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Bus-stop Based Real Time Passenger Information System – Case Study Maribor

Marko Čelan¹, Mitja Klemenčič¹, Anamarija L. Mrgole¹, Marjan Lep¹

¹Faculty of civil engineering, transportation engineering and architecture, University of Maribor, Smetanova ulica 17, 2000 Maribor, Slovenia
marko.celan@um.si

Abstract. Real time passenger information system is one of the key element of promoting public transport. For the successful implementation of real time passenger information systems, various components should be considered, such as: passenger needs and requirements, stakeholder involvement, technological solution for tracking, data transfer, etc. This article carrying out designing and evaluation of real time passenger information (RTPI) in the city of Maribor. The design phase included development of methodology for selection of appropriate macro and micro location of the real-time panel, development of a real-time passenger algorithm, definition of a technical specification, financial issues and time frame. The evaluation shows that different people have different requirements; therefore, the system should be adaptable to be used by various types of people, according to the age, the purpose of journey, experience of using public transport, etc. The average difference between perceived waiting time for a bus is 35% higher than the actual waiting time and grow with the headway increase. Experiences from Maribor have shown that the reliability of real time passenger system (from technical point of view) must be close to 100%, otherwise the system may have negative impact on passengers and may discourage the use of public transport. Among considered events of arrivals during the test period, 92% of all prediction were accurate. The cost benefit analysis has focused only on potential benefits from reduced perceived users waiting time and foreseen costs of real time information system in Maribor for 10 years’ period. Analysis shows that the optimal number for implementing real time passenger information system at the bus stops in Maribor is set on 83 bus stops (approx. 20 %) with the highest number of passenger. If we consider all entries at the chosen bus stops, the total perceived waiting time on yearly level could be decreased by about 60,000 hours.

1. Introduction
Intelligent transportation systems (ITS) have become common in public transport (PT) systems, particularly providing real time passenger information (RTPI) systems [1]. The small and medium size cities often face the problem where the financial resources to increase use of PT should be put. Therefore, the cost of RTPI system should not exceed the budget and there must be some measurable benefit of implementing [2].
For the successful implementation of RTPI systems, various components should be considered, such as: passengers needs and requirements, stakeholder involvement, technological solution for tracking, data transfer and power supply, supportive elements as bearing construction for RT display installation, integration between different transport modes, different data models and different intelligent transport systems (ITS), operational and maintenance cost of the system and monitoring of the system to verify its quality [3]. On the other hand, there might be various effects of RTPI on PT users, such as [4]:

- Reduced perceived wait time,
- Positive psychological factors, such as reduced uncertainty,
- Increased Ease-of-Use and greater feeling of security,
- Adjusted travel behaviour such as better use of wait time or more efficient travelling.

RTPI system should be adapted to different groups of people. Information should be reliable and accurate, otherwise the system might have negative impact on the PT users and discourage them using PT.

This research investigates experience from RTPI system implementation in the Municipality of Maribor, Slovenia. The paper is organized as follows: Section 2 presents approach for choosing the most appropriate bus stops to implement RTPI system. Section 3 describes user needs and expectations from RTPI system based on interviews. Section 4 evaluates proposed algorithm for bus real time arrival prediction. Section 5 examines cost-benefit analysis (CBA) of RTPI system implementation in Maribor. Finally, we present the conclusions in Section 6.

2. Design of RTPI on macro level
The Municipality of Maribor has about 110,000 inhabitants. The city PT system is operated by one municipality owned operator. The city bus network includes 19 city bus lines and just over 400 bus stops. The regional buses enter the city from five directions and have stops at approximately 10% of all bus stops in the Municipality of Maribor. Additionally, the travellers have option to travel to/from Maribor by train.

![Figure 1: Specification of proposed RTPI display rows per chosen bus stop](image)
A hierarchy of priority bus stop for RTPI implementation was made according to the passengers boarding rate, number of city lines and number of city/regional bus arrivals/departures per peak hour. Based on this analysis, a specification system for proposed number of rows on one RTPI display was introduced. The specification considers the number of bus lines and the number of bus arrivals/departures at chosen bus stop. Figure 1 represents the proposed specification for needed rows of RTPI display.

A hierarchy of priority bus stop for RTPI implementation was made according to the analysis presented in figure 1. An additional specification of bus arrivals and bus lines was used to define the needed number of lines on displays.

Table 1: Hierarchy of Bus Stops for Implementation of Real Time Passenger Information in Maribor

| Bus stop Name                  | Direction (City Centre) | N° of passengers (city bus) (per month) | N° of city lines | N° of bus arrivals per hour (city bus) | N° bus arrivals per hour (regional bus) | N° of needed RTPI lines on display (city/regional) |
|-------------------------------|-------------------------|----------------------------------------|-----------------|----------------------------------------|----------------------------------------|--------------------------------------------------|
| Kneza Kočlja – Vetrinjska    | From                    | 40863                                  | 14              | 34                                     | 8                                      | 7/2                                              |
| AP Mlinska                    | From                    | 39904                                  | 17              | 39                                     | Main bus Terminal                      | Main Bus terminal                                 |
| City Center                   | From                    | 39865                                  | 17              | 38                                     | 12                                     | 7/3                                              |
| Tabor                         | From                    | 9848                                   | 4               | 13                                     | 5                                      | 3/2                                              |
| Gosposvetska – rondo          | To                      | 7832                                   | 4               | 8                                      | 2                                      | 2/1                                              |
| Magdalenski park              | From                    | 6373                                   | 3               | 8                                      | 5                                      | 2/2                                              |
| Ptujška – Autoommerce         | To                      | 7034                                   | 2               | 6                                      | 6                                      | 2/2                                              |
| Ptujška – Pošta               | To                      | 6264                                   | 2               | 6                                      | 6                                      | 2/2                                              |
| Dogoška – vrtec               | To                      | 5596                                   | 2               | 6                                      | /                                      | 2/2                                              |
| Magdalena                     | From                    | 5537                                   | 7               | 11                                     | /                                      | 4                                                |
| KS Silvira Tomassini          | To                      | 5232                                   | 2               | 6                                      | /                                      | 2                                                |
| Radvanjska – samoposstrežna   | To                      | 4993                                   | 1               | 3                                      | /                                      | 1                                                |
| Ljubljanska – Pariške kom.    | To                      | 8393*                                  | 3               | 8                                      | 6                                      | 2/2                                              |
| Ljubljanska – Pariške kom.    | From                    | 8393*                                  | 3               | 8                                      | /                                      | 2                                                |
| Ptujška – Kovinar             | To                      | 4854                                   | 2               | 6                                      | 6                                      | 2/2                                              |
| Gorkega – Preradovičeva       | To                      | 5015                                   | 2               | 7                                      | /                                      | 2/2                                              |
| Bolnica                       | To/From                 | 3761                                   | 7               | 21                                     | 2                                      | 4/1                                              |
| Koroška – Poštarna            | From                    | 4134                                   | 4               | 7                                      | /                                      | 2/2                                              |
| OŠ Tabor I                    | To                      | 4008                                   | 1               | 4                                      | /                                      | 1                                                |
| Tovarna vozil                 | To                      | 3985                                   | 2               | 2                                      | 6                                      | 2/2                                              |

*Number of passengers in both directions

3. User view on implementation and need of RTPI system

There are various components that influence the passenger’s satisfaction and have indirect impact on the mode choice [5]. The question “what” is the needed content of the information and “how” this information is to be communicated to passenger depends very much on “to whom” this information is addressed. The traveller’s population is heterogeneous. For these purposes, the classification of users into typical groups is required (by frequency of PT usage, by age, by status, by kind of handicap).
Surveys (n=216) about passengers/people opinion of implementation and need of RTPI system in Maribor were conducted at the bus stops, on the buses and at the main railway station in Maribor. Interviewees (users) were asked:

- Would they use PT more often if RT information were available?
- Are they prepared additional money for the real-time information?
- Do they need RT information?
- Is the content of the displayed information at bus stop (easy) understandable? If not – what would they change?
- What would be better information media (displays at stops, mobile phone) to obtain RT information about bus arrivals?

Majority of passengers answered that the RTPI display is the most appropriate way to give passengers information about real-time bus arrivals. 60% of interviewees answered that they would use city buses more often if bus stops were equipped with RTPI system and some of them (approx. 30%) were prepared to pay more for fare with city buses. Although it is expected that “younger” people would rather get the RT information through mobile phones or the internet, the relatively high number of users (76 %) prefers displays. Among interviewees at the bus stops equipped with real-time displays, majority (85 %) observed information about bus arrivals. As additional information on the displays, passenger would also like to have weather prognosis and current time. 98 % passengers understood the content shown at the display. Approximately half of the passengers answered that map with current position of buses would also be added value to RTPI information.

4. Evaluation of the RTPI system

A robust prediction of bus arrival times has been gaining more importance in designing an effective trip planning in the ever-increasing traffic conditions with and increasing computing and communication means [6]. There might be various factors effecting bus arrival times. Such a list can easily be augmented by many parameters such as traffic conditions, number of passengers, weather impact, validation system, traffic accidents, signalling and driving times. Various models about bus arrival prediction were suggested. The model could be divide into 4 different categories: Models based on historical data, Statistical models, Kalman Filtering Model and Machine learning models [6]. Various researches developed different model based on artificial neural network [7, 8, 9, 10] Kalman filter model [9, 10, 11], Support vector machine [8, 10, 12] linear regression [10] and k-nearest neighbour [10].

An algorithm for prediction of bus stop arrival was developed. The data used in the algorithm were:

- Timetable information (bus lines, runs, regimes and itineraries).
- Segmented bus/road network data (network segments).
- Segment travel time for different periods (peak hour, off-peak hour, holiday).
- Bus tracking information (current position of a bus, bus identification and direction).

If we take into consideration that the buses running on different bus lines spend the same time to pass road segments and that dwell time at the bus stops varies between bus lines, the following equation is stated:

$$T_{L,P}^{L,S} = t_{S_t}^s \times (1 - n_{S_t}^s) + \sum_{x=S_{t+1}}^{x=p-1} t_x^s + \sum_{p=s_{pn}}^{p=p-1} t_{p}^{L,S_s}$$

where,

- $T_{L,P}^{L,S}$ is predicted time of bus from current position L to the bus stop P, on line l, moving direction s,
- $t_{S_t}^s \times (1 - n_{S_t}^s)$ is predicted bus travel time from current position to the end of current segment in direction s,
\[ \sum_{x=s_{t+1}}^{x_{p-1}} t^x_s \] is predicted bus travel time between current bus network segment and last segment before bus stop \( P \), in direction \( s \).

\[ \sum_{p=1}^{p_{n-1}} t^L_p \] is predicted dwell time on all bus stops on line \( l \), in direction \( s \).

To calculate the expected travel time from certain position to the bus stop, three options were verified:

i) long time period average travel times – long term history data,

ii) travel time of previous buses – short term history data and

iii) combination of the long-time average values and short term travel times.

For the evaluation of the arrival prediction, the following definition of accuracy was used. The prediction is classified as accurate, when:

- for predictions of five-minutes or less in advance, the error is one minute or less,
- for ten-minute predictions, the error is less than two minutes,
- for fifteen-minute predictions, the error is less than three minutes.

During the observation period, the long-term history data option was identified as the best solution. Among 3702 events of arrivals at 9 different bus stops during the observation period (arrivals classified as unreliable are not included), 92% were accurate.

5. Costs and benefits of RTPI

Costs of RTPI systems are not only related to the implementation of the system but should also consider costs of the operation and maintenance of the software and hardware. Therefore, life cycle costs (LCC) were identified for RTPI displays for a 10 years’ period, which is the disposal time according to the supplier. Welde et al. [13] have divided potential cost into 4 categories: investment costs, reinvestment costs, maintenance and operating costs and marginal cost of public funds. They underlined the following benefits: reduction of dwell time, reduction of passengers’ wait time, increasing passenger satisfaction and increasing the total number of passenger.

The CBA of the RTPI system in Maribor considers 3 types of costs (investment, maintenance and operating, marginal costs) and only benefit of saved passenger waiting time. Perceived passengers’ waiting times were measured by methods of observation and interviews. The goal of the observers was to obtain information about:

- Time of passenger arrivals to the bus stop.
- Time of bus arrival to the bus stop.
- How long has the passenger already waited for the bus.
- Passenger’s purpose of the trip.

At 4 different bus stops 245 observations and interview were performed about passengers’ arrival time to the bus stops, passenger waiting time, passengers perceived time and actual bus arrival time. Results from the observation showed that the passengers come to the bus stop in average 7 minutes before bus arrivals according to the timetable and 7.5 minutes before actual bus arrivals. At the bus lines with headway under 20 minutes, the average waiting time for a bus is just below 6 minutes. At the bus lines with headway between 20 and 30 minutes, the average passenger waiting time is almost 9 minutes.

At the bus lines with headway between 20 and 30 minutes, the perceived waiting time for a bus is 35% (2.7 min) higher than the actual waiting time. At the bus lines with headway between 20 and 30 minutes, the perceived waiting time is 3.45 minutes (47 %) higher than actual waiting time and at the bus lines with headway under 20 minutes the perceived waiting time is 23% higher than actual waiting time. This leads us to conclusion that real-time information about bus arrivals and departures is even more important at the bus stops and lines with higher headway of bus runs.
Overall, bus PT services in Municipality of Maribor per year is offered to about 3.5 million users. If we consider all entries at the bus stops in Municipality of Maribor, the average difference between perceived and actual waiting time on yearly level is about 155,000 hours. If we consider that value of time by using PT is 35% of the value according to the average salary in Slovenia than the value of one hour is 2.7 Euros [14]. Taking into account this value of time, the total benefit as a result of RTPI system in Maribor is estimated at 420,000 Euros per year.

The average costs of project planning, design and project management per bus stop is decreasing with the number of bus stops equipped with RTPI system. On the other hand, the benefits of RTPI system are increasing with number of bus stops equipped with RTPI system. The bus stops with low number of passengers have higher additional costs for providing RT information than benefits of perceived waiting in 10 years’ period. Thus, the optimal number for implementing RTPI system at the bus stops in Maribor is set on 83 bus stops with the highest number of passenger (figure 3).

Table 2: Foreseen costs of RTPI implementation at 83 bus stops for 10 years period

| Costs                        | Amount     |
|------------------------------|------------|
| Investment costs (40%)       | 638,000 €  |
| Operation and maintenance costs (40%) | 638,000 €  |
| Marginal cost of public funds (20%) | 319,000€   |
| Life cycle costs (10 years)  | 1,595,000 €|

The total number of entries to the buses at the chosen stops is 1.35 million per year. Considering the average difference between perceived and actual waiting time, the total perceived waiting time could be decreased by about 60,000 h. The benefit - monetized value of perceived waiting time – at chosen bus stops for 10-year period is estimated to 1.62 million Euros. Entire costs of implementation of RTPI system at 83 bus stops are estimated to 1.6 million Euros.

Figure 2: Average actual and perceived waiting time at Maribor bus stops
Figure 3: Optimal number of stops equipped with RTPI system

6. Conclusions
Pilot project in Maribor shows that people like the RTPI system. Low cost solution may be appropriate but RTPI implementation is not an easy task. Such a system is primary meant for passengers, so it should be first implemented at the most occupied stops. Different people have different requirements; therefore, the system should be adaptable to various groups of people, according to the age, the purpose of journey, experience of using PT, type of town or type of neighbourhood, etc. Implementing RTPI system, an important technical issue to provide RT information is the power supply and internet connection at the bus stop. Additional infrastructure works to ensure power supply and wired internet connection may influence the total amount of costs at the stops a lot. Appropriate alternative solution could ensure power supply through solar energy and Wi-Fi internet connection and thus decrease the costs of the implementation. Integration of different transport modes is very important. Even if the system today is intended only for one PT subsystem, it is very important to enable possible extensions to other systems. For example, tracking information may be useful in another IT system such as bus priority or design of timetables in the future. All phases, from the preparation and implementation of the PTI system to the operation and maintenance of the system, must be considered carefully, particularly the maintenance of the system. Experience from Maribor have shown that the reliability of RTPI system (from technical point of view) must be close to 100%, otherwise RTPI system may have negative impact on passengers and may discourage the use of PT. However, it is practically impossible to provide seamless information all the time, because of different reasons such as accidents, weather conditions, congestions, bus breakdowns, etc.

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