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**SUGGESTED OPTIMAL NUMBER AND LOCATION OF FREIGHT
TRANSPORT CENTRES**

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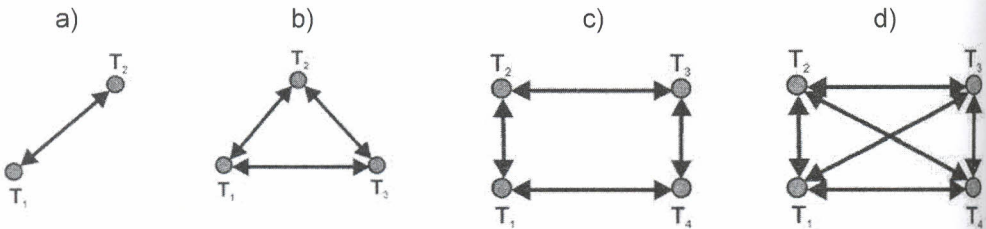
1. Implementation of the system mobiler to the freight transport centres

The Mobiler technology is as reliable as railway transport and flexible as road transport. The system supports and creates new relationships between railway transport operators and road carriers. Determination of Freight Transport Centre functions (hereinafter FTC¹) are derived from activities characteristic of centres for transportation and logistic, industrial zones and requirements for integrated transport (retail) chains in the Czech Republic. A Logistic approach enables optimization of transportation processes as a whole. It means logistic systems of goods circulation management, including storage, packaging, labeling, consolidation and deconsolidation of dispatches, trans-shipment, distribution and transportation. These cannot be implemented without permanently functioning transport systems and therefore transportation is considered to be an integrated element of logistic systems. FTC extends the present function of trans-shipment points in a substantial way and reduces the amount of manpower required. Areas within an FTC centre can also be used for industrial plants location - production

¹ A Freight Transport Centre (FTC) is a centre of intermodal character, which operates a minimum of two types of transport. It is set up according to the overall concept based on regional principle, where more providers render wide range of logistic services to all customers in the region including small and medium- sized companies and the establishment of which is supported by public finance on the basis of the tender. It enables provision of services to all customers without discrimination.

and production services can then expand their main function. Light industrial zones (LIZ) can be identified as a phase of FTC development.

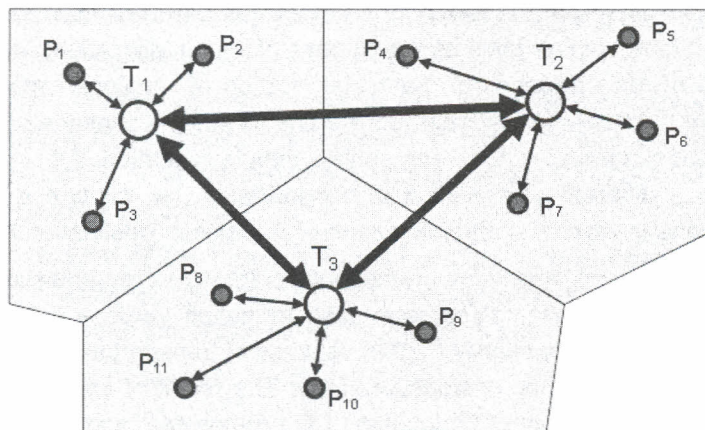
Possibilities of the Mobiler technology implementation to FFC are displayed in the following **Fig. 1** (alternatives a-d). Implementation of the Mobiler technology can be used between two local terminals T_1 and T_2 (alternative a). It is especially appropriate in case of shuttle traffic. Alternative b is the case of triangle tour, where the Mobiler technology units are transported among three terminals T_1 , T_2 and T_3 . In case of four terminals, there is a possibility of the so-called round-robin tour – it means that there is no direct train connection between terminals and so it is necessary to lay out the line through another terminal. Interconnection of all terminals (T_1 , T_2 , T_3 and T_4) can be seen as a specific type of upgrade (alternative d), but for that situation we must assume higher volumes of transportation, which would ensure profitability of running all lines. It is possible to replace the line, when there is not much traffic, by a circular route through another terminal, so that the delay of the transport will be only slight.



Source: Authors

Fig. 1 System of railway lay-outs for the Mobiler technology

When the transportation is carried out through more than two terminals, it is possible to integrate the arrangement Hub-and-Spoke using the Mobiler technology. This is the network interconnection of three or more terminals (see **Fig. 2** with three terminals), with laid-out direct links between them. Individual terminals T_1 , T_2 and T_3 are then interconnected with particular customers (P1-P10) by Mobiler system trucks. In case of three terminals implemented into the system of train connection, it is possible to realize any transportation between two terminals simply using laid out lines demonstrated by the two-way arrows. However, it is not possible to use more than three lines.



Source: Authors

Fig. 2 Schematic demonstration of Hub-and-Spoke system

2. Suggested optimal number and location of freight Transport centres

The lay-out of the ideal number of Freight Traffic Centers and their location, comes out of the presumption that goods transportation on railway lines is carried out on the basis of the "Hub-and-Spoke" arrangement. Model transportation of the full wagon load would proceed as follows:

1. The load is prepared for dispatch from the railway station to the first train formation yard, which serves as a hub.
2. It is transported to the next train formation yard (next "hub")
3. It is transported to the final destination.

When the dispatch station and the destination station lie within the area of the same station (train formation yard), the load is transported from the first station (train formation yard) to the destination, through one "hub". Transportations carried out by more than two train formation yards are not allowed in the model situation, because every other processing or halting of the load in the train formation yard means time delays. This implies that direct trains will be dispatched in every train formation yard to all other train formation yards. Situation diagram is described in **Fig. 1**. Any transportation between two points of junction can be carried out only by using railways demonstrated by two-way arrows, while it is not possible to use more than three railways.

Particular junction points can be assigned to just one "hub" (so-called simple allocation; situation is demonstrated in **Fig. 2**), or they can be located to working zones of several "hubs" (so-called multiple allocation). The advantage of the multiple allocation is in partial elimination of so called "duplicated transport" and so there is a reduction of the objective function value in comparison with the simple allocation; the disadvantage lies in

more complicated organization (transport is not carried out to or from the junction point but only through one junction point as it is in case of simple allocation. The choice of the relevant couple of hubs depends on particular relation of junctions i and j). There also arises a general necessity to dispatch more trains to ensure transportation to and from "hubs". The basic suggested model represents a simple allocation, if it is convenient. It is possible to use a different organization of transportation i.e. through a different "hub", rather than the one to which the attraction zone of dispatch or destination belongs).

The advantage of the above –mentioned transport organization arises from concentration of transportation streams to train formation yards – hubs, which makes transportation possible economically (higher volumes of transportation) and in acceptable time periods (higher frequency of transportation). The result of load processing in train formation yards and possibility of prolonging of the routes can lead to extending delivery times in comparison with direct transportation; that is why it is suitable to organize preferred transportations and transportations on lines with high volume of traffic as certain values H . Each railway is evaluated by the number d_{ij} , which direct transportations (shuttle trains).

The question of optimal location of train formation yards is thus dependent on the question of ideal location of "hubs". The aim of this task is to decide about the location of particular hubs and allocation of attended junction points to these hubs. The traffic network is simulated by a complete diagram G with a set of junctions V and set of railways with represents the distance of i junction from j junction in real traffic network. The volume of the traffic stream from junction i to junction j is labeled as b_{ij} .

Every transportation movement between junction i and junction j consists of three elements:

1. transportation from the junction i to the hub k (collection part),
2. transportation from the hub k to the hub l and
3. distribution of the load from the hub l to the junction j (distribution part).

Direct transportation between junctions that are not simultaneously hubs are forbidden; as well as transportation through more than two hubs is not possible. Transportations through only one hub are allowed, because hubs k and l can be identical (in case that junctions i and j lie within the attraction zone of one hub). Transportation costs for the stream unit from junction i to junction j through hubs k and l are calculated according to the relation $c_{ij} = \chi * d_{ik} + \alpha * d_{kl} + \delta * d_{lj}$.

Parameters χ , α , δ enable distinguishing costs of collection, transportation between hubs and distribution. Parameters χ and δ are usually equal to 1. (It is possible to distinguish collection and distribution costs in some applications). By selecting the value of parameter α , we can reflect the amount of cost savings resulting from transportation concentration between hubs (parameter α value in practical tasks ranges between 0,6-0,7). Transportation costs per unit c_{ij} can be expressed in monetary units by

corresponding values of parameters χ , α , δ ; assuming that the growth of financial costs is linear in dependence on distance in kilometers.

The decision to assign junction i to hub j or not will be simulated by variables h_{ij} . Value $h_{ij} = 1$ means that junction i is assigned to hub j , or else the value of $h_{ij} = 0$. Because every junction k , which became a hub is assigned to itself, the value $h_{kk} = 1$ expresses that junction k is a hub.

In the basic form of the task the number of hubs is given before, labeled as p . Every junction is assigned to just one hub (simple allocation); it means that every transportation to/from this junction is carried out through this hub.

Mathematical formulation of the task is following:

$$\text{Minimize } \sum_i \sum_j b_{ij} \left(\sum_k \chi d_{ik} h_{ik} + \sum_k \sum_l \alpha d_{kl} h_{ik} h_{jl} + \sum_l \delta d_{jl} h_{jl} \right) \quad (1)$$

$$\text{Under conditions: } \sum_k h_{kk} = p \quad (2)$$

$$\sum_k h_{ik} = 1 \quad \text{for } i \in V \quad (3)$$

$$h_{ik} \leq h_{kk} \quad \text{for } i, k \in V \quad (4)$$

$$h_{ik} \in \{0, 1\} \quad \text{for } i, k \in V \quad (5)$$

Objective function (1) expresses total costs (e.g. in tkm, if the transport streams b_{ij} are expressed in tons and distances d_{ij} in kilometers). Condition (2) ensures that we selected just p hubs, condition (3) ensures, that every junction is assigned to just one hub. Condition (4) ensures that all the goods are transported only through junctions, which are simultaneously hubs (that forbids direct transportation between junctions, which are not hubs).

From the group of limiting conditions, condition (2) will be deleted and the objective function (1) is then following:

$$\sum_i \sum_j b_{ij} \left(\sum_k \chi d_{ik} h_{ik} + \sum_k \sum_l \alpha d_{kl} h_{ik} h_{jl} + \sum_l \delta d_{jl} h_{jl} \right) + \sum_k h_{kk} f_k$$

Formulated task belongs to so-called NP-hard problem; This means that its exact solution is restricted to tasks with a very small scope. To solve hub location tasks, heuristic and metaheuristic methods are used. These methods are based on the principle of BBMIP (branch-bound mixed integer programming), theory of neural network, simulated annealing, Tabu Search or genetic algorithms. Efficiency and correctness of existing methods is tested on standard data CAB (Civil Aeronautics Board) and AP (Australian Post) –The first contains data of transport streams from passenger air

transport between 25 biggest US cities, the second gathers data of mail transports between 20 Australian cities. The best existing methods enables finding practically ideal solution in real time for tasks ranging within about 50 junctions. For larger tasks, it is necessary to find an acceptable (sub-ideal) solution to make both ends meet.

Because, there is probably no existing common accessible software enabling solution of the formulated task, it was necessary to create new software. Software HubLoc works on the principle of genetic algorithms, by means of which there have been achieved ones of the best results in the field of optimal location of hubs.

Genetic algorithms serve to find sub-ideal solution of combinatory tasks. The principle of genetic algorithms is simulation of evolution processes in nature, which lies in:

- coding the task solution into the shape of so-called chromosomes (genes are the structural elements of chromosomes) and assigning the fitness value (representing the level of solution quality – it means the value of the objective function) to every chromosome,
- creating initial population (the set of chromosomes),
- choosing individuals for reproduction (on the basis of their fitness value),
- process reproduction (by cross breeding of operators and mutation),
- creating new generation,
- repeating the process of simulated evolution until the required values of the objective function are reached or until the previously defined number of generations is reached.

The task was solved without considering fixed costs for building or running a train formation yard. All the junctions were equal and existing train formation yards lost their advantage of lower fixed costs (expenses). The task was solved alternatively for numbers of located train formation yards ranging from 3 to 12. Acquired solutions thus represent a lower limit of the objective function for particular numbers of located train formation yards.

Transport streams between particular junction railway stations were considered in numbers of wagons. Values of parameters χ , δ were equal 1, value of parameter α was set 0,7 (for comparison we carried out calculations also for value $\alpha = 0,6$, with similar results). We considered simple allocation. This means that every junction was assigned to the attraction zone of just one train formation yard. The experiment verified that, in the case of multiple allocation of junctions to train formation yards, the final optimal location of train formation yards more or less differs. Nevertheless the quality of the solution, acquired on the basis of simple allocation, is not far from the ideal solution corresponding to multiple allocation. In other words – the results acquired from the solution of the simple allocation task represent quality solution even for the case of multiple allocation.

Individual solutions were analyzed in details, while following criteria were monitored:

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Suggested optimal Number and Location of Freight Transport Centres

- sufficient intensity of freight traffic volume (at least 20 trains per day),
- acceptable number of relations created between train formation yards,
- acceptable average extent of the transportation effort when ensuring freight collection to train formation yards and distribution from them.

Considering the above-mentioned criteria, we selected, as a suitable solution, the alternative with 7 train formation yards. It is possible to organize goods transportation (with the above mentioned number and location of train formation yards) as the model „Hub-and-Spoke“. Program output for 7 hubs, when processing data file A, looks as follows: Břeclav, České Budějovice, Kolín, Ostrava, Plzeň, Přerov, Ústí nad Labem. Regarding the existing infrastructure, there were carried out corrections in some stations: Břeclav → Brno-Maloměřice, Kolín → Nymburk, Ústí nad Labem → Most. Quality of the objective function got worse for 1,6 % (from 222,25 to 225,89). Considering a relatively high frequency of transportation between suggested train formation yards, it is possible to introduce the system of small quantity shipment.

Tab. 1 Suggested location of train formation yards using the arrangement „Hub-and-Spoke“

Suggested location of train formation yards:

Brno-Maloměřice, České Budějovice, Nymburk, Ostrava, Plzeň, Přerov, Most

Source: Authors

Tab. 2 Rate of dispatched trains among train formation yards (percentage of the total number of transported wagons)

Brno-Maloměřice	České Budějovice	Most	Nymburk	Ostrava	Plzeň	Přerov
13 %	8 %	11 %	24 %	23 %	8 %	12 %

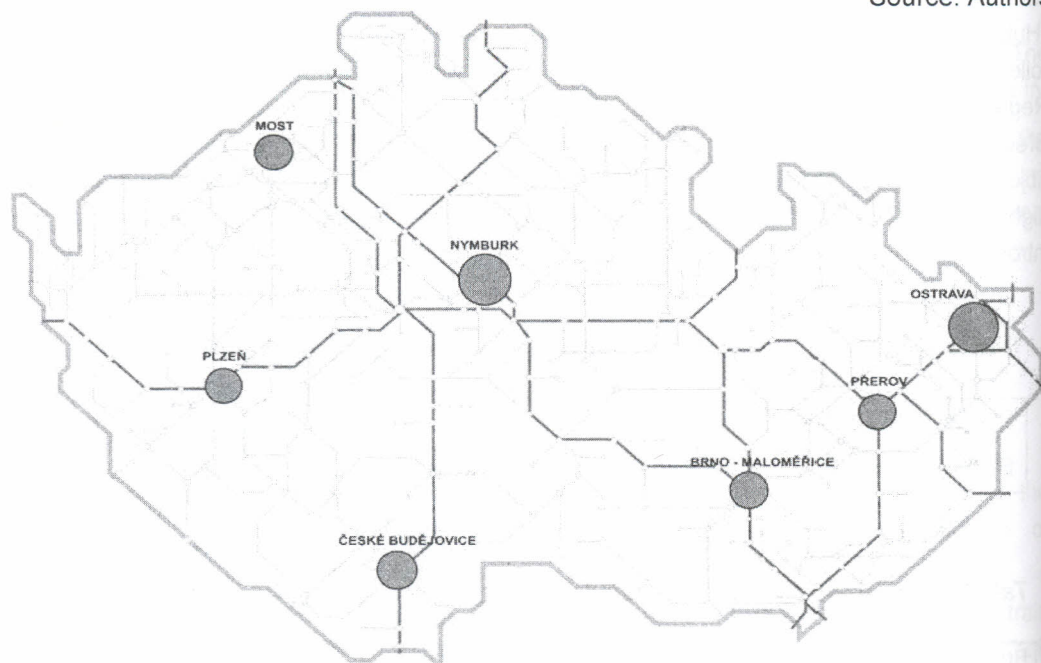
Source: Authors

When the number of train formation yards is lower, then the distances for freight collection to hubs and their distribution are quite high. This disadvantage can be eliminated by introducing the system of secondary sorting stations, permitting direct transportation between them. This is a different kind of organization than the considered arrangement „Hub-and-Spoke“. While correcting location of train formation yards, considering existing infrastructure, it is possible to select suitable location of a smaller number of main train formation yards, which are presented in **Tab. 3**.

Tab. 3 Selected location of a smaller number of train formation yards when introducing the system of secondary train formation yards.

Number of main stations	Possible location of train formation yards
3	Nymburk, Ostrava, Přerov
4	Most, Nymburk, Ostrava, Přerov
5	České Budějovice / Plzeň, Most, Nymburk, Ostrava, Přerov
6	České Budějovice, Most, Nymburk, Ostrava, Plzeň, Přerov

Source: Authors



Source: Authors

Fig. 3 Location of train formation yards

When the number of train formation yards is higher, then the intensity of the freight traffic volume decreases to under 20 trains per day (for 8 train formation yards the intensity is, in case of 5 relations, under this limit – when processing data file A) and the requirements for the train formation yards effectiveness goes up (in accordance with the number of relations being created, the absolute number of processed wagons decreases). However, the suggested arrangement „Hub-and-Spoke“ becomes ineffective. Presented optimization of number and location of FTC is one of the examples of using mathematic methods in transportation. Regarding the fact that this issue is very wide, we presented only the main points of the approach leading to Freight Transport Centre optimization. There are many other aspects, which could be included into this model. However, this is the subject of further solution development of this question.

3. Conclusion

The Mobiler technology is characterized by its reliability as much as the railway transportation and flexibility as trucks in road transportation. This system supports and creates new relations between railway operators and road carriers. It is possible to use the FTC to introduce this system in Czech conditions. The presented optimization of number and location of FTC is one of the examples of using mathematic methods in transportation.

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Resumé

NÁVRH OPTIMÁLNÍHO POČTU A ROZMÍSTĚNÍ CENTER NÁKLADNÍ DOPRAVY

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Příspěvek se zaměřuje na problematiku center nákladní dopravy, jejich základní charakteristiku a úlohu v logistickém řetězci. Hlavní částí příspěvku je optimalizace počtu těchto center a jejich lokace. K řešení bylo použito metody genetických algoritmů. Součástí příspěvku je možnost využití nové přepravní technologie systému Mobiler, který by byl v těchto centrech aplikován.

Summary

SUGGESTED OPTIMAL NUMBER AND LOCATION OF FREIGHT TRANSPORT CENTRES

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Authors in this paper describe the centre of freight transport, their characteristics and function in logistics. Main of paper is the optimization and location of centres. For the solution of this problem has been used the genetic algorithms.

Zusammenfassung

DAS KONZEPT DER OPTIMALANZAHL UND DER LOKATION DER GÜTERVERKEHRZENTREN

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In diesem Beitrag sind die Güterverkehrszentren und ihre Aufgabe in Logistik präsentiert. Der hauptsächlichste Teil des Beitrags ist Optimierung der Anzahl dieser Zentren und ihre Lokation. Für die Lösung wurde die Methode des genetischen Algorithmus benutzt.