SMALL SHIPMENT DELIVERY'S QUALITY IMPROVEMENT IN CITIES WITH UNSTABLE TRAFFIC

Pavels PATLINS
Faculty of Engineering Economics and Management
Riga Technical University,
1st Kalku Street, Riga, Latvia
pavels.patlins@rtu.lv
Remigijs Pocs
Faculty of Engineering Economics and Management
Riga Technical University,
1st Kalku Street, Riga, Latvia
Remigijs.Pocs@rtu.lv

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ABSTRACT

The paper deals with small shipment delivery planning problems for cities with hard and unstable or intensive traffic. The problem is very significant today especially for big cities. When planning road transportation and routes within a big city it is expedient to work out the optimal system and achieve the best result. The most important criteria is a ratio customers' demand satisfaction – it is not enough to plan minimal transportation costs or vehicle's run only.
Total delivery time as well as a rate of accuracy often is a corner-stone factor, which influence the quality of delivery. It is necessary to choose the best order how to serve customers into each circular route.
The authors divide small shipment delivery problem into two groups – "problematic" and "non-problematic" routes planning (depending on the traffic intensity in the particular city). The authors of the paper recommend using of the minimal growth method (MGM) to improve vehicle route planning problems especially in cities with intensive traffic.

INTRODUCTION

Local deliveries planning specificity connected with the various restrictions as well as with the fact that small-quantity loading and transportation management is different from full-cargo transportation.
Actually, small shipment delivery problem is extremely important step into the total logistics chain (figure 1). Intercity (also international transportation) usually managed as simply-scheme FTL (full truck load) transportation, whereas local transportation often may be planned using circular route scheme.
Circular routes connect more than 2 points within one route, namely, the forwarder should take cargo from the consigner and deliver small quantity of cargo to a great number of recipients (multi-drop route).
This is daily problem for forwarders, trading companies and manufacturers in big cities.

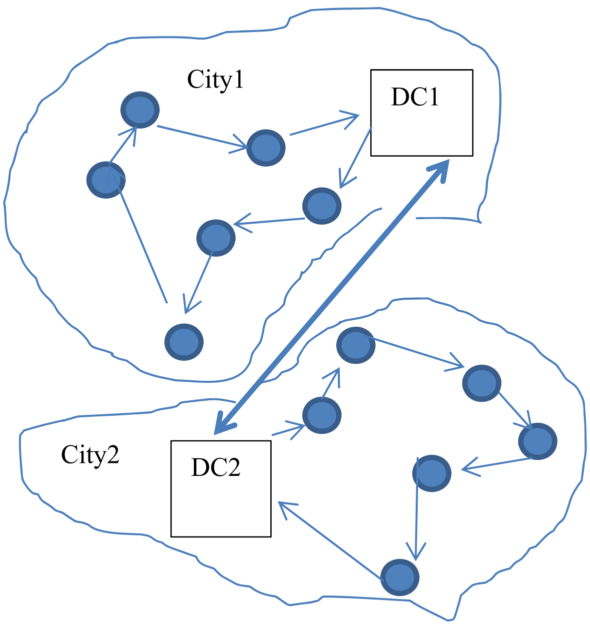

Figure 1. Intercity and city transportation's scheme.
DC1- Distribution centre of the first city (e.g. – wholesaler's warehouse);
DC2- Distribution centre of the second city (e.g. – wholesaler's warehouse);

Intercity transportation;
Transportation in cities.

The total delivery time on the j multi-drop route (from j-consignor to the customers assigned to him) is determined by using the formula:

$$T_{Tj} = t_{Lj} + \sum_{i=1}^{k}(t_{LD_{ij}} + t_{UN_{ij}}) + t_{R_j}\,, \qquad (1)$$

where t_{Lj} - j-consignor loading time, h; $t_{LD_{ij}}$ – the time while driving car on the i-length of j-multi-drop route (from i-1 to i-route point, where zero point is the depot or loading point),h; $t_{UN_{ij}}$ – unloading time at i-consumer on j-multi –drop route,h; k – the number of unloading points on j-multi-drop route; t_{R_j} - return journey time to j-multi-drop route,h.

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It should be noted that the delivery time depends not only on the forwarders' planning, but also on the management system of suppliers and consumers, particularly on their schedule (the number of breaks, length of dinnertime, etc.). The logistics approach of time modelling for transportation services necessitates the coordination between the motor transport and working schedule of the suppliers and cargo consumers, talking about the JIT(just-in-time) fulfilment of motor transport contractual obligations to the customers and suppliers. So, the corner-stone of planning is to determine the delivery time of the daily load just in time. So, the vehicle initial time may be determined, using following formula:

$$T_{in} = T_{JIT} - \sum_j T_{oj} - T_{i.r.}^1 , \qquad (2)$$

where T_{JIT} – the time of delivery of the "contractual" volume of goods JIT, h;
$T_0 = \sum_j T_{oj}$ – consumer goods delivery total time, h;
$T_{i.r.}^1$ – idle running time (from the motor carrier to the first point of loading),h.
All components of the formula 2 are random values. While determining the total delivery time on j-multi-drop route and realizing statistic modelling, it is necessary to take into account the work of supplier and a consumer, in particular, start and end time of the technological breaks of clients. So, the formula 1 should be transformed as follows:

$$T_{oj} = t_{Lj} + \sum_{i=1}^{k}(t_{LD_{ij}} + t_{UN_{ij}}) + t_{R_j} + \eta_j + \sum_{i=1}^{k} \psi_{ij}, \qquad (3)$$

where η_j – the random component, taking into account j-supplier's technological breaks, h; $\sum_{i=1}^{k} \psi_{ij}$ – random component, taking into account j-supplier's technological breaks assigned to j-consumer, h.
Thus, in a real life it is a difficult and complex task to plan accurate deliveries in a big city with intensive traffic.
There are many special methods and algorithms to optimize circular route planning and reduce delivery costs as well as vehicle's run and transportation costs. Various authors investigated it. Often it is impossible to provide the needed result, because use of these methods is connected with the following problems:
- it is impossible to provide accurate result;
- it is impossible no satisfy customers' individual needs;
- it is impossible to take into account traffic intensity changes depending on days of the week and hours of a day.

The authors suppose that various computer programs often provide non-optimal solution to transport problem due to different restrictions; on the one hand, it is possible to use only these programs to solve theoretical problems.
On the other hand the real situation is changing daily, because demand is not stable, it is possible to use heuristic methods. But in a real life many computer programmes are used in combination with heuristic method to achieve the optimal result. Because of lack of information, criteria of optimization used in practical conditions often are vehicle's run and transportation costs, not delivery time factor.

REVIEW OF LITERATURE

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 product to find each channel and source capacity for each recipient.
When transportation costs of the given route are non-linear dependent on the quantity of production for transportation, this problem becomes a non-linear transportation problem. To find the optimal solution for this problem (NTP), it is necessary to make many investigations in logistic management. Many heuristic methods as well as mathematical program methods are created to solve NTP problems.
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 NTP, 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). However, research effort has been also devoted to nonlinear programming (NLP) techniques for the optimum solution of the NTP. For instance, Michalewicz et al. (1991) have applied the reduced gradient (RG) method to obtain the optimal solution of the NTP.

NEW CONCEPTS OF SMALL SHIPMENT HIGH-QUALITY DELIVERY'S PLANNING IN CITIES WITH UNSTABLE TRAFFIC

The authors divide transport network optimization models using the following classification (figure 1):

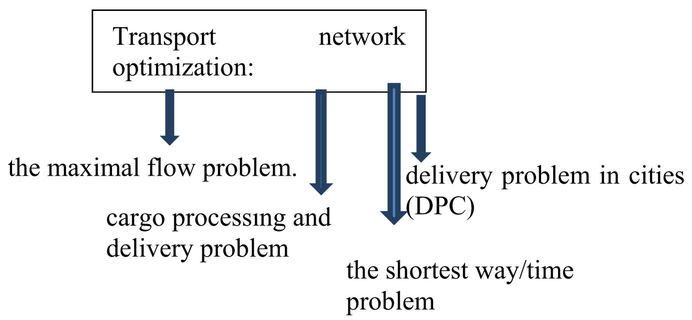


Figure 2. Transport network optimization models.

So, the main transport network optimization problems are:

a) cargo processing and delivery problem;
b) the shortest way/time problem;
c) the maximal flow problem.
d) delivery problem in cities

The authors divided (b) and (g) like separated problem, because usually it is necessary to use the special approach to solve it in a real life.

Delivery problem in cities (DPC) description is following. It is necessary to deliver the particular amount of goods Q through the known-before route with n roads' segments, providing particular m objects with the needed d_j units of cargo.

$$\sum_{j=1}^{m} d_j = Q \qquad (4)$$

The most important is the restrictions of the model: each road segment distance is known before, but the speed of a vehicle in each road segment i may be different depending on the day of the week or hour of a day as well as amount of cargo qi may change for objects m; unloading processes labour-intensity also changes as a result of the different objective circumstances.

Of course, there are many known methods and algorithms to optimize circular route planning and reduce delivery costs as well as vehicle's run and transportation costs, but these usage often is not efficient to plan goods deliveries in cities by optimal way due to traffic intensity fluctuation by hour of a day or day of a week. In additional, often it is impossible to provide the needed result, because use of these methods is connected with the following problems: using the method is work-consuming or it is impossible to provide neither accurate result, nor satisfy customers' individual needs, nor take into account traffic intensity changes depending on a day of the week and hour of a day.

The authors conclude that computer programs often provide non-optimal solution to transport problem due to different restrictions; on the one hand, it is possible to use only these programs to solve theoretical problems. On the other hand the real situation is changing daily, because demand is not stable, it is possible to use heuristic methods. But in a real life computer programmes are used in combination with heuristic method to achieve the optimal result. Because of lack of information, criteria of optimization used in practical conditions often are vehicle's run and transportation costs, not delivery time factor.

Traffic intensity uncertainty makes inefficient a usage of traditional route planning and optimization methods (for cities), based on vehicle's run or transportation costs minimization, assuming that vehicle's speed is fixed or constant. Therefore, it is necessary to use special approaches and new technologies, to solve delivery problem in cites in the real life.

After that managers may plan circular routes to serve a couple of customers within one route. Planning of the optimal customers' serving order allows improving of small shipments delivery system especially in cities with hard traffic. Problems like VRP (The Vehicle Routing Problem), TSP (Travelling Salesman Problem), SRP (Street Routing Problem) also are known for a long time and often require individual solution for the particular situation. It is expedient to use Minimal Growth Method (MGM) to plan optimal customers' serving order within one circular route. This help to improve customers' serving quality system, minimizing total vehicle's run or/and delivery time, or/and delivery cost. Thus, transport managers may use MGM to plan competitive deliveries in cities and other built-up areas.

SOLUTION WITH THE MINIMAL-GROWTH METHOD COMBINATION EXAMPLE

The authors worked out three steps' algorithm for small shipment delivery's quality improvement in cities with unstable traffic (figure 3). It is expedient to make following steps to improve quality of small-shipment deliveries in cities and define the optimal customers' serving order:

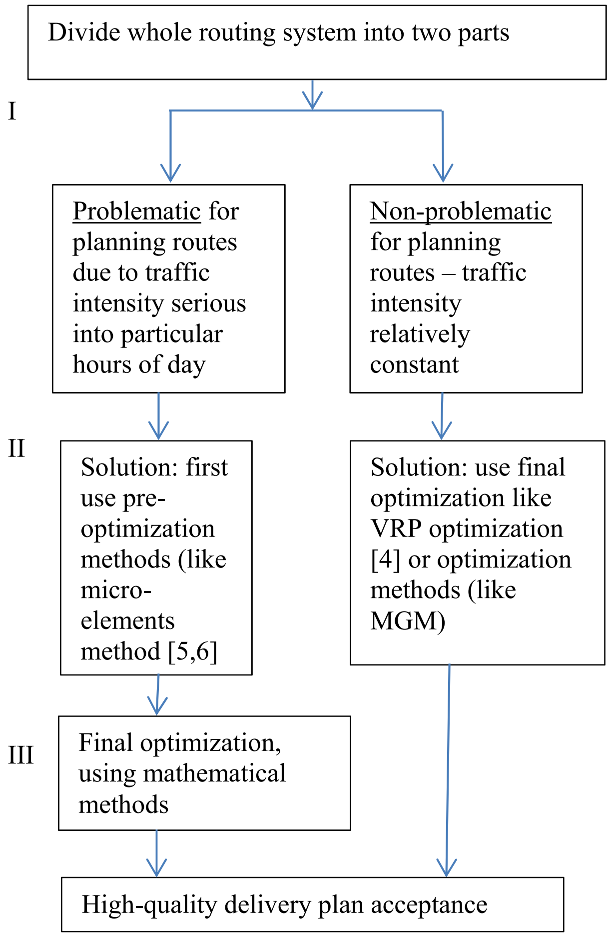
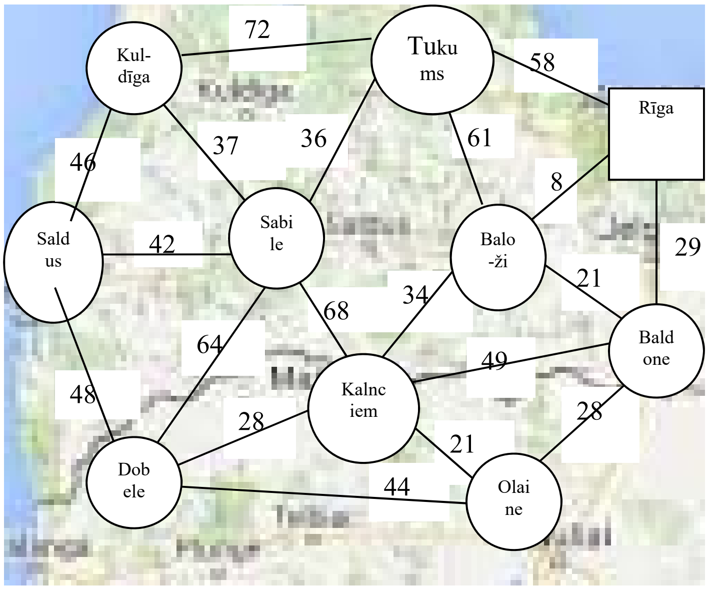


Figure 3. Three steps for small shipment delivery's quality improvement in cities with unstable traffic.

Actually,, it is possible to use only micro-elements method [7,10] like pre-optimization methodology to improve problematic route planning in cities with intensive and traffic (not analyzed into this paper in details; the problem analyzed into the other P.Patlins's papers[6,7,10]). Specialists divide vehicle's moving time into separated elements to make easy and more accurate vehicle's moving time. Therefore, it is expedient to use minimal-growth method to plan circular routes in cities with hard traffic.
There are some ways how to improve non-problematic routes planning in cities and towns. Necessary to find a solution of Travelling Salesman problem or Vehicle Route problem to serve couple of customers, grouping them within one route, which starts and finishes at the same warehouse to minimize total vehicle's run or/and delivery time, or/and delivery cost, when given following information: Customers coordinates; each customer's demand q_i; distance between each two customers: $l_{ij;}$ delivery cost of each route segment: $C_{ij;}$driving time between each two customers: $t_{ij;}$ capacity of vehicle is $Q_{i;}$
The model allow to calculate *the optimal quantity of vehicles* to serve customers as well as *customers ' serving order* for each route to reduce vehicle's run or/and delivery time, or/and delivery cost:

$$\sum_{i,j=1}^{n} l_{ij} \ or \sum_{i,j=1}^{n} C_{ij} \ or \ \sum_{i,j=1}^{n} t_{ij} \rightarrow min \qquad (5)$$

For example, company has warehouse (Riga) and some customers (other cities). It is necessary to serve customers by optimal way, finding the best order to serve them (Figure 2)- see customers location scheme.



Riga – warehouse/wholesaler/logistics company
Tukums, Kuldiga, Sabile, Saldus, Dobele, Kalnciems, Balozi, Baldone, Olaine – customers/serving objects

Figure 4. Location of the customers and warehouse.

Customers' demand given in the table 1.

Table 1.Customers' demand

Customer	Demand, kg
Dobele	375
Saldus	500
Kalnciems	400
Balozi	425
Baldone	500
Tukums	575
Sabile	125
Olaine	675
Kuldiga	425

Vehicle's capacity is 2 000 kg
How to find the optimal quantity of vehicles to serve customers as well as *customers ' serving order* for each route to reduce vehicle's run ?

First of all it necessary to build so called "minimal three" or the shortest objects' connection network to connect all objects of the task, using the nearest neighbour method.

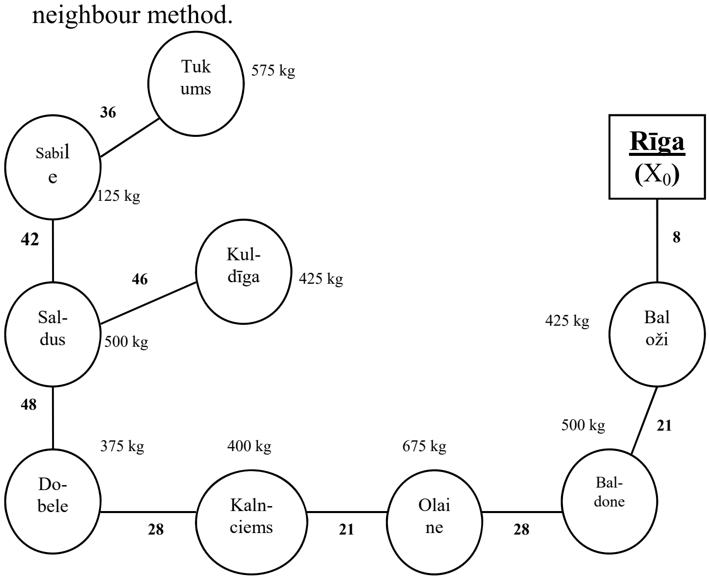


Figure 5. The "minimal three"

Checking objects' demand as well as vehicles' capacity may conclude, that it is necessary to plan two routes (see table 2).

Table 2. Customers division into two routes

Route I		Route II	
Objects	Demand, kg	Objects	Demand, (kg)
Tukums	575	Kalnciems	400
Sabile	125	Olaine	675
Saldus	500	Baldone	500
Kuldīga	425	Baloži	425
Dobele	375		
Sum:	2000	Sum:	2000

The next step is: to find the best customers serving order for the first route. First of all build the shortest ways matrix for the first route (table 3), using information about objects' location from the Figure 2. Calculate the total sum for each column of the matrix.

Table 3. The shortest ways matrix for the first route

Rīga (R)	58	94	103	130	62
58	**Tukums (T)**	36	52	72	39
94	36	**Sabile (Sb)**	42	37	64
130	72	37	**Saldus (Sl)**	46	89
103	52	42	46	**Kuldīga (K)**	48
62	39	64	48	89	**Dobele (D)**
∑447	**∑257**	**∑273**	**∑291**	**∑374**	**∑302**

After that choose 3 biggest sums [4] from the last line of the table 3 as well as appropriated objects: A, H and B.
Create a basis of the route.

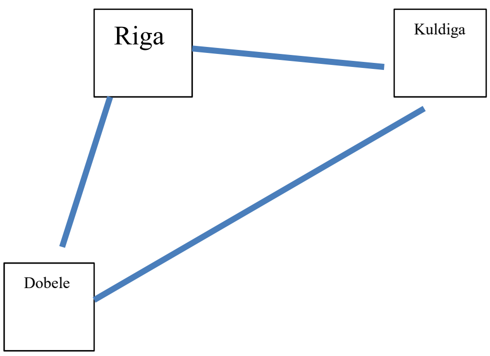


Figure 6. The basis of the route.

The next step is: to choose the column with the next biggest sum and include appropriated point in the route, using following principle:

Δ = Cfn+C ns - C fs, (6)

where:
- growth of the route, putting new object into appropriated routes' interval. .
C - distance, km;
n– new customer's index; ;
f – first point of the pair;
s – second point of the pair.

So, calculate Δ for G:

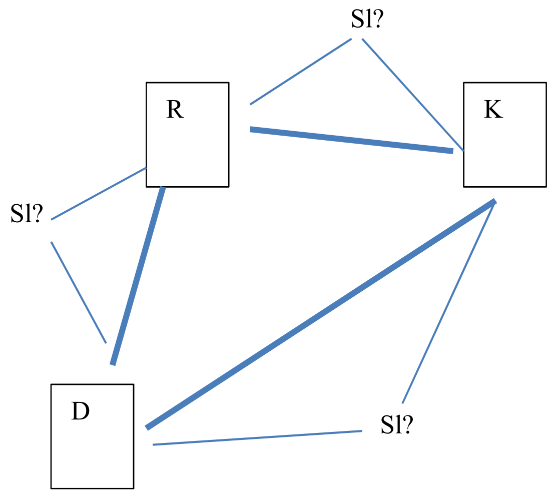


Figure 7. The interval for G customer

Using formula 6:
$\Delta RK = CRSl + CSlK – CRK$
$\Delta KD = CKSl + CSlD – CKD$
$\Delta DR = CDSl + CSlR – CDR$

So:

ΔRK = 103 + 46 – 130 = 19 km
ΔKD = 46 + 48 – 89 = 5 km – The minimal growth. Put Sl between K and D.
ΔDR = 48 + 103 – 62 = 89 km

Repeat the same steps for Customer Sb :

$\Delta RK = C_{RSb} + C_{SbK} - C_{RK}$ = 94 + 37 – 130 = 1 km- the minimal growth. Put Sb between R and K.
$\Delta KSal = C_{KSb} + C_{SbSl} - C_{KSl}$ = 37+ 42 – 46 = 33 km
$\Delta SalD = C_{SlSb} + C_{SbD} - C_{SlD}$ = 42 + 64 – 48 = 58 km
$\Delta DR = C_{DSb} + C_{SbR} - C_{DR}$ = 64 + 94 – 62 = 96 km

Then repeat the same steps for customer E:
$\Delta RSb = C_{RT} + C_{TSab} - C_{RSb}$ = 58 + 36 – 94 = 0 km

Finally plan the optimal route A - H - G - E - C - B - A (Figure 8) which provides the shortest way to serve all customers and return to the company' warehouse.

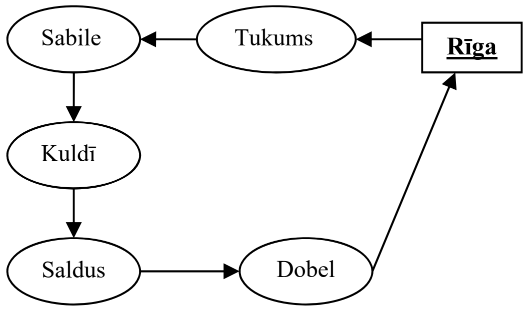


Figure 8. Route I. The optimal customers' serving order.

Repeat the algorithm to find the optimal solution also for the second route (Figure 9).

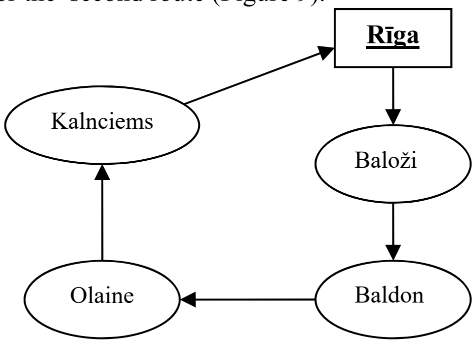


Figure 9. Route II. The optimal customers' serving order.

The method provide the best results for "non-problematic" circular routes, planning small- shipment deliveries in cities and other built-up areas. The Minimal Growth Method is quite simple and effective to be used into practical situations.

CONCLUSION

Various computer programs often provide non-optimal solution to transport problem due to different restrictions; on the one hand, it is possible to use only these programs to solve theoretical problems.

Usage of minimal-growth method allows planning the optimal serving order of customers within the route as well as minimizing of the total transportation costs, time or vehicles's run.

The minimal-growth method is an universal method for circular routes planning; it allows to solve a lot of problems and serve customers by optimal way. The method allows also to divide a couple of customers into particular groups and "connect" them with the vehicle depending on its capacity and define needed quantity of vehicles and routes for the best planning.

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AUTHORS' BIOGRAPHIES

Pavels Patlins was born in Riga, Latvia and studied Economics and Logistics and obtained his Logistics Doctor degree in 2011 in Riga Technical University. He has been working for the Consulting companies as a logistics expert as well as for Riga Technical University since 2003, conducting Logistics and Transport Managements lectures. His e-mail is: pavels.patlins@rtu.lv.

Remigijs Pocs. is a dean of the Faculty of Engineering Economics and Management;Head of Division of Foreign Economic Relations, Transport Economics and Logistics at Riga Technical University. He is aaan Expert of the Latvian Council of Science ; Head of Promotion Council (Economics), Riga Technical University ; Member of the Council of Professors of RTU Faculty of Engineering Economics and Management, LU Faculty of Economics and Management and LUA Faculty of Economics; Scientific Editor -in-Chief , Scientific Proceedings of Riga Technical University "*Economics and Entrepreneurship*". His e-mail is: remigijs.pocs@rtu.lv