SMALL SHIPMENT SUSTAINABLE DELIVERIES WITHIN AND BETWEEN CITIES

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Abstract. The paper deals with small shipment delivery-planning problems either within cities or between cities. The small shipment delivery planning is a corner stone for forwarders, couriers, express-mail companies, retailers, wholesalers and other companies, which are responsible for delivery processes. It is significant to plan the delivery by optimal way, reducing both rates – time and cost of delivery. It is important to satisfy customers' needs simultaneously. Pendulum route planning is the main problem for small cargo delivery planning between cities. It is necessary to choose the best transport mode combination, the most appropriated hub, the best route and the best forwarding company. Small shipment delivery planning in cities has another problem. Despite of the smaller transportation distance, it often takes more than half into total delivery costs. Smaller vehicles are used in transportation within cities. Hard intensity of traffic, great number of customers and cargo loading circumstances make the delivery problem more difficult. Managers have to plan efficient transportations. The author of the paper recommends analyzing the specification of demand at first to choose the most appropriated strategy of delivery. It is expedient to divide the route into separated blocks; picking out the main mode of transport, the best hubs into the route as well as last 500 kilometer problems of delivery (*FHD problem – the main novelty of the paper*) planning. Then it is necessary to find the solution for the last 50 kilometer delivery and, finally, to solve the last mile delivery problem.

Keywords. small shipments, delivery, transportation, road transport, cargo, FHD method.

Introduction

When analyzing material flows and trading routes it is obvious to find that these are different in different regions and countries. For example, economic development level of European countries is different today; each country has particular needs for different resources; export and import also are different for each country.

Final production, especially micro-small cargo (1-20 kg heavy packs) or small cargo (which does not exceed 1 FCL) may be delivered to customers using different transport opportunities today. This branch should be developed and improved, optimizing the route planning process, improving logistics service quality, enhancing the quality of roads, railroads, and air and sea transport infrastructure, involving state, private and international investments to develop the transportation system of different countries.

There is a time factor and place unity of international or inter-cities transportation service nowadays. The time factor is extremely significant, because specification of international transportation is as follows: if the transport enterprise does not satisfy the demands, it may lose customers. So, the transportation beginning should be very accurate [1]. Also, transportation finish moment should be precise. Only in this case both the cargo consigner and recipient may be satisfied. One of the most important quality ratios of the transportation process is the period of delivery. This is very significant both for cargo and for passenger international transportations, because time is money, but it is difficult to spend the transportation process time with use. So, fast transportation service normally is more expensive than large cargo transportation using slow modes of transport.

It is important to note that logistics creates an additional value (VA). It is significant for customers, for forwarders, for manufacturers as well as for trading enterprise shareholders or owners. The additional value of the logistic process expresses itself as place and time factors. Goods and services have no value, if these are not located in the time and place where they can be consumed. If the logistic system is developed, each additional operation provides increased added value. The more precisely the particular route is planned; the shorter is the process time without VA [2]. For instance, if the enterprise reduces goods warehousing time, it is possible to improve VA in general. It is possible to use Just-in-Time system elements to improve the logistic process planning.

If the particular logistic process element does not provide any added value, then it is necessary to evaluate if this element is needed for the whole process at all [2; 3]. Anyway, the additional value exists when the customer is ready to pay additional money for products, more than the actual costs of the products and delivery.

The business environment analysis nowadays shows that there are some additional requirements for the deliveries within and between cities – for instance, safety, regularity, continuity and rhythmical pace. It is extremely important to plan both types of deliveries by optimal way.

Between-cities small cargo delivery planning problem

Delivery between cities as well as international deliveries are often planned, using the pendulum route principle. It is connected with various planning problems:

- large distance between cargo consignor and consignee;
- combinations of transport modes;
- combination of transport modes and terminals;
- safety problem;
- expensive transportation of small-cargo;
- delivery time and lead time uncertainty.

Large distance between the cargo consignor and consignee usually requires a special approach of planning not only deliveries, but also other logistics operations, such as acquisition and inventory, purchasing and warehousing, etc., because of the expanded delivery time for large distance.

How to choose the best transport mode or the transport mode combination – this problem is extremely important when a lot of transport mode combination opportunities are available.

Combination of transport modes and terminals- couriers are express mail delivery typical problem, as well as other companies which have a lot of terminals into particular territory.

Safety of cargo during transportation – cargo has not to be damaged during delivery processes between cities.

It is well known that small cargo transportation average delivery cost is higher than full-cargo transportation average delivery cost.

These five problems are investigated into publications quite often; while the last problem often is a corner-stone of delivery planning between cities.

Lead time uncertainty requires necessity to create additional guarantee inventory. The level of inventory is connected with the accuracy of a particular supplier's operations in general and for particular process elements.

Too fast deliveries sometimes also provide a negative effect, so the company should find new ways how to reduce delivery lead time dispersion. Actually, both forwarder and cargo recipient enterprises should come to an agreement about requirements for precise delivery; what level of dispersion is not the critical one. Usually, the cargo recipient company wants to reduce delivery lead-time dispersion, but the forwarder or supplier wants to increase it (Fig.1).

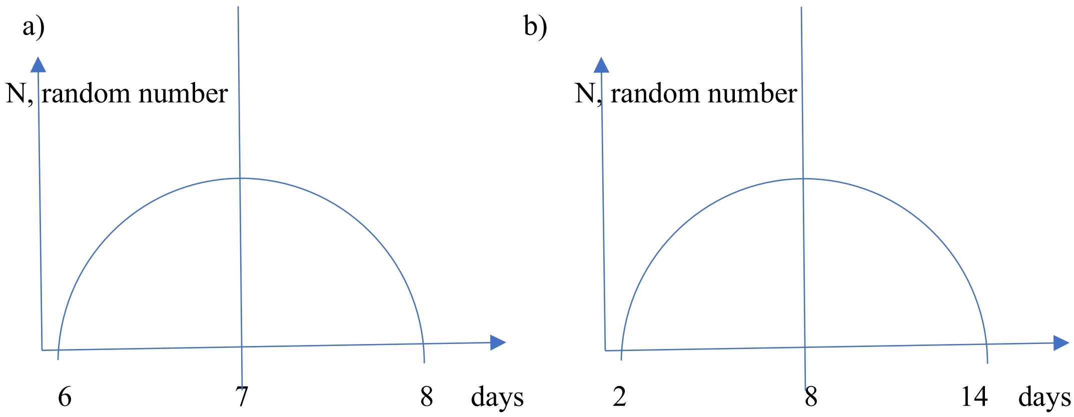

Fig. 1. **Evaluation of accurate international delivery from cargo supplier or forwarder (a) and the consignor's (b) opinion**

In accordance to Figure 1, the consignor would like to conclude an agreement where accurate delivery is after 6 days from the moment of order with 7 days dispersion (from 6 to 8 days), but cargo supplier is going to expand the dispersion to 6 days (between 2 and 14 days) [1]. According to the investigation of the real data, when an enterprise provides international transportation in real life, delivery time dispersion may be more than 6 days, because delivery lead-time consists of various elements, and each of them has its time dispersion. It is necessary to plan the time uncertainty factor for each element of delivery between cities to reduce the total delivery time dispersion.

Accurate delivery planning in cities

When planning deliveries in cities, the delivery time dispersion is measured using hours, not days; so it is necessary to plan delivery moments very accurate, to organize the best deliveries and satisfy the customers' demand.

Many authors investigated these problems; there are well-known problems like Vehicle-routing problem (VRP), Street-Routing problem (SRP), Travelling salesman problem (TSP) and others. When planning goods deliveries within a big city, it is important to note the level of traffic intensity on particular roads. SRP (Street Route Planning) problem is very important for route planning specialists of the EU big cities with intensive traffic.

Actually, the transport problem is a well-known network optimization problem, first created by F.Hitchkok (1941). The goal was to find the optimal costs of distribution plan for one product delivery, multiplying it with quantity of the product to find each channel and source capacity for each recipient.

Many authors and researchers have worked out different methods and algorithms to solve NTP. As regards approximate heuristic optimization methods, genetic algorithms (GA) by Holland (1975), tabu search (TS) by Glover (1977), particle swarm optimization (PSO) by Kennedy and Eberhart (1995).

Many specialists solve these problems, using also linear programming models. For instance, Cao (1992), Dangalchev (1996), Bell et al. (1999), Kuno and Utsunomiya (2000), Dangalchev (2000) and Nagai and Kuno (2005) [4].

However, research effort has been also devoted to nonlinear programming (NLP) techniques for the optimum solution of NTP. For instance, Michalewicz et al. (1991) have applied the reduced gradient (RG) method to obtain the optimal solution of these problems.

Not only transport mode combinations, specification of the route of factors connected with vehicles, but also specification of cargo flow, location of cross-docking places, distribution centers and forwarders influence the transportation process total time and accuracy. It is important to decide, if the company uses its own transport or buys transportation service from other enterprises. It is essentially important to organize fast and precise deliveries, because these criteria often are the main measure of delivery quality. Anyway, it is necessary to analyze all factors influencing the delivery time; so the author investigates different factors and theories, which influence delivery accuracy and time, such as the number and location of forwarders and suppliers in the territory served.

Non-compliance between the number of vehicles and the speed of infrastructure developments today creates vehicle moving speed irregularity, which is significant for different parts of roads, days of the week and hours of a day. Simultaneously development of trading within a city creates additional requirements to deliver goods to enterprises and retailers on time.

Actually, it is necessary to provide customers with high-level delivery service using forwarders' vehicles. To solve this task in an optimal way, it is important to investigate the city infrastructure in details. The forwarder should evaluate which methods are appropriate to use to plan routes both within cities and between cities [5].

For example, the intensity of traffic in particular streets of Riga city is changing, too. There are approximately 100 bridges in Riga, as well as other infrastructure objects, from which 36 are in good condition, 46 – in satisfactory condition, but 17 - in unsatisfactory condition. During road work hours it is impossible to use these objects for transportation.

It is necessary to know the most problematic hours of the day when planning the transportation process in a city, when the number of vehicles in a city is huge and traffic congestions are in many places. Usually, traffic congestions are connected with population working day beginning and end.

Working days are hard for route planning. For instance, traffic congestion hours in Riga center usually are between 5.00 and 7.00 p.m. The same situation is in the mornings.

Often it is not expedient to apply the “classical” route planning methods for city transportation; it is not effective because of the city traffic intensity specifics. Both computer programs, mathematical and other methods may not provide the optimal planning result, because the intensity of traffic in Riga changes depending on the hours of the day.

The time for cargo unloading process also influences the total delivery lead time. This ratio may change not only depending on the particular object capacity, but also on the quantity of cargo, number of forwarders near the object (in the queue) as well as the serving hours of the object.

Inaccurate deliveries stimulate customer dissatisfaction and provide idle time (if deliveries are too late) and too high costs for the manufacturer. Too early delivery also is connected with a negative effect, for example, if a company uses some principles of JIT system, it requires frequent deliveries of small quantities of goods, and if production is delivered too early, there may be not enough place to put it.

Table 1

Efficient in-city delivery planning factors

Factor of efficient delivery planning within city	**Specification/ description**
Choose the strategy of delivery	Firm vehicles or outsourcing
Main requirements of customers	Depending on the requirements, may plan delivery: - Minimizing total costs; - Minimizing total run; - Minimizing total time
Demand, intensity of demand	Analyze structure of demand, as well as customers’ location, importance of customer, number of deliveries per period, type/quantity of cargo needed to the customer
Delivery, time windows	To plan successful deliveries, it is necessary to plan the particular delivery time or time window to provide the optimal delivery
Capacity of vehicle	Limiting factor
Unstable intensity of traffic	Additional limiting factor
Unloading circumstances	Additional limiting factor; total unloading time often takes more than ½ into total delivery time

After investigating the modern logistics requirements for transportation, we may conclude that efficient delivery planning between cities as well within cities is a complex process (Table 2). It is necessary to generalize information about traffic intensity in streets, the average speed of vehicles in streets depending on days of the week and hours of the day, to divide “hot places” - where the intensity of traffic is very unstable.

Transportation efficiency improvement in the conditions of economic globalization is the main direction of logistic development. It is possible to realize it by minimizing the blocked fund amount during the transportation process as well as by providing JIT deliveries [6-8]. Different factors such as the traffic intensity increase, infrastructure development level and others influence delivery time minimization as well as precise delivery planning. As a result, the intensity of traffic is a changeable ratio for different streets, days of the week and hours of the day.

The author of the paper has worked out the efficient approach, which helps connect deliveries between cities into one system with deliveries into cities and solve these problems in one model.

Last five-hundred kilometer delivery (FHD) problem

Various authors investigate last-mile delivery problem. A lot of researches analyse last 50 miles delivery problem. Actually, it is extremely important to work out and analyze the delivery of last 500 hundred kilometers because of the following reasons.

- Last 500 kilometer delivery (FHD, *novelty of this paper*). Let us explain why it was the last 500 kilometers delivery? Simply, it is the maximal average optimal distance for cargo to be delivered by road transport per 1 day by one driver in accordance to the AETR Convention. Of course, it is possible to use road transport also for longer distance transportation, but it is no expedient. No one has defined this problem before, analyzing small shipment sustainable delivery within and between cities, while a lot of researchers write about the last-mile delivery problem.
- Transportation between cities for long distances require a lot of combination, joining some modes of transport into one network. Therefore, for instance, main transportation modes and hubs often are known without additional analysis. (For example, transportation between Asia and Europe, Asia and America, Europe and America).
- Last (from the seaport) 500 kilometer delivery usually has a lot of opportunities how to plan the optimal transportation process to satisfy customers' needs by optimal way.

It is expedient to use the following *FHD solution algorithm* to provide the optimal delivery for the last 500 kilometer delivery. The method allows finding the optimal hubs or terminals within the delivery system and connecting them with the most appropriated modes of transport. The method is good for combined transportation delivery. The algorithm consists of 7 steps (see Figure 2):

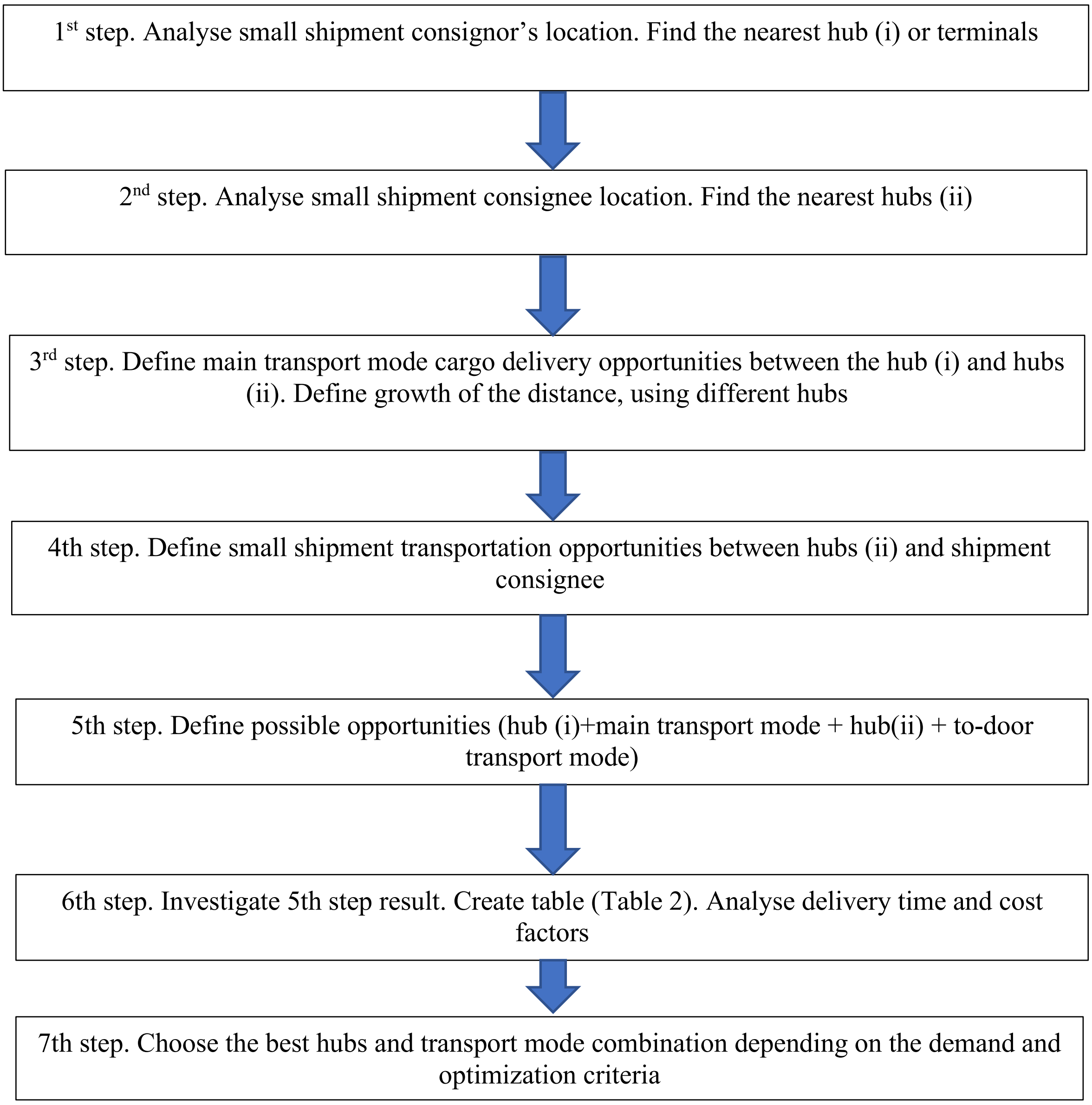

Fig. 2. **FHD solution algorithm – step by step**

Table 2 illustrates the usage and explanation of FHD solution algorithm. The author recommends comparing the main elements of the delivery, which are different into different combinations. It makes no sense to add also X0, because it is constant into all analyzed combinations.

Table 2

Usage and explanation of FHD solution algorithm

Find the distance between small cargo consignor and the hub (i), km		0	X0	X0	X0	X0
Find (ii) hubs Number of (ii) hub		1	(ii hub) 0	(ii hub) 1	(ii hub) 2	(ii hub) 3
Cumulative distance between (ii) hubs, km (main transport mode)		2	0	+ X1	+ *X2*	+ Xn
Cumulative costs of the main mode of transport, (between (ii) hubs), delivery hub(i) – hub (ii)		3	0	+ T1x	+ *T2x*	+ T3x
Distance between hubs (ii) and small shipment consignee		4	d1	d2	*d3*	dx
Total delivery costs, EUR	Second mode of transport costs, EUR (delivery hub(ii) - consignee)	5	T1y	T2y	*T3y*	T4y
	Total costs: delivery hub(i) – hub (ii) + delivery hub(ii) - consignee)	6	(3) + (5)	(3) + (5)	(3) + (5)	(3) + (5)
	N(ext) modes of transport costs, EUR (delivery hub(ii) - consignee)	7	T1n	T2n	*T3n*	T4n
	Total costs: delivery hub(i) – hub (ii) + delivery hub(ii) - consignee)	8	(3) + (7)	(3) + (7)	(3) + (7)	(3) + (7)
Total delivery Time, h		9	T1	T2	T3	T4

The last step of optimization: find the minimal meaning into 6 and 8 column to define the best transport modes and the best hub combination to optimize transportation costs. Find the minimum into the last (9) column to identify the minimal delivery time.

The author concludes that the FHD solution algorithm allows to find the optimal route especially for the last 500 kilometer delivery, especially for the situation where there are a lot delivery opportunities, using delivery terminals and different modes of transport.

The algorithm allows, "connecting" the optimal terminals with the most appropriate modes of transport within the particular route.

It is possible to use the FHD solution algorithm also for longer distances (2000 km and more) as well as for full cargo delivery to find the best solution (see the example), but the problem often is too easy-to-be-solved in this case.

Example of FHD algorithm usage

It is necessary to transport one TEU cargo from Victoria Station Bank, Manchester, England to Riga, 88 Deglava Str., Latvia (providing to-door transportation), choosing the best sea-ports and the best transport mode combinations.

The following data known (Table 3):

Table 3

1 TEU transportation information

Factor	Factor meaning
Auto transport tariff	0.5 EUR·km^{-1}
Sea transport tariff	0.2 EUR·km^{-1}
Rail tariff:	0.25EUR·km^{-1}
From Victoria Station Bank to Tilbery port (hub (i)) by auto transport, mileage	365 km

Distance between Victoria Station Bank and Tilbery port (hub (i)) (auto transport) is 365 km (Fig. 5).

The author is going to compare following hubs (ii) opportunities: seaport Klaipeda, seaport Liepaja, seaport Ventspils, seaport Riga and seaport Tallinn (Table 4 illustrates the FHD algorithm usage to solve the given example).

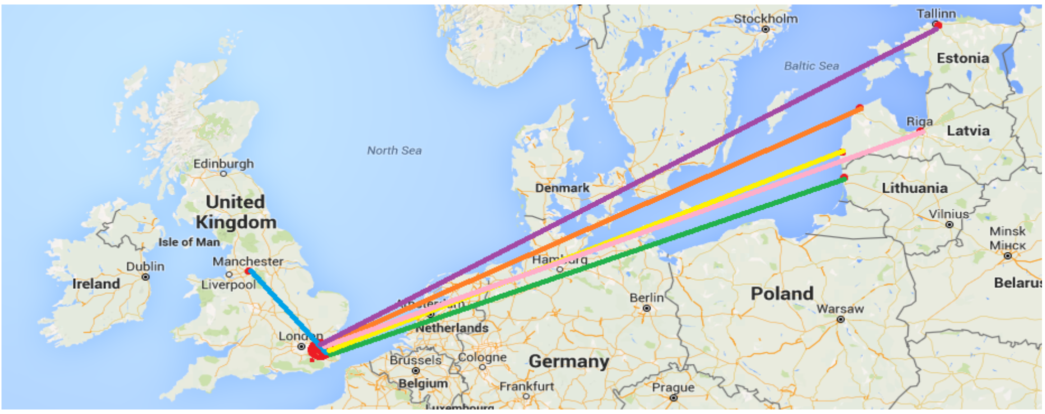

Fig. 5. **Possible schemes of transportation: consignor – hubs (ii)**

Figure 5 illustrates the route by the main mode of transport from the hub (i) to the possible hubs (ii).

Table 4

FHD algorithm usage for transportation England – Latvia

Victoria Station Bank – Tilbery port (auto transport)	= 365km * 0.29 = 105.85	105.85	105.85	105.85	105.85
Hubs/sea-ports	Klaipeda	Liepaja	Ventspils	Riga	Tallinn
Cumulative distance between (ii) hubs, km (main transport mode)	0	+ 100	+ 220	+ 310	+ 615
Sea-transport cumulative cost, EUR	0	+ 50	+ 110	+ 155	+ 308
Distance between hubs (ii) and small shipment consignee km	290	230	200	20	305
Auto transport costs, EUR (delivery hub(ii) – consignee)	232	184	160	16	244
Total costs: delivery hub(i)– hub (ii) + delivery hub(ii) – consignee)	232	234	270	***171***	552
Rail transport costs, EUR (delivery hub(ii) – consignee)*	x	x	x	**x**	x
Total delivery, days	3 days	3 days	3 days	***3 days***	4 days

**rail transport may not provide to-door delivery to the given address, so rail transportation is not investigated in the task*

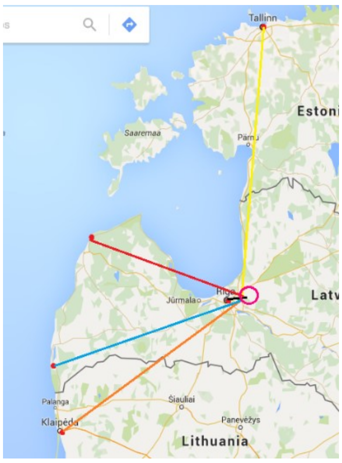

Fig. 6. **Possible schemes of transportation: hubs (ii) – consignee**

Analyzing Table 4, we may conclude that the cheapest combination is sea transport + auto transport, sending cargo through Riga sea port (171 EUR). Delivery time: 3 days.

Conclusions

1. Customers require accurate transportation, so it is necessary to plan both between-cities deliveries and within – cities deliveries by optimal way, using the most appropriated methods and techniques.
2. Last five-hundred kilometer delivery (FHD) problem is especially important organizing deliveries from America to Europe or from Asia to Europe; because last 500 kilometers are the most "difficult" for delivery planning.
3. The FHD solution algorithm allows finding the optimal route especially for the last 500 kilometer delivery, especially for the situation where there are a lot delivery opportunities, using delivery terminals and different modes of transport.
4. The algorithm allows, "connecting" the optimal terminals with the most appropriated modes of transport within the particular route. It is possible to use FHD also for longer distances (2000 km and more) as well as for full cargo delivery to find the best solution (see the example), but the problem often is too easy-to-be-solved in this case.
5. It is expedient to combine the FHD solution algorithm with known solutions of the last-mile delivery problem, last fifty mile delivery problem and others. The example about the algorithm shows that the FHD solution algorithm is very effective and quite simple to be used into practical business environment, finding the optimal route with minimal cost (171 EUR) and delivery time (3 days).

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