

Psychological Effects of and Design Preferences for Real-Time Information Displays

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Abstract

This article investigates the effects of real-time information, located at stops and stations, on the public transportation customer. Perceived wait time, feelings of security, and ease of use were considered to be sensitive indicators. The case of newly implemented traveler information on tramline 15 in the Hague, the Netherlands, was used for a before-and-after evaluation study containing questionnaires given to travelers. One month before and 3 months and 16 months after implementation, the same sample of travelers completed in a questionnaire. Further, four orientations of the displays at tram stops, assembled for testing purposes, were evaluated. The main results were that the perceived wait time decreased by 20 percent, while no effects on perceived security and ease of use were found. Displays installed perpendicular to the tracks and separate from the shelter were ranked highest.

Introduction

Real-time information systems are becoming more and more and ubiquitous in public transportation (PT) (Yeung 2004). A considerable amount of money is being spent on IT-based applications, such as real-time, at-stop displays. Many projects have shown that this kind of information is appreciated by the customers (Infopolis2 1998; GoTiC 2002; Lehtonen and Kulmala 2001; Coogan 2003;

BMBF 2002; Intermobil 2002), but actual knowledge about the behavioral effects these have on customers or potential customers in the real world is quite sparse (Dziekan 2004). Due to combined implementation measures (such as opening a new tramline or running an accompanying marketing campaign), it is often difficult to separate the effect of real-time information systems on traveler numbers. Very few sources report increases of traveler numbers as a direct effect of installing real-time information systems.

Effects of real-time information displays at stops are considered to be of a more psychological nature (Dziekan 2004). Systems displaying the next train or bus departure time at stops or stations can greatly reduce anxiety. Just the existence of such a system creates trust in the whole PT system and may improve its image. Perceived security at stops is considered to be influenced positively by the new displays (Consortium Infopolis 1999; Kronborg, Lindkvist, and Schelin 2002), and the service is perceived as being more reliable (Infopolis2 1998 Annex F).

Wait time holds a negative quality for transit users (Li 2003; Karlsson 1997). Thus, reducing actual wait time or decreasing the perceived wait time can make PT systems more attractive. Real-time information displays have the potential to shorten the perceived wait time (Infopolis2 1998). Wardman, Hine, and Stradling (2001) found that real-time information at transfer points was very important, especially for occasional users.

Optimizing product utility has a long tradition (Karlsson 1996). Services or products should be "easy to use" in order to match customer needs and thereby increase satisfaction and sales figures (Consortium Infopolis 1999). Focusing on aspects of the experience and thinking of the traveler is a rather new approach in PT (Stradling 2002). In addition to saving time and money, people want to save effort when using PT. Stradling (2002) names three types of effort: physical effort, cognitive effort, and affective effort. While physical effort concerns the physical activity on a journey, cognitive effort is expended on a journey via information gathering and processing for route planning, navigation, progress monitoring, and error correction. Affective effort is the emotional energy expended on a journey in dealing with uncertainty regarding safe and comfortable travel and timely arrival at intermediate and final destinations. This article presents a special measurement developed to show the effects in the ease of use of a tramline as a part of the cognitive and affective effort. Further, it is known from service research that a product recommended to others tends to be of a relatively high quality. So, the willingness to recommend was measured as one aspect of service quality.

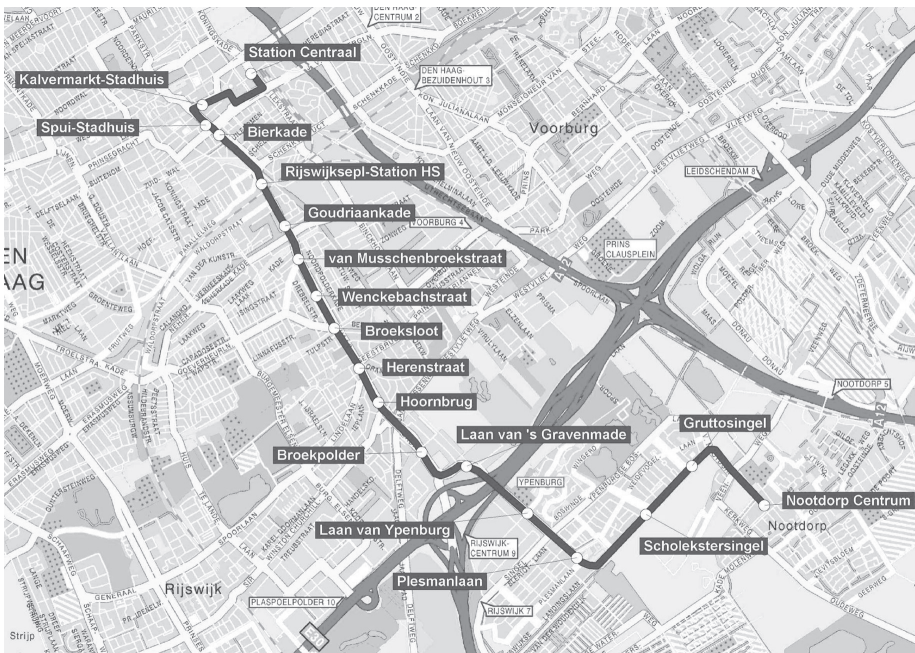
Finally, the placement of the displays was examined. At-stop displays are very often installed perpendicular to the tracks and bus lanes, meaning in the direction of the arriving vehicle (Infopolis2 1998 Annex F). But is this the design travelers prefer? The case of tramline 15 in The Hague offered the possibility of investigating many of the above issues.

Methods

The Case

The local PT company, HTM, in the Hague, the Netherlands, installed real-time, at-stop displays along tramline 15 (see Figure 1). This was completed in January 2004 as a part of the MOBIEL project (Vermeulen and de Jong 2003). Additionally, the real-time departure information for the tram was accessible via SMS and the Internet. A before-and-after evaluation offered the possibility to investigate behavioral effects, especially the influence on perceived wait time, perceived security, and influences on ease of use. HTM installed four different design solutions for

Figure 1. Route of Tramline 15 in The Hague (2004)



the displays: parallel to the tracks in the shelter, parallel to the tracks and separate from the shelter, perpendicular to the tracks in the shelter, and perpendicular to the tracks standing separately from the shelter (see Figure 2). Traveler reactions and preferences for these different solutions were investigated.

Before-and-After Questionnaire

In December 2003, one month before the introduction of the real-time, at-stop displays, 840 questionnaires were distributed to individual travelers on line 15. Travelers were asked to complete and return the questionnaires to HTM. By returning the surveys, travelers were given the chance to win a prize of EUR 20 (approximately USD \$24). A total of 370 questionnaires were returned (return rate of 44%).

The before test contained questions about boarding time for the respective journeys, use frequency per week for line 15, age, and gender. Further, the perceived security at the boarding stop was to be rated by the respondents from 1 (very bad) to 10 (very good). The perceived average wait times at the stops on line 15 were to be stated in minutes. The question asked was: "How long do you have to wait, on average, for a tram on line 15?" Finally, ease of use was evaluated. To make PT easy to use, it seems preferable to keep the cognitive effort for the passengers as low as possible. The hypothesis is that the displays at the stops reduce the cognitive effort and in that way make it more convenient and easier to travel by public transport. Further, the willingness to recommend can be seen as an indicator of good service quality. To measure these two aspects of "ease of use" of a PT journey, the following two scales were developed and used in both before- and after-test questionnaires:

"For the statements below, please indicate how strongly you agree, on a five-point scale:

- It is hard to determine when exactly the tram 15 departs.
- If somebody else has to make the same trip as I do right now, I would recommend that they choose line 15."

The answer categories were: fully agree (1), agree (2), neutral (3), disagree (4) and fully disagree (5).

Figure 2. Four Placement Design Variants of the Real-Time Information Displays at Stops on Line 15



Display separate and perpendicular to tracks



Display in the shelter and perpendicular to tracks



Display in the shelter and parallel to tracks



Display separate and parallel to tracks

The 175 persons who indicated their addresses in the before questionnaire for participation in an after test received a new questionnaire via mail in March 2004. It was assumed that after only three months, people who still live in the same place will not have changed their boarding stop on line 15 or their user frequency. For evaluation and comparison, the questions regarding perceived security, wait time, and ease of use were asked again. Further questions were added regarding highest level of education, car availability, use of the displays, and evaluation of the line's reliability. Finally, photographs from the four different placement types (Figure 2) were presented and ranked by the respondents.

Sample Characteristics

Based on a detailed comparison of sample characteristics (Dziekhan and Vermeulen 2004), it was shown that, apart from the five years' higher average age in the after-test sample, both samples can be considered comparable. Therefore, it can be assumed that the after sample is a representative selection of the before-test sample. Hence, data from the people who participated in both the before test and the after test (N=53) will be the basis for the before-after analysis of the effects of the real-time information displays and the results presented below.

In the sample, males and females were represented equally; ages ranged from 17 to 79 years (mean 40 years). Sixty-six percent of the respondents had a car available to them. More than one third of those participating in the sample had a university degree; 30 percent finished secondary school as their highest education; 13 percent finished primary school; and 11 percent were skilled workers.

The people in the sample use line 15 very frequently: 55 percent travel four days or more per week on line 15 and only 17 percent use line 15 less than 1 day per week.

A detailed nonrespondents analysis was conducted for the subgroups of participants who returned the before survey but did not receive the after survey and the participants who received the after survey but did not return it.

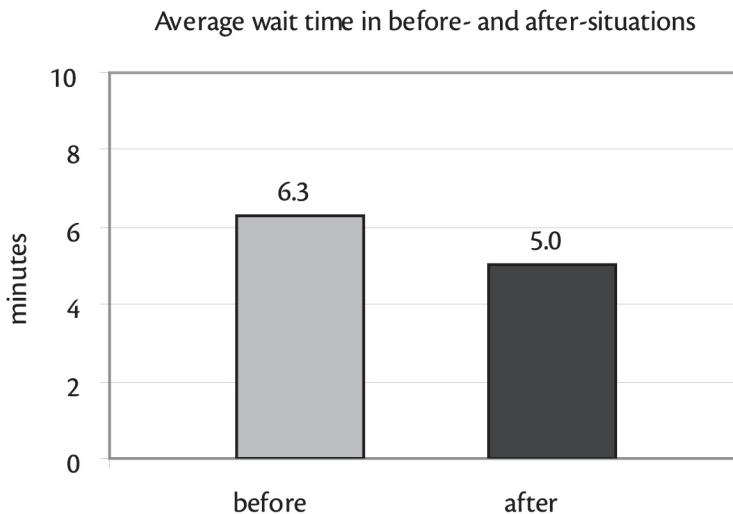
There were no significant differences between the nonrespondents and the 53 participants in the after survey in terms of gender, boarding stop, boarding time, user frequency, mobile phone ownership, and Internet access. Only the average age was different. Participants in the after sample were, on average, four to eight years older than the nonrespondents. So, the higher average age may have lead to some biases in the measured impacts.

Results from the Before-and-After Test

Effects on Wait Time Perception

The perceived average wait time at stops along line 15 was estimated in minutes. In the before test, the mean perceived wait time was 6.3 minutes (standard error 0.4) and the mean in the after test was 5.0 minutes (standard error 0.3). As illustrated in Figure 3, the average perceived wait time at stops along line 15 was shortened significantly (t-test, significant on the 1% level) by 1.3 minutes. That means people perceived, on average, a 20 percent shorter wait time.

Figure 3. Average Perceived Wait Time on Line 15 Before and After Installing the Real-Time Information At-Stop Displays (N=53)



The route and the schedule for the investigated part of line 15 were the same in the before and after situations. Between 6A.M. and 7P.M., the headways were 10 minutes in length, but HTM reported an average irregularity (schedule deviation) of 10 percent. Thus, the actual average wait time ranged between 4.5 and 5.5 minutes.

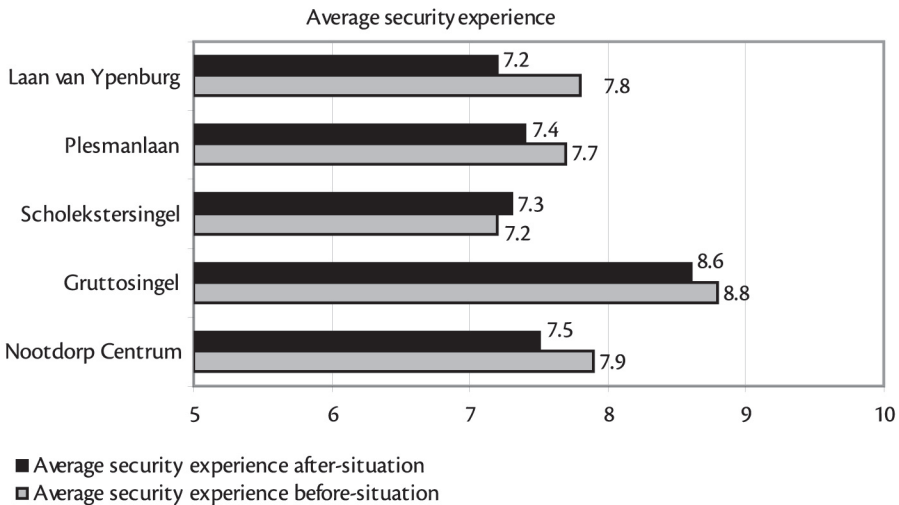
Through an analysis of the distribution of wait-time estimation, it can be seen that people tend to round down or up their answers. In the before situation, people used a range from 0–15 minutes; 35 percent indicated that they waited an average

of 5 minutes and 21 percent indicated a 10-minute wait. In the after test, however, 40 percent of all respondents indicated a 5-minute wait time and only 9 percent specified 10 minutes, which was also the highest wait time indicated in the after test.

Effects on Security Experience at Stops

The perceived security at the boarding stop was rated on a scale from 1 (very bad) to 10 (very good). The total average security experience in the before study was 7.9. In the after study, the average perceived security worsened to 7.6 (Figure 4). However, no significant differences between the security experiences for the boarding stops could be calculated.

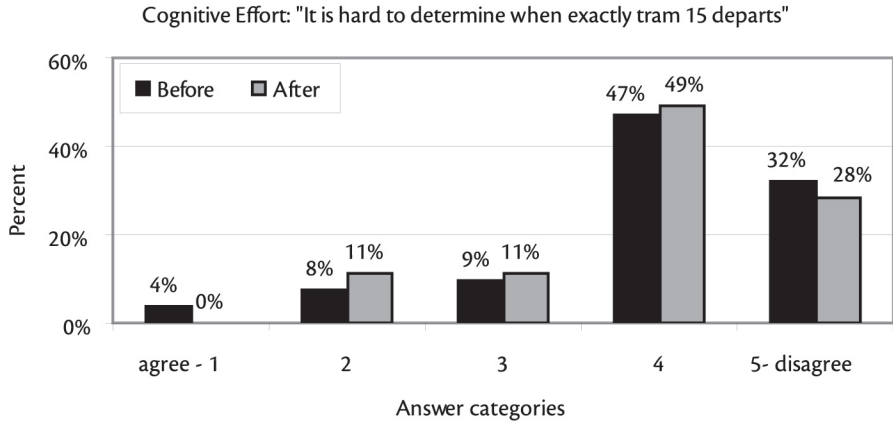
**Figure 4. Average Security Experience at the Boarding Stop in Before-and-After Situations (N=53)
(Scale: 1 = very bad to 10 = very good)**



Effects on Ease of Use

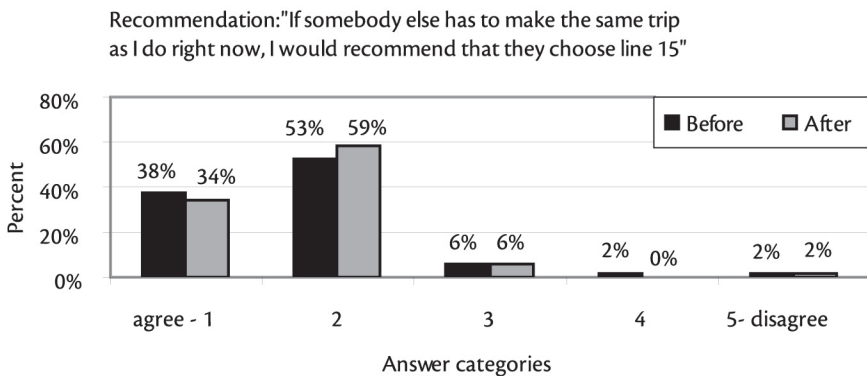
For cognitive effort, the same average values were achieved in the before-and-after tests (Figure 5). The mean for the cognitive effort measurement was 4 in both samples, which means that people do not think it is very difficult to determine when exactly line 15 departs. No significant differences between the before-and-after situations can be reported for cognitive effort. Even without real-time information displays at the stops, it was not considered difficult to determine when the next tram would depart.

Figure 5. Cognitive Effort Distribution in Before-and-After Test Situations (N=53)



A similar picture—that is, no differences between before-and-after situations—can be reported for the recommendation willingness factor (Figure 6). The mean of the willingness to recommend is also quite high at 1.8 (1=high willingness to recommend and 5=low willingness to recommend).

Figure 6. Recommendation Distribution in Before-and-After Test Situations (N=53)



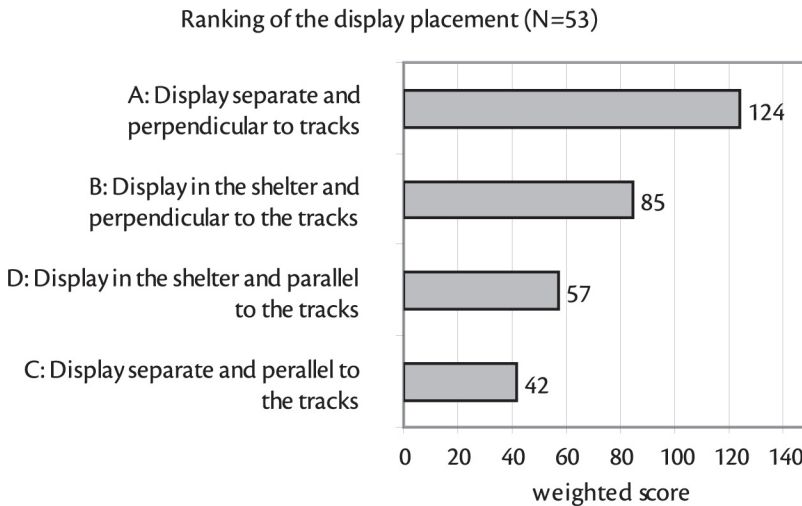
In the analysis of the after-test sample, no significant correlations between cognitive effort, recommendation willingness, perceived wait time, or perceived security were found.

Evaluation of Design Variants of the Placement of Displays

Along line 15, four different design variants (see Figure 2) were installed to test the convenience of different placements. In the questionnaire, each of the four alternatives was ranked.

To build the final rank order, the rank numbers were weighted: The highest rank received a weight of 3; the second highest, a weight of 2; the third highest, a weight of 1; and the lowest rank, no weight. Figure 7 depicts the score that each design obtained. Results of the ranking are quite clear: Display positions perpendicular to the tracks are preferred in general. Parallel placement is unfavorable. Displays located separate from the shelter and perpendicular to the tracks were most preferred.

Figure 7. Weighted Ranked Scores of Four Placement Design Variants of Real-Time Information Displays at Stops Along Line 15

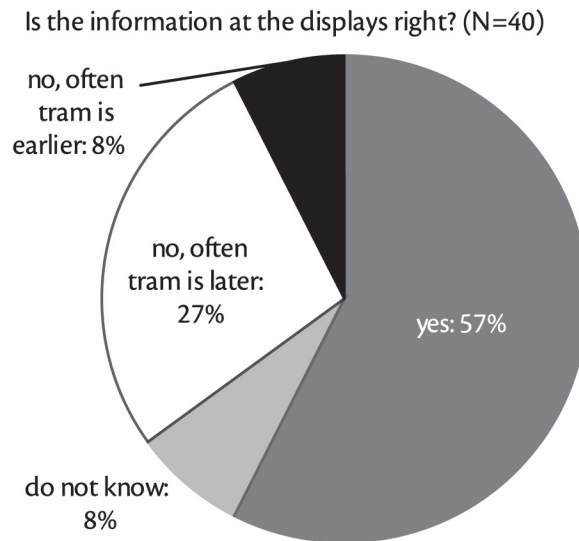


Use of Displays

The majority (79%) of respondents in the after situation stated that they had looked at the displays at the stop, but this also means that almost every fifth person had not yet looked at the displays.

More than half of the people who looked at the displays evaluated the information shown as reliable (Figure 8). However, 35 percent felt that the presented information was not reliable; they believed that the tram often arrived later or earlier than displayed.

Figure 8. Perceived Reliability of Information Shown by Displays (N=40)



A comparison was calculated between the people who assumed the information was not reliable (N=14) and those who trusted the information (N=23). The results showed that the cognitive effort for people who doubted the reliability of the information displays increased, while those who trusted the information had an easier journey. Due to the low number of cases, these differences did not reach a significant level.

The Second After Test: Long-Term Effects

To prove long-term effects and to validate the results gained in the first after test, a second wave was conducted 16 months after implementation of the real-time displays. The same after questionnaire was sent out, but without the questions regarding design solutions for the display installations. From 175 questionnaires, 81 were returned (a response rate of 46%). Again, the nonrespondents were younger on average but all other characteristics were comparable. The total number of people who answered all three questionnaires dwindled to 32 respondents. Table 1 shows the results for the repeated measurements of the 32 people.

Table 1. Values for the Sample N=32, People Who Participated in All Measures

Variable	Before Test	After Test <i>(After 3 months)</i>	Second After Test <i>(After 16 months)</i>
Security experience ¹	8.10	7.84	7.78
Wait time ²	6.22	5.00	4.81
Cognitive effort ³	3.87	3.84	3.84
Recommendation ³	1.59	1.75	1.56
Looked at displays	-	72%	81%
Good reliability of displays	-	43%	53%

1 No significant differences (one-sample t-test).

2 Differences between the values in the before-and-after tests as well as in the before and second after test are significant at the 5 percent level (one-sample t-test); between the wait time in the after test and the second after test there is no significant difference.

3 No significant differences (one-sample t-test).

Generally the results of the second after test confirmed the findings seen in the first after test (as presented in Table 1). The experience of security remained constant over time and neither cognitive effort nor levels of recommendation were impacted. On the other hand, the impact of the real-time displays on decreased perceived wait time could be seen over time. In the after test, 42 percent of the respondents perceived a 5-minute wait time while only 9 percent believed that they waited an average of 10 minutes. This is in comparison to the before test in

which 35 percent of the respondents perceived a 5-minute wait time while 21 percent perceived 10-minute wait time.

More people looked at the displays in the second post-test and, additionally, more people trusted the information provided by the displays. This could be a hint that HTM improved service quality as a result of overcoming the growing pains of the system.

Discussion and Conclusions

This study provided evidence for the positive impact of real-time information displays at tram stops on perceived wait times. Some weak points in the methodology that might bias the result should be mentioned. One question forced people to write a number of minutes representing average perceived wait times. It seems, however, that people tended to round that number down or up, for example writing five instead of six minutes. This effect was also seen in the data presented here, so a bias cannot be excluded. This could be because the analysis of the nonrespondents showed that the data used in this article was gained from people who were older than the average traveler on the tramline. However, this investigation showed that perceived wait time decreased and this decrease was stable even after 16 months.

In the before situation—without displays—people believed that they had to wait at the stop for an average of 6.3 minutes. After the implementation of the real-time displays, the same people indicated that they waited an average of 5.0 minutes. How can this effect be explained? One possible explanation is that wait time for public transport is considered negative and wait time is perceived as longer than any other part of journey (Li 2003). It is, therefore, considered unused or wasted time. Further, the traveler is exposed to an unfulfilled goal; he or she has not arrived at the final destination. Finally, an unpredictable setting is expected to result in a longer perceived journey time. Li (2003) called this aspect expectancy. These effects in combination cause discomfort and dissatisfaction that lead to the overestimation of the traveler's temporal judgment. What are the effects, then, of displays that show, quite reliably, the amount of time left until the next departure?

First, the actual wait time may decrease since people arrive at the tram stop closer to the departure time. The provision of real-time information, also by the SMS information service or the Internet travel planner allows people to plan their trips

more effectively. Another possibility for decreasing actual wait times is that people may simply walk by the stop, see that there are still several minutes until tram departure, and decide to use the remaining time to do something else. Whether this might be applied in this case cannot be concluded from the presented data. Second, it is possible that people may arrive at the stop in the same way as before, but due to the displays, the time spent waiting seems shorter. Thus, perceived wait time decreases. Causes for this might be that the enhanced predictability through the reliable information reduces uncertainty and enhances the experience of being in control of the situation. Hence, the traveler's mood is influenced positively and a good mood allows subjective time to pass faster. Another aspect can be that the display installation enhances the traveling environment by providing higher comfort, which also according to Li (2003), reduces perceived wait time.

What are 1.3 minutes of saved wait time worth in money? To put a value on wait time, several studies were conducted. Wardman (2001) summarized PT values of time cited from a study done in the Netherlands in 1999: The Dutch value of IVT (In-Vehicle-Traveltime) for commuters with respect to buses or trams is reported as 9.93 guilders (EUR 4.51/USD 5.40) per hour. Further, the IVT value of waiting for urban buses is 1.59 guilders/hr and for subway, 1.17 guilders/hr. The overall IVT value of waiting is 1.70. If, as in our case, the perceived wait time decreased by 1.3 minutes, this would be worth 0.37 guilders ($1.3\text{min} * 9.93\text{ guilders}/60\text{minutes} * 1.70$). This means that one could raise ticket prices by EUR 0.16 (1 Euro= 2.20371 Guilders) or USD 0.19 without losing passengers or one can gain passengers while prices remain constant. To calculate the amount of expected traveler increase, the concept of travel time elasticities can be applied. Elasticities are defined as the percentage change in consumption of a good caused by a 1 percent change in its price or other characteristics. For example, a PT service elasticity is defined as the percentage change in ridership resulting from each 1 percent change in service, such as frequency. A negative sign indicates that the effect operates in the opposite direction from the cause (Victoria Transport Policy Institute 2005; Litman 2004).

Perceived wait time at stops was reduced by 20 percent. On average, we assume the total travel time (walk time, wait time, and IVT) of an urban transit trip to be 45 minutes. Thus, the displays caused a decreased travel time of 2.88 percent ($1.3\text{minutes}/45\text{minutes}$). Each 1 percent in reduced travel time causes a 0.8 percent increase in ridership if we use an average travel time elasticity of -0.8 which is recommended by Mackie et al. (2003). That means that in our case, a widespread

real-time information system could theoretically cause an increase in ridership of about 2.3 percent.

Cost for the real-time at-stop information on tram line 15 was about EUR 200.000 (approximately USD 240.000). An internal calculation at HTM showed that a 20 percent increase in service frequency on this tram line to 8-minute headways, which would lead to a similarly reduced perceived wait time as was achieved by the displays, would cost EUR 1.1 million (USD 1.32 million) (Vermeulen and Dziekan 2005). Thus, real-time information seems to be a worthwhile investment.

The experience of security at the stops was not positively influenced by the new displays. In fact, the security experience in this sample was nearly constant. Reasons for this unexpected result could be gleaned from the methodology. This factor was not controlled in that the questionnaire was not completed in direct relation to behavior (meaning directly in the situation at the stop when the security was perceived), which could have led to biases. This bias could possibly also have influenced all other variables measured in this questionnaire, which was not completed directly in the immediate situation in question. Further, the way in which the security question was worded [“Which grade (1= very bad to 10=very good) would you give to your boarding stop regarding perceived security?”] may have led respondents to mistakenly consider other aspects of security (e.g., lighting). That is, the question did not specifically ask if the presence of real-time displays changed the feeling of security and since this is not an obvious contributor to perceived security, it may have been overlooked.

That the questionnaires were not filled in with direct relation to the behavior could also be a reason why ease-of-use values did not show any changes. On one hand, people might have misinterpreted or overanalyzed the question. In that case, the method itself to measure ease of use must be revised. On the other hand, the values in the before test were already so positive that a ceiling effect might be observed here. Thus, other methods, such as comparing traveler numbers, must be used to evaluate the effects. But in this case, a comparison of traveler numbers is not useful because many people have been moving into the newly built living quarters along line 15. So, the rising traveler numbers cannot be based solely on the real-time information system. It also might be that ease of use does not play such a salient role in the experience of the travel chain. There might be other factors, such as habits (Aarts 1996; Verplanken, Aarts, and van Knippenberg 1997), former experiences, or attitudes toward PT that influence the experience of the cognitive effort of using a PT system.

The majority of the respondents looked at the real-time information displays at the stops. However, the reliability of the displays was perceived as unsatisfactory. Real-time information is calculated by a central computer that receives position information from the trams every 20 seconds. Potential sources for errors in the information include: problems with the GPS units in the trams, problems with sending and receiving the radio signals, and a deficient calculation algorithm. Here, the PT agency should put more effort into winning and preserving its customers' trust in the system by assuring that the system always works reliably, which was not the case in the starting phase of the project. Otherwise, all positive effects of this measurement will be neutralized or may even make the travelers more worried about the reliability of the information provided.

The design solution in which displays were perpendicular to the tracks and separate from the shelter was preferred. The perpendicular position allows passengers to read the displays, even from within the arriving vehicle. This offers the future possibility of receiving information about service connections and transfer options at each stop. Passengers could further benefit by learning more about the service which they might previously have been unaware. The position separate from the shelter might have received a positive response since it can be seen from far away when approaching the stop.

The main result, that real-time information displays at stops reduce the perceived wait time significantly, can be generalized more fully to stops of trams and trains with headways of about 10 minutes. Buses tend to have poor schedule adherence, and thus the importance of such displays, by reducing uncertainty, may be even higher. The same might be true for lower frequency tram or bus lines; here, the information about the next departure is even more important than for lines with short headways

Further, the result that placement of displays perpendicular to tracks is the most customer-friendly variant can be seen as proof of the design solution that was already adopted by most of the systems in metropolitan areas around the world. One further recommendation is that the displays should be visible from all sides, even for people just passing by, for example pedestrians or motorists. In that way, displays play a positive role for marketing and communicating the service offered by PT. New technologies offer an added value to the customer, especially psychologically, and have the potential to change their behavior and contribute to solving mobility problems.

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