ŽILINSKÁ UNIVERZITA v
Žiline, Slovensko
CETRA – Centre for
transportation research

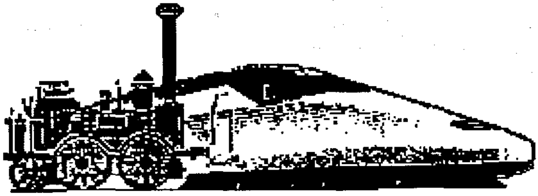
za podpory EURÓPSKEJ KOMISIE V BRUSELI

18. medzinárodné sympózium
18th International Symposium

„Oživenie ekonomiky - nová výzva pre železnice"

" Revitalisation of Economy - New Challenge for European Railways"

EURO - Žel 2010



Zborník prednášok
(1. diel)

26. - 27. máj 2010

Žilina
Slovenská republika, EÚ

DEVELOPMENT RAILWAY AND CITY TRANSPORT CONTROL PROCEDURE FOR CO – MODAL TRANSPORTATION OF PASSENGERS

Antons Patlins[1], Nadezhda Kunicina[2], Alina Galkina[3], Leonids Ribickis[4]

Summary: The integration of railway transport in Riga city public transport control is important for passenger's service, using existing recourses. However the integration of transport control systems just started developed in 3 years. The first implemented system was bus control system – ASOS. The using of transport control procedure for co – modal transportation of passengers in Riga city. The dynamic control for transport modes in pre - defined time interval and composite the final control procedure for each transport mode and harmonize the motion with aim to arrive transport in time and harmonize railway and public transport motion. An effective tool of research of problems of optimum control is the principle of a maximum by Pontryagin's Maximum Principle representing a necessary condition of optimality in such problems. The procedure deals with, consists of two main parts: operating procedure in this case, routing of passenger's flow and object of control in this case passenger's transport. The objects of control are divided in three levels: transport means, a vehicle, or all system of public transport of city etc. can be considered. The operating kernel since occurrence of problems of control has undergone evolutions from the elementary regulator to modern informational systems – intelligent transports system.

Introduction

The development conception of city transport foresees the integration of regional railway passenger transportation in the common passenger transport system. However, there are many difficulties in this task: there is no appropriate transport connection from railway stations till city transport, the usage of both transport means is expensive for passengers, because of tarification problem, there are two separate management teams, and there is no informational support for common passenger information system.

The problem of integration of railway transport in Riga city public transport system are discussed, the three level of problem decision are offered in the article:

---

[1] Researcher, Institute of Industrial Electronics and Electrical Engineering, Riga Technical University, 1, Kalku Str. LV 1658 Riga, Latvia, Phone: +371 67089051, Fax:+371 67089039, Antons.Patlins@rtu.lv

[2] Senior researcher, Institute of Industrial Electronics and Electrical Engineering, Riga Technical University, 1, Kalku Str. LV 1658 Riga, Latvia, Phone: +371 67089051, Fax:+371 67089039, Kunicina@latnet.lv

[3] Project manager, Riga Technical University, 1, Kalku Str. LV 1658 Riga, Latvia, Phone: +371 67089051, Fax:+371 67089039, Alina.Galkina@rtu.lv

[4] Vice-rector for Research, Riga Technical University, Head of Institute of Industrial Electronics and Electrical Engineering, 1 Kalku street, room 214, LV 1658 Riga, Latvia
+371 670893415, Fax: +371 67820094, Leonids.Ribickis@rtu lv

informative support system for passengers, control procedures for transport managers and control procedures for vehicles, according passengers priorities. The integration of railway transport in Riga city public transport control is important for increasing of passenger's service quality, using existing recourses. However the integration of transport control systems has just started to be developed. The first implemented system was bus control system – ASOS (Automated Surface Observing ***System).*** The three levels of integration in vehicle control, transport mode control and all city transportation system control in one system are described. The dynamic control for transport modes in pre - defined time interval and composite the final control procedure for each transport mode and harmonize the motion with the aim to arrive transport in time and harmonize railway and public transport motion. An effective tool of research of problems of optimum control is the principle of dynamic system control, representing a necessary condition of optimality in such problems. The example of improving Riga city transport system is described.

Use of modern technologies of monitoring and the transport control integrated in intelligent transport system. Such systems are means of considerable reduction of non-productive expenses for transport and increases of an overall performance of transport system as a whole. The first step in Riga city is bus control system ASOS. Systems of satellite monitoring of motor transport now are widely used in the transport, however the strategic development in city and implementation in tree levels of control is not just engineering issue, and it is also an issue for decision makers. In article the usage of such system for passenger's transportation are discussed.

Necessity of working out of the centralized system of wireless dispatching of city passenger transport in Riga is obvious. The centralized dispatching of city passenger transport presumes to use more effectively transport resources and to provide higher level of service for passengers. It will be promoted also by integration of railway transportation into system of passenger transport of the city of Riga, with including into the general control system.

1. The problem formalization

The control procedure methodology development is based on Pontryagin's Maximum principle. Principle applies to a particular type of problem called a Bolzano Problem. Most optimization problems can be put into the form of a Bolzano problem, but more about that later. A Bolzano problem involves a number of state variables which can change over time where time t runs from 0 to T. Let us suppose the state variables are $X_1(t)$, $X_2(t)$, ..., Xn(t).

To maximize

$$Q(T) = c_1X_1(T) + c_2X_2(T) + ... + c_nX_n(T), \qquad (1)$$

Each $c_nX_n(T)$ is fragment of passenger's route in defined time moment. Given that we start at the point $X_1(0)$, $X_2(0)$, ..., $X_n(0)$, and where the coefficients c_1, c_2, ..., c_n are given and T is some definite finite time. We are given so-called steering functions for controlling the changes in the state variables; i.e.,

$$dX_1/dt = f_1(X_1, X_2, .., X_n, u_1, u_2, .., u_m) \qquad (2)$$
$$dX_2/dt = f_2(X_1, X_2, .., X_n, u_1, u_2, .., u_m)$$

....

$$dX_n/dt = f_n(X_1, X_2, .., X_n, u_1, u_2, .., u_m)\,,$$

where the variables u_1, u_2, ..., u_m are functions of time and are called the control variables. The objective is to choose the control variables at each instant of time so as to steer the state variables from their initial values

$X_1(0)$, $X_2(0)$, ..., $X_n(0)$, to some point $X_1(T)$, $X_2(T)$, ..., $X_n(T)$, where $Q(T) = c_1X_1(T) + c_2X_2(T) + \ldots c_nX_n(T)$ is maximized.

The mean of Q(T) is quality of service of passengers, Q=Q[P, D, T] the quality of service characterised as function of price (expenses), distance and time of transportation. The quality of service are widely used in logistic task's solving. The passenger's are not analysed individually, for simplicity, they are analysed as passenger's flow, however the method's for analysing of passenger's are described in details in [8]. The analysing of passenger's flow allow to reach pseudo optimality in system mean, the effective structure for city transport system, but do not provide the optimal solution for every passenger. This seems to be a very difficult task. Pontryagin's Maximum Principle provides a neat, systematic solution.

To implement Pontryagin's method one defines a Hamiltonian function

$$H = \varphi_1 f_1 + \varphi_2 f_2 + \ldots + \varphi_n f_n = \Sigma \varphi_i f_i, \qquad (3)$$

where the set of adjoint variables φ_1, φ_2, .., φ_n are such that $d\varphi_i/dt = -\partial H/\partial X_i = -\Sigma_i \varphi_j(\partial f_i/\partial X_i)$

and $\varphi_i(T) = c_i$ for i=1,2, .., n. Note that if H does not depend upon X_i then $d\varphi_i/dt = 0$ for all t and thus $\varphi(t)$ is a constant. In physics φ_i would be said to be conserved.

The optimum value of the control variables at time t is the ones that maximize H.

This usually means that the optimum $u_j(t)$ is such that $\partial H/\partial u_j(t) = 0$, which means

$$\Sigma_i X_i(\partial f_i/\partial u_j(t)) = 0$$

$$\text{for } j=1, \ldots, m.$$

2. Description of the controls of transportation trajectories

It will be worthwhile for us to be quite careful about characterizing the sorts of controls we will consider, and the trajectories generated by them. A consequence of this care is a pile of notation. Let's define conditions on the character of the control functions T→u(t). The following definition encodes one of the weakest notions of control that one can allow.

Let Q = (P, D, T) be a control system. An admissible control is a measurable map X: D→U defined on an interval $I \subset R$ (real number), such that T→ f(X, u(t)) is locally integral for each $x \in X$. The set of admissible controls defined on I is denoted by U (I). A controlled trajectory is a pair $(i_1;i_2)$ where, for some interval $I \subset R$, $i_2 \in U(I)$ and $i_1: I \rightarrow X$.

I called the time interval for $(i_1;i_2)$.

$i_1(P)$, where $P_1, P_2, \ldots \in P$ is possibility to cross interval I in time moment T, with defined transport mode.

A controlled arc is a controlled trajectory defined on a compact time interval.

Let's convert linear control system Q = (P, D, T) where D is a convex polytope in R^m. In practice one often takes

$D= [d_1; d_2] x \ldots x [d_n; d_m]$ for some $d_1; d_2; \ldots. d_m \in R^m$.

3. Mathematical definition procedure of problem solving

The following designations will be used in this work:

Se – power system;

St – transport system with vehicles $S^t_1, S^t_2, \ldots, S^t_n \in St$; S^t_{direkt} – Minimum of vehicles, which is necessary to provide the passengers transportation;

Ste – consumption of power resources of the vehicles with its components $S^{te}_1, S^{te}_2, \ldots, S^{te}_n \in Ste$; n=1,2, ...,

Sp – set of passengers with subsets $S^p_1, S^p_2, \ldots, S^p_k \in Sp$; k=1,2, ...,

t –time, t1, t2, .. ti – moments of time;

$P^{tr}=\{ P^{tr}_1, P^{tr}_2, \ldots, P^{tr}_n\}$ set of tram stops n=1,2, ...;

$P^t=\{ P^t_1, P^t_2, \ldots, P^t_u\}$ set of trolleybus stops u=1,2, ...;

D – distance (roots); d- nodes/stops of transport network $d_1; d_2; \ldots. d_m \in D$

Z°_p – priorities of the passengers;

W - environment

W_v – influence of environment;

$W^{(I)}$- feedback (transport control system);

W_x – input of the transport system (resources, passengers);

W_y – output of the transport system (resources, passengers);

A^s – set of intelligent agents (intelligent agent network) with subsets $A^{st}_1, A^{st}_2, \ldots, A^{st}_m, A^{sp}_1, A^{sp}_2, \ldots, A^{sp}_{m,..} \in A^s$; m=1,2, ...,

A^{supra} – Supra intelligent agent;

Dp - distributed data bases;

Wd - distributed Web server (servers);

$\exists\ S^t_n\ \forall\ S^p_k\ S^{te}_j\ (S^t_n,\ S^p_k) \to \min$, (exists when S^t_n, as for each S^p - $S^{te}_j\ (S^t_n, S^p_k)$ exists;

Target function $S^{te}_j \to \min$, $S^t_n \geq S^t_{direkt}$.

4. The structure of interactions in intelligent transport system

The intelligent agents have such advantages for public transport control: autonomous fulfilment, interaction with other agents and/or users, surrounding control, ability to adaptation for achieving goals, ability for learning from environment, non sensitivity to mistakes and/or wrong signals, real time work, coordination with other agents and ability for making decision. The structure of intelligent agent system is described in figure 1. Passengers, according to their goals Z°_p choose transport system, then they change transport system and this passengers groups reforming in other groups Sp (t2). Information about this process and informative support, vehicle control are organised by intelligent agent network A^s, with control with Supra agent A^{supra}. Supra agent A^{supra} has an ability to order optimal amount of electrical energy.

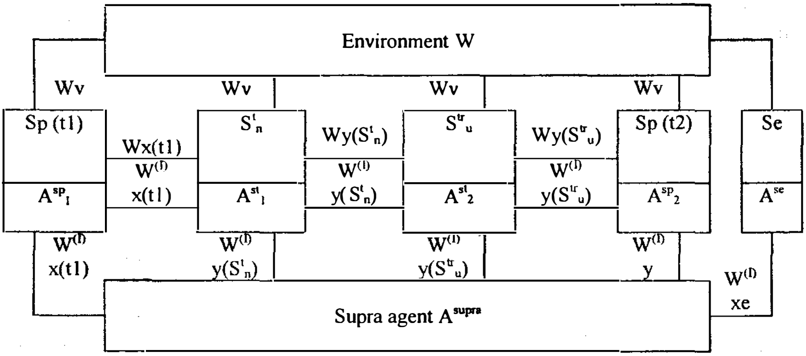


Fig. 1 Interaction of intelligent transport system scheme - intelligent agent's net model for the achievement of the passenger's goals with particular power consumption

5. The transport rooting procedure

Step 1. To define transport system St according to transport types S^t_i.

Step 2. To evaluate requirement to public transport S^t_i, taking it into account during the variable time.

Step 3. To define which apices of the public transport P^{tr}; P^t are apices of hypergraph P.

Step 4. To define minimum social requirements to transport S^t_{direkt}, taking into account environment W_v.

Step 5. To define time of a route of each type of public transport between stops P^{tr}; P^t, in a period of time.

Step 6.To optimize route, number of vehicles S^t_i and to provide an informative support W_x, W_y, W_v.

Step 7. To supply the public transport system and vehicles with an input control signal W_x.

Step 8.To control speed, breaking, acceleration of the vehicle and other parameters.

Step 9. To inform on the number of passengers in wagons, to distribute the information W_y.

6. The transport scheduling procedure

There are the methods of the problem solving, the structure of problem solving algorithm is given in the article. The experimental check of the algorithm and main conclusions are given in the article. There is time to travel from a starting time to the end of the journey, the expenses of city.

Transport for energy consumption for this travel, the delineated minimum of transport vehicles for route by our and risk of passenger flow will be changed very fast.

The algorithm of scheduling for intelligent agent is developed.

Public transport schedule for intelligent agents are modelling, using such elements and its interaction (fig.2).

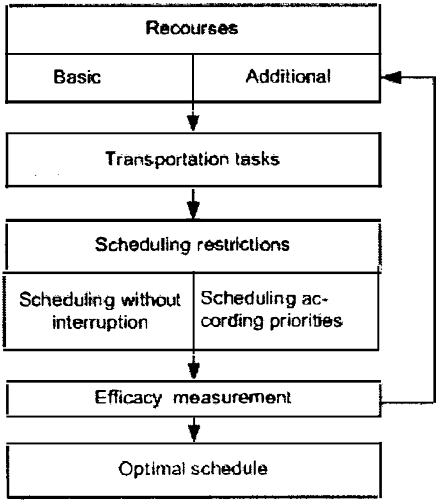


Fig. 2 General sequence model structure of public transport scheduling

In the article is suggested sequence of a transport mean, transporting passengers taking into account purposes of the passengers according to logistic criteria, scheduling theory methods to suggest a procedure for effectively improvement of city transport.

7. Railway subsystem description

A section of railway line is divided into several control areas, in each of which a ground controller and a radio base station are set up. The ground controller in each area has functions such as train location, interval control, switching control, level crossing control and security for maintenance work. The ASOS exchanges information with the on-board computer. As the appropriate interval between stations is determined according to the service area covered by ASOS transmissions, several base stations may be linked to the same ground controller.

The on-board computer controls brakes according to control data supplied by the ground controller and also transmits data on the train location to the ground controller through the on-board ASOS station.

The first step in the control procedure is to determine the accurate location of a train as measured by the on-board computer. The initial position of a train is input when the train passes belies put up on the system boundary across which trains enter or exit.

Subsequently, the on-board computer keeps track of the train location by detecting its speed and processing the speed data. The train location is corrected when the train passes a belies set at appropriate points (fig.3.)

The train location as detected by the system is structured into the identification number of the ground controller in the relevant control area, the virtual blocks into which the control area is divided, and the position within the relevant track block, and these data are processed by the wayside and on-board computer.

ASOS stations are set up at intervals of three kilometres or so based on the reach of transmissions. For on-board operation, the frequency is so chosen as to be receivable by the radio base station in each area. Each base station needs to communicate with several trains running in its area, assuming that it communicates with each train on a one-second cycle. Accordingly, one second is divided into several time slots. An error may occur in the data during the transmission.

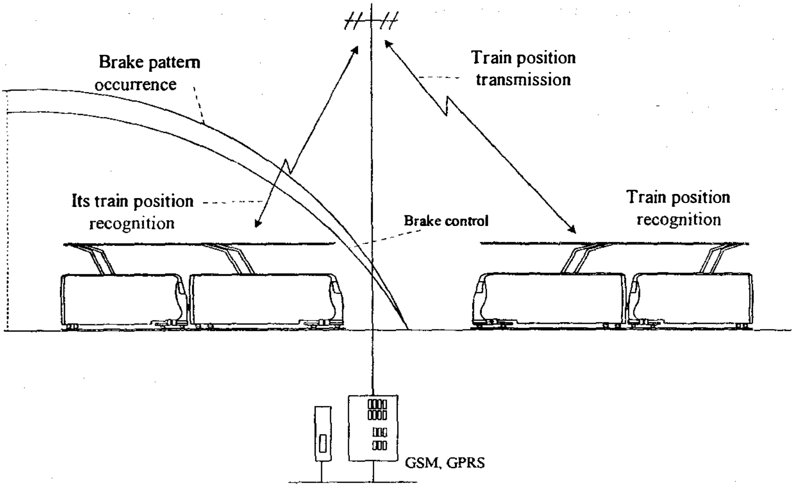


Fig.3 Structure of railway transport control

8. The Control System

The public transport system control in additional requires on board equipment with application of GPS, all of which utilizes three basic components of the GPS; absolute location, relative movement, time transfer. There is railway control system, which is first component of intelligent transport system figure 4.

The intelligent transport system requires having control procedures, which should:

- carry out the control over movement of passenger transport of a city with possibility of the operative control of movement;
- provide possibility of carrying out of vocal communication sessions between dispatchers and mobile objects in certain places of a city, for example on movement terminal points. The given function allows to regulate an exchange order in an air manually, in case of any non standard situation;
- provide support of an emergency communication in case of breakage of vehicles on all city territory; the driver of the Vehicle receives a direct communication channel with emergency services or communicates through dispatching knot. The emergency communication can be made active in any point of a city the driver;
- give possibility at any moment to carry out a call of any subscriber of system from dispatching service.

At the I th level the control of each type of transport separately (something similar now well only for the Riga buses) will be carried out (ASOS system). The II level will allow supervision system as a whole. It will allow to plan more competently work of transport system using corresponding methods of the theory of management, more effectively to transport passengers. Thereby the system of passenger transport will work more in coordination, in the best way carrying out the main function - timely delivery of passengers in the place of a city necessary to them.

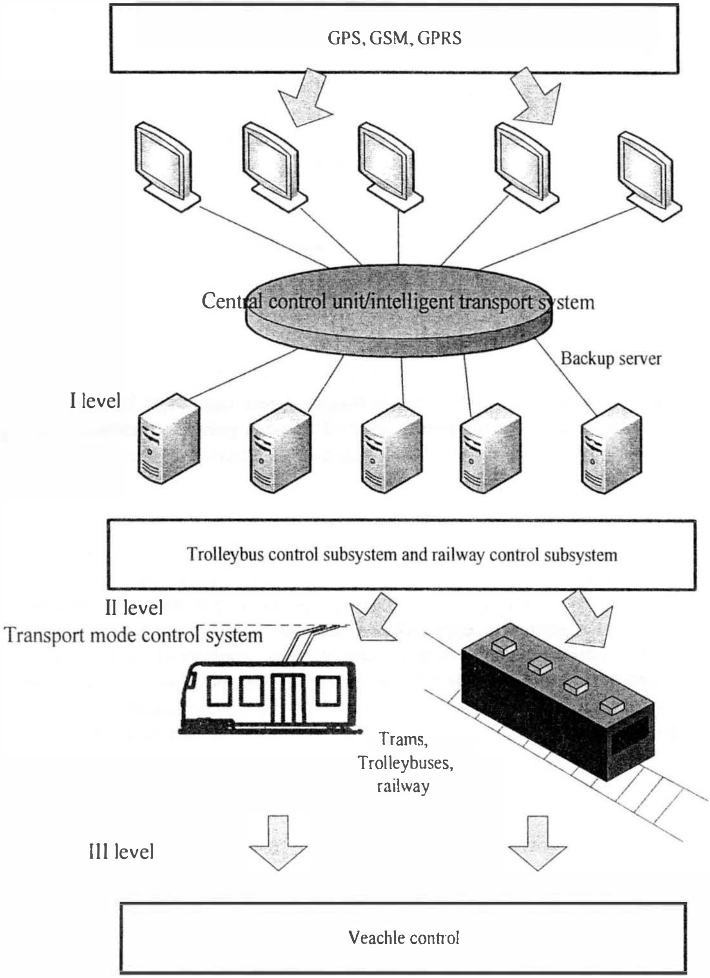


Fig. 4 Structure of extended common railway and public transport management system

Gantt graphic is realised with the obvious relocations of passengers at the rush hours (fig.5.).

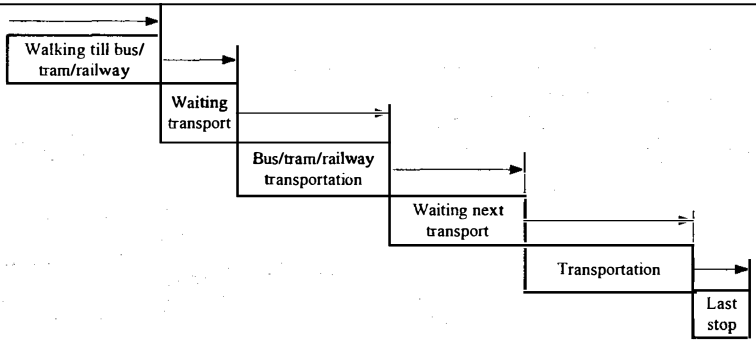


Fig 5 Fragment of Gantt graphic for pasanger relocation in the rush hours

The development of public roads foresees new highways but in Riga the transportations are realized with public as well as with private transport. The optimization of transportation of passengers in Riga can effectively use railway.

Conclusions

The task of development of electric power application effectively improvement for the public transport system is formed as a formal task of model investigation that can provide the affectivity of the exiting transport system investigation that has a significance for economy especially under the conditions of city hard traffic. The task of the power consumption optimization is connected with technologies and methodology that can provide passenger's transportations with more effective application of the available resources and avoiding duplicated routes to provide effective use of electric energy. Graph theory is applied for development of power consumption affectivity improvement. The procedure of improvement of electro energy use affectivity. The role of Supra intelligent agent is defined. The suggested theory is assessed with the use of homomorphic model.

Analyzing world experience it is possible to tell that it can essentially improve system of passenger transport in Latvia The authors suggest to continue researches in this area and as a result to consider possibility of introduction of a two-level control system of city passenger transport. The authors recommend except traditional buses, trolley buses and trams, to include into the railways system as well fixed-routes. In this case also it makes sense to equip all these vehicles with devices of reading of e-tickets. It will allow more competently, conveniently and precisely to trace and analyze volumes of passenger traffic in a city. That, in turn, will allow planning work of system of public transport more competently.

The authors of the article offer to develop a centralized control system of public transport of the city of Riga. Analyzing world experience it is possible to tell that it can essentially improve system of passenger transport. The authors suggest continuing researches in this area and as a result to consider possibility of introduction of a two-level control system of city passenger transport. The authors recommend except traditional buses, trolley buses and trams, to include into the system taxi and train as well fixed-routes. It will allow more competently, conveniently and precisely to trace and analyze volumes of passenger traffic in a city. That, in turn, will allow planning work of system of public transport more competently.

Future autonomous train control systems will consist of an on-board system only, without a ground system. Each train will communicate directly with others and each train will control its own brakes autonomously, based on information from other trains. ASOS technology, information technology and communication technology is the key to realize the future train control system.

References

[1] C. Berge, HYPERGRAPHS, Elsevier Science & Technology, 1989

[2] "Position Paper On Energy Efficiency – The Role Of Power Electronics" ECPE European Centre For Power Electronics, Nuremberg, EPE European Power Electronics And Drives Association, Brussels, March 2007, Brussels, 18p.

[3] Latvian Energy In Figures Latvian Investment And Development Agency, 2006, P.43.

[4] L. Ribickis, A. Levchenkovs, N. Kunicina, M. Gorobetz Modelling Of Decision Support System For Intelligent Public Electric Transport, In E - Proceedings Of International Conference On Industrial Engineering And Systems Management, 8p. Beiging, China, 2007.

[5] Development passengers transfer procedure for city transport in Riga, 17th ITS World Congress, Busan , BEXCO, Korea, 2010, 11p.

[6] N. Kunicina, A. Galkina, Development of a procedure for increasing the electroenergy consumption efficiency in the public transport system, Scientific proceedings of Riga Technical university, Power and Electrical Engineering, Rīga, Latvija, Nr. 20, ser.4 , 2007, 150-158 p.

[7] The Revolution of Train Control System in Japan, Masayuki Matsumoto, East Japan Railway Company, IEEE, 2006, 8p.

[8] Ceder, A. "Public Transit Planning and Operation: Theory, Modeling and Practice", Elsevier, Butterworth-Heinemann, Oxford, UK, 640 p. March 2007.