Information to passengers as enabler of demand management and delay reduction

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***Abstract*—Information dissemination is an important tool to reduce the impacts of an unexpected disruption. In case of a disruption between Zurich HB and Zurich Oerlikon, different agent-based simulations were executed with different information dissemination strategies. The simulations determine the impacts on the agents and analyses the influence of different information dissemination strategies. For each attribute of an affect trip, a best point in time is defined, when the agent should obtain the information.**

***Keywords*— Agent-based modelling, information dissemination strategies, unexpected disruption**

I. Introduction

In Switzerland, public transport is an important means of transportation. Public transport disruptions occur almost daily. They can be a result of unexpected events or planned restrictions. If such a disturbance occurs, the passengers want to continue their trip and do not want to be affected by the disorder.

In order to improve the satisfaction, the public operator can try to avoid the disruptions or minimize their impacts. It is important to understand the behaviour of the passengers and how it can be influenced. A good information dissemination may solve this problem in an efficient way. Therefore, the focus of this master thesis is on passengers' changed behaviour caused by disruptions and the information dissemination.

The goal is to understand and quantify the efficiency of information dissemination in public transport disruption. To achieve this, the following three tasks are executed in the area of Zürich.

A. Current information dissemination strategies

Based on a literature research a basic understanding of the current information dissemination strategies shall be gained. The aim is to examine how the SBB and VBZ provide information about the current traffic state. It should be determined how many passengers can know the information and when they receive the information.

B. Passengers' reaction strategies

Passengers react differently to a disruption. As soon as they know about the interruption, they look for an alternative. The time the passengers receive the information can vary. This work aims to investigate the influence of the information dissemination on passengers' satisfaction. The work should also take into account that different passengers with different trips respond in different ways.

C. Information dissemination strategies

Based on the results from the second task B, possible improvements should be developed. Which actions lead to an improvement of passenger satisfaction and reduce the delays? The results from the second task should be used to obtain an optimal information dissemination strategy depending on diverse passengers' expectations.

II. LITERATURE REVIEW

A. Solution Strategies

Previous research mainly focuses on the impacts of a disruption. They take a closer look at the replanning phase.

Leng, De Martinis and Corman [1] examined the impact of a disruption in Matsim. They took into account that there are more solutions than just rerouting with the public transport.

The work of Van der Hurk, Kroon, & Maróti [2] focus on the combination of passengers and public transport operator. They developed an algorithm, which consider the free route choice of the passengers and the rolling stock rescheduling of the public transport operator.

Bruglieri, M., Bruschi, F., Colorni, A., Luè, A., Nocerino, R., & Rana, V. [3] developed in their work a real-time information system. This system should guide the passengers in case of a disruption. The passenger can make a request during a trip and receive a recommendation of an alternative that avoids the disruption.

B. *Information dissemination strategies*

The information dissemination strategies of the SBB and the VBZ differ in few points. The SBB uses location-dependent information systems, such as speaker announcements at the station and passenger information system on the platforms. Further, the SBB have digital displays, which inform passengers about train arrivals and departures. An additional digital display shows all disturbances that impact the Swiss railway traffic.

The SBB also uses location-independent information systems. Their mobile app and website contain all information about the railway traffic. Actually, they are improving the push notifications [4]. The passenger should be informed with individually configurable information.

The VBZ use more real-time information. At the station, the digital displays show the duration until the next vehicle departure at this station. It also informs about any disruption on their traffic network. The VBZ have also a mobile app and a website with real-time information. The mobile app also supports push notifications. The focus of further developments is also on improving these systems and provide individually tailored information [5].

C. *Receiving information in case of a disruption*

Informing passengers consists of two parts. On the one hand the information dissemination and on the other hand the time and location a passenger receives the information. The passengers have to notice the information. This is an important aspect, especially in the event of a disruption. He must be informed about the disruption so that he can consider alternatives. Receiving the information is crucial, because only an informed passenger can search for an alternative.

It is difficult to quantify the information receiving, because there are no precise statistics. There are many influencing factors difficult to measure. In the case of the location-dependent information, it is assumed that the probability of receiving the information is high. This dissemination corresponds the two-sense principle. Acoustic and visual information are distributed at specific locations. These specific locations are usually located at the access points to the vehicles. The passenger is inevitably exposed to the information if he wants to use the public transport.

The behaviour is different in the case of location-independent information dissemination. The passengers do not receive the information passively. They have to use the Internet to get the information. Viergutz, K. and Brinkmann, F. [6] has created a few statistics about this behaviour. Only 40% of passengers use a mobile app every day. They also show that behaviour varies with gender and age. It is assumed that the probability to receive the information from an online timetable request is low. The probability increases if the passenger checks the timetable shortly before the trip.

The probability to receive the information can be improved with push notifications. Push notifications can be set for frequently used connections. The passengers get information about the disruption without making a request.

According to the article of Fischhaber & Hauck [7], people look at the smartphone 88 times per day. Assuming a daily duration of 18 hours, this corresponds to an average of 5 times an hour. Three million people uses the SBB mobile app [8]. If push notifications are used frequently, the fast dissemination of information has a huge reach.

In case of a major disruption, the dissemination of information has a certain dynamic. The newspaper and the radio can report the disruption. Especially when the disruption has a large impact. The mobile apps of the newspaper can also offer push notifications. As a result, such media can also reach a large coverage.

Furthermore, information can also be disseminated via direct interpersonal communication. This allows the range to be increased even further. However, this cannot be controlled and is more random.

Therefore, the question of how many people know about the disruption can hardly be answered without further investigation. There are too many influencing factors very difficult to measure. There exist many possibilities to inform the passengers and none of them can be really quantified.

III. AGENT-BASED MODELLING

This work uses the open-source software Matsim. Matsim is an activity-based and expandable simulation [9]. It enables a multi-agent simulation of large-scale scenarios with all means of transport. The traffic demand is the set of agents with their daily plans. A daily plan consists of a chain of activities. An agents' daily plan is the sequence of all his activities for one day. The travel demand arises from the necessary trips to reach all locations for these activities. It tells Matsim at what time the agent wants to perform which activity and where. The initial demand arises normally from empirical data [9].

Matsim simulates each second oft the day. In each time step, it executes the daily plan of the agents. It calculates for each second where every agent is located.

After the simulation, Matsim evaluates the score of every executed plan. The score corresponds to the utility of a plan and allows a comparison between the different executed plans.

The output data of Matsim contains the executed events of each agent. This means that every action by an agent is precisely described with the time, the location and other attributes.

IV. METHODOLOGY

A disruption between Zürich HB and Zürich Oerlikon was simulated at two different periods during the day. The first disruption occurs between 6:00 and 9:00 in the morning. The second disruption occurs between 16:00 and 19:00 in the afternoon. The trip's purposes are different in the morning and in the afternoon. In the morning, the agents want to go to work or education. In the evening, the agents want to go home, go shopping or other perform other leisure activities. The utility may vary when different purposes are affected and should be examined. The following scenarios are simulated.

A. Basic scenario

In a first scenario, the ordinary daily routines of all agents are simulated. There are no disruptions in this scenario. Every agent executes its daily plan and has the entire public transport and the road network available. This scenario is used to determine the everyday behaviour of the agents. The basic scenario was simulated with 1,000 iterations. It is the normal plan, which the agents use every day. It is assumed, that the agent wants to perform this plan on a normal day. The output of this scenario serves as input for all of the next scenarios that include a disruption.

B. Worst-case scenario

The worst-case scenario intends to simulate the worst dissemination of information. The agents get no information at all. As a result, the agents will continue their normal trip until the station where the affected train would leave. The agent waits at this station until the next train will leave.

C. Worst-case scenario with learning effect

The agents are still not receiving any information. At the beginning, they wait at the station until the next train leaves. This scenario simulates the disruptions with 500 iterations. The agents have to deal with the same disruption every day.

D. Worst-case scenario with a limited information

The information dissemination has been slightly improved. In this scenario, the agents get the information that their train was cancelled. They get the information when they are at the station and are waiting for the train. However, no alternative is suggested. As a result, the agent does not just wait until the next train leaves. It takes the next connection, which will take it to the next destination.

E. Dissemination at different point in time

This scenario aims to determine the influence of when an agent receives information regarding a disruption. Therefore, this scenario was simulated multiple times with different points of time. Every agent receives the information at the same time. That means, in the first simulation every agent gets the information, when it is at the last station before the affected leg. In the second simulation every agent receives it at the first station. Furthermore, the receiving time at the end of the activity was simulated. After that, four more points of time were simulated: 15 minutes, 30 minutes, 45 minutes and 60 minutes before the end of the last activity. A total of seven points of time were simulated.

F. Optimization of the replanning step

This scenario is similar to the last scenario. Also the simulated points of time correspond to the ones in the last scenario. The difference to the previous scenarios is that the replanning step is improved. An agent does not take the first possible solution.
The replanning step still starts when the information is received. But this scenario checks if there would be a better solution a few minutes later. A better solution is when the travel time is shorter.

G. Real mode

The real mode simulates a more realistic behaviour. In the previous scenarios, a specific point in time of the information reception is assumed. Every agent receives the information at the same point in time.
The real behaviour is different. It is not known how many agents know about the disorder at what time. Only approximate estimates of the probability can be made. Three main probabilities are assumed in real mode. The first probability $p_{station}$ is the probability of receiving the information at the station. The information can be received passively at a station. Therefore, the probability is assumed to be 80%. That means, there is an 80% chance that an agent gets informed when it is at a station. The second probability $p_{vehicle}$ is about the information reception in the vehicle. The information can also be received passively by the agents. Therefore, this probability is also assumed to be 80%.
The last probability is the probability of receiving the information per second. This probability p_{online} is relevant for receiving information via the Internet or the app. This is possible every second and is independent of the location or the activity. In contrast to the other probabilities, this information cannot be received passively. Because of that and the fact that the probability is per second, it is assumed to be very low. It is assumed based on this formula.

$$A_{inf} = 1 - (1 - p_{online})^t$$

A_{inf} is the proportion of informed agents and t the time step in seconds. Both scenarios are simulated four times. Different probabilities were assumed in these simulations. Different levels of information dissemination are examined. The assumed percentage of informed agents after three hours are 20%, 40%, 60% and 80%. The probability p_{online} can then be calculated from this assumption. This probability was further reduced due to the attributes of an agent.

V. RESULTS

A. *Worst-case scenario*

The agent does not get any information and waits until the next train leaves. As a result, the score decreases and the delay increases. The resulting delays are shown in table 1.

	Delay in the morning [min]	Delay in the afternoon [min]
Minimum	30	30
Average	160	108
Maximum	990	217

Table 1: Delays in the worst-case scenario due to the disruption in the morning and in the afternoon

It can be seen, that the delay is minimum 30 minutes in both cases. The average delay is almost three hours in the morning and almost two hours in the afternoon. The maximum delay is over 16 hours in the morning. No information dissemination in case of an unexpected disruption leads to a large delay and decreases the satisfaction of the passengers.

The evaluation of the worst-case scenarios shows that the agents have to be informed about the disruption and should do the replanning step. Otherwise, the impact of the disruption is huge.

B. *Worst-case scenario with learning effect*

This scenario aims to determine how many agents still travel with public transport, even when other transport modes are possible. The selected transport modes in case of the disruption in the morning is shown in figure 1.

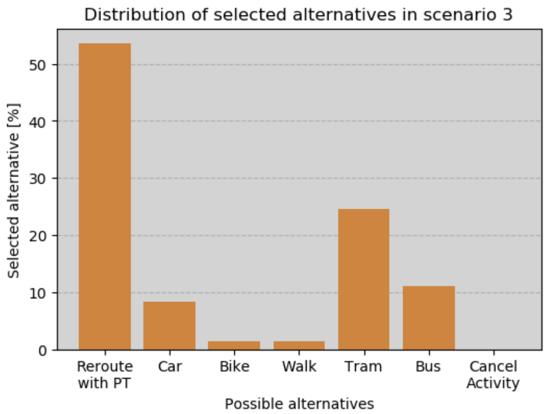

Figure 1: Distribution of selected alternatives in the morning

The figure shows that most of the agents do not change to another mode of transport than public transport. In the morning, approximately ten percent of the agents take the car, the bike or walk instead. The rest of the agents still take public transport. No agent chooses to cancel the activity in both scenarios. 25% of the agents now use the tram and 11% the bus. These agents can also use several means of transport. Compared to the basic scenario, they are now also using the bus or tram. As a result, approximately 90% of the agents still use public transport.

Figure 2 shows the delays of the trips. It is compared to the basic scenario.

	Delay in the morning [min]	Delay in the afternoon [min]
Minimum	- 38	-48
Average	- 1.48	5.7
Maximum	48	200

Table 2: Delays in the scenario with the learning effect due to the disruption in the morning and in the afternoon

The average travel time is shorter in case of the disruption in the morning than in the basic scenario. In the scenario with the disruption in the afternoon is it a few minutes longer. The maximum delay could be improved only in the morning.

C. *Worst-case scenario with limited information*

These scenarios aim to evaluate how a limited information can improve the situation for the passengers. The agents take the first train, which takes them to the next destination. The delays of the affect trips are shown in table 3.

	Delay in the morning [min]	Delay in the afternoon [min]
Minimum	0	- 15
Average	113	100
Maximum	570	217

Table 3: Delays in the scenario with limited information due to the disruption in the morning and in the afternoon

In the morning, the delays could be reduced considerably compared to the worst-case scenario. The average delay is under two hours. The worst-case delay shows that an agent had almost ten hours to reach the next activity. This is unrealistic, because there are trains running to the next destination within the next 10 hours. Matsim does just not identify these trains as possible alternatives.

In the afternoon, the improvements are just a few minutes. Only in the best-case, the travel time is shorter than in the basic scenario. This is just possible, if the agent arrives at the station before the start of the disruption and catches an earlier train.

The results of this scenario verify again, that a good information dissemination is necessary to minimize the impacts of a disruption. Especially in the afternoon, a limited information corresponds almost to no information.

D. Dissemination at different point in time

This scenario simulates different points in time for the information reception. The score, the delay and the number of transfers can vary between the different points in time. Table 4 shows the minimum, average and maximum delay in minutes for each point in time.

	Disruption in the Morning			Disruption in the afternoon		
	Min	Avg.	Max	Min	Avg.	Max
First station	-33	1.2	60	-37	5.5	60
Last station	-30	1.4	60	-38	6.3	60
End of activity	-31	1.7	60	-39	5.3	60
15 min before	-35	2	55	-43	4.7	45
30 min before	-30	1.2	60	-30	5.5	48
45 min before	-37	2.7	60	-44	4.9	89
60 min before	-35	2	33	-60	4.7	50

Table 4: Minimum, average and maximum delay for each point in time for the disruption in the morning and in the afternoon

Compared to the previous scenarios, the delays could be reduced considerably. The average delay was reduced to a few minutes. Even in the worst case, the delay is maximum 89 minutes. In the best-case the agents are faster than in the basic scenario.
In the scenario with the disruption in the morning, no best point in time exists. If the agents get the information 60 minutes before the end of the activity, the longest delay is 33 minutes. The best minimum is reached 45 minutes before the end of the activity and is -35 minutes. The best average has the point in time 30 minutes before the end. The scenario with the disruption in the afternoon has no best point in time. The best minimum is -60 minutes and is reached, when the information is received an hour before the end of the activity. The best maximum and average has the point in time 15 minutes before. The point in times vary and no clear pattern can be recognized. This scenario confirms the assumption, that a good information dissemination leads to less delay and increases the satisfaction of the passengers.

E. Optimization of the replanning step

The optimization process is developed to reduce the travel time. The minimum, average and maximum delay due to the optimization process for each point in time is shows in table 5.
Despite the optimization, the delay is not reduced in each case compared to scenario D. The average delay could be reduced by a few minutes in case of a point in time during or at the end of the activity. The maximum increased considerably in some cases.

	Disruption in the Morning			Disruption in the afternoon		
	Min	Avg.	Max	Min	Avg.	Max
First station	-33	1.1	60	-37	5.3	60
Last station	-30	5.1	38	-30	9	60
End of activity	-48	-0.4	60	-43	2.9	60
15 min before	-41	-2.8	64	-47	1	60
30 min before	-38	-2.4	69	-44	2.3	147
45 min before	-40	-2.6	60	-38	0.9	48
60 min before	-44	-3.6	58	-48	1.8	270

Table 5: Minimum, average and maximum delay for each point in time for both disruptions

In scenario with the disruption in the morning, no best point in time exists. If the agents get the information at the end of the activity, the minimum is 48 minutes. The best average delay is reached with the point in time 60 minutes before. The best maximum is when the information is received at the station. The scenario with the disruption in the afternoon, has also no best point in time. The best average delay is reached when the agent gets the information 45 minutes before the end of the activity. The best minimum is at the point in time 60 minutes before. No clear pattern can be recognized in this table.

F. Real mode

The real mode simulates a behaviour that is as realistic as possible. Four different assumptions were made regarding the percentage of informed agents. The assumed percentage of informed agents after three hours are 20%, 40%, 60% and 80%. The resulting minimum, average and maximum delay for each assumption is shown in table 6.

	Disruption in the Morning			Disruption in the afternoon		
After 3h	Min	Avg.	Max	Min	Avg.	Max
20%	-33	1.9	60	-39	5.7	60
40%	-30	1.9	60	-39	6.3	60
60%	-30	1.8	60	-39	5.5	60
80%	-30	1.9	60	-30	5.7	60

Table 6: Minimum, average and maximum delay for each assumption for both disruptions

It can be seen, that the delays do not vary between the different assumed percentage of informed agents. The average delay varies in the size of seconds and the minimum has a maximum difference of 3 minutes. The different assumed percentage does not influence the average delay. However, compared to the scenarios A, the delay is reduced considerably. As a result, the real information dissemination reduces the delays and increase the satisfaction of the passengers.

VI. CONCLUSION

Information dissemination improves the situation for the passengers considerably. Without any information, the delays can easily reach several hours. Already basic information dissemination can keep passenger delays under 30 minutes in almost each case. The delays can be further improved with an optimal information dissemination.

The influence of the information dissemination is examined by assuming the time of reception. It turned out, that different points in time of reception lead to different scores and delays. Further has been shown, that the scores and delays depend more on the attributes of the trips, than on the attributes of the passenger itself. As a result, the latest best point in time of information reception is determined for each trip attribute. It enables the public transport operator to propose an optimal solution to the passengers at the corresponding time.

The best points in time were defined to inform the agents. They are mostly before the trip. The transport operator should aim to reach this information dissemination as early in the trip as possible. The information can only be received before the trip via online media. The most promising variants are push notifications combined with available passenger data like regularly repeating trips. The dissemination of information based on the trip attributes can only be achieved if the data about the trip are available. The trip's attributes should be known in each individual case. This enables an individualized push notification for each agent. Each passenger can get the information adapted to his trip attributes.

VII. FURTHER WORK

Different aspects were neglected in this work. A future work could be to consider more alternatives and find a way to compare the alternatives in the within-day replanning. Other alternatives, such as cancelling the activity, are difficult to compare to a rerouted trip. A process could be developed, which let the agents decide between different alternatives based on configurable rules. It could take into account the information dissemination.

Further, only an unexpected disruption is considered. There may exist disruptions, which occur frequently. It could be examined how the passengers react to a disruption that occurs for example every fifth day and how it could be influenced through information dissemination. The same investigation could be done on disturbances, which are not a fully blockage of a section but only cause long delays. It could be determined, how the information dissemination in case of delays in public transport affects the behaviour of the agents.

This work does consider a disruption with a defined start and end time. The identification of the affected agents identifies all agents, which want to use the blocked section in this time interval. Agents who want to use the blocked section after the disruption can also be informed about the disruption. If the agent does not know the end of the disruption, it can do the replanning step without knowing that it really should not have to. It could be investigated how the information about the end of the disruption influences the decisions of the agents.

Further evaluations on the information reception could be planned. As described in the previous chapter, the point in time of the information reception is an important factor to do the replanning step and it is known. No statistics exists about it. Surveys could evaluate passenger behaviour that would allow to improve the information dissemination model.

VIII. REFERENCES

[1] Leng, N., De Martinis, V., & Corman, F. (2018). *Agent-based simulation approach for disruption management in rail schedule*. Zürich.

[2] Van der Hurk, E., Kroon, L., & Maróti, G. (2018). Passenger Advice and Rolling Stock Rescheduling under Uncertainty for Disruption Management. *Transportation Science, 52(6)*, 1391-1411.

[3] Bruglieri, M., Bruschi, F., Colorni, A., Luè, A., Nocerino, R., & Rana, V. (2015). *A real-time information system for public transport in case of delays and service disruptions*. Delft: Elsevier B.V.

[4] Schweizerische Bundesbahnen SBB. (2020, January 10). *Vier Gründe, weshalb die Kundeninformation 2020 besser wird. Retrieved from* https://news.sbb.ch/artikel/94001/vier-gruende-weshalb-die-kunden informati on-2020-besser-wird

[5] Zürcher Verkehrsverbund. (2015). *Strategie 2018 – 2021 Grundsätze über die Entwicklung von Angebot*. Zürich.

[6] Viergutz, K., & Brinkmann, F. (2018). Anforderungen von Nutzern flexibler öffentlicher Mobilitätskonzepte an digitale Fahrgastinformationen mit Echtzeitdaten. In H. Proff, & T. M. Fojcik, *Mobilität und digitale Transformation* (pp. 331-346). Wiesbaden: Springer.

[7] Fischhaber, A., & Hauck, M. (2017, January 14). *Tagesanzeiger*. Retrieved from https://www.tagesanzeiger.ch/digital/mobil/smartphonenutzer-schauen-taeglich-88mal-auf-ihr-geraet/story/24730680

[8] Schweizerische Bundesbahnen SBB. (2019). *SBB-Mobile - der persönliche digitale Reise-begleiter.* Retrieved from https://company.sbb.ch/content/dam/sbb/de/pdf/sbb-konzern/medien/hintergrund-dossier/Factsheet%20SBB%20Mobile.pdf

[9] Andreas Horni, K. N. (2016). *The Multi-Agent Transport Simulation*. London: Ubiquity Press