Passenger Path Plan Reliability Improvement Proposal

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***Abstract*—We made the passengers' path planning more reliable by predicting irregularities in public transportation. The prediction is based on historical data. Two levels of refinement are introduced and tested on sample data. Applying prediction on actual timetables allows us to plan the path up to 19% more resilient against change loses. This can significantly help passengers to reach the destination in time.**

***Keywords*-public transportation; timetable correction; path plan reliability;**

I. Introduction

People need to get to work, to school, or to other places to fulfill their duties quite every day. In large cities they can choose whether they use individual transportation or public transportation. In the second case the path could be planned using the public transportation timetables.

In some cases is such solution reliable enough – either the transportation mean is reliable enough or the time reserve was large enough or we simply had luck? There are, however, also cases when the plan fails and we are late.

Sometimes a small delay causes no problem but sometimes it is undesirable. What to do in such case? How to plan the journey? We propose here a procedure allowing improvement of the precomputed path plans base on the use of public transportation.

> **Use case, part 1:** Jim wants to get to school tomorrow morning. It is a first school day in a new school. It is good to be there in time – not too late and not too soon. The schooling starts at 8:00am. Jim therefore searches for connection that arrives at 7:50am at latest. It is reasonable to have some reserve.
> Jim got the plan to use line 4 starting at 7:34 and then line 14. There should be three minutes for change. The other connection starts at 7:35 and is longer. The Figure 1 shows the plan.
> It could happen that the first connection is delayed and the second is in time. In such case Jim misses the change and arrives late, would be the 10minutes reserve sufficient?

The movement of individual vehicles of public transportation is influenced by many factors. Many of them occur repeatedly and they are therefore expectable. For example the density of traffic in certain daytime is taken into account to a limited extent when the carrier is creating the timetable.

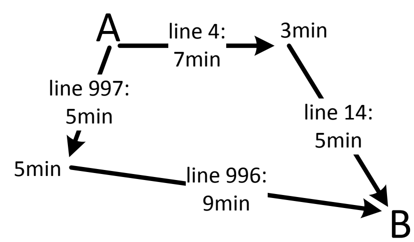

Figure 1. Jim's path plan

For some time we are studying the mechanisms of public transportation in a city environment, especially in the city of Prague. We have discovered that the reliability of planning a connection with one line change is about 70% to 80% in considered examples. Applying prediction based on historical data about delays we have increased the reliability at 80% to 90%. The reliability increase would be even more significant for connections with more than one line change. These results could use well both the passenger (connection planning) and the carrier (checking connection continuity).

The structure of the paper is as follows: The first section introduces the problem and goal. The second section recalls some related work. The third section focuses on the problem background. The section four remembers known solutions. The fifth section describes and discusses our method and our tests. And the final (sixth) section sets the conclusion.

II. Related Work

The planning of a connection in public transport network is typically based on timetables given by the carrier. The behavior of a real transportation network contains an element of randomness. The irregularities in following the timetables (delays) are well known phenomenon, which occurs through various levels of public transportation system – see e.g. Rietveld et al. [1].

The delays are studied from various viewpoints. There are many statistical evaluations. Yetiskul and Senbil [2] study distribution of travel times throughout a day and with respect to geographical partition of the city of Ankara. Olson and Haugland [3] partition delays to primary and secondary. The first ones are caused by a direct influence on the transportation mean, whereas the second is induced by the delays of connections that should be wait for. Börjesson and Eliasson [4] use average train delay as a measure of train reliability. Coffey et al. [5] try to estimate bus arrivals for a single route. An interesting view on various aspects of transportation is given by Litman [6]. He assigns subjective costs to the individual aspects (like comfort, waiting, transportation time). These values can be used to estimate passenger preferences. Improvement of some of the factors could raise the popularity of public transportation. We could use this idea to motivate ourselves for searching public transportation improvement opportunities.

III. Problem Analysis

Let us recall some factors influencing the timeliness of individual connections:

- separation of the line from other traffic;
- sensitivity of given transportation mean to weather conditions (like snow or icy road);
- variability of station turnaround;

The lines with routes separated from other traffic could be considered reliable enough (underground-only, lines using reserved routes). For lines that could be influenced by surrounding traffic and other factors, it could be useful to be able to take such issues into account. We therefore focus on lines and line changes being more sensitive do delays.

Currently we have operation data of trams in Prague in 2008. Data were obtained from the Automated Vehicle Location (AVL) system. Comparing the data from the system with the valid timetables we have reconstructed the delays in a certain time period. The Figure 2 shows the average delay of line 22 at a certain stop during various times of a day in the given period.

A. Reliability of Line Change

When planning a line change, the destination line is selected based on the arrival time of the source line, time for the transition and the arrival time of the destination line. If the source line is delayed or the destination line is too early according the planned arrival, the passenger can miss the change planned. Then the passenger is forced to reschedule the remaining path plan. However this can typically lead to a delay of the passenger's destination arrival time compared to the original connection plan. This situation can be very unpleasant for the passenger. The failure of the line change leads more or less to the failure of the overall connection plan.

The reliability of line change planning can be seen as the ratio of planned line changes that fail to all planned line changes. The line change fails usually occur only in some cases. The probably most typical one is that the source line is more often late and the second line is closer to be in time and there is no duty to wait for the change.

The connection plan can contain one or more line changes, whereas the success of the change is not typically ensured. We suppose that the critical point is that we could miss some of the planned line changes. Rising reliability of the planned line change could raise the reliability of the entire path plan. We therefore focus on the line change reliability.

IV. Existing Approaches

There are several techniques to cope with the irregularities in public means operation. The simplest approach for the passenger is to take sooner connection. If more lines should be used and if at least some of them have longer interval then taking a sooner connection can be ineffective.

If we have an idea of a probable line delay, we can plan the line change according to it. We can even choose a different line to change to. Actually this can lead to a different path plan.

We suppose that it could be useful to get a plan that is reliable enough to balance the time used as reserve and the probability that we reach the place in time.

One way to cope effectively with the delays is to update the path plan with actual information about the line timeliness. This kind of information can provide AVL (Automated Vehicle Location) system. The problem is that such update has only a short-term validity [7], [8]. So the passenger can only change the plan while already travelling.

Interesting approach has been tested by Mazloumi at al. [9]. They tested application of neural networks for delay prediction.

To reach the long term effect we need to process historical AVL data [10]. Then we can provide passenger with expected spare time needed to cover the line delays and assemble the path plan according to it.

V. Processing

We have tested the hypothesis that historical data can help in rising reliability of passenger route plans on real tram traffic data collected in the city of Prague.

The question is whether the periodically bound irregularities are stable. That is, whether it is possible to create a prediction based on historical AVL data for future periods of a sufficient quality. How much will the reliability of transfers increase in a given period when the delays were estimated from the values of delays in the previous period?

A. Historical AVL Data Prediction

The average delay of the given line can be obtained from the operation data of a certain time interval. So we can correct timetables of the given line for the future time interval with this value. This would be done for all the lines the passenger is changing.

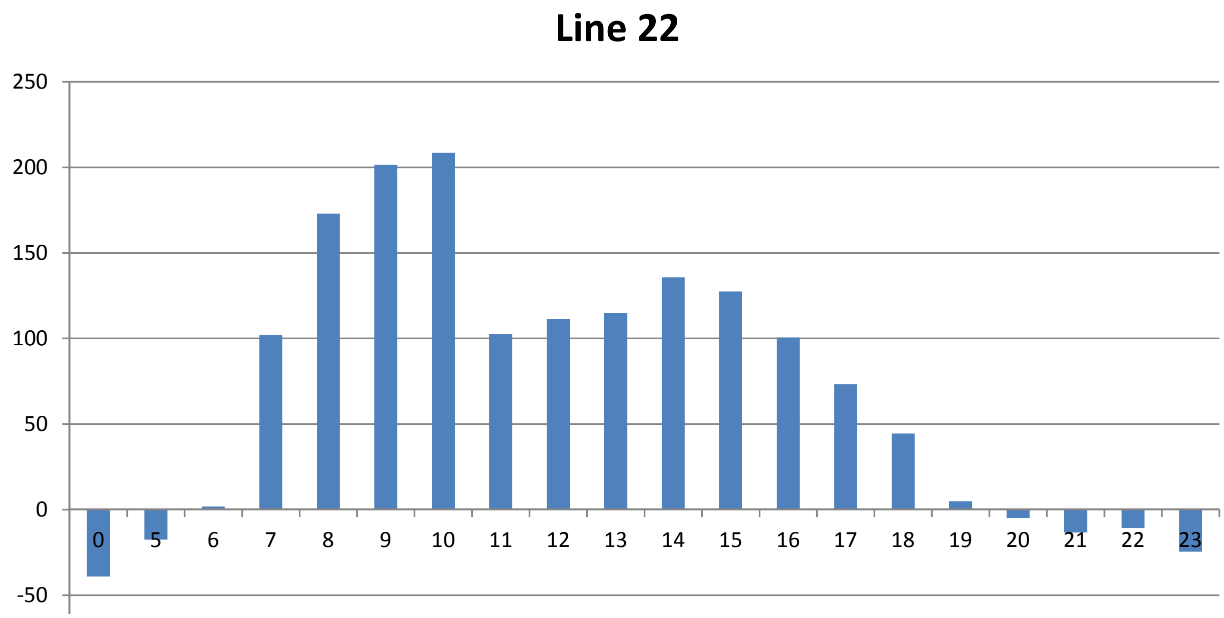

Figure 2. Average delay – dependency of average delay on daytime

From the available operation data we select all the transfer situations between given lines in given time interval as the connection planner would plan them according to corrected timetables. For the selected transfer situations we find the time of real arrival of the vehicle from the operation data. Based on these times we easily find out which planned transfers fails.

B. Fine Historical AVL Data Prediction

In some cases it is advantageous to consider the periodicity of delays in context of the time of day. Data processing is the same as in the previous case, except that the average delays are calculated for each hour of the day separately. This brings a much finer prediction that follows the dependence of the transport network state on the time of day.

C. Results

We used the data from March to make the predictions for April and then compared the produced path plans with the ones created using timetables only and with the April traffic data. We then have these three sets of operating data:

- scheduled traffic – the vehicles operate exactly as the timetable expects;
- predicted traffic – the vehicles operate according to the predicted timetable;
- real traffic – available operational data.

In the following examples the transfers are realized within the same stop refugee, so we do not have to determine the transfer time between platforms. The time for line change is the time required for getting off the vehicle and the time for waiting at the stop on the destination vehicle. In the following cases the minimum transfer time is set to one or two minutes. The overall transfer time depends on the arrival intervals.

Although the tested routes have just one change (line 20 to line 18 and line 12 to line 9 in Table I), it appears that the path plans made using timetable in combination with historical data give better results than the plans using timetable only. Moreover, the plans computed using hour-based prediction are usually slightly better than the predictions made by day-based prediction.

Reliability of transfers made according to a timetable:	**min. time for transfer** 1min	2min
of a carrier	86,91%	84,12%
predicted for days	89,33%	86,19%
predicted for hours	89,38%	86,45%

a) line 20 to line 18

Reliability of transfers made according to a timetable:	**min. time for transfer** 1min	2min
of a carrier	78,27%	70,11%
predicted for days	80,63%	89,26%
predicted for hours	87,59%	88,82%

b) line 12 to line 9

Table I
PREDICTION RELIABILITY FOR LINE CHANGE

The achieved reliability improvements vary in line change, change time, and prediction model. The reliability improvements are between 2,3 % points (84,12% $\rightarrow$ 86,45%) and 19,1% points (70,11% $\rightarrow$ 89,26%).

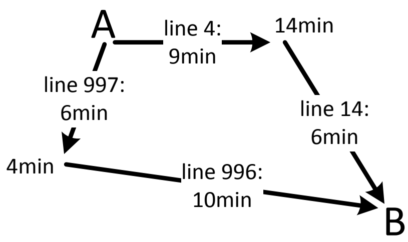

Figure 3. Jim's adjusted path plan

The observed differences were dependent on the line and change nature:

- The changes from less precise lines to more precise lines appear to be most sensitive to be broken and are candidates for highest plan reliability improvements.
- For lines with very short interval (5 minutes or less) it could be in some simpler to use one connection sooner than to handle historical data.

Use case, part 2:
Using the original plan Jim has a 84% probability, that he will make the change between line 4 and 14. Otherwise he can miss the change. The Figure 3 shows the situation. At this point he cannot correct the path plan and he has to wait for the next vehicle of line 14. Time interval of line 14 is 10 minutes. It causes that Jim could arrive to the destination at 8:03. That is quite late even he has a 10 minutes reserve at the beginning.
The reliability of the change between lines 997 and 996 is 98% during morning hours. If he took the connection via lines 997 and 996 he would arrive at 7:54. If he know that the change between line 997 and 996 is more reliable, he would be at school in time for his first day.

VI. Conclusion

We have shown that it is possible to improve public transportation path planning reliability for lines and connections being often late. The timetable data can be adjusted according analysis of historical data on the vehicle movements. In our test the failure rate of pre-computed path plans has been reduced up to 1/3 comparing to path plans using original (non-adjusted) timetable only.

We suppose that from the passenger point of view the availability of reliable path plans rises the reliability and usability of the supported public transportation network.

The collected data and used principle can be useful for partial checking of new timetables and comparing them with the existing ones.

A. Future Plans

We want to apply our method to network with more precise data (Prague trams have data only from certain points of the track). We also want to focus on path searching algorithms taking into account reliability and timeliness of individual connections to raise the overall path reliability to a given level.

Acknowledgment

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