DEVELOPMENT OF A PROCEDURE FOR INCREASING THE ELECTROENERGY CONSUMPTION EFFICIENCY IN THE PUBLIC TRANSPORT SYSTEM

ELEKTROENERĢIJAS IZMANTOŠANAS EFEKTIVITĀTES PAAUGSTINĀŠANAS PROCEDŪRAS IZSTRĀDE SABIEDRISKĀ TRANSPORTA SISTĒMAI

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Introduction

Analysis of the current situation allows to conclude that control of public transport is a complex multi criterial task with a high social and economic importance. Transport is an important comsumer of power resources. Transport comsumes about 31% of power resources [1] in Lithuania, 25% in Latvia, in Estonia these are 17% [6]. The largest amount is consumed by over-ground transport - 82% in Estonia, 85% L in Latvia and 91% in Lithuania. Table 1 demonstrates consumption of power resources in transport and its prognosis in Latvia (2002-2008).

Table 1.

Consumption of power resources in transport and its prognosis in Latvia (2002-2008)

Power resources	Consumption by city electric transpor (GW•h)	Consumptio by railway (GW•h)	Amount of power energy (GW•h)
Electric energy	80	40	120

The public transport motion and control in most of the world's cities including also Latvian cities is organized by intuition with taking into account experience of the previous periods, but the situation in the transport system is quickly changed, but nowadays it is not taking into account while planning transport schedule and control. Whenever something is moving - 60% of industrial energy is used by electric motors, for each 1 EUR is spent to purchase a motor, 100 EUR are spent for energy cost during its lifetime, many motors still run at fixed speeds, power-electronic drives can control the speed of the motor to match output with the needs [5].The task of the investigation is improvement of electric power application efficiency in public transport, that can be solved with the help of modern technical methods and equipment as well as applying control of the systems. The problem of optimization of electric power comsumption is solved in the article with the help of graph and systems theory and homomorpho modeling. The goal of the work is to form and plan the work of a transport mean transporting pessengers taking into account purposes of the pessengers according to logistic criteria (expenses, time, quality of service) and to suggest a procedure for effectivity improvement of electric power use.

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. This research was supported by Ministry of education and science republic of

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Problem formulation

The following systems are considered for the task of electric energy consumption optimization in transport systems: 1.) Power system (Se); 2.) Transport systems (St); 3.) Set passengers Sp).
Figure 1 demonstrates the homomorphic model of interaction of subsets of passengers and means of transport. Subsets of pessengers $S^p{}_1, S^p{}_2, ..., S^p{}_k \in Sp$ at the time moments t1, t2, transport system St with vehicles $S^t{}_1, S^t{}_2, ..., S^t{}_n \in St$, taking into account influence of invironment W_v.

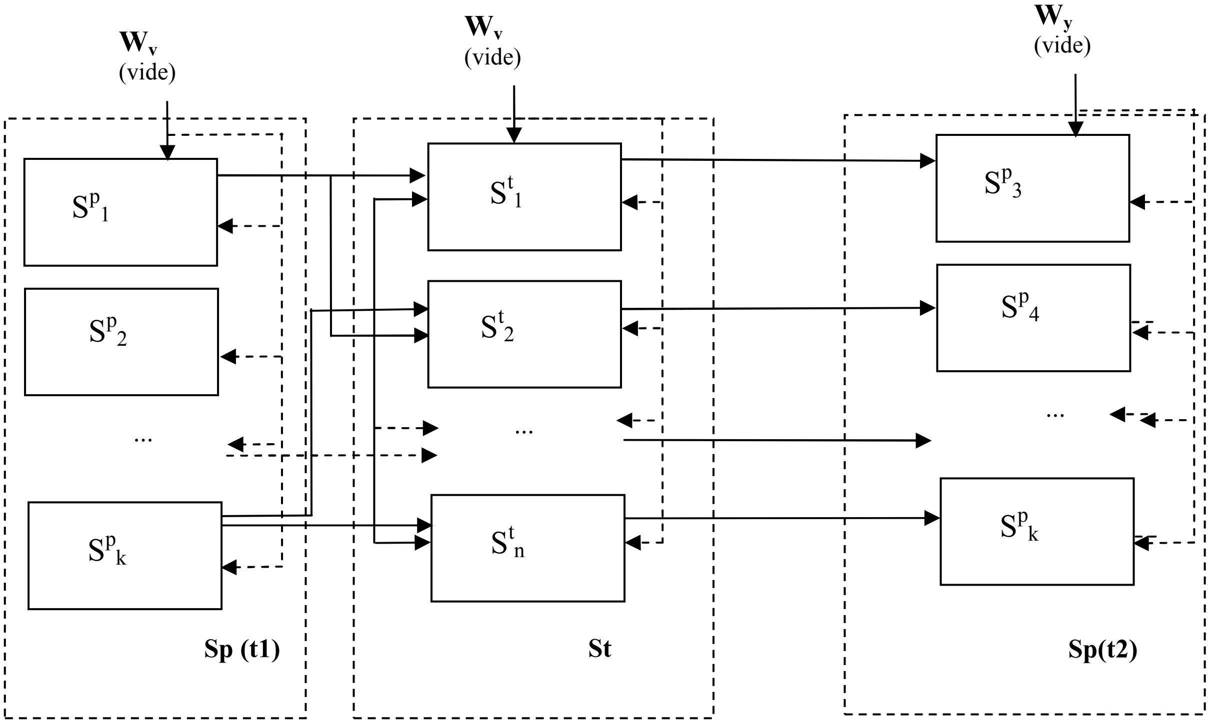

Fig.1. Logistic chain of public transport

The public transport is used by passengers from the sets of passengers $S^p{}_1, S^p{}_2, ..., S^p{}_k \in Sp$. The sets of passengers are formed according to the priorities $Z°_p$. Passengers subsets are changed in time, passengers can change the transport in order to achieve their goal and for acceptable expenses.
Transportation of passengers with minimum number of transport types (number of routes) with a particular quality of service (passengers need achive the goal) allow achiving power and fuel economy in public transport.
For solution of the task of power use effectivity the autors consider application of the intelligent agents modeling in the system of public transport.

Mathematical definition of the research task

The following designations will be used in this work:

Se – power system;
St – transport system with vehicles $S^t_1, S^t_2, ..., S^t_n \in St$; S^t_{direkt} – Minimum of vehicoles which is necessary to provide the passengers transportation;
Ste – comsumption of power resources of the vehicles with its components $S^{te}_1, S^{te}_2, ..., S^{te}_n \in Ste$; n=1,2, ...,
Sp – set of passengers with subsets $S^p_1, S^p_2, ..., S^p_k \in Sp$; k=1,2, ...,
t –time, t1, t2, .. ti – moments of time;
$P^{tr}=\{ P^{tr}_1, P^{tr}_2,... ,P^{tr}_n\}$ set of tram stops n=1,2, ...;
$P^t=\{ P^t_1, P^t_2,... ,P^t_u\}$ set of trolleybus stops u=1,2, ...;
$P = (p_{ij})$ – surface of hypergraph;
$Z°_p$ – 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 $A^{st}_1, A^{st}_2, ..., A^{st}_{m,}$ $A^{sp}_1, A^{sp}_2, ..., A^{sp}_{m, ..} \in A^s$; m=1,2, ...,
A^{supra} – Supra intelligent agent
Dp - distributed data bases,
Wd - distributed Web server (servers),
$\exists\ S^t_n\ \forall\ S^p_k\ S^{te}_j\ (S^t_n,\ S^p_k)$ -> 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 -> min, $S^t_n \geq S^t_{direkt}$.

Research method

For the improvement of the power use effectivity in public transport graph, flows and schedules theories are applied. The tasks are solved with the help of homomorphic modeling.
The goal of the work is to form and plan the work of a transport mean for transportion of passengers taking into account purposes of the pessengers according to logistic criteria (expenses, time, quality of service) as well as to define the power consumption during a particular route time period.
The operation research methods are investigated in the article. The stops of the city public transport are considered as apices of the graph, possible routes of public transport between the apices are considered as the loops of the graph.
The system of public transport will be considered as a hypergraph, where $P^{tr}=\{ P^{tr}_1, P^{tr}_2,... ,P^{tr}_n\}$ and $P^t=\{ P^t_1, P^t_2,... ,P^t_u\}$, each graph which has n and u is noted with an indication matrix $P = (p_{ij})$, where

$$r_{ij}= \begin{cases} 1, \text{ if } n_i \in u_j \\ 0 \text{ in opposite.} \end{cases}$$

In fact the apices of the graph could be considered as an existed kernel even in those cases when it is located geographically distant but concerns to the system's infrastructure.

The method of the problem solving is to make optimisation of public transport roads with the defined transport modes.

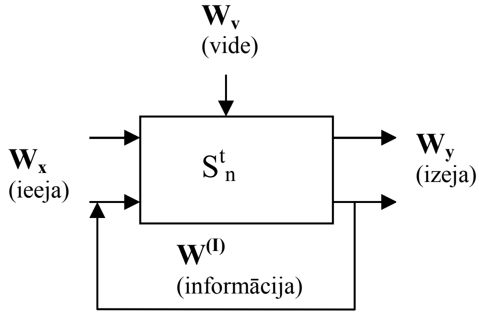

Fig. 2. Control system of vehicle

Figure 2 demonstrates a control scheme of a transport system [7], St – transport system; where $W^{(I)}$-feedback (transport control system); W_x – input of transport system (resources, passengers, signals), W_y – output of transport systems (resources, passengers, signals) W_v – influence of environment.
Functioning of the transport control system is provided according to the passengers priorities ($Z°_p$) $W_y \Rightarrow Z°_{p.}$
The task is solved with the use of methods of system theory, each of the systems St; Se; Sp is described with input, output and influence of environment, the performance of the passengers priorities requires to define Z° (Z° (St); Z° (Se); Z° (Sp)) for each system – goal of the consumer: expenses, quality, time.
The transport system is described with the following parameters: type of transport - S^t_i ($_{i-1,2,3\ldots t}$- (tram, trolleybus, bus). Each vehicle is described with capacity, distance of the route, energy consumption.

Tools for problem solving

The aim intelligent agents [4] are used for public transport control, taking in account electro energy consumption efficiency increasing.

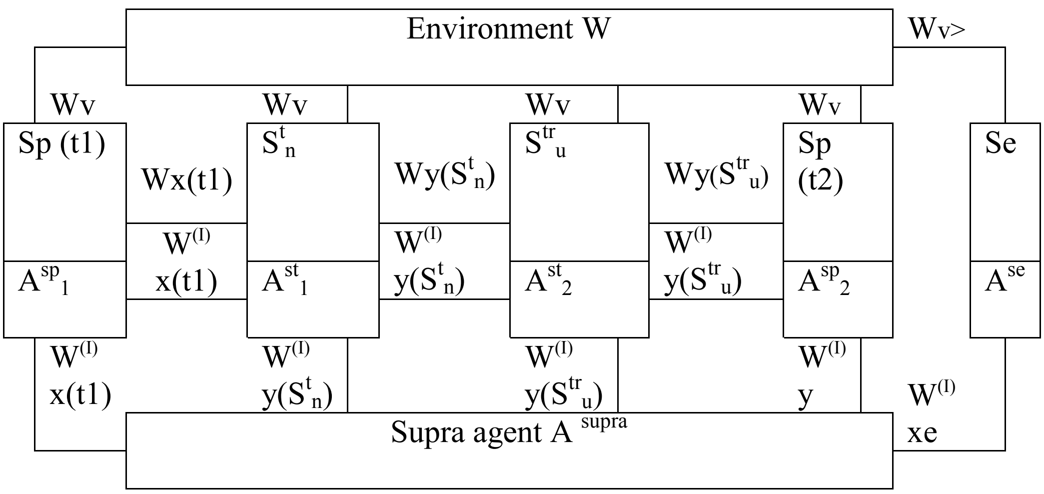

Fig. 3. Interaction of intelligent agents net model for the schievement of the passengers goals with a particular power consumption

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 3. 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.

Procedure of problem solving

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.[3], 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 [2] 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.

The role of Supra intelligent agent

By the means of logistics Supra intelligent agent provides electro energy consumption efficiency increasing procedure development for public transport system and take of task optimum in a dynamic S^{te}_j (t)→ min, $S^t_n \geq S^t_{direkt}$.

Numerical example

Let's describe a route of public transport scheme as a graph, where its apices are stops but routes of public transport between the apices are considered as the loops of the graph. The system of the public transport is considered as a hypergraph, where Riga (Latvia) tram 4 from stop „Botāniskais dārzs" till „Grēcinieku iela" $P_4^{tr}=\{ P_4^{tr}{}_1, P_4^{tr}{}_2,... ,P_4^{tr}{}_n\}$ and trolleybus 9 $P_9^t=\{ P_9^t{}_1, P_9^t{}_2,... ,P_9^t{}_u\}$, the apices of the hypergraph in this case are „Botāniskais", „Slokas iela" and „Grēcinieku iela"
The considered in the example hypergraph of the public transport system is in fig.4.

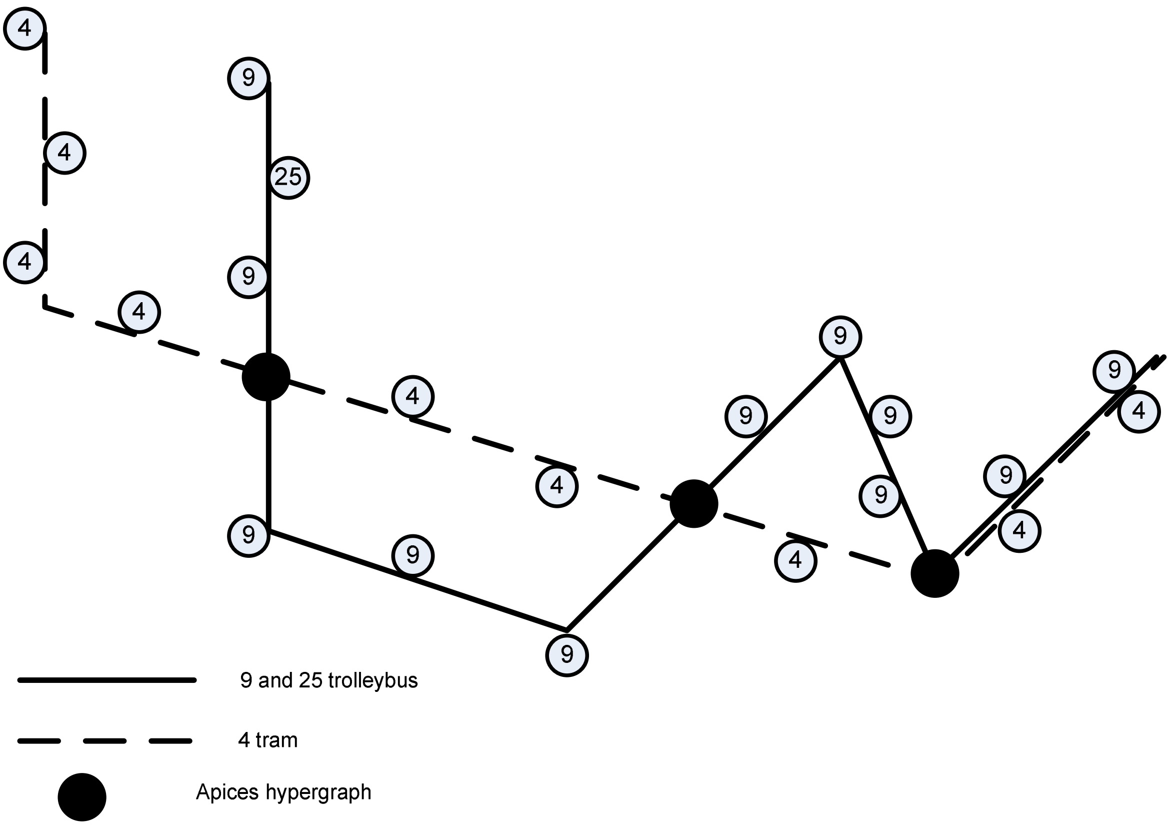

Fig. 4. Fragment of hypergraph of public transport sytem in Riga for tram 4 and troleybus 9

With an enshortening of the 9th route upto the 1st apex of the hypergraph the economy will be 7430.18 Ls per year, including only power consumption on working days. Marking with S^t_{direkt} a minimum number of vehicles to provide transportation of the passengers S^t_{direkt} =2 times per hour. The total number of the routes per day is 71, the optimal number of the routes is 71-36=35 times. Time economy is 18 min. In each direction, that is total 36 min per one route. An average power consumption for a trolleybus is 1.94kW/km, an average tariff for 1 kWh, is Ls 0,035981, the efficiency S^{te}_j (t) is calculated for 22 working days per month for 12 months per year, an average speed is 0.32 km/min.

S^{te}_j (t) =36*35*1.94*22*12*0,035981*0.32= 7430.18 Ls.

Conclusions

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

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Kuņicina N., Galkina A., Elektroenerģijas izmantošanas efektivitātes paaugstināšanas procedūras izstrāde sabiedriskā transporta sistēmai.

Pētījums ir saistīts ar elektroenerģijas lietošanas efektivitātes paaugstināšanu sabiedriskajā transportā. Rakstā elektroenerģijas patēriņa efektivitātes paaugstināšanas problēma tiek risināta ar hipergrafu palīdzību. Darba mērķis ir saplānot transporta līdzekļu darbību, pārvadājot noteiktu pasažieru skaitu, ņemot vērā pasažieru mērķus, pēc viena no loģistikas kritērijiem (izmaksas, laiks, pasažieru apkalpošanas kvalitāte), kā arī piedāvāt procedūru elektroenerģijas izmantošanas efektivitātes paaugstināšanai. Tika formalizēta elektroenerģijas patēriņa izmantošanas efektivitātes paaugstināšanas procedūra. Tika definēta Supra intelektuālā aģenta loma uzdevuma risināšanā. Piedāvātā metodoloģija tika skaitliski pārbaudīta, izmantojot homomorfo modeli. Elektroenerģijas izmantošanas efektivitātes paaugstināšanas piemēram tiek analizēti 4 tramvaja un 9 trolejbusa maršruti.

Kuņicina N., Galkina A., Development of a procedure for increasing the electroenergy consumption efficiency in the public transport system.

The research is intended for improvement of the efficiency of electricity use in the public transport. The problem is solved with the help of hypergraphs. The aim of the research is to develop the mathematical formalism for planning of the public transport, taking into account the number of passengers and their routes in compliance with

one of the logistic criteria (expenses, time, quality of service), as well as to propose and formalise a procedure for the efficiency improvement. The authors consider the role of Supra intelligent agent in the solution of the task. The proposed methodology is digitally assessed with the use of homomorphous model and exemplified by the routes of tram 4 and trolleybus 9.

Куницына Н., Галкина А., Повышение эффективности использования электроэнергии в разработке процедуры для общественной транспортной системы.

Проводимое исследование связано с повышением эффективности использования электроэнергии в общественном транспорте. Проблема эффективного потребления электроэнергии решается с помощью гиперграфа. Цель работы - спланировать движение транспортных средств для перевозки заданного числа пассажиров, учитывая предпочтения пассажиров по одному из логистических критериев (затраты, время, качество обслуживания пассажиров), а также предложить процедуру повышения эффективности использования электроэнергии. В статье проводится формализация процедуры повышения эффективности использования электроэнергии. В статье определяется функция для интеллектуального Супра агента. Предлагаемая процедура численно проверена, используя гомоморфную модель. Как пример, анализируются маршруты 4 трамвая и 9 троллейбуса.