Optimizing Public Transport Planning and Operations Using Automatic Vehicle Location Data: The Dutch Example

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Abstract

There is a growing pressure on urban public transport companies and authorities to improve efficiency, stemming from reduced budgets, political expectations and competition between operators. In order to find inefficiencies, bottlenecks and potentials in the public transport service, it is useful to learn from recorded operational data. We first describe the state of publicly available transit data, with an emphasis on the Dutch situation. The value of insights from Automatic Vehicle Location data is demonstrated by examples. Finally, a software tool is described that makes quick comprehensive operational analysis possible for operators and public transport authorities, and was able to identify several bottlenecks when applied in practice.

Keywords: public transport, AVL data, service reliability, monitoring

1 Introduction

Similar to in other countries, public transport in the Netherlands has to face substantial cost-cutting measures. Although higher quality and more capacity are needed, funding for public transport is reduced. Improving public transport quality and extending capacity under reduced finances is a hard challenge, but we believe that several possibilities exist. The key factors to enhanced and more cost efficient public transport are travel time and service reliability.

Service reliability is the certainty of service aspects compared to the schedule as perceived by the user and is, next to travel time, one of the main quality aspects in public transport. (Potential) public transport passengers take these aspects explicitly in consideration while planning their trip mode [Oor13].

In several studies reliability-related attributes have been found among the most important service attributes in a variety of situations. Balcombe et al. [Bal04] report that service reliability is considered by passengers twice as important as frequency. König and Axhausen [Kon02] conclude that the research done over the last decade shows that the reliability of the transportation system is a decisive factor in the choice behaviour of people.

Much research illustrates the potential of improving travel time and service reliability. One could think of improvements of vehicles, infrastructure, planning and operations. Literature shows that in urban public transport, substantial attention is given to ways to improve services at the operational level [Vuc05, Ced07, Oor09a]. Concerning strategic and tactical instruments, much research is already available on the planning instruments of priority at traffic lights, exclusive lanes and synchronization. The implementation of bus lane schemes and traffic signal priority are the most used solutions in this field (as shown by e.g. Waterson et al. [Wat03]). Both Ceder [Ced07] and Vuchic [Vuc05] present the different methods and effects, and also give an overview of the issues which need to be considered in synchronization. During the design of the schedule, optimising trip time determination and holding are potential instruments improving operational quality [Oor12, Del12, Xua11].

Less researched so far, but potential instruments are available during network design as well, for instance line length and design of terminals [Oor09b, Oor10]. A study of a new tram line in Utrecht, the Netherlands [Oor13], showed that about 65% of the (societal) benefits are related to these aspects, being over € 200 million during the total lifetime of the tram infrastructure. On busy bus trunks in Utrecht, a reduction of 30 seconds of trip time per bus saves about € 100,000–400,000 in operational costs per year.

The first step to increase operational performance is a proper analysis of historical operations. This paper focuses on bus and tram modes. Operations performance for heavy railways based on track occupation data is described in [Gov11]. Automatic vehicle location systems (AVL systems [Str00, Hic04]) are of great help to provide databases of historical performance with regard to travel time and reliability. Although such data has already been available for years to many operators, it is only recently that this valuable data is becoming available also to Dutch transit authorities, researchers and developers. In addition to facilitating analysis of performance, proper data also enables forecasts of future service quality [Kan08, Wil09]. In this paper we analyse a practical example of such a data set to illustrate the usefulness of these kinds of analyses: several bottlenecks are identified, providing transport authorities with insight into setting investment priorities.

2 Public Transport and Open Data

Public transport companies have always dealt with large amounts of data when designing timetables, scheduling vehicles and staff, collecting fares and more recently tracking vehicle locations. However, it has only recently become possible to store large amounts of historic vehicle location and fare collection data, and therefore to analyse this data. Furthermore, in line with other “Open Data” initiatives in the public sectors, data related to public transport is currently becoming publicly available in more and more areas, notably in North America and more recently in certain European cities.

The first type of public transport data that became publicly available is timetable information. Besides supplying public transport route planners with timetable data, computer-readable timetable information also allows for efficient analysis and comparison of public transport networks, describing spatial coverage, commercial speeds, frequencies, and connections to adjacent public transport networks. Timetable information provides no insight yet, however, in the performance of the timetable realization and hence the service reliability of public transport and the real-time timetable information.

Accurate real-time vehicle location data (Automatic Vehicle Location systems, AVL) has become available for public transport operators with the wide availability of GPS and GSM devices. AVL data has also become publicly available in many areas in the recent years, albeit often with the condition that it is only used for passenger information. Early examples include the transit agencies of Washington, Boston and some other US bus companies. We note that these days most Western public transport operators provide some kind of real-time vehicle location (or expected vehicle arrival time) information to the public, but often this information is still not technically or legally available for storing or further processing by third parties.

2.1 The Dutch example

In the Netherlands, most public transport operators are on board with the initiative called Borderless Public Transport Information (“Grenzeloze Openbaar Vervoer Informatie”, GOVI [Gov13]), aiming at making a wide range of public transport information available and processable from timetables to fares, vehicle location and punctuality. The data exchange interfaces (“*koppelvlakken*”) are defined by the set of standards called BISON [Bis13]. Another source of open public transport information, such as a GTFS feed on the national level, is the company 9292 REISinformatiegroep BV [Rei13], a company specialized in passenger information owned by Dutch operators.

GOVI was designed to facilitate data communication between vehicles and the land side to enable dynamic passenger information. As an additional benefit, the actual and scheduled vehicle positions and times are logged in a database. Although this database was not the objective of the GOVI system, it is extremely helpful to monitor and analyze public transport performance.

In particular, in 2012, the first Dutch public transport operator agreed to legally release AVL data via GOVI for storage and analysis by third parties, such as researchers and developers [Gvb13]. Since then several other operators joined. Such data streams are in practice publicly available via the Dutch OpenGeo Foundation [Ope13]. The source of the data later presented in this paper is either directly from the transit authorities or via OpenGeo.

3 Insights from AVL data

As a first step, it is important to understand the structure and the quality of the data source. In our case, AVL data was available for several months from multiple operators in the format described by interface KV6 of the BISON standard mentioned earlier. An example extract of the most important data attributes and the first and last few records related to a single public transport vehicle trip is presented in **Table 1**.

Table 1: Example data output from BISON interface KV6

Time	Message type	Operator	Line	Journey	Stop	Punctuality
08:29:00	INIT	...	B120	7001	99990140	
08:29:00	ONSTOP	...	B120	7001	99990140	60
08:29:22	DEPARTURE	...	B120	7001	99990140	82
08:31:28	DEPARTURE	...	B120	7001	99990290	88
...						
08:51:04	ONROUTE	...	B120	7001		
08:52:37	ARRIVAL	...	B120	7001	99990500	-202
08:52:37	END	...	B120	7001	99990500	

This data table consists of timestamped messages of important events of the vehicle trip. In particular, a trip starts with an INIT initial message and ends with an END message, and all departures are logged with a DEPARTURE message. In case of some stops an ARRIVAL message is recorded too, allowing for an estimate of the dwell time. Furthermore, in case that there is no departure and arrival event taking place for a longer time duration (about a minute), an ONSTOP or an ONROUTE message is recorded, including exact location. Our data source already includes a value for delay, which equals to the difference of the message timestamp and the planned arrival or departure time.

Line-based analysis

A commonly used visualization [Fur06, Oor09a] of the performance of a transit line is plotting each trip as a line chart in a coordinate system of stops versus delay. **Figure 1** (left) shows one month of bus trips of a certain line, as well as the median and 15th and 85th percentiles. Such a chart is useful to see both the level of variations in the execution of the timetable and the systematic deviations. Other phenomena that are shown by this particular chart are the ample time reserve used just before the last stop and the use of some holding points during the trips.

Another way to look at the same data is to plot vehicle headways instead of delays. A high frequency line with a high level of delays but regular headways remains attractive to the passengers. The chart is shown on **Figure 1** (right), the scheduled headway is 10 minutes. This location-headway chart points out the regularity of high-frequency services along the line, as well as possible bus bunching.

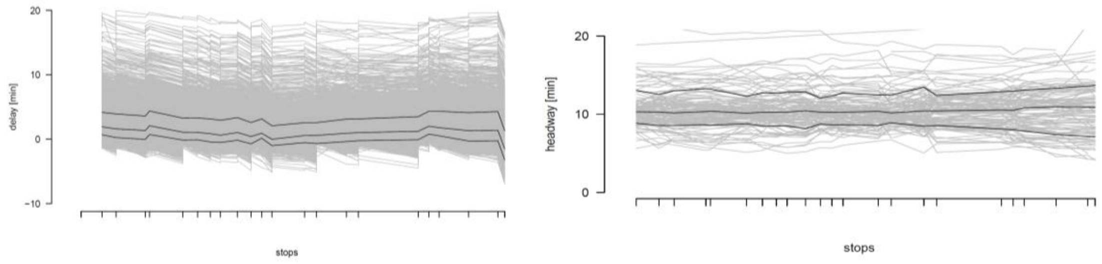

Figure 1: Vehicle delays (left) and headways (right) along a single route

Network-wide analysis

The ubiquitous availability of vehicle locator devices allows one to take a step further from line-based performance evaluation and investigate patterns at the network level. Phenomena only visible on the network-level are the reliability of transfers, area-related issues and possible bunching or interference on multiple lines with shared sections. An example of a network-level data visualization is the average delay at each stop, including stops with several transit lines, shown on **Figure 2**.

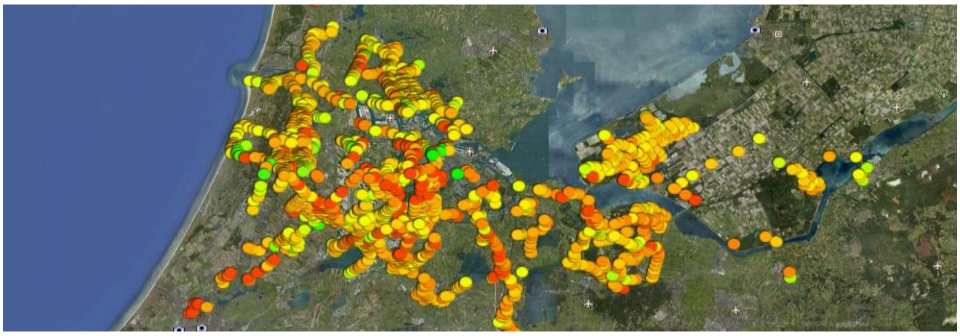

Figure 2: Average delay per stop (green: early, yellow: on time, red: late)

Inter-operator transfers

An aspect of public transport travel that was previously invisible to the public and to each operator, but of substantial importance to the passenger, is the reliability of transfers between multiple operators, such as between a long-distance train and a local bus. With open data, it is possible for anyone (so also to any operator) to investigate the actual reliability of inter-operator transfers – and for the operator to take steps if necessary.

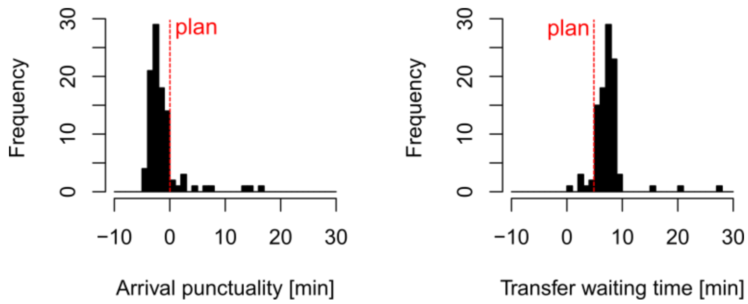

Figure 3: Arrival punctuality of a vehicle and transfer waiting time for the passenger at a transfer location.

Figure 3 shows a discrepancy between vehicle punctuality and passenger experience, for an example transfer that is scheduled to take 5 minutes excluding walking time. It is common that a public transport timetable includes a substantial time reserve before an important stop, and therefore as the left part of the figure shows, the vehicles are consistently early at the transfer stop. However, this means that the passengers structurally have to wait much longer at the transfer stop than they can expect from the timetable. As waiting time on the platform is perceived much less comfortable than in-vehicle time [Waa88], this means that trips including this transfer are perceived of a less quality than expected from the timetable.

The relevance of open AVL data with regard to improving transfers is the following: open information on the reliability of inter-operator transfers makes it possible for any operator and the transport authorities to gain insight into the reliability of these transfers and take steps if necessary, such as synchronizing timetables, holding vehicles in case of minor delays and informing passengers. See Sparing and Goverde [Spa13] for example for identifying transfers of interest and choosing which vehicles to hold in a multi-operator setting.

4 The GOVI-tool

To generate helpful insights from AVL data, the transport planning consultant firm Goudappel Coffeng developed a tool that translates data to information: the GOVI-tool. The GOVI database consists of all actual and scheduled arrival and departure times at all stops of all trips of the participating public transport operators in the Netherlands. This implies big data sets: a month contains 100.000-200.000 records per line. By subtracting the actual departure and actual arrival time, dwell time may be calculated. Comparing actual and scheduled times provide insights in the level of punctuality of the service. Finally, trip times may be calculated using departure times at a certain stop and arrival times at the following stop. Since information about stop distances is available as well, operating speed may also be generated.

To gain insight in the performance, mean values, 15- and 85-percentile values are calculated for the above mentioned aspects. This way, information about the variability is provided. The tool also provides information about cumulative values, such as total trip time, thereby illustrating the quality of actual performance compared to the schedule along the line. All information may be presented for every stop, per line and direction, period of the week (working day, Saturday or Sunday) and period of the day (AM peak, PM peak, daytime or evening).

In addition to showing the data in tables and figures, the tool is also capable of finding bottlenecks. The tool easily finds its way through all the data and selects (predefined) outlier values. The tool could for instance present a list of all stops where the average dwell time is larger than 30 seconds or where the schedule deviation is below zero (i.e. operating ahead of time).

The above described GOVI-tool has been used in the Utrecht region to analyze all bus lines, gaining insights in the actual performance and the largest bottlenecks. For 4 periods per working day and Saturday and Sunday, insights where generated with regard to driving, dwelling and punctuality. Several performance indicators were compared to the Sunday values to gain insights into the maximum improvement potential. Below, we present examples of the generated graphs from both Utrecht and another line in North Holland, applying the GOVI tool (**Figure 4**-**Figure 6**): punctuality along a line, travel speed between stops and dwell times.

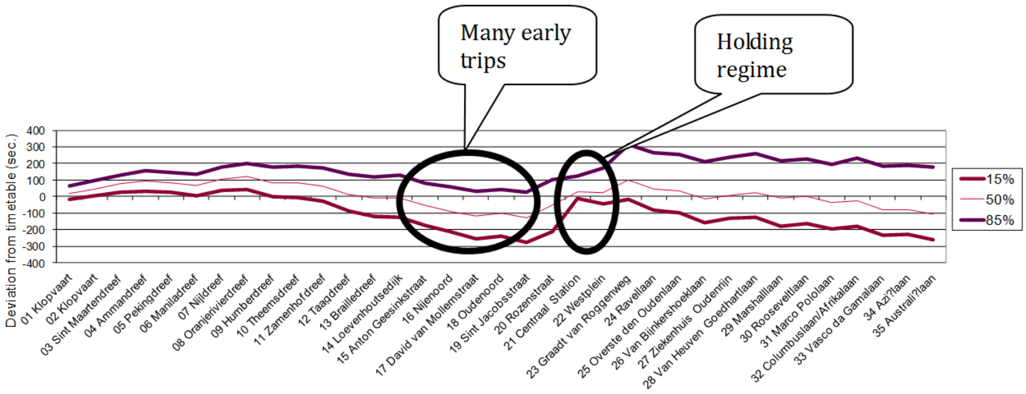

Figure 4: GOVI-tool graph of schedule deviation, bus line 7 Utrecht, evening rush hour

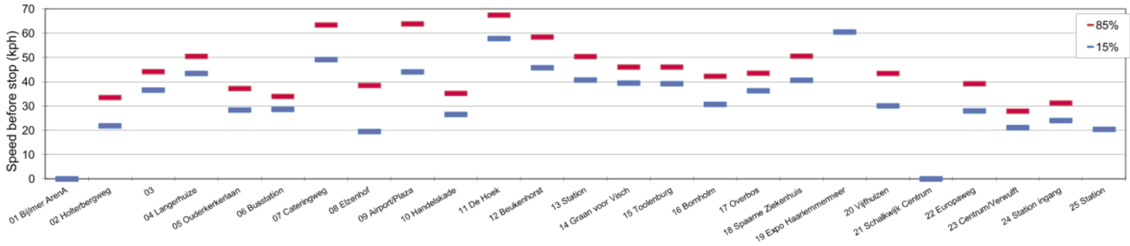

Figure 5: GOVI-tool graph of speeds between stops

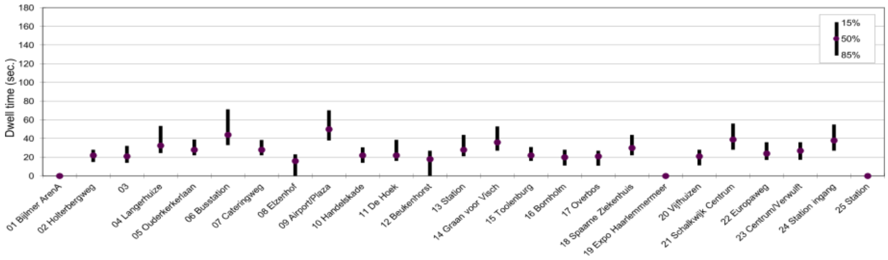

Figure 6: GOVI-tool graph of dwell times at stops

5 Conclusions

While the funding of public transport is under pressure, the need to enhance quality is increasing. The key element to better and more efficient public transport are shorter and more reliable trip times. By removing bottlenecks of the operations, costs may be reduced while the quality will be increased, thereby increasing ridership and revenues. This way, the cost effectiveness of public transport is improved in two parallel ways.

To find the bottlenecks and the potential benefits of improvements, data of historical operations is required. In the Netherlands, this data is has become recently available via GOVI. The objective of the GOVI system was to facilitate dynamic travel information, but the recorded data also provide huge insights into actual and scheduled performance. Goudappel Coffeng developed a tool to translate all these data into information, so that bottlenecks can be identified and measure can be taken by the transport authorities to solve them, enhancing public transport.

A next step in the development of the tool is translating vehicle data into passenger impact. When additional data on passenger behaviour and flows is available, service reliability impacts per passenger per stop may be calculated (i.e. additional travel time and its distribution [Oor13]).

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