Communication of bus arrival time predictions to users

Severina Fischer
Institute for Transport Planning and Systems
Swiss Federal Institute of Technology, ETH
Zurich, Switzerland
severina.fischer@gmx.ch

***Abstract*—This thesis investigates how people want to be informed in real-time about bus arrival times. The graphics existing nowadays provide information without uncertainties, in other words, with point estimates. But probabilistic estimates are more transparent and lead to a greater trust. To assess if such information is wanted by people, two surveys were developed. With the first survey, insights were collected from the respondents regarding this topic. It turned out that some people thought that the bus arrives rather at a random time and not exactly according to the timetable. They would also like to be informed if they reach the connecting train when taking the bus to the train station. In both surveys the respondents were asked whether they would like to be informed about the uncertainty regarding bus arrival time. The second survey consisted mainly of the ranking of different information provision strategies for online timetables and electronic displays at bus stops. For this purpose four different graphics of timetables and six of electronic displays were provided for selection. Some graphics were with presentations of how to find them nowadays and others contained uncertainty illustrations. Although in both surveys about 80% of the people wanted to be informed about the uncertainty, in the end, the most popular ones were the already existing graphics.**

***Index Terms*—real-time information of bus arrival time, point estimates, probabilistic estimates**

I. Introduction

The provision of real-time predictions has the potential to reduce uncertainties in waiting time. This predictions can be provided as point or probabilistic estimates. Point estimates of bus arrival times, as they mainly exist nowadays, can visualize predictions quickly. But they do not contain any information on uncertainties. Probabilistic estimates, however, help people to assess if one gets on time to the destination in spite of the bus delay and if there is enough time to do some shopping like buying a coffee before the bus arrives. They are also more transparent in decision making which leads to greater trust. To assess how the bus arrival time or travel time information can be communicated to users, a two-way survey approach was performed and evaluated. The surveys were conducted through a survey online platform.

II. Literature review

A. Real-time bus information

The public transport like a bus can be improved by a real-time arrival information-system for travelers. Real-time information reduces worries of when the bus will actually arrive [1]. Real-time information can be provided by electronic displays at bus stops, internet, call centers, smartphone applications, short message services (SMS) and Twitter [2].

B. Point estimates and probabilistic estimates

Bus arrival time information can be provided for these mentioned media and is divided into point and probabilistic estimates. Even though some people prefer point estimates without uncertainty to make fast decisions on when to arrive at the bus stop it will provide false precision. An example therefore is when the bus comes unexpectedly early. A person checks the predicted bus arrival time with an application and sees that the bus arrives later than planned at the bus stop. He trusts the information and plans to go the bus stop at this predicted arrival time. But it happens that the bus makes up lost time and arrives earlier than the predicted delay. The bus is then missed. Probabilistic information is more transparent for decision making which leads to greater confidence. Hence, people can make more optimal decisions [3].

C. Representation of graphics

It is important to recognize the importance of uncertainty information for the users and to identify an effective way to communicate it [4]. Therefore, some literature are studied to get ideas for creating own graphics for the two surveys. The representation of probability distributions of arrival times in a station is updated as the trains approach to further stations. When the event of an arriving train becomes closer the standard deviation gets smaller and converges to a one-point distribution [5]. There are other presentations of visualization of delay uncertainty for trains. An important point to illustrate is the critical delay, which means that a delay may cause a change of plan, arriving late at the destination or missing a connecting public transport [6].

III. Existing real-time applications

There are already some real-time applications like the ”Schweizerische Bundesbahnen (SBB)” online timetable or smartphone app which is the most popular transport application in Switzerland [7]. This real-time information is provided as point estimates. There are other applications not only from SBB. On the one hand, ”Wemlin” is established by the company ”netcetera” and offers timetable information and precise information on current departure times at each stop for various public transport operators. It is available as online timetable and as smartphone app [8]. On the other hand, a similar application is ”Time for Coffee!” which offers real-time timetables for different public transport stations which are next to oneself. It indicates whether real-time information is available for the different public transport modes [9]. The data of the two mentioned applications comes from Open-Data-Plattform Mobilität Schweiz. As with the SBB app, the delays in these two applications are also given as point estimates.

IV. First survey

The objective of the first survey is to assess what people think about real-time information and in which situations they would need such information. Therefore, some questions have to be answered like what commuters actually demand from information on public transport, which information they need and what should the electronic display look like at bus stops. For this purpose, some graphics for timetable and electronic display illustrations are created. It turned out that many respondents wanted to have the information when exactly the bus leaves at the stop and whether they can reach the connecting train when taking the bus to the train station. They would also like to be informed about alternative routes and their probabilities of arrival time in case of a delay. On the basis of these findings from the first survey, the second survey was prepared accordingly.

There are some lessons learned from the survey. First of all, the first survey lasted longer than expected. But it can be said that there were too many open questions. Therefore, it should be adapted for the second survey that it takes only 10-15 minutes for filling it out. Also a survey platform should be found where the pictures can be displayed larger and in better quality. Regarding the content, it turned out that the respondents would like to be informed if they reach the connecting train when taking the bus to the train station. This is because people think the bus arrives rather at a random time not exactly according to the timetable. Hence, it makes it more difficult for them to assess whether the connection can be reached or not. The second survey should put the focus on the provision of the different timetable and electronic display illustrations and some interpretation questions about it.

V. Second survey

A. Methodology

The second survey consisted a ranking of different alternatives of timetables and electronic displays which were created for this survey. Some of them includes illustrations concerning the uncertain bus arrival time. Therefore, it is possible to assess which alternatives are preferred and which were not desired at all. After each of the two rankings it follows the question, which graphics the respondents have not understood. In addition to the two questions with the rankings, some questions of interpretation of timetables and electronic displays were also asked. Before the rankings with the graphics come, a question is asked about whether travelers want to be informed about uncertainties regarding public transport arrival or journey times. The same question is asked again at the end of the survey. Respondents might want to change their mind after seeing the graphics.

1) Creation of different timetable illustrations: For creating a timetable, an example of a journey will be presented with artificial names, locations and public transport stations. This artificial journey is a journey from home to the final destination. In other words, the specific artificial journey should be one that is represented by many commuters every day and which is taken when not living in the same city as one works and not living next to the train station. Therefore, an artificial journey with multiple trips is displayed and not only a single trip. According to the results of the first survey most commuters do not trust the bus arrival times and are worried about catching the train at the station when traveling by bus to the station and train connections are not so frequent. Therefore, a scenario with the critical delay should be included, for example, if the transfer from the bus to the train can be ensured (see Fig. 1). This results in an artificial journey with a bus trip to the railway station and, after the train trip, a bus trip to the final destination. The idea behind the illustration of this timetable corresponds to the one of the ”Schweizerische Bundesbahnen (SBB)” smartphone application. It is deliberately chosen that the train arrives in B-Stadt before the half hour and the bus leaves after the half hour as it is at the main station of Zurich (Zurich, HB). A delay of 3 minutes for each bus ride is included. All times in this graphic (Variant A) are given as point estimates.

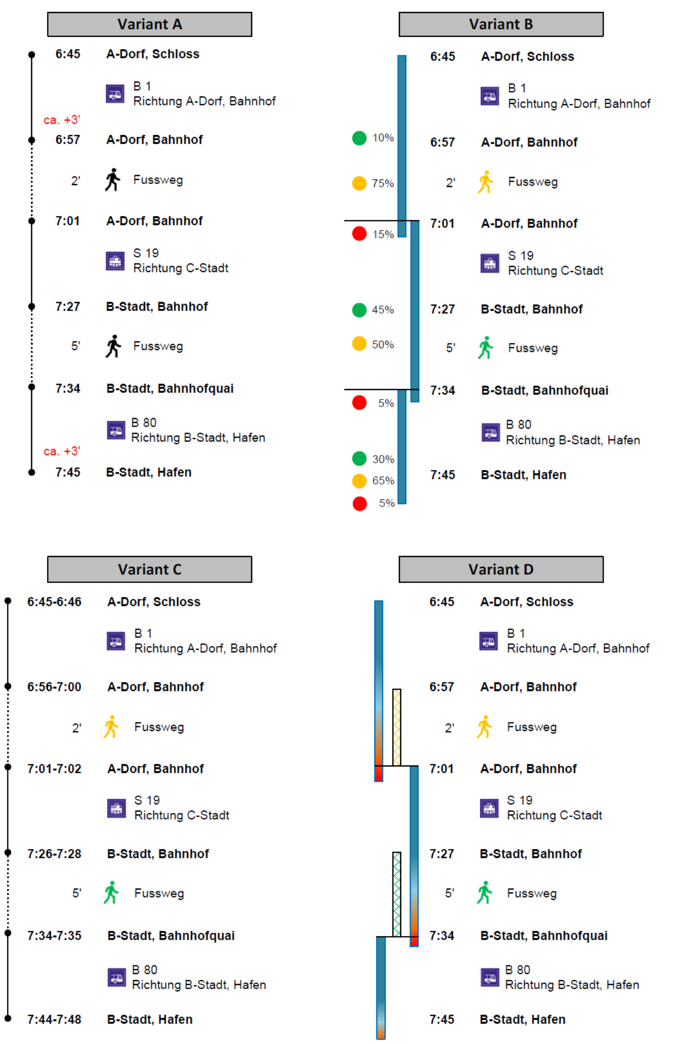
After Variant A is created, the graphics from the first survey including probabilistic estimates are revised. The revised graphics can be found in Fig. 1. The graphics (Variants B, C and D) now include a colored pictogram for the footpath (”Fussweg”). This can be used to show whether the transfer time is sufficient. In most cases the transfer time is more important than the arrival and departure time of the transport mode. For the determination of the color, the arrival time of the first transport mode and the departure time of the following one is crucial. The color green indicates sufficient transfer time, while yellow shows that one has to walk faster to reach the transport mode. Red signals that the transfer time is not sufficient. The aim is that with the color yellow people can judge for themselves if they want to and have the possibility to hurry even faster to catch the train.

For Variant C not much has changed since the first survey. In contrast to the first survey, this graphic also includes the uncertainties in the bus arrival times at the boarding points.

The two Variants B and D originated among others from a sketch by Prof. Dr. Francesco Corman. For Variant B, dots with probabilities for the quantitative delay illustration are used instead of the different colored clocks. The definition of the determination of colors is analogous to the first survey. Green illustrates that the transport mode is on time, yellow for a little bit delay and red symbolizes a big delay which could be based on real-data and/or historical data. The journey time is displayed with blue vertical bars and black horizontal lines between the colored dots. The black lines symbolize the departure time of the transport mode. For a simpler presentation of the different dots, the presentation of uncertainties of arrival times at the boarding point (A-Dorf, Schloss and B-Stadt, Bahnhofquai) is omitted. The latter mentioned also applies to Variant D.

Variant D shows the qualitative uncertainties with the blue and red intermixing bars (analogues to [6]). Dark blue illustrates the planned travel duration whereas light blue, orange and red shows the delay probability. Light blue and orange symbolize a little delay probability whereas the color red is for a bigger one. In contrast to the final design, the color red for a bigger delay probability is taken to catch the user's attention [9]. On the basis of the colors and the length of the bars, it can be qualitatively estimated whether the public transport connection is still reachable. For a better estimation of the remaining transfer time, the latter mentioned is also shown as a bar with the length of the planned transfer time. The bars have the same color as the pictogram for the footpath.

Fig. 1. Different illustrations of timetables



2) Creation of different electronic display at stops illustrations: Variant A is the same as what already exists nowadays with the remaining time in minutes until departure as point estimate (Fig. 2). A VBZ bus stop electronic display served as a template. To keep the presentation simple, the pictogram wheelchair is not used here.

Variant F will be newly added. It shows the same illustration as can be found at a SBB electronic display for trains. Here the departure time is indicated (instead of the remaining time until departure) with the quantitative delays in red. This variant is added, because people are already used to it. Variant C shows a range of arrival times like in the first survey. The accuracy of the bus arrival time increases as the event approaches. This means that the range is getting bigger with the second (line 2) and the third bus (line 1).

Based on the specified range in Variant C, the graphics Variants B, D and E are created. These three mentioned graphics have the remaining time until departure as horizontal axis below the diagram. The different lines are colored in blue and orange to make it easier to understand. Variant D is the graphical version of Variant C. The height of the blocks illustrates the uncertainty probability. In other words, a higher block means a more precise information. Therefore, the height of the block decreases as the remaining time until departure increases. On the top of the blocks the same numbers as in Variant A as point estimates are added. Point estimates can provide false information. But here it is presented in the context of uncertainty and provides a faster understanding.

In a more precise way is Variant E. It shows if the bus comes sooner or later than planned. The asymmetric distribution indicates that the bus arrives normally rather later than sooner, because in Switzerland buses should not leave before the scheduled departure time. The different heights of the blocks are similar to Variant D. This before mentioned asymmetrical representation of the arrival times can only be displayed with Variants E and B where the probability of a delay is greater than that of an early departure. The boxplot in Variant B shows the asymmetrical representation with the median to the right of the center of the box.

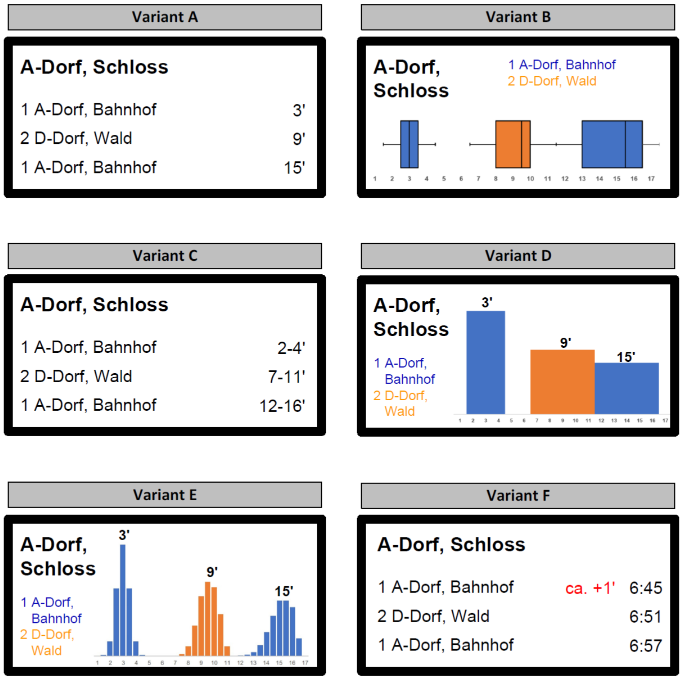
For this survey, the selection of the respondents will be not random and will not contain any quotas.

B. Results and Interpretation

The survey lasted from 11-27 May 2020. 364 people took part in the second survey, but just 264 completed it which is a share of 73%. Only the results of completed respondents will be considered, as most of the dropouts have canceled the survey before the first ranking question.

80% of the respondents want to be informed about uncertain bus arrival times. Approximately 10% more women than men wanted to be informed about the uncertainty concerning bus arrival times. The statistical significance will be verified in a next step which is checked with a logit model in R (nnet package) according to (Eq. 1) if there exists a statistical significance of some parameters. Hence, it is assumed that there is no dependency between it. In other words, if the

Fig. 2. Different illustrations of electronic displays



null hypothesis can be rejected, then there is a statistical significance. If the Z score is between -1.96 and +1.96 then the p-value will be larger than 0.05 when using a 95% confidence level [10]. The null hypothesis cannot be rejected. In this case, if the Z score is outside this range, the p-value is smaller than 0.05 and the null hypothesis can be rejected. Since the data set is not very large, some subcategories are combined.

$$ln\left(\frac{P(predictor2)}{P(predictor1)}\right) = b_0 + x_1 \times b_1 \quad (1)$$

using the following parameters
b_0 : coefficient of the intercept
b_1 : coefficient of predictor2
x_1 : either 0 or 1

For checking the statistical significance between Uncertainty1 (first uncertainty question before the ranking took place) and gender, the coefficient of predictor is the one of gender:woman (Table I). It indicates that the Z score is higher than +1.96 and the p-value is lower than 0.05. The null hypothesis can be rejected. This means, that the parameters of Uncertainty1 and gender:women show a statistical significance. The positive Z score indicates that women are more interested in uncertainty illustrations than men.

In Table II the different subcategories of how often people use public transport are distinguished (Frequency1: 5-7 days per week, Frequency2: 1-4 days per week and Frequency3: less than 1 day per week). The Z score is higher than -1.96 and the p-value less than 0.05 which means that there is a statistical significance. The negative Z score indicates that people who travel by public transport less than once a week want to be less informed about the uncertainties than people who travel by public transport 5-7 days per week.

TABLE I
MULTINOM: UNCERTAINTY1 ∼ GENDER

Predictor	Coef	Std. Errors	Z score	p-value
Intercept	1.721	0.231	7.435	0.000
gender:women	1.051	0.453	2.320	0.020

TABLE II
MULTINOM: UNCERTAINTY1 ∼ FREQUENCY

Predictor	Coef	Std. Errors	Z score	p-value
Intercept	2.866	0.389	7.376	0.000
Frequency2	-0.953	0.528	-1.805	0.071
Frequency3	-1.499	0.498	-3.014	0.003

But the age of the respondents does not play a role according to the results of this survey. Also Uncertainty2 (second question about uncertainty at the end of the survey) shows no statistical significance to the different subcategories neither for gender and frequency. Therefore, the combination of gender and frequency is not checked for Uncertainty1.

In general, it can be said that only sporadic conclusions concerning the statistical significance can be drawn. The data size was too small.

The ranking of the different variants from Fig. 1 resulted in Fig. 3. The x-axis shows the ranking position whereas the y-axis illustrates the cumulative probability at each ranking position. For a better understanding of this figure, the ranking presentation of Variant A is explained. Variant A which is nowadays available is the variant ranked the most in the first place by 65% of the respondents which can be seen by x-value of 1. 24% of them have chosen Variant A in the second place. This means that 89% of the respondents selected Variant A in the first or second place (x-value of 2) and so on. A larger gradient of the line means that this ranking place received more answers. It can be seen well on Variant C for the line between x of 1 and 2 where this variant is very popular in the second ranking position. From these findings it follows that Variant D is by far the least popular version which was usually placed in fourth place.

When evaluating the timetable ranking, it can be seen that Variant A, which already exists, is the most popular one. This graphic is, however, without indication of probability of the arrival times or uncertainty. Variant C follows with a small change to Variant A to illustrate the uncertainty. In third place follows Variant B with the three different colored dots, which remind of traffic lights. A single person is able to do more with these traffic lights than Variant D with the blue and red intermixing bars. A majority of the respondents chose the option of being informed about the uncertainties, but they again chose graphics in the first place, which do not illustrate

Fig. 3. Ranking of timetables

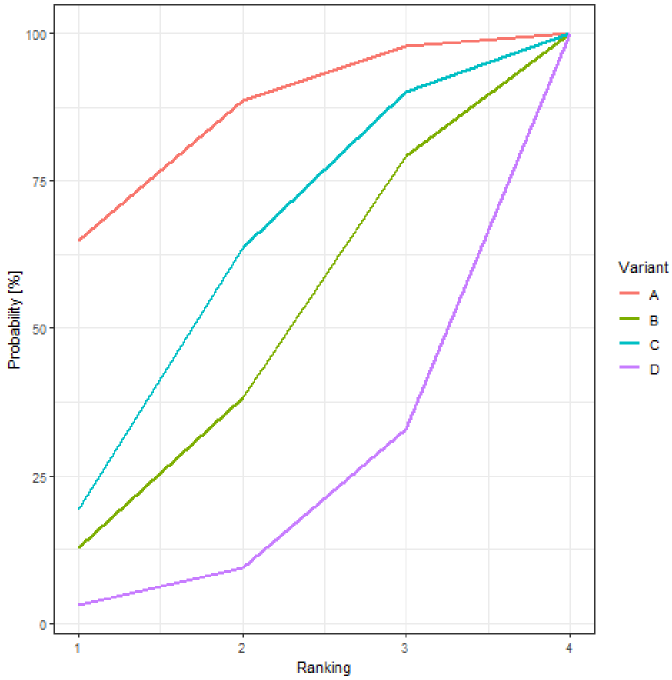
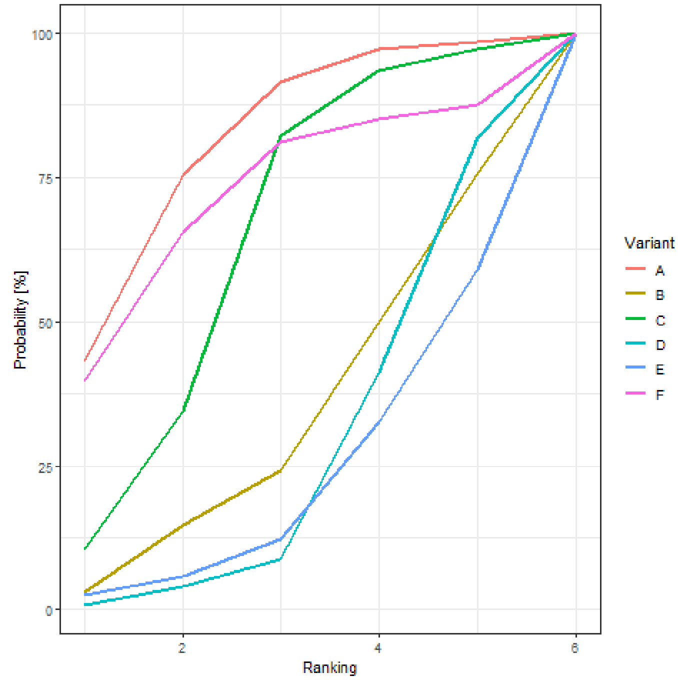


Fig. 4. Ranking of electronic displays at stops



the uncertainties. On the one hand, this suggests that people are increasingly choosing what they already know. On the other hand, the graphics with the uncertainties may not have met the wishes of the respondents.

In the case of Variant C, it is not due to the understanding that it was chosen so little in the first place because only 6% of the respondents did not understand this graphic. Generally, the number of the respondents who understood all graphics is rather low at 35%. This may also be a reason why many people have dropped out at this point of the survey. As a conclusion of the first ranking question it can be said that many respondents, depending on the device where they filled out the survey, had difficulty understanding how the move and drag ranking buttons worked. This could also have led to a high dropout rate.

On the interpretation question where it is asked if the train at A-Dorf, Bahnhof in Variant C (Fig. 1) will be caught. Following alternatives were available: ”Yes, for sure”, ”50-50 chance” and ”No, certainly not”. Almost half of all respondents thought that there is a 50-50 chance for catching the train in A-Dorf, Bahnhof. Only 20% think they will get the connection for sure. 44% of the people over 65 are more likely not to catch the train whereas 40% of the people between 20 and 39 are of the same opinion.

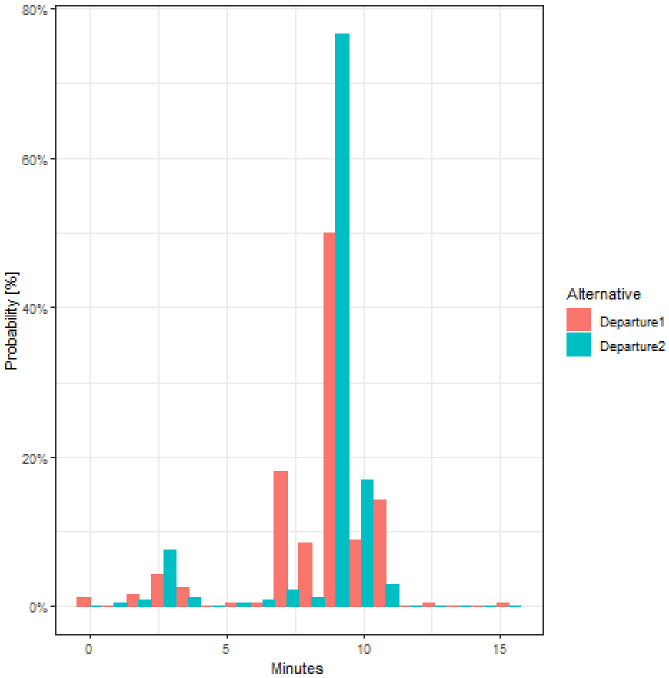
Variants A and F are the most popular ones when ranking the different electronic displays (see Fig. 2) again, followed by Variant C (Fig. 4). Variants B, D and E were chosen rather as ranking places 4-6.

The ranking of electronic displays at bus stops shows a similar picture to that of the timetable. Also the graphics already in use today (Variants A and F) provide the highest values followed by Variant C which is modified from Variant A. The three variants with the diagrams (Variants B, D and E) were not so popular. They were also not understood by one third of the respondents. In return, almost half of the respondents understood all the graphics, which is much higher than for the timetables. 96% of the respondents have understood Variants C. Approximately 80% of the respondents are in favor of knowing the uncertainty, but have chosen Variants A or F which do not illustrate any uncertainty. Again, the respondents mainly chose graphics they already know or did not like the graphics including the uncertainties.

The first interpretation question of electronic displays is with Variant C (Fig. 2) where they are asked when exactly the bus of line 2 leaves for D-Dorf, Wald. For this purpose, the respondents can enter a number between 0 and 20 in the number field. Exactly the same question is asked but in this case with Variant E. So it can be seen if people answer differently or in the same way because of the various variants. Almost 80% of the respondents chose the exact departure time of 9 minutes for Variant E (called Departure2). For Variant C (called Departure1) the answers are more distributed (Fig. 5). The high number of the respondents who have chosen 9 minutes for Variant E might be due to the fact that there is a 9 above the diagram in this graphic. Therefore, point estimates on graphics should be avoided, otherwise people will not look at the graphics as closely. In the case of this survey, it might also be that the respondents wanted to answer this question quickly and have chosen the number 9.

The respondents are also asked in how many of 10 times the bus arrives in less than 2 minutes and in more than 4 minutes. People are more likely to think the bus is arriving

Fig. 5. Exact departure of the bus according to two illustrations (Variants C and E)



later than earlier. This is also consistent with the fact that buses in Switzerland are not allowed to leave earlier. Many people also thought that the bus will leave later than planned. This means that people are aware that there is a large uncertainty about arrival times. On the other side, people are well noticing that buses could also leaving earlier.

VI. Discussion and Conclusion

This thesis showed that the majority of people wants to be informed about the uncertainties regarding the bus arrival times and journey times of buses or in general, public transport. Additionally, it can also be shown that people are more interested in simpler graphics. It also demonstrates that the need of uncertainty illustrations should be implemented as soon as possible. Although more respondents said they would like to be informed about the uncertainties, they did not choose these graphics. This is because either people only like what they already know or the graphics did not meet their needs. With additional explanations to the different graphics, more illustrations with uncertainty representations might then be chosen in the first place. Furthermore, people also estimate arrival times differently when consulting different graphics including uncertainty illustrations.

When revising the diagrams, the probability for a timely arrival should be given for the whole journey and not only for a single trip, which was done in the second survey. An example to cover this would be that a person can enter the probability of arriving on time at the destination in an online timetable or smartphone app and then it will return a public transport connection.

In this thesis, the probability of the arrival and departure time was mainly discussed. But more emphasis should be placed on the transfer time, whether it is sufficient for the transfer. This is also a major concern for commuters when using a bus to a train station and not to miss the train due to an unreliable bus. Therefore, the interplay of bus arrival time and train departure with the transfer route should be considered. A start was made with the colored pictograms in timetables for the transfer times (see e.g. Variant C in Fig. 1).

Future research should also develop graphics showing alternative routes in case of a delay or, in general, with their probability in arrival times. In this way it can be estimated whether another route has a higher probability concerning the arrival time at the destination.

These two surveys were mainly distributed in the family and friends circle of the author and at the IVT, ETH Zurich. Such a survey should be further spread, possibly throughout Switzerland to gather more answers.

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References

[1] B. Ferris, K. Watkins and A. Borning, “OneBusAway: Results from Providing Real-Time Arrival Information for Public Transport”, paper presented at the 28th Annual CHI Conference on Human Factors in Computing Systems, Atlanta, April, 10–15, 2010.

[2] M. M. Rahman, S. C. Wirasinghe and L. Kattan, “Users’ view on current and future real-time bus information systems”, Journal of Advanced Transportation, vol. 43, no. 3, pp. 336–354, 2013.

[3] M. Kay, T. Kola, J.R. Hullman and S.A. Munson, “When (ish) is My Bus? Usercentered Visualizations of Uncertainty in Everyday, Mobile Predictive Systems”, paper presented at the 34th Annual CHI Conference on Human Factors in Computing Systems, San José, 7–12, 2016.

[4] J. Hullman, “Why Authors Don’t Visualize Uncertainty”, IEEE Transactions on Visualizaiton and Computer Graphics, vol. 26, no. 1, 903–913, 2020.

[5] F. Corman and P. Kecman, “Stochastic prediction of train delays in real-time using bayesian networks”, Transportation Research Part C: Emerging Technologies, vol. 95, 599–615, 2018.

[6] M. Wunderlich, K. Ballweg, G. Fuchs and T. von Landesberger, “Visualization of delay uncertainty and its impact on train trip planning: A design study”, Computer Graphics Forum, vol. 45, no. 3, 317–328, 2017.

[7] SBB, “SBB Mobile”. [Online]. Available: https://www.sbb.ch/de/fahrplan/mobile-fahrplaene/sbb-mobile.html. [Accessed: 09-06-2020].

[8] Ostwind, “Wemlin (Fahrplan App)”. [Online]. Available: https://www.ostwind.ch/de/services/apps/wemlin-(fahrplan-app).html. [Accessed: 09-06-2020].

[9] Time for Coffee!, “Time for Coffee!”. [Online]. Available: http://www.timeforcoffee.ch/.html. [Accessed: 09-06-2020].

[10] Esri, “What is a Z score, What is a p-value”. [Online]. Available: http://resources.esri.com/help/9.3/arcgisdesktop/com/gp_toolref/spatial_statistics_toolbox/what_is_a_z_score_what_is_a_p_value.htm. [Accessed: 14-06-2020].