_{1_1m} + \sum_{1_2=1}^{20}\sum_{m=1}^{4}\left(CF_{1_2} + ET_{1_2m} + \overline{EF}_m\right) y_{1_2m} \qquad /5a/$$

where: KF_{1_2} - unit price of milk-powder paid to each milk-powder plant,

KT_{1_2m} - unit transportation cost of milk-powder transported between milk-powder plant 1_2 and city milk plant m,

$\overline{KF}_m$ - unit storing cost of milk-powder paid by each city milk plant m,

EF_{1_2} - energy consumption of storing raw milk to produce a unit of milk-powder in milk-powder plant 1_2,

ET_{1_2m} - energy consumption of raw milk unit transported between milk-powder plant 1_2 and city milk plant m by 5 ton vehicles,

$\overline{EF}_m$ - energy consumption to regenerate a unit of liquid milk from milk-powder plant 1_2 in city milk plant m in Warsaw.

The first criterion effects the minimization of the total cost of purchase of the raw milk as well as the milk-powder to regenerate the liquid milk in Warsaw and their transportation costs. The second criterion leads to the minimization of the total energy consumption in the transportation process as well as in the several stages of the liquid milk production in Warsaw.

3. Simulations for 1984 and 1990 models

The "Winter" and the "Summer" models are of a different size. The "Summer" model consists of 245 decision variables and 42 constraints, whereas the "Winter" model contains 259 variables and 60 constraints.

For ex-post optimization the period of three years 1984-1986 has been selected. Exactly, July, as the period of the minimum level of the milk transfer area, has been used in the "Summer" model and January, as the period of the maximum level, has been used in the "Winter" model. Over 110 experiments were made for 1984-1986: 36 experiments for each of three years. Half of them with the "Winter" model and half with the "Summer" one. The experiments includes:

- three types of the road tankers: 5 000, 10 000, and 18 000 litres,
- two kinds of local markets offering the liquid milk products or liquid and solid ones,
- three kinds of the optimization techniques: the lexicographic method for both hierarchies of the objective functions and the parametric analysis to identify objective functions and the parametric analysis to identify all the efficient vertices. The computations were performed with the MPSX/370 package /see [3]/.

The results of the experiments for the lexicographic method were compared with the real routes of the raw milk transported to Warsaw in 1984 for the "Winter" and "Summer" models. To get more comparable results we assumed: raw milk was transported only by 18 000 litres road tankers and the local markets were offering both: the liquid and the solid milk products. The results are presented in Table 1.

Table 1

The results of ex-post analysis for "Winter" and "Summer" models for 1984 obtained by the lexicographic method

Criteria	"Winter" model			"Summer" model		
	Computer solution	Real solution	% of sav.	Computer solution	Real solution	% of sav.
"Energy" /MJ/1000l/	718,1	809,5	12.8	732,5	830,6	13.4
"Cost" /zł/1000l/	27897	35185	26.1	18998	27936	47.0

The parametric analysis allows us to create all the Pareto - optimal efficient solutions to the model /1/ - /5/ or /1a/ - /5a/. The efficient frontier were generated by the standard parametric procedure of the MPSX/370 package by solving the following problem:

$$\text{minimize} \left\{ f_{k_1} + \alpha\left(f_{k_2} - f_{k_1}\right) \quad \alpha \in [0,\ 1] \quad \text{subject to: /1/-/3/ or /1a/ - /3a/} \right\} \qquad /6/$$

The bicriterion transportation models /1/-/5/ and /1a/-/5a/ were used to determine the future destinations and amount of the raw milk transported to Warsaw. Optimization was made for 1990 including period of the maximum level of the milk transfer area to Warsaw in the summer /in July/ and in the minimum one in the winter /in January/. For the 1990 - model the additional assumptions - were taken into considaration:

- two level of the milk consumption in Warsaw: at the level of 96 and 120 litres per capita annually respectively;

- two alternatives of the forecasted raw milk purchase prices and transportation tariffs;
- two kinds of the road tankers /5 000 and 18 000 litres/ respectively;
- two kinds of the local markets providing the liquid milk products or the liquid and solid ones respectively;
- a various Warsaw supplying area covering nine districts or only the Warsaw Macroregion /6 districts/ respectively;
- a stable use of energy in the forecasted period including transportation energy and processing energy in several stages of liquid milk production.

For the 1990 model, 48 experiments have been made including 36 experiments for the "Winter" model and 12 for the "Summer" one. The experiments used three kinds of optimization techniques: lexicographic method with two hierarchies of the objective functions as well as the parametric analysis which treated both the objective functions simultaneously.

4. Conclutions

The main application of the model is the analysis of the circumstances that will have influence in the choice of the best raw milk supply routes to Warsaw for both criteria functions: "energy" and "cost" in the future. The most important circumstances concerns:

- changes in the level and in the structure of the milk consumption in Warsaw,
- seasonal fluctuation of the milk purchase level,
- changes in the forecasted prices of raw milk purchase and in the forecasted transportation tariffs,
- changes in the depth of the local markets, i.e. in the level of raw milk surplus over and above the local market needs, predestined for Warsaw,
- changes in the policy of acquiring new vehicles for the raw milk transportation to Warsaw.

The bicriterion transportation model and the procedures of its solution discussed in this paper can be implemented on the microcomputer type IBM. PC/AT as the first step to construct the Multicriterial Decision Support System /MCDSS/ for the raw milk supply for Warsaw.

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