Mechanics Transport Communications
Academic journal
ISSN 1312-3823
issue 3, 2007
article № 0172
http://www.mtc-aj.com

MODELLING OF PUBLIC TRANSPORT SCHEDULING FOR ELECTRO ENERGY CONSUMPTION EFFICIENCY INCREASING

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Abstract: *The research is connected with improvement of electric power use effectivity in public transport. The task can be solved with the help of modern technical methods and equipment as well as applying control of the systems. The problem improvement is solved with the help of hypergraph and scheduling theory. The goal is to plan work of the public transport, transporting particular number of passengers taking into account goals of the passengers according to one of the logistic criteria, as well as to suggest a procedure for the improvement.*
Key words: *intelligent agents, power supply, public transport system, schedule*

INTRODUCTION

The problem of electrical city transport schedule modelling is described. The modelling of public transport could be done, taking in account the following logistic criteria: time, expenses passengers' quality of service and risk. Analysis of the current situation allows concluding that control of public transport is a complex multi criteria task with a high social and economic importance. Transport is an important consumer of power resources. Consumption of power resources by the city electric transport is about 80 (GW•h) Consumption by railway 40 (GW•h). The amount of power energy (GW•h) 120 per year [4].

Consumption of electric energy in transport is more than 2,5 % of the total consumption [10].

The goal of the work is to make scheduling [9] of a transport mean transporting passengers taking into account purposes of the passengers according to logistic criteria (expenses, time, and quality of service) and to suggest a procedure for effectively 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.

The 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.

Energy saving problem is analyzed in the article. The modeling of dynamic schedule of public electrical transport is developed. The algorithm of scheduling for intelligent agent [6, 7] is developed.

1. PROBLEM FORMULATION

The distance between crossings is given in the matrix representation (fig.1.).

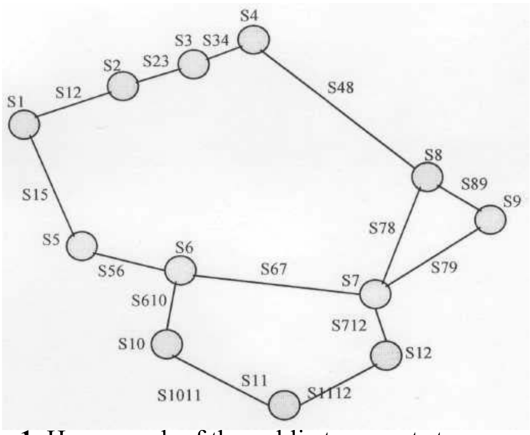

Fig. 1. Hypergraph of the public transport stops

Table 1. The length between stops

	S_1	S_2	S_3	…	S_m
S_1	∞	s_{12}	s_{13}	…	s_{1m}
S_2	s_{21}	∞	s_{23}	…	s_{2m}
S_3	s_{31}	s_{32}	∞	…	s_{3m}
…	…	…	…	∞	…
S_m	s_{m1}	s_{m2}	s_{m3}	…	∞

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 Fig.1. The system of the public transport is considered as a hypergraph [1, 2].

The problem decision demonstrates the homomorphic model of interaction of subsets of passengers and means of transport. Subsets of passengers 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 environment W_v.

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 $Z°_p$. Transportation of passengers with minimum number of transport types (number of routes) with a particular quality of service (passengers need achieve the goal) allows achieving power and fuel economy in public transport. The procedure of decision making [8] for energy consumption efficiency increasing the modelling using of public transport scheduling [9] are investigate in the article, taking in account co – modality of public transport means.

2. RESEARCH TASK MATHEMATICAL FORMULATION

The passenger amount per vehicles $P'=P_1'$, P_2', P_3'

The passengers amount per stops are $P^{si}=P_1^{si}$, P_2^{si}, P_3^{si}

$P_1^{si}=\sum_{i=1}^{r} p_i$,r – time moment between transport vehicles

Maximum departure per road Td^r

Directive arriving time, according passengers priorities $T^a d^{Z0}$

Distance between two stops $Si \in S$, $s_{ij} \in$ s value of the distance is positive.

Set of crossroads K-$Kj \in K$;

Set of roads R, $ri \in R$;

Set of the transport schedule H, $hi \in H$;

Capacity of the buffer (how much time the passengers have to change the vehicle) – B(t);

Distributed data bases Dp,

Distributed Web server (servers) Wd,

Electric power systems Web servers Wri;

Set of intellectual agents models Pa (Pa1, Pa2, …, Pai); $Pai \in Pa$;

Se – power system;

St – transport system with vehicles S^t_1, S^t_2, ..., $S^t_n \in St$; 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, ..., $S^{te}_n \in Ste$; 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;

$P = (p_{ij})$ – surface of hypergraph;

$Z°_p$ – priorities of the passengers;

Sv- environment [5];

W_v – influence of environment;

A^s – set of intelligent agent's (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.

The purpose of the task: to minimize logistic task – to create the schedule H, that requires minimum number of vehicles Tm', in order to deliver passenger p_i, along a particular route R, taking into account the possibilities of the transport change:

$\exists H \, \forall S^t_n (S^p_k S^{te}_j)$ -> min, (exists when $S^t_{n,}$ as for each S^p - S^{te}_j (S^t_n, S^p_k) exists.

S^{te}_j -> min, $S^t_n \geq S^t_{direkt}$.

The task is set to supply the requirements for the transport information systems solving it with the use of intelligent agents systems.

3. METHOD OF PROBLEM SOLUTION

The solving of the complex task applies the theory of schedules, the theory of flows as well as operation investigation, further the task is solved using elements of artificial intelligence.
The problem solution method is modelling of public transport schedule, using multi criteria model by energy consumption effectiveness criteria.
Public transport schedule [9] are modelling, using such elements and it's interaction (fig.2).

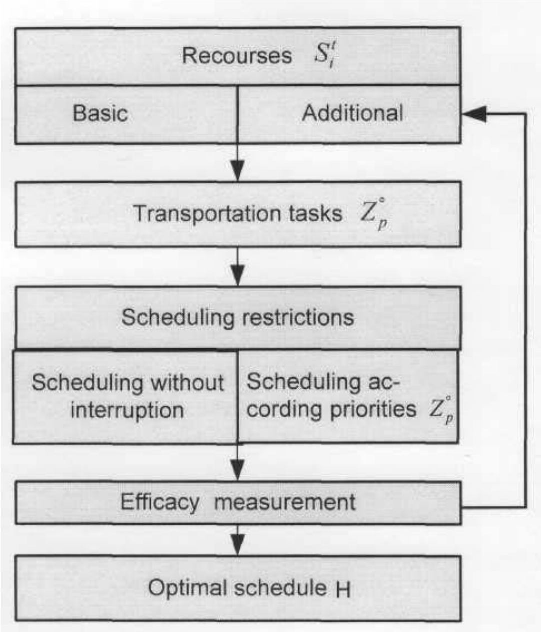

Fig. 2. General sequence model structure of public transport scheduling.

4.ALGORITHM OF PROBLEM SOLUTION

The problem solution algorithm is modelling of public transport schedule, using multi criteria model [11] by energy consumption effectiveness criteria.
Step 1. Task formulating.
Step 2. To formalizing set of possible decisions.
Step 3. To define set of criteria's.
Step 4. To define set of efficiency criteria measurement scale. Steps 3, 5.
Step 5. Possible alternatives efficiency measurement by criteria scales. Steps 3, 4, 6.
Step 6. Getting and sequencing information about priorities.
Step 7. To define set of decision making rules.
Step 8. Possible decisions ordering.
Step 9.Ordering results analysis.
Step 10. Sequence satisfactorily priorities? If yes Step 12, If no Step 11
Step 11. Non – satisfactorily reasons analysis, and definition of improvements. Steps 2, 3, 4, 5, 6.
Step 12. Sequence satisfactorily problem decision? If yes Step 13, If no Step 6 ore 1
Step 13. Finish of problem decision.
The first step of the algorithm states the common case of the task of the passengers transportation, defines the goal of the investigation (optimization) and conditions for the task solution – schedule of the passengers transportations.
The second step formulates the set of the schedule, tests its correspondence to the purpose, and elaborates a procedure testing possible schedules correspondence and set of solutions (schedules).
The third step realises possible analysis of the results. The schedules are compared with each other according to the power efficiency indices.
The scale of the distributed criteria evaluation is elaborated in the fourth step of the algorithm. Public transport scheduling are measured by energy efficiency criteria, energy consumption reducing for transportation of existing passengers amount.
The correspondent schedules are evaluated in the fifth step of the algorithm with the use of identified criteria of power efficiency.
The sixth step defines the priorities of the passengers and city transport authority.
The information on the priorities is applied in the seventh step of the algorithm to define the set of decision making regulation.
Taking into account the defined optimization condition the variants are compared and evaluated at the eighth step.
The ninth step realizes analysis of transportation sequence.
The tenth step evaluates whether the sequence corresponds to the priorities.
At the eleventh step non – satisfactory reasons are evaluated.
The twelfth step evaluates whether the sequence corresponds to the problem solving.
The problem decision is completed at the thirteenth step.

5. 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 scheduling task optimum in a dynamic $S^{te}_j(t) \rightarrow \min$, $S^t_n \geq S^t_{direkt}$.

6. EXPERIMENTAL PART

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.

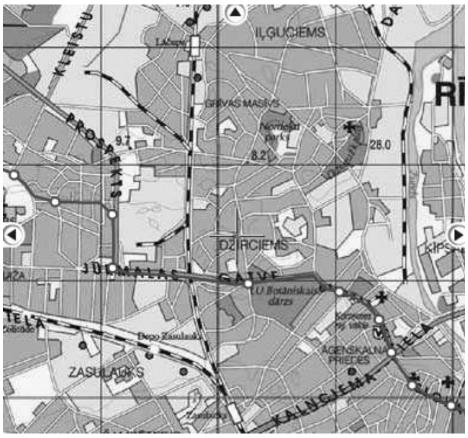

Fig. 3. Route of 4 tram in Riga (Latvia)

The system of the public transport is considered as a hypergraph, where Riga (Latvia) tram 4 (Fig.3.) from stop „Botāniskais dārzs" till „Grēcinieku iela" P4tr={ P4tr1, P4tr2,... P4trn} and trolleybus 9 (Fig. 3.) P9t={ P9t1, P9t2,... P9tu}, the apices of the hypergraph in this case are „Botāniskais", „Slokas iela" and „Grēcinieku iela".

The passengers use two means of public transport, first using trolleybus and then change for tram (Fig.4.)

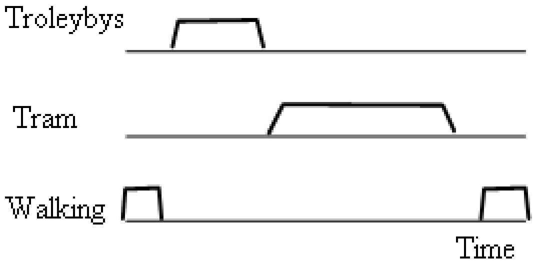

Fig. 4. Passenger route sequence

The considered in the example hypergraph of the public transport system is in fig.5.

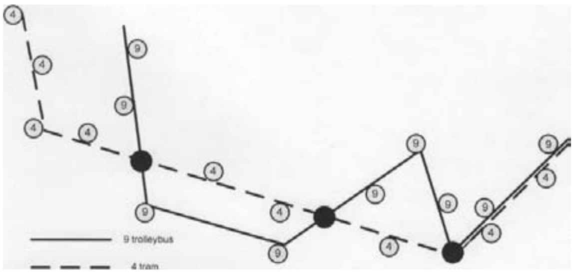

Fig. 5. Fragment of hypergraph of public transport system in Riga for tram 4 and trolleybus 9

Table 2. The parameters value in morning time

	S_2	$S_{2(9)}$	B(t)	P_1^{si}
S_1	5	5	20	8
S_2	∞	1	40	8

With an enshortening of the 9 th route up to the 1st apex of the hypergraph the economy will be more then 10 th. Ls per year. The 4. tram (table.3.) scheduling are fragment for working days shoved including only morning time of 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.

Table 3. 4. tram timetable

Hours	for stop «Dzirciema iela» Minutes
6	05;20;34;43;51;56
	01;06;12;18;23;28;33;38;43;47;51;55
	00;05;10;16;22;27;32;37;43;49;51;55
	01;07;10;14;21;28;34;37;41;47;53;59

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 and for trams 1.45 kW/km, an average tariff for 1 kWh, is Ls 0,05026, the efficiency S^{te}_j (t) is calculated for 22 days per month for 12 months per year, an average speed is 0.,2 km/min. S^{te}_j (t)=(36*35*1.94*22*12* 0,05026*0.32)-(54*2*1.45*22*12* 0,05026*0.32)= 9713,92 Ls

But we have to take in account, that passengers transportation till stop „Botāniskais dārzs" is more that existing amount passengers, that means, that we have increase amount of 4. tram by 2.

Finally passengers road (4.fig) with average time are decreased by 10 minutes.

7. CONCLUSIONS

For solution of the task of power use effectively the authors consider application of the public transport schedule, using multi criteria model by energy consumption effectiveness criteria modelling in the system of public transport.

The problem decision was achieved, using graph theory, multy criteria decision making, scheduling theory and intelligent agent systems, modelling. The measurement of suggested method was made by energy efficiency criteria in case of Riga public transport.

The suggested theory is assessed with the use of homomorphic model. The research is connected with improvement of electric power use effectively in public transport.

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МОДЕЛИРАНЕ НА РАЗПИСАНИЕТО НА ОБЩЕСТВЕНИЯ ТРАНСПОРТ ЗА УВЕЛИЧАВАНЕ НА ЕФЕКТИВНОСТТА НА ПОТРЕБЛЕНИЕТО НА ЕЛЕКТРИЧЕСКА ЕНЕРГИЯ

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ЛАТВИЯ

Резюме: *Изследването е свързано с подобряване на ефективността при използването на електричество в градския транспорт. Задачата може да бъде решена с помощта на модерни технически методи и оборудване, както и прилагане на контро върху системите. Проблемът за подобряването е решен с помощта на хиперграф и теорията на разписанията. Целта е да се планира работата на обществения транспорт чрез превозването на определен брой пътници, като се вземат предвид целите на пътниците според един от логистичните критерии, както и да се предложи процедура за подобряване..*

Ключови думи: *интелигентни носители, електроснабдяване, система на обществения транспорт.*