MODELLING AND SIMULATION OF PUBLIC TRANSPORT SAFETY AND SCHEDULING ALGORITHM

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KEYWORDS

Transport Safety, Scheduling, Algorithm, Energy Saving, Optimization, Database, Intelligent Systems, Logic, Mathematical Model

ABSTRACT

The main objective of the transport operations is a safe transportation process with minimal energy consumption. There are various methods for gaining these tasks. This paper discusses one of the possible problem solving - proper planning of public transport operations. The main goal of the research is to develop the adaptive algorithms for transport control and optimization. The main task of the target function is to minimize total downtime at intermediate stations. The specific unique Web-based computer model was developed. It uses Web database for simulation data storage and processing. Simulation results shows the workability of the developed algorithm.

1. INTRODUCTION

Safety is one of the first priority tasks in transport domain. For example, in the report of European Railway Agency (European Railway Agency 2010) the most part of railway accidents and crashes caused by the human factor.

Nowadays a lot of scientists make researches about energy saving process (Staņa et al. 2014) and time planning on railway transportation process (Nikolajevs and Mezitis 2016), that proves the actuality of the chosen topic. There are some studies made separately in fields of scheduling, planning and transport systems. For example, in (Shui et al. 2012) the solution of optimization of public bus timetable is proposed using a cultural clonal selection algorithm based approach is proposed to obtain a vehicle scheduling solution. However, scheduling for public electric transport energy saving and schedule overlapping is not so well studied.

In the previous works, the system and the algorithm for anti-collision system reducing human factor has been developed and tested (Levchenkov and Gorobetz 2014) Also intelligent transport safety system was investigated and designed by paper authors (Levchenkov et al. 2012). This research is a development of the intelligent public transport safety system also, but it is based on the scheduling theory (Conway et al. 2003).

Transport safety is actual problem and the control instruction infringements and human factor may cause crashes (Matsumoto et al. 2015). Schedule planning is one of the opportunities for reaching safety and energy efficient public transport movement process (Alps 2012; Alps et al. 2016) The main advantage of the proposed system is transportation safety performance without human being. At present time special worker – dispatcher or other person makes the biggest part of public transport timetables. Proposed system saves human labor by easy planning opportunity, reduces possibility of unsafety movements, minimize energy consumption by reducing stops and downtimes at intermediate points.

2. PROBLEM FORMULATION

The main purpose of the proposed system is still to minimize amount of collisions, safe the amount of energy consumption and avoid traffic jams, but new system is designed for public transport, because public transport vehicles have timetable.

The goal of current research is to develop the algorithm for optimizing timetable, to improve safety and prevent collisions in public transport, to use fast and comfortable transportation planning process, which could save dispatcher or work planner time and labor, to reduce energy consumption.

The following tasks are defined and solved:
1) to define the structure and functions of the system.
2) to develop the mathematical model and target function for optimizing the transportation process.
3) to develop the adaptive algorithms of the system functions for optimization
4) to develop the database for the mathematical model.
5) to develop the computer model and simulate the developed algorithm to compare the results before and after optimization.

3. PROPOSED STRUCTURE AND MAIN FUNCTIONS

The general structure of the system is presented on the Figure 1.

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Scheduling algorithm proposed in this study can be used in different transportation tasks. In this study is described the example of algorithm use in railway transportation process.

Proposed system structure consists of:

- Tdep – preferred departure time from the first station.
- Route - road between stop points, stations. On the one route at the same moment only one transport vehicle can run. After transport vehicle intersects stop point, previous route can be engaged by another transport vehicle. This type of running can lead to no traffic jam and equable distance between transport vehicles
- TD – train device, which consists of an algorithm, is connecting to the database on the server by using an internet and calculates optimal schedule for the train.
- Algorithm – method of analyzing the route busyness, possibility of route intersection and optimizing the transportation process by reducing routes intersections and regulating distance between the transport vehicles.
- Optimal schedule – schedule, which meets the conditions of the preferred departure time, safety transportation process, minimization of downtime and reduced energy consumption.
- Internet – needs to make the connection to the server.
- Coordinating algorithm – needs to refresh the information about the timetables in the database and to connect other intelligent devices.
- DB – database, which consists of:

\- Schedule – public transport timetables.

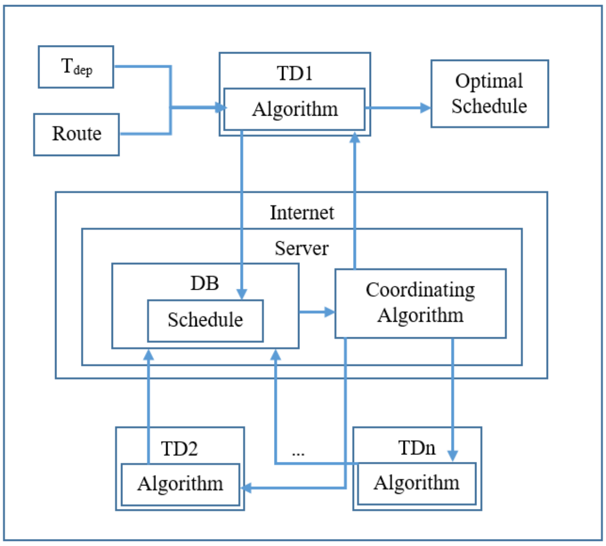

Figure 1. Structure of the system

Preferred departure time and selected route are on the entrance. Train device TD connects to the server. The nearest possible departure time is found and checked in the coordinating algorithm. Other train devices TD might be connected to the server as well and can chose their optimal schedules also. Time interval for the transportation process needs to be checked, to prevent the situation when two trains chose the same schedule. After the free schedule is chosen, the algorithm of train device TD is checking the possibility of downtime and minimizes it by finding in the database another departure time.

4. MATHEMATICAL MODEL AND TARGET FUNCTION

The mathematical model is represented with following sets:

- $SP = (SP_1, SP_2, \dots , SP_n)$ – set of stops;
- $R = (SP_1SP_2, SP_2SP_3, \dots , SP_{n-1},SP_n)$ – set of routes;
- $U \subset (U^1,\dots,U^n)$ - set of transport units as a subsets of different types, where for different transport safety task it could be:
  - $U^1 = (u_1^1,\dots,u_{n_1}^1)$ - subset of railway transport units;
  - $U^2 = (u_1^2,\dots,u_{n_2}^2)$ - subset of buses;
  - $U^3 = (u_1^3,\dots,u_{n_3}^3)$ - subset of trams etc.
- Schedule $A = \Sigma^{U}{}_i = (t_1, t_2, \dots t_j, \dots t_m)$ – time moments of arrival of j-th vehicle if i-th SP is included in vehicles route.
- Schedule $D = \Sigma^{U}{}_i = (t_1, t_2, \dots t_j, \dots t_m)$ – time moments of departure of j-th vehicle if i-th SP is included in vehicles route.

Target function:

$$T = \sum_{i=2}^{n}(t_i^s - t_{i-1}^b) \rightarrow min \qquad (1)$$

Where,
t_i^s– time of departure from the station;
t_{i-1}^b– time of arrival to the station.

Target function can be explained by following time axes:

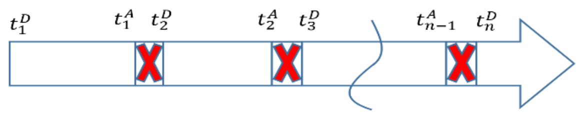

Figure 2. Explanation of the target function

Where:
t_1^D - departure from the first SP time, s;
t_1^A - arrival into second SP time, s;
t_2^D - departure from the second SP time, s;
t_2^A - arrival into third SP time, s;
t_3^D - departure from the third SP time, s;
t_{n-1}^A - arrival into n-1th SP time, s;
t_n^D - departure from the nth SP time, s.

The main task of the target function is:

$$T = (t_2^D - t_1^A) + (t_3^D - t_2^A) + \dots + (t_n^D - t_{n-1}^A) \rightarrow min \qquad (2)$$

Downtime at intermediate stops reduced to zero. This will lead to non-stop running through the intermediate stops and energy consumption will be decreased (Beinarovica et al. 2017).

5. ALGORITHM OF SAFE SCHEDULING

The steps of the algorithm are described for HMI (human-machine interface). The algorithm is presented in 33 steps.

STEP 1. Connecting to the server and database.
STEP 2. Departure point SP_1 and destination point SP_n, time of departure t^D_1, the buttons "Check" output.
STEP 3. Data checking.
STEP 4. Storing of the set parameters SP_1, t^D_1, SP_n.
STEP 5. Spans ID finding SELECT * FROM `spans`.
STEP 6. Departure point SP_1 and destination point SP_n names output. Spans ID output.
STEP 7. Number of j-th vehicle output from the table "Timetables", time moment of arrival and departure of j-th vehicle output.
STEP 8. Additional limitation "Closed" output.
STEP 9. Calculation of the remaining spans included in the route SP_1SP_n.
STEP 10. The buttons "Continue" output. It clicking check.
STEP 11. The direction of movement checking.
STEP 12. Spans ID finding.
STEP 13. Departure point SP_1 and destination point SP_n names output.
STEP 14. Unlimited array $arr create.
STEP 15. Additional limitation entering into an $arr array.
STEP 16. All the chosen vehicles entering into an $arr array.
STEP 17. Saved timetables entering into an $arr array.
STEP 18. Sorting an $arr array.
STEP 19. Setting a time interval from $date_now to $date_p.
STEP 20. Intervals entered in an array separation on the beginning of time interval 'time from' and the end of the time interval 'time to'.
STEP 21. The condition of the closing of the day, if before the end of the day is no more busy intervals.
STEP 22. The condition of the coincidence of the free interval with a noted additional limitation interval.
STEP 23. Calculation of the free intervals. And saving in $memory variable.
STEP 24. Time of departure t^D calculation and saving in $first variable.
STEP 25. Time of arrival t^A calculation and saving in $second variable.
STEP 26. Free intervals $first.'-'.$second entering into an $arr array.
STEP 27. All free intervals from an $arr array output.
STEP 28. Departure time t^D output.
STEP 29. Downtime $dd (on passing points) calculation and output.
STEP 30. From the first point recommended departure time t^D output.
STEP 31. "Cancel" and "Save" buttons output.
STEP 32. Results saving in the database.
STEP 33. Return to the STEP 1.

The developed algorithm can be also represented as it is shown on the Figure 3.

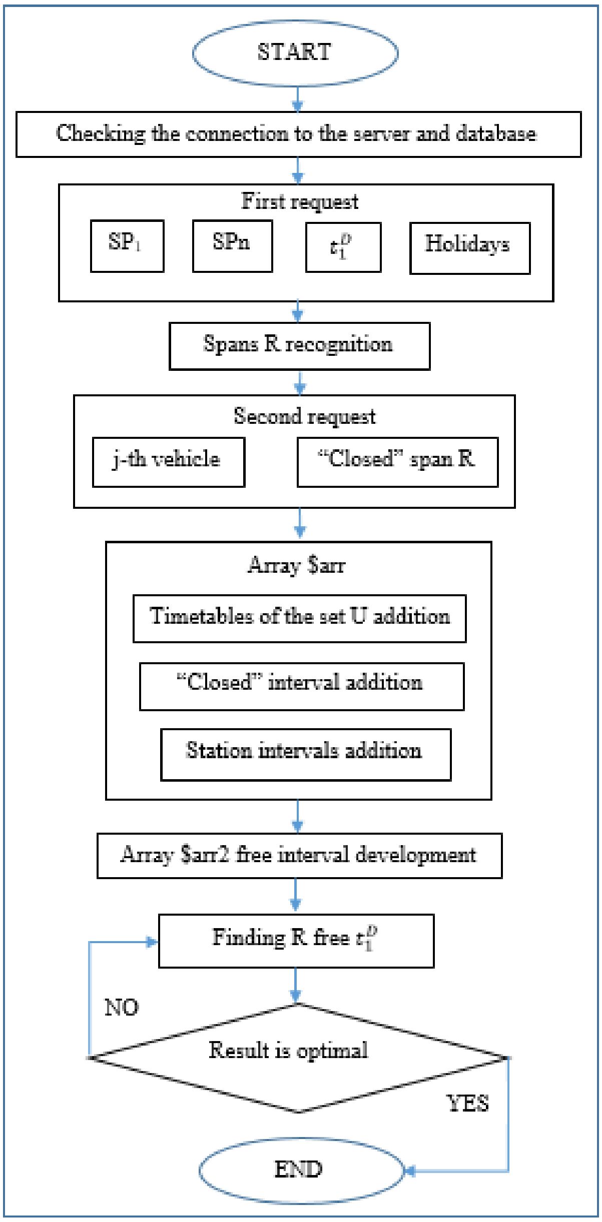

Figure 3. Scheduling algorithm

6. STRUCTURE OF THE DATABASE FOR THE MODEL

For the simulation model the database in MYSQL DBMS was developed for the railway transport. The usage of database improve the control of the data processing of the model. If conditions are changed, there is no need to rewrite the entire code of the model.

Proposed database contains 4 types of tables:
1) Table of the departure and arrival points (Figure 4). It can be stops, stations or other points on the route. Each post, park or station in this table is marked with an unique number ID.
Columns of the table: <Point ID, Station>

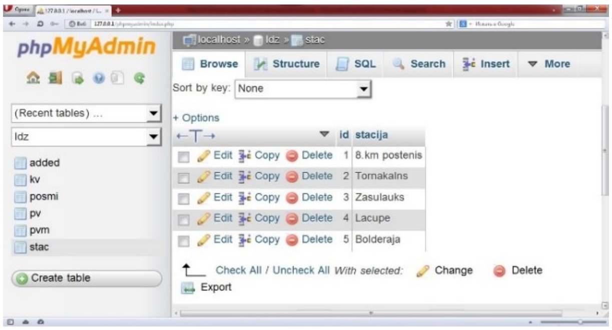

Figure 4. Table of departure and arrival stations

In this table ID numbers are given to all the necessary stations.

2) Table of the spans between departure and arrival points (Figure 5). Each span is marked with an unique number ID.

Columns of the table: <Span ID, Departure point ID, Arrival point ID>

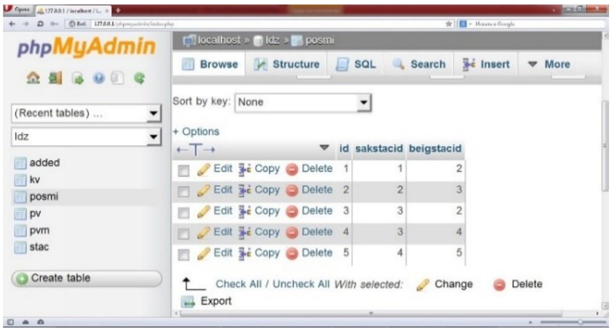

Figure 5. Table of spans

Before making the table about spans it is necessary to find out the direction of the movement.

3) Tables with transport vehicles timetable. One table for each span.

Columns of the table: <Vehicle ID, Span ID, Number of the vehicle, Departure time, Arrival time>.

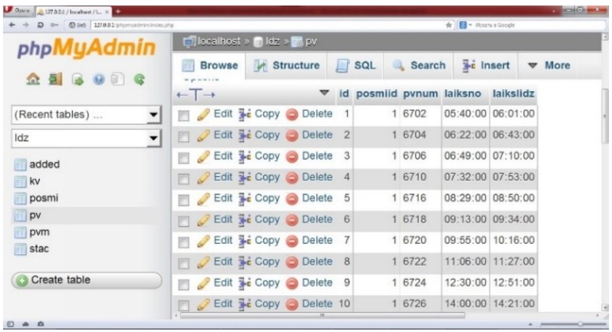

Figure 6. Table of passenger trains timetable

For the experiment, two tables with timetables for the passenger trains were made. One table for the passenger trains running every day (Figure 6).

Another one table was made for passenger trains, which run depending on the weekday or weekend (Figure 7). Uniqueness of this table is availability of train finding by using clear logic. Depending on either under the weekday is “1” – train is running today, either under the weekday is “0” – train is not running today.

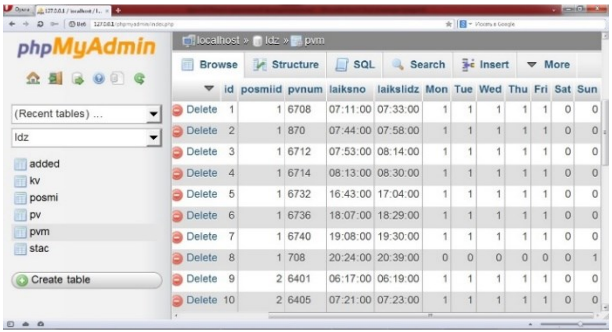

Figure 7. Table of passenger trains, which runs depending on the weekday, timetable

Table with timetable of the freight trains was made as well. The principle is same as for the tables with timetables for the passenger trains.

4) Tables with saved results were made (Figure 8).

Columns of the table: <Schedule ID, Span ID, Departure time, Arrival time, Date>

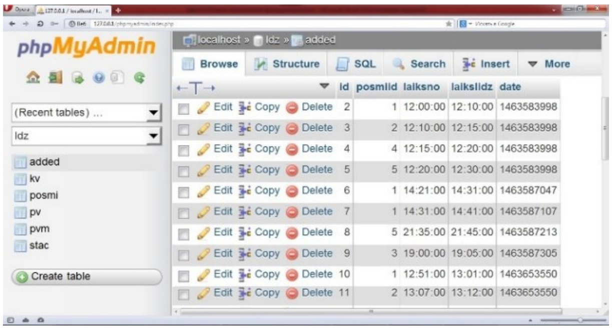

Figure 8. Table of saved results

After the timetable for transport vehicle is chosen, it is saved in the database, and is considered that saved in the database time interval is busy, and no other vehicles can use the same transportation time on the same route within one day.

7. DEVELOPED SIMULATION MODEL AND EXPERIMENTS

The specially developed software is offered as the system of planning safe transportation process, which makes a selection from the database, makes calculations and records the obtained results in a database.

At first movement directions for the experiment were chosen (Figure 9). For the experiment, real part of the Latvian railway was taken.

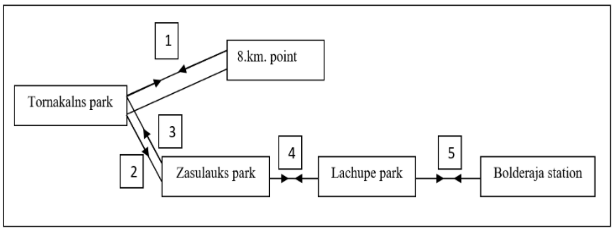

Figure 9. Movement directions

The first request was entered to the developed system (Figure 10).

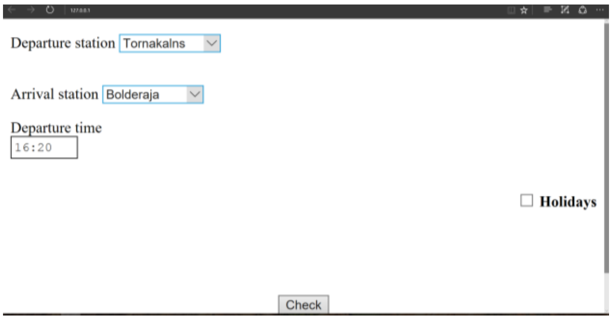

Figure 10. First request

Where,
Departure station – Tornakalns;
Arrival station – Bolderaja;
Departure time – 16:20;
Not a holiday.

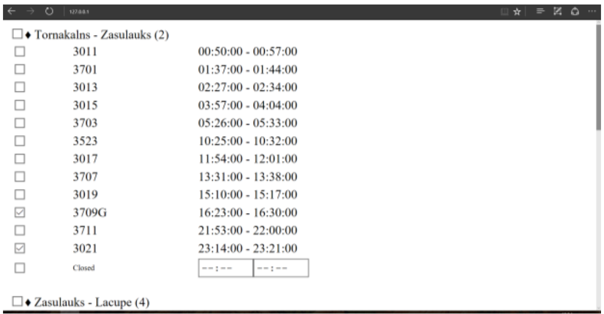

Figure 11. Second request

Figure 12. All available intervals

After all the request was entered, the button "Check" was pushed and the second request was received (Figure 11). All the necessary freight trains were marked.

After both request were entered, "Check" button was pushed and the result was received. The result is divided into two parts. The first part - display of all available intervals on the running line during the day (Figure 12).

The second part - calculated time on the running line before the optimization (Figure 13) and after the optimization (Figure 14).

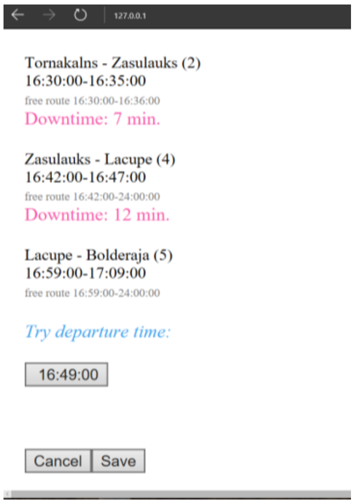

Figure 13. Results before optimization

Figure 14. Results after optimization

The comparison of two results, that were received in experiment, is displayed on the Table 1.

The preferred departure time was 16:20. Before optimization the system showed that the first span will be free on 16:30, and train can be sent to the next station – Zasulauks. But, second span will be busy till 16:42 and for the safety transportation process, train needs to make a stop on the Zasulauks park. The same situation is at the next station – Lacupe. Train arrives at Lacupe park at 16:47, makes a stop, and stands for the 12 minutes, because the third span is busy till 16:59. As the result, to gain a safety transportation process, train makes two stops on the intermediate stations with the common downtime 19 minutes.

After optimization - Tornakalns cargo terminal train is sent from Tornakalns park for 29 minutes later the preferred shipping time: at. 16:49. It is send through the intermediate stations without stops and downtime. And arrives on the Bolderaja station at the same time as before optimization: at. 17:09.

Table 1: Results Comparison

Operation	Park / station	Before optimization	After optimization
Departure	Tornakalns	At 16:30	At 16:49
Departure time shift from the desired time 16:20	Tornakalns	10 min.	29 min.
Arrival	Zasulauks	At 16:35	At 16:54
Downtime	Zasulauks	**7 min.**	**0 min.**
Departure	Zasulauks	At 16:42	At 16:54
Arrival	Lacupe	At 16:47	At 16:59
Downtime	Lacupe	**12 min.**	**0 min.**
Departure	Lacupe	At 16:59	At 16:59
Arrival	Bolderaja	At 17:09	At 17:09
Downtime sum		**19 min.**	**0 min.**

After the comparing the two results, was made the conclusion that in the first variant of the result, was offered the closest departure time for the safe transportation process. But this result might be suboptimal in time and energy economy. In the second variant of the result stops at intermediate stations and downtime was reduced to zero and safety task is performed as well.

8. CONCLUSIONS

Experiment shows, that system takes into account all the possible risks and advices to use safe and the most efficient time for public transport running process. Amount of stops at intermediate stations was reduced to zero, downtime was reduced to zero as well, routes were free from another vehicles during advised time, the result was received by using the information from the database, that means, that there is no need to have a special worker for planning transportation process, because it is automatized.

Proposed in this research goal was reached. In this research clear logic was used. All the conditions were clearly described. In real life human being while making a decision reasons about the possibility of the event. To make the system be artificial it is necessary to use fuzzy logic and authors started a new research based on it.

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