TRANSPORT OPTIMIZATION IN MOBILE FODDER DISTRIBUTION

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Abstract: Effective organizing of transport processes in distribution allows for effective customer service and distribution costs decreasing. IT support or logistics providers offer various tools for route planning and control however its application requires relatively high investments, especially for small enterprises. Therefore authors present application of method for transport optimization that is simple and not expensive in usage.

Keywords: mobile distribution, transport optimisation.

Introduction – problem definition

Transport performance is clearly important to the process of distribution, companies have steadily expanded the geographical scale of their distribution operations and increase the level of customer service.

Each business which undertakes independent transport activities has to make decisions concerning organization of routes during distribution or supplying process, which considerably impact on efficiency of operation in the company and the whole supply chain [1.]. The employed methods, particularly in case of small and medium businesses, frequently depend on knowledge and abilities of dispatchers and are generally randomly chosen. This does not ensure optimization of solutions [3., 4., 9.]. Obviously, some efficient IT tools can be used during transport route planning, including software transport modules in ERP packages [10.].

Unfortunately, purchase of such top-class software means large expenditures to these businesses. Thus they should search for simplified tools which would cause improvement in transport efficiency.

Analysis of transport routes optimisation has been performed in Chempest Krzepice as a pilot project for mobile distribution of fodder.

Chempest Krzepice is a branch of Chempest Company which has its 32 locations of sales in southern Poland, where it distributes the following goods:

- fodder
- crop protection measures
- fertilizers
- seed
- agricultural machines

- horticulture goods

Its scope extends over Silesia and Opole Voivodeships. (see Figure 1.)

Figure 1. Area of operation and sales locations in Chempest Company
Source: Internal materials from Chempest Company

In area of distribution, fodder accounts for 78.8% of the whole amount of products distributed by the company. Fertilizers contribute to 12%, seeds – to 3.2%, crop protection measures – 2.8% of the distribution value (see Figure 2.).

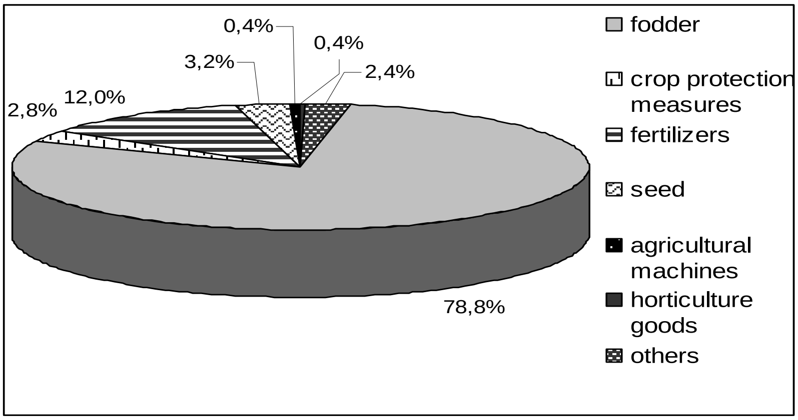

Figure 2. Contribution of each group of products in distribution in Chempest Krzepice
Source: Authors' elaboration on the basis of data from Chempest Krzepice

Modernity of fodder distribution in Chempest Krzepice is based on mobile distribution. Chosen distribution locations in Chempest Company participate in mobile distribution programme. This programme sets in systematic supplies of fodder to farmers. Such a distribution enables weekly supplies to around 400 locations.

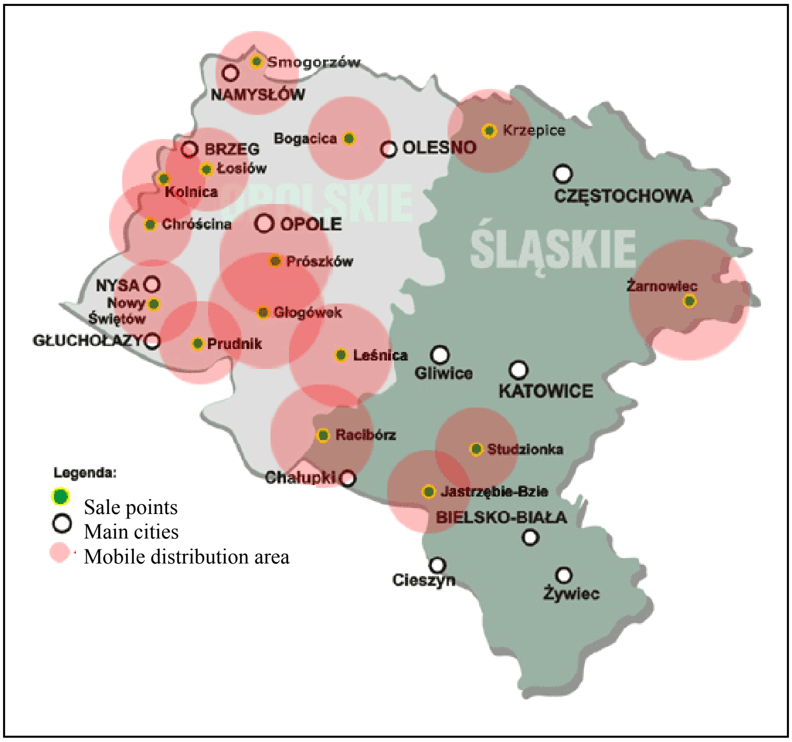

Figure 3. Scope of mobile distribution of fodder in Chempest Company
Source: Authors' elaboration on the basis of the data from Chempest Krzepice

Chempest Company distribution points which offer mobile distribution are marked in the Figure 3. It can be seen that Chempest Krzepice offers mobile distribution with the operation scale determined in this figure.
Common practice and increasing contribution of mobile distribution in sales show that this type of distribution is becoming more and more popular, due to the fact that:

- it enables purchasers a reduction in transport costs – products in mobile distribution are slightly more expensive than in the case of fixed points sales
- it ensures time effectiveness
- it enables trouble-free transport of goods – an appreciable part of farmers do not have means of transport which can be used in public roads.

Solution search methodology

While analysing optimal planning of previous transport routes in distribution one can use a modified method of task optimization in transport base, presented by S. Krawczyk [7., 8.], using Cartall Mapa Polski and Excel software.
Using planning of routes for multiple vehicles by S. Krawczyk, one can optimize transport tasks in supply and distribution through minimization of time, distance and cost of a particular solution.
Solving the transport problem described by S. Krawczyk was adapted to a specific nature of fodder distribution in Chempest Krzepice through making the following assumptions:

1) goods are homogenous and can be transported by a uniform means of transport. Homogeneity of goods enables implementation of a common units of load capacity (kg)

2) product is to be delivered to *n* recipients marked by D_1......D_n symbols from one distribution centre marked by C_0 symbol. In further part the recipients will be identified by index No.;
3) amount of orders placed by each supplier d_i expressed with load capacity units is known
4) orders are to be delivered by means of transport, each with Q load capacity. Assume also that $Q>d_i$ $i=1,...,n$.
   This limitation is not entirely essential since if a number of orders D_i is higher than Q it is known that a number of full rides without paying attention to other recipients and only for last course one should consider if this customer should not be served together with other consumers.
5) essential and realistic assumption is implementation of permissible length of route L for a particular means of transport, whose covering is associated with time of transit
6) in practice, delivery of goods requires some time for its unloading and transactional formalities: delivery of invoice, cashing payments. In order to simplify the task notation only a time of transit T was assumed as border value.

Considering the presented limitations, the task was formulated as following: number of means of transport and transit routes should be determined so that they enable serving all customers with minimization of total length of the routes.
The formulated problem clearly consists of two partial tasks:

- allocation of recipients to a particular means of transport;
- determination of routes for each of them.

In order to determine a route which starts in point C_0 then going through i_1 i_2.....i_r and ending anew in C_0, *H* symbol was used. Let l_{ij} be length of part of transit from *i* to *j*. Having made the assumption of permissible length of transit, the following inequality must be fulfilled:

$$l_{0i} + l_{i0} \leq L$$

Considering a route of $H = [0, i_1, i_2, ...i_r, 0]$ for a vehicle, one notes the following:

- length of the route: $l(H) = l_{0i_1} + l_{i_1 i_2} + ... + l_{i_r 0}$,
- total amount of delivery for route recipients: $d(H) = d_{i_1} + ... + d_{i_r}$.

Route H is assumed to be permissible if:

$$b(H) \leq Q \qquad i \qquad l(H) \leq L$$

In order to solve the task, a heuristic procedure was presented, since algorithms which guarantee optimal solution are, due to a time for calculations, completely useless [8].
The search was started from initial variant, which assumes that each recipient is served individually. This means that, in order to serve all *n* customers one needs *n* vehicles and each of them has a simple route from C_0 to its recipient and back. Total length of the routes amounts in this case:

$$z = \sum_{i=1}^{n} \left(l_{0i} + l_{i0} \right)$$

It seems to be proper to check if several recipients can be allocated into one group which could be served with one vehicle within its route.

Consider for example two recipients *i* and *j*. Total length of the route for individual services amounts to:

$$l_0 = (l_{0i} + l_{i0}) + (l_{0j} + l_{j0})$$

In consideration of the route length which will be covered after connection of these two recipients and connection of two individual routes into one from *0* to *i* and then to *j* and back to *0*, route length is:

$$l_1 = l_{0i} + l_{ij} + l_{j0}$$

Calculating the difference of route lengths in the above solutions, the following holds true:

$$s_{ij} = l_0 - l_1 = l_{i0} + l_{0j} - l_{ij}$$

If $s_{ij} > O$, a total length for individual recipients services is longer than for joint route. *s* value denotes a value of saved length for the route. Notion 'saved' should be understood in a relative way since it can not be excluded that $s_{ij} < O$ was obtained, thus a negative 'safety'. Such a result means that individual routes should not be connected into a joint route.

Considering a more general case for two routes H_1=[0, h,..., i, 0] and H_2=[0, j,...,k,0] a connection of these routes was made. During individual service of first route, after arriving to the last recipient from first route a return to start point should occur. Instead of that, next visit at first recipient from second route and then a continuation of distribution according to a determined second route occurs. Determination of which are first and second route plays only a descriptive role.

A new route H* = [O, h,..., i, j,..., k, 0] requires realization of delivery with total load capacity:

$$d(H^*)=d(H_l)+d(H_2),$$

while route length is:

$$l(H^*) = l(H_1) + l(H_2) - l_{0i} - l_{0j} + l_{ij} = l(H_1) + l(H_2) - s_{ij}$$

H* route is found to be more efficient than H_1 and H_2 if $s_{ij} > O$, i.e. when total length of transit is reduced and conditions of permissibility, i.e. d(H*) < Q and l(H*) < T are fulfilled. The route length effectiveness was accompanied by reduction in number of means of transport, since only one vehicle is used instead of two. A number of routes will be equal to a number of vehicles necessary to provide services. Considering the role of s_{ij}, which determines a length of the saved transit route one should note that the values of s_{ij} depend only on the considered connection between *i* and *j*, while they do not depend on the analysed routes. Thus they can be determined before any attempts to connect the routes and use them as purpose indexes for such connections, because if for a particular pair of nodes negative values are obtained for the route length, a possible connection of the routes between these nodes should be neglected. This statement is unequivocal, while it results from the fact of s > O that connection between these two nodes is purposeful. Moreover, it should be checked if the conditions of permissibility are fulfilled after the connection.

Additionally, the cases should also be excluded for which, despite meeting all the mentioned conditions, there is no point in considering of saving in distance between new and any intermediate recipient from the group already considered within the route.

Full algorithm of procedure for economical connection of the routes should contain:

- Starting assumptions:
  1. Consider a problem where length of transit routes l_{ij}, $i, j = 0, 1,..., n$ is known. On the basis of l_{ij} route length calculate potential savings in s_{ij} route lengths. Arrange s_{ij} values in reverse order, neglecting all $s_{ij} < 0$;

2. Initially accept that each recipient is served individually, which means that *n* vehicles has been sent to provide services and then *n* routes have been accepted.

- Next it is possible to execute each solution stages:
  - Stage I
    Take highest value of s_{ij} and read indications of recipient numbers. If the set of these value is empty – the procedure ends. The highlighted routes – thus the indicated number of means of transport – make up a suggested solutions.
  - *Stage II*
    Check which position is taken by indicated recipients *i* and *j* in their routes and, depending on their location one either connects these routes or leaves routes unchanged.
  - *Stage III*
    If neither *i* nor *j* do not belong to a number of recipients jointly served, thus they are served individually, create a group of *{i, j}* and check if *[0, i, j,0]* route fulfils conditions of transit permissibility. If the conditions are met, create *[0, i, j, 0]* route. Thus a number of vehicles predicted to serve recipient can be reduced, s_{ij} is crossed out from the list and move to next effectiveness index. If not, also cross out s_{ij}. list and move to another iteration.

A comparison of delivery routes and a number of vehicles necessary for realization of the task is obtained as a result. From the point of view of optimization of the solution, determination of the sequence of individual recipients within the particular route seems to be interesting.
One of the following procedures [2.] can be employed in this case:

1) Furthest connection. Each route, initially having only distribution centre C_0, is connected with the recipient with determination of minimal increase in route length in case of another recipient being associated with the route. This process is then continued until all remaining recipients, previously qualified to this route, are included.
2) Closest connection. Similarly to previous case, allocate recipient to a route which initially has only C_0 distribution centre with determination of an increase in route length in case of associating a particular recipient with the route. The recipient whose allocation causes smallest rise in route length is allocated to the route. Then the process is continued until all remaining recipients, previously qualified to this route, are included.
3) Nearest neighbour. Starting from distribution centre, add nearest recipient to the route and widen the route. At each step, the route is built by extending it over the nearest, in relation to the previous point, recipient. The procedure takes place until all recipients are included.
4) Allocating the recipient clockwise or counter-clockwise. This procedure determines location of recipients on the map and treating distribution centre as central point of the dial, allocate recipients in a clockwise or counter-clockwise way, starting from any point.

Using algorithms for optimization of the transport base, one obtains solution in the form of a determined number of means of transport and transitions routes which enabled serving all the recipient so that total length of the routes for all the recipients is minimal.
Because of rising fuel prices and increasing competitiveness in individual farmers customer service also in fodder market, Chempest Krzepice was chosen by the management for pilot

project to elaborate and implement inexpensive and efficient procedure of transport planning and scheduling.

Before optimisation, the mobile fodder distribution was managed in radius of 15 kilometres from distribution centre to 42 localities containing from 1 to 4 ordering farms in average. Weekly delivery route was divided on fife daily routes with total distance of 572 kilometres and average weekly fodder delivery volume of 6950 kg. The fodder in 25kg paper bags was delivered to farmers, using lorry of 1550 kg total load.

Detailed localities map of fodder distribution in Chempest Krzepice is presented on the Figure 4.

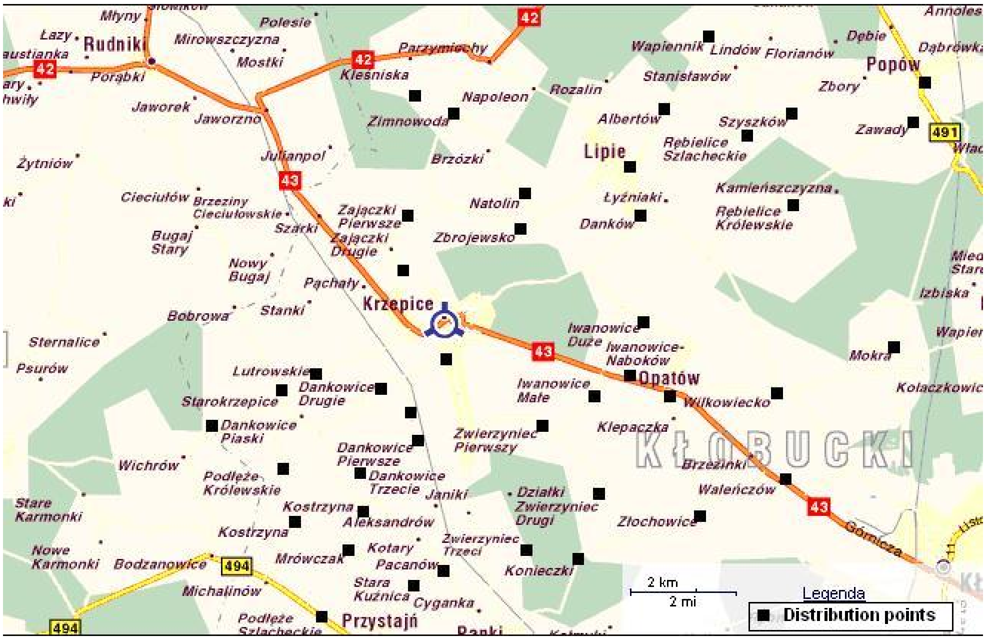

Figure 4. Distribution points in mobile distribution in Chempest Krzepice

Source: Authors' elaboration

Before the verification of performance in transport distribution through optimization of transport scheduling, It must be noticed that there had not been any tools used for planning and scheduling or tracking the vehicle position and the routes had been elaborated and corrected using sale manager experience. His scheduling decision gave the transport efficiency ratio (sale volume/kilometer) – 12,15 kg/kilometer in analyzed 2009. There was deviation in this ratio connected with larger orders in spring season when farmers needed more fodder (rise of efficiency) and with smaller orders after the harvest period (decrease of efficiency).

Preparing procedure of delivery planning and scheduling, the above mentioned theoretical assumption was used. First, the using the "Cartall Mapa Polski" or web based application as www.viamichelin.pl, the minimal distances between particular delivery points as well as between them and the distribution center were found, the data were introduced to the "distance matrix" elaborated in spreadsheet. Then according to procedure the "distance saving matrix"(*S*) was calculated and the average volume of orders in kilograms (d_i) were added. Such prepared data were a base for planning and scheduling the routes according to above mentioned procedures. The determination of the sequence were elaborated basis on the “Closest connection” procedure. Proposed solution consider the lorry total load and the maximal length of route l_{max}=200km, taking into account the average vehicle speed of 25km/h (speed limit zones, the driver is responsible for unload, invoicing and payment receiving as well). The constrains consist also 8 hours work day with 30 minutes break, so we decided to have one full load route each day.

Results discussion

Following the procedures, the five routes have been planned (one for one day of the week), the delivery points on the routes have been sequenced and the routes have been drawn on the map.

The elaborate solution consists 5 routes with total distances amounted to 464 kilometers, so it is 18,9% less then before optimization (572 kilometres). The routes length are various from 55km (route 4) to 132km (route 3). The free loads share are from 3 to 8 percent (except route 4 – last elaborated there was no additional order) to fulfill emergency orders. Also the efficiency in transport have risen using the ration presented above from average 12,15 kg/kilometer to 15kg/kilometer in delivered fodder.

The results of solution was enough interesting for the managers that they decided to implement it in practice and to order such an optimization for other areas of mobile fodder distribution.

This example shows that there is no need for large investment in IT tools to optimise transport processes. There is a possibility to apply simple methods to make transport processes more effective.

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