# COMPUTER SYSTEM FOR MANAGING THE SUGAR BEET TRANSPORT TO SUGAR FACTORY

**Andrzej Marczuk**

*University of Life Sciences in Lublin*
*Department of Agricultural Machines and Devices*
*28 Głęboka Street 20-220 Lublin, Poland*
*tel. +48 81 4456141*
*e-mail: andrzej.marczuk@ar.lublin.pl*

***Abstract***

*An appropriate solving the transport organization in agriculture requires, among others, to work out the method for transportation means work organization. Issues associated with transportation means work organization are impossible to be optimally solved by a controller in the case of developed transport network, instead they require computational techniques for fast information processing. One of such methods is presented in the paper as a system for sugar-beet transport to sugar works.*

*In sugar industry, large amounts of raw material are transported between sugar-beet producers or storage centers and processing works. Presented program makes possible to select transportation means for carrying the sugar-beet, and then working out the schedule of routes realized by vehicles. The paper presents the management system of sugar-beet transporting to the sugar works that optimizes the transportation means work. Minimization of courses length, because it directly affects the reduction of transportation costs by means of decrease of fuel and other exploitation parts used, shortening the driver's work-time, and decrease of fees for vehicle rental. The system was verified using real data for a given day, which confirmed the correctness of the software functioning. Working out and launching the software required to write databases containing necessary information on: sites the material was received from, amount of transported loads, transportation means, loading/reloading machines and devices along with their technical and exploitation parameters, as well as the project required to draw digital map with all analyzed purchase centers, sugar works, and all the road network. Minimization of routes was accepted as a purpose function, because it directly affects the reduction of transport costs through reducing the fuel and other exploitation means used, shortening the driver's work time or decreasing the fees for vehicle rental. The system was verified using real data for a particular date, which confirmed the correctness of the software functioning.*

*Activity aiming at reducing production costs through elimination of unnecessary expenditures resulting from bad work organization would contribute to the improvement of competitiveness of Polish agriculture and enhancing its opportunities on EU markets. Proposed system for sugar-beet transport management at Sugar Works is an example of the system meeting such expectations.*

***Keywords:*** *transport, agriculture, system, optimization, sugar-beet.*

## 1. Introduction

At the beginning of 21st century, transport has to copy with very strict norms forced by international organizations and free markets. More and more rigorous legal acts on environment protection are obligatory - at present, Euro 5 norm refers to the heavy road transport. Works upon reducing the harmful transport influence on the environment are still conducted [3, 7]. Producers of transportation means expend enormous sums on research and incorporation of newer and newer constructional solutions aiming at copying with the requirements on environment protection and reducing the fuel utilization [6], which is important for recently observed fast increase of liquid fuels prices. The optimization systems, application of which contributes to reduce costs associated with transportation realization [5], help to achieve these goals.

When optimizing the agricultural farm activity, as well as enterprises cooperating with agriculture, an appropriate solving the transportation issues that have great effects on their

financial results, is very important. Interaction of many factors affecting the transport of goods in agriculture makes a complex information system. Quality and time of achieving the data as well as the way of its processing is one of the principle conditions determining the efficiency of undertaking the action associated with the improvement of up-to-date functioning transport solutions. It seems that it particularly refers to perspective planning issues both for agricultural goods producers, processing plants, specialized transportation firms, and whole national economy. For each above issues, not only the scale of predicted transportation tasks, but also means they would be done, is important. It should be emphasized that both elements may vary in subsequent years or production cycles.

Optimization of transportation processes in an agriculture is very complex issue. It requires different view if it is considered in regional or national scale, and different one in the case of a farm or specialized transportation enterprises working for the agriculture. In a micro-scale, the structure of economy unit with all its surrounding conditions, is a basis for optimization. In reference to the transportation unit, the knowledge on the demands for such services is additionally necessary. Optimization of transportation problems in macro-scale needs to take into account solutions used in micro-scale. Evaluation of the number and localization of agricultural producers, and in consequence structure and distribution of purchase centers within analyzed area of transportation system, is the most important issue at transport organization. Recognition of purchase and goods receiving centers characteristics as well as available transportation means is also significant. Organization of transportation means work-time for a given transporting task is another important element. Depending on the complexity level of a transportation task, the work may be organized directly by a man (controller) or applying a computer system for operative planning, and the operative planning should be understood as short-term planning (e.g. 8 hours or daily). Improper solution of above issues leads to needless increase of transport costs that are expended both by producers, and goods purchasing or processing units.

## 2. Aims and range of the study

The study was aimed at working out the computer system for management the sugar-beet transport to the sugar factory and verifying of the system under real conditions. The work range included collecting data on organization of transport associated with the raw material achievement. Information referred to:

- Distribution of sugar-beet storage points,
- Transportation means, loading machines, and devices along with their technical and exploitation parameters,
- Determining of the purpose function for transportation means selection.

Worked-out structure of technological procedures was verified using the example of sugar factory Cukier Małopolski SA in Garbów.

## 3. Method of transport optimization

To solve such issue, Ford-Fulkerson's algorithm [1] was applied; it solves the problem in a form of:

$$\min\left[\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} \cdot x_{ij}\right], \tag{1}$$

at restrictions:

$$\sum_{j=1}^{n} x_{ij} \le a_i, \quad i = 1, 2, ..., \mathrm{m}, \tag{2}$$

$$\sum_{i=1}^{m} x_{ij} \geq b_j, \quad j = 1, 2, ..., n, \tag{3}$$

$$\sum_{i=1}^{m} a_i \geq \sum_{j=1}^{n} b_j, \quad x_{ij} \geq 0, \tag{4}$$

where:

$m$ - number of material supply points,
$n$ - number of material demand points,
$c_{ij}$ - matrix of distances between demand and supply points,
$x_{ij}$ - unknown size of transport between demand and supply points,
$a_i$ - supply of materials,
$b_j$ - demand for materials.

Flow with minimum costs within oriented closed transportation network, in which every arc has its upper and lower capacity, as well as unit purpose function can be found through minimization of the expression:

$$\sum_{A} c(X,Y) \neq f(X,Y), \tag{5}$$

at conditions:

$$f(X,N) - f(N,X) = 0 \text{ for all } X \in N, \tag{6}$$

$$l(X,Y) \leq f(X,Y) \leq h(X,Y) \text{ for all } [X,Y] \in A, \tag{7}$$

where:

$N$ - set of all network nodes,
$A$ - set of all arcs,
$l(X,Y)$ - lower limit of the flow on an arc,
$h(X,Y)$ - upper limit of the flow on an arc,
$f(X,Y)$ - unknown flow,
$c(X,Y)$ - unit value of purpose function.

The method was used to optimize grain transport and verified at works that purchase cereals from former Zamość and Lublin districts [2, 4]. Complex practical problems associated with organization of transportation means work in an agriculture (impossible to be optimally solved by a controller in the case of developed transport network) require computational techniques using means for fast information processing and selecting the appropriate optimization method. The choice of method for transport organization in an agriculture depends on the issue type to be solved.

## 4. Studied object and conditions

Sugar factory Cukier Małopolski S.A. in Garbów was the studied object. The sugar factory belongs to German sugar consortium „*Sudzucker*". It cooperates with farmers from communes in Lublin region. Study was carried out during the sugar campaign in 2003 that lasted since October 12 till December 4. The sugar factory daily capacity was about 1860 t/day. During the whole campaign, 115131.39 tons of material was purchased. Sugar supplies to Garbów Sugar factory were realized by:

- farmers who personally supplied sugar-beets,
- carrier, to whom the campaign service was commissioned by sugar factory.

Farmers who wanted to transport sugar-beets by themselves, supplied them to the sugar factory or to the local purchase centers (t.p.s.) localized in Tomaszowice and Wojciechów near Nałęczów. The sugar factory received sugar-beets from other farmers and local purchase centers using carrier's transportation means. In 2003, the carrier was Cukro-Trans Ltd. Having 12 self-reloading vehicles of 16 and 18 tons capacities. Daily sugar-beet supply size was 1400 t/day, the rest was supplied by farmers who used their own transporting means. Following rates were obligatory at calculating fees for transport by the carrier:

[1] 1. Rate for sugar-beet transport from t.p.s. - 0.24 PLN/ t km,
[2] 2. Rate for sugar-beet transport from fields - 0.26 PLN/ t km.

In total in 2003, 16192.38 tons of sugar-beets was supplied to the sugar factory from local purchase centers, including 5190.33 tons from Tomaszowice and 10916.64 tons from Wojciechów. The loading was realized using FADROMA loader of 80-100 t/h capacity. Applying such very efficient device for loading was possible at t.p.s., because existing storage fields are hardened. The system of sugar-beet receiving directly the producer's field was widely introduced ins sugar factory Garbów in 2002. To do this, a modern purifying loader ROPA-MAUS L8.2000 of about 200 t/h capacity works for all season. Every sugar-beet producer, goods of whom had to be supplied to sugar factory by the carrier, had to agree with the conditions. Annex to the contract described in details the conditions of sugar-beets receiving from prisms. Not complying with the agreements released the producer from sugar-beet receive. In such case, farmer should have personally supply material at time and place appointed with the producer.

## 5. Results

Borland Delphi 3.0 software was used to build system for management of sugar-beet purchase. Altogether with Delphi package, following tools have been included:

- DataBase Desktop,
- Data Access components,
- Data components,
- Qreport components,
- DataBase Form Wizard.

Due to DataBase Desktop, there is an opportunity to view tables and to edit data contained, to use questions to find some information, to create new tables and to modify the existing tables structure. The software is aimed at facilitating the management of transportation means in transport enterprises or those involved in mass shifting. The module processes following operations:

- stores data,
- solves issues related to load assignment,
- optimizes transportation means selection,
- determines the vehicle's courses,
- calculates times of driver's work,
- displays map of a given area,
- displays maps of vehicle's courses,
- displays the shortest selected route.

At the first program launching, the accessibility paths for database should be defined. To do this, one should choose *Zmień ścieżki dostępu* from menu *Program*, then find and select appropriate tables. After the operation complete, the software will be automatically read specified accessibility paths previously defined. General keys for program control are: dostawy (supplies), mapa (map), tabor (vehicles), kursy (courses). They make possible to jump between selected forms. Form Dostawy (supplies) is default at the program start-up. It is database of sugar-beet supplies to sugar works in Garbów (Fig. 1).

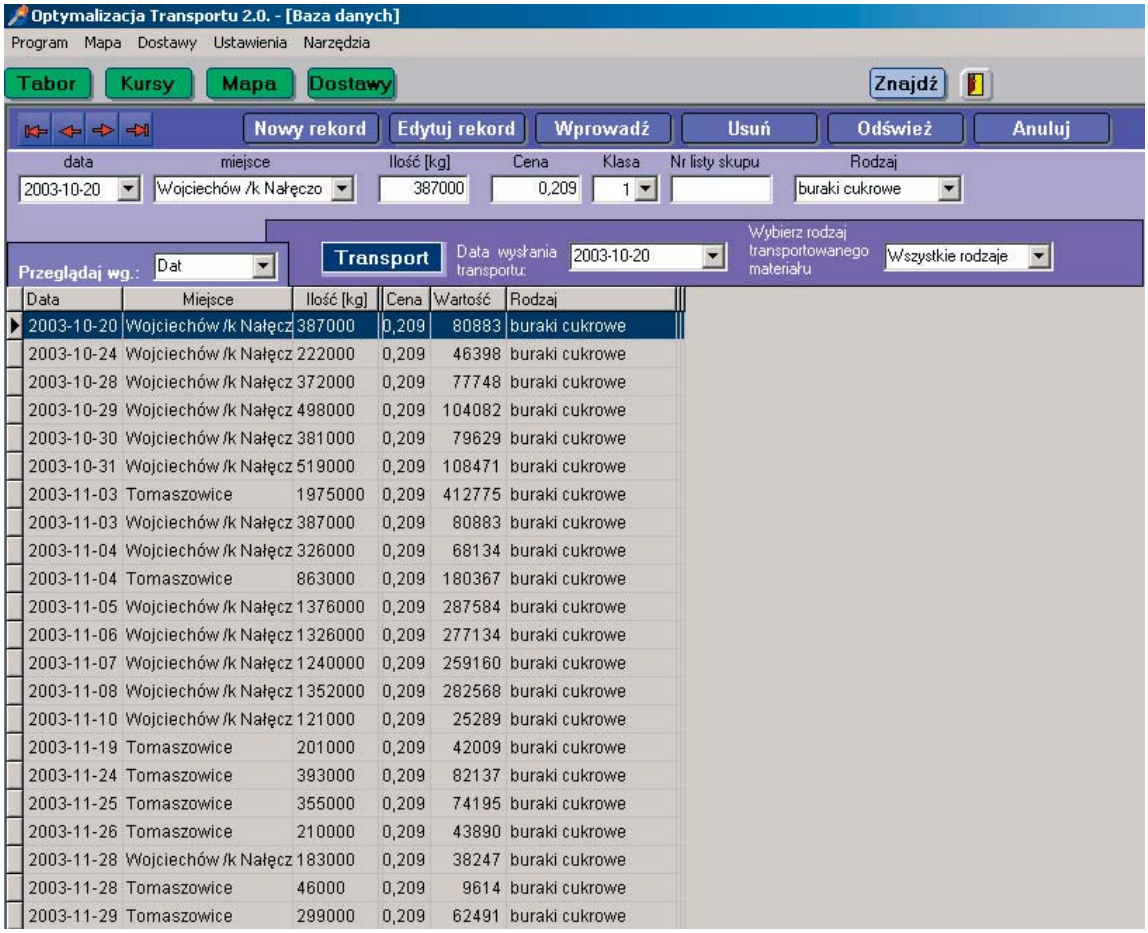


*Fig. 1. Database of supplies*

At the top of the interface, there are navigation keys for database, do to which records can be entered, deleted, and modified. In the window *Przeglądaj* (browse), there is an opportunity to sort according to date or localization. Bookmark Mapa (map) makes possible to view all area, on which transportation tasks are made. In this paper, we present map of Lublin region; however, the software for creating digital maps allows for drawing new maps and modifying existing ones.

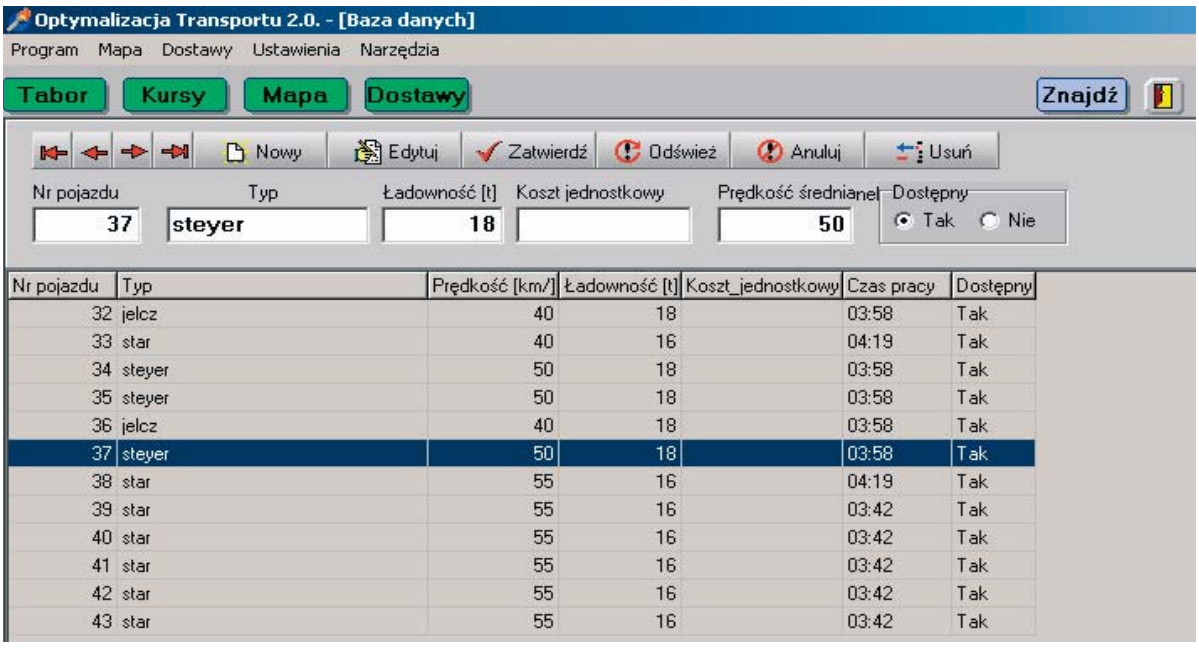


*Fig. 2. Form for transportation means*

Key *Znajdź* (find) results in finding the shortest route between two points on digital map. There is a possibility to write digital map in a file for further modifying or printing. The bookmark also makes possible to observe goods receiving points (purchase centers), particular routes, and all notes and routes from purchase centers for all the period of supplies from database. Other form is *Kursy* (routes) that contains all information on courses of transportation means. *Tabor* (vehicles) (Fig. 2) is the fourth form.

All available transportation means along with their parameters can be seen in it.

### 5.1. Program settings

A given point on an area map should be selected in the program; it will be interpreted as material purchase base. In this case, it is sugar factory in Garbów. Then time variables should be setup; they make possible to set times for particular operations:

- material loading time (it is set to 1t = 20 seconds),
- operative time related to, e.g. preparing the purifier, vehicle maneuvers, etc. (10 minutes),
- upper limit for driver's work time; it cannot be exceeded (set to 8 hours).

If work time is exceeded, procedures will automatically remove given transportation mean from a list of available vehicles. When needed databases and settings are read, program works according to procedures presented in Figure 3.

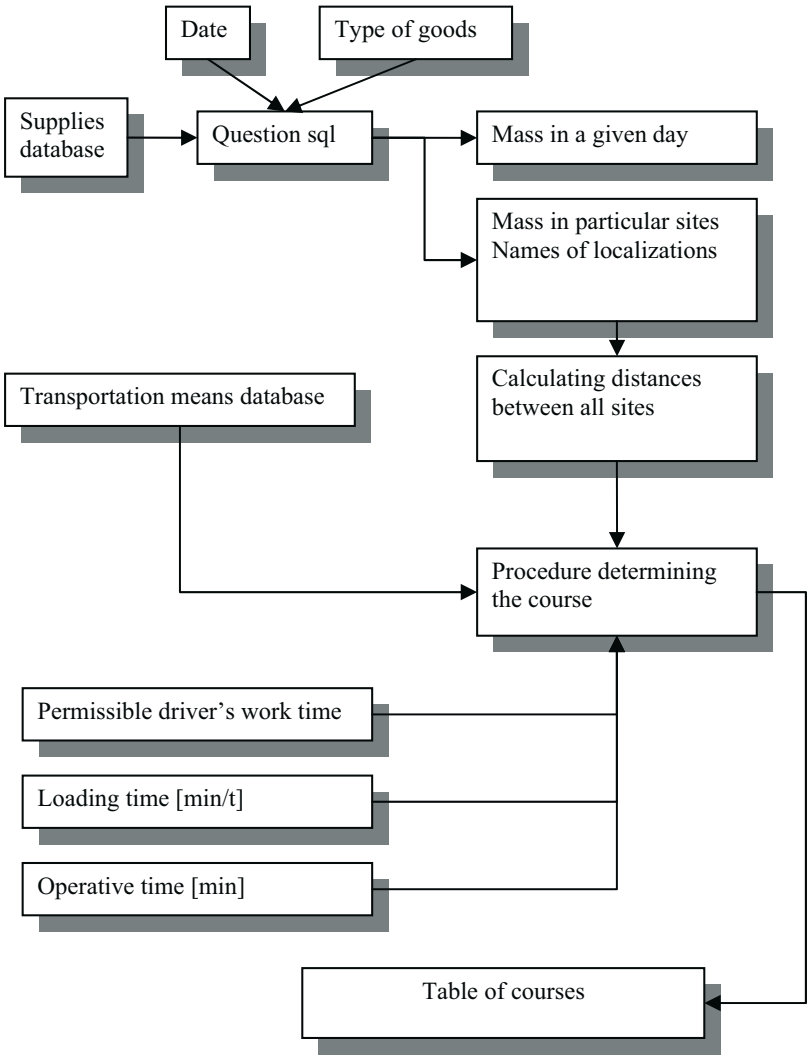


*Fig. 3. Scheme of working the program for sugar-beet transport management*

## 5.2. Study effects and analysis

During the sugar-beet campaign in 2003, the material purchase was performed every day except from holidays. The receiving capacity and daily capacity of the sugar factory was about 1860 t/day. Only single day, when sugar-beets were transported from farmer's fields, was analyzed in the paper. The main transport was provided by Cukro-Trans Ltd., and farmers who supplied material using their own transportation means. The individual farmer's sugar-beet transport was not subjected to optimization studies. The simulation referred to receiving of material from farmers on October 14, 2003. In total, 919 tons of sugar-beets were received by sugar factory that day from villages: Lesice - 228.65 tons, Miłocin - 263.35 ton, Szczuczki - 426.01 ton. The simulation assumed that 12 trucks were used to transport purchased material: seven *Stars* of 16 tons capacity each, and five *Jelczs* and *Steyrs* of 18 tons capacity each. Realizing the transport, vehicles carried mass equaled to their permissible capacity. At the startup of transportation procedure, the software assigned to every transportation mean the course described by the car's departure from a base (Sugar Factory Garbów), taking the load from purchase center and return to the base. Sum of the courses realized by a truck at a given day is a route. Figure 4 presents the fragment of truck courses list for analyzed day, while Table 1 - the courses report.

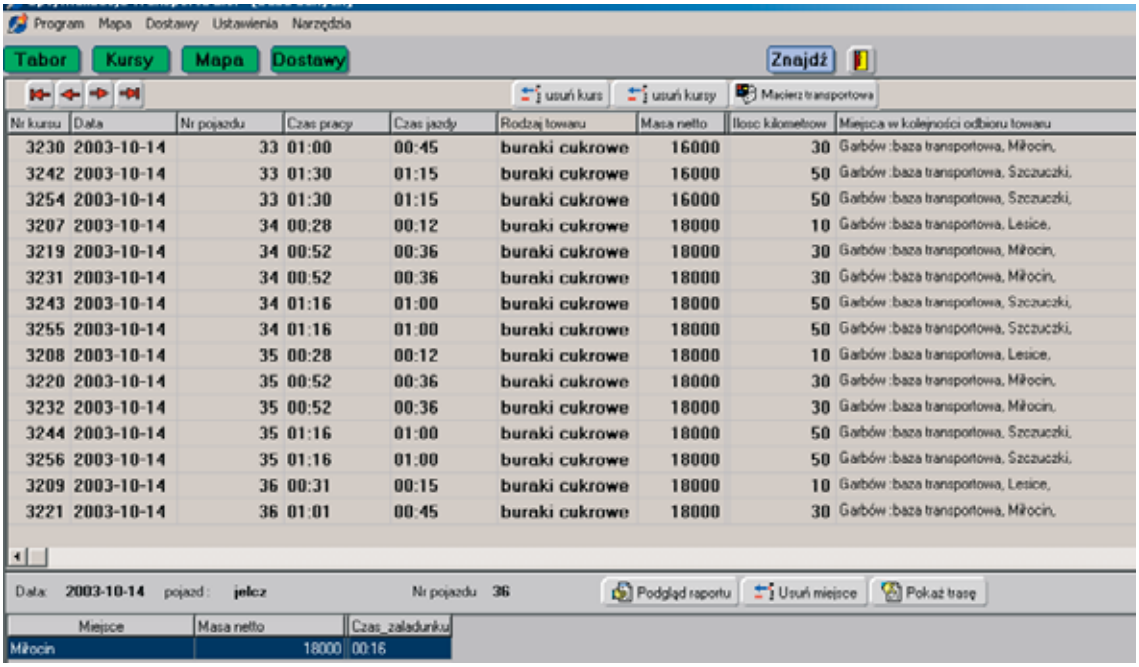


*Fig. 4. Courses determined by the program at analyzed day*

*Tab. 1. Courses report on October 14, 2003*

| No of truck | Capacity [t] | Number of courses (route) | Total load [t] | Kilometers |
|---|---|---|---|---|
| 32 | 18 | 5 | 90 | 150 |
| 33 | 16 | 5 | 80 | 168 |
| 34 | 18 | 5 | 90 | 170 |
| 35 | 18 | 5 | 90 | 170 |
| 36 | 18 | 5 | 90 | 170 |
| 37 | 18 | 5 | 90 | 195 |
| 38 | 16 | 5 | 69 | 190 |
| 39 | 16 | 4 | 64 | 140 |
| 40 | 16 | 4 | 64 | 140 |
| 41 | 16 | 4 | 64 | 140 |
| 42 | 16 | 4 | 64 | 140 |
| 43 | 16 | 4 | 64 | 140 |

The software determined two courses, in which given transportation mean, to complete its capacity to 100%, had to receive goods from two sites. For instance, course No 3218 of 38 km length is presented in Figure 5.

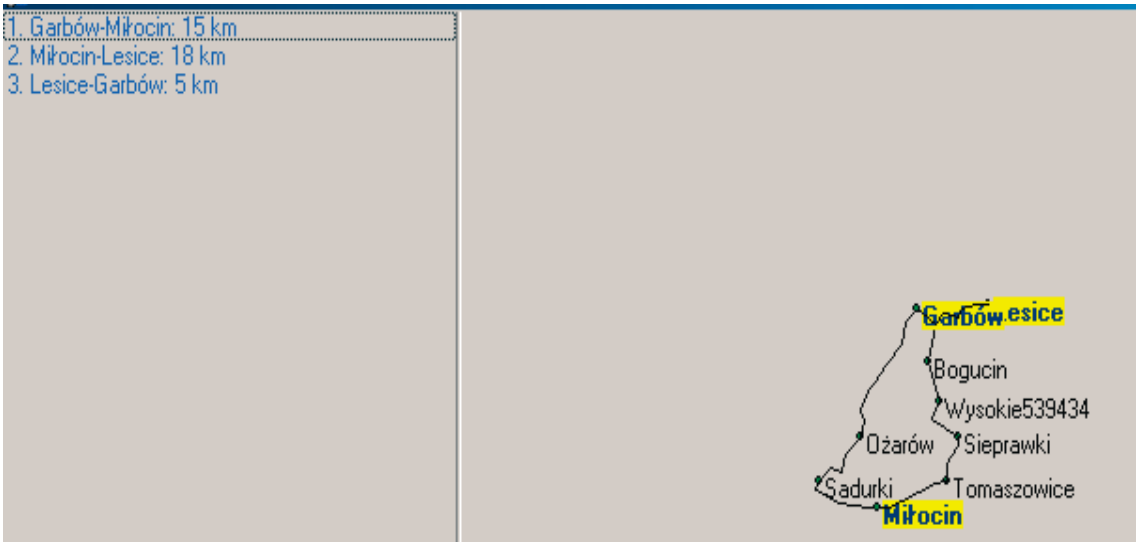


*Fig. 5. Course No 3218 for truck No 33*

Vehicle No 33 of 16 tons capacity received 7345 kg of sugar-beets during the course No 3218 from Miłocin and 8655 kg from Lesice. For course No 3234, program determined the route 55 km long presented in Figure 6.

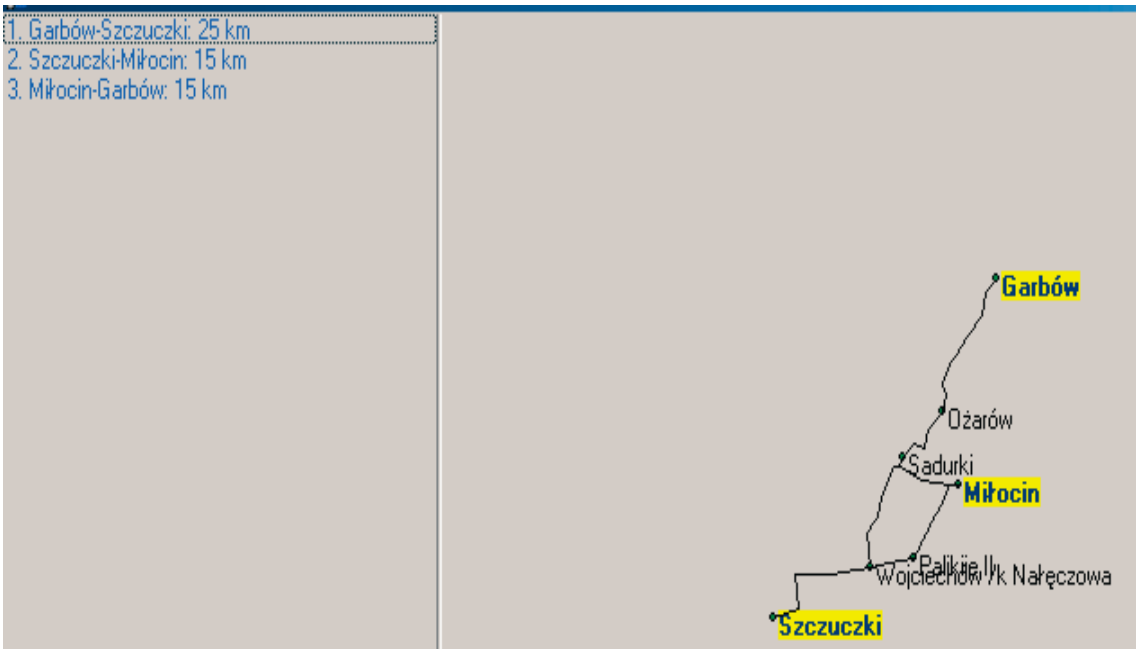


*Fig. 6. Course No 3234 realized by vehicle No 37*

Driving the course No 3234, the truck received 10800 kg of sugar-beets from Szczuki and 7200 kg from Miłocin. In both analyzed courses, it is apparent that program assigned truck's mass to a maximum vehicle's capacity, and completed it to 100%.

## 6. Summary

To properly solve issues of transport management in an agriculture it is necessary, among others, to work out the method for transportation means work organization. Complex practical

problems associated with organization of transportation means work in an agriculture (impossible to be optimally solved by a controller in the case of developed transport network) require computational techniques using means for fast information processing and selecting the appropriate optimization method. One of them may consist in the method presented in this research, the tool of which is the management system of sugar-beet transport to sugar factory. The worked-out software was created at the Department of Agricultural Machines and Devices, University of Life Sciences in Lublin. It makes possible to select transportation means for carrying purchased material, and then working out the route schedule realized by those means. All this required writing databases containing necessary information on: sites the material was received from, amount of transported loads, transportation means, loading/reloading machines and devices along with their technical and exploitation parameters, as well as the project required to draw digital map with all analyzed purchase centers, sugar factory, and all the road network. Minimization of routes was accepted as a purpose function. Minimization of route length affects the reduction of transport costs through reducing the fuel and other exploitation means used, shortening the driver's work time or decreasing the fees for vehicle rental.

The simulation was performed for October 14, 2003. That day, sugar-beets were transported to sugar factory from farmers from specially prepared prisms on field. The transport was realized by 12 trucks of 16 and 18 tons capacities; in total, they carried 919 tons of sugar-beets. Vehicles made 4 and 5 courses covering 1773 km. Two trucks received material from two sites to complete their capacity.

Activity aiming at reducing production costs through elimination of unnecessary expenditures resulting from bad work organization would contribute to the improvement of competitiveness of Polish agriculture and enhancing its opportunities on EU markets. Proposed system for sugar-beet transport management at sugar factory is an example of the system meeting such expectations.

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