The role of alternative routes in pedestrian transport

Added value of route alternatives in terms of walking attractivenss

Andrea Weber
Institute for Transport Planning and Systems (IVT)
Swiss Federal Institute of Technology Zurich (ETH)
Zurich, Switzerland

***Abstract*—By means of three case study areas, the role of alternative routes, route choice behaviour of pedestrians and their perception has been assessed. A survey has been performed to collect data about the route pedestrians have chosen and to get further information about pedestrians' behaviour. By means of a network audit, important factors for walkability revealed from the literature have been validated quantitatively. The results of this thesis show that a positive correlation between the number of known routes and walking attractiveness is possible. However, the results depend strongly on the context. Furthermore, between multiple equally long route options several routes have been used. However, one route is most often preferred by a vast majority of pedestrians. Route choice in general depends strongly on pedestrians' perception.**

Keywords—pedestrian transport; alternative routes; walking attractivenss; distribution of pedestrians; factors determining route choice

I. Introduction

The widely studied research about walking attractiveness is called walkability. However, it remains unclear how to quantitatively measure walking attractiveness. Such a measurement requires better understanding of the perception, the behaviour and the needs of pedestrians to figure out how walking attractiveness can be improved. A possibly important factor in determining how walking attractiveness can be measured is the presence of alternative routes. Alternative routes are useful to divide traffic flow in a network or to provide an alternative in case of road constructions or accidents. However, to this date we do not know whether the presence of multiple routes increases pedestrians walking attractiveness and thus their quality of life.

To research the role of alternative routes, the following research questions will be assed:

- What is the importance of the presence of alternative routes in terms of walking attractiveness?
- How does a given traffic demand divide itself over multiple, equally long route options?
- Which factors determine the choice between multiple alternatives?

This paper starts with an overview on the existing literature about pedestrians' walking behaviour. Secondly, the theoretical framework will be outlined, and the hypothesis will be defined. Thirdly, the approach and methods to examine the research questions will be outlined. Fourthly, three case studies will be presented in which the phenomena of alternative routes was researched. This is followed by a description of the survey, the network audit and the data collection in the case study areas. Finally, the results of the models will be presented and analysed to make conclusions about the role of alternative routes in terms of walking attractiveness.

II. Literature review

The purpose of the literature review is to get an insight into pedestrians' walking behaviour and to understand the different aspects of route choice and factors influencing rout choice. This helps to further understand the role of alterative routes in the distribution of pedestrian traffic and walking attractiveness.

A. Alternative routes and route choice

Route choice is the process, where a traveller has to choose a route from different alternatives. However, the traveller can only choose between routes he or she knows. Furthermore, the pedestrian might set some constraints for routes he does not consider in his choice set. The alternatives considered in the choice set are called the available alternatives. However, the route choice process does not only depend on the available routes, it also depends on individual travel needs and the level of spatial knowledge (see Fig. 1.) [1]. Furthermore, the theory of route choice behaviour is based on the economic concept of utility maximization [2][3][4][5][6]. This means that a traveller tries to find the route that satisfies his needs best. According to Stern and Leiser (1988) [4], pedestrians with only small knowledge about the available routes are more likely to choose a poorer alternative over better ones.

B. Factors determining route choice

There are many studies about factors determining route choice [6][7][8][9]. Most of them indicate that pedestrians tend to take the shortest route. However, the preferred shortest route is different from the actual shortest route [10]. Urech (2017) [11] criticized the approach of other research in this thesis because almost none discussed and argued their choice of factors. Therefore, he performed an in-depth literature review on existing research about the parameters determining walkability. The collected parameters have been rated accordingly to their importance regarding the influence on pedestrian.

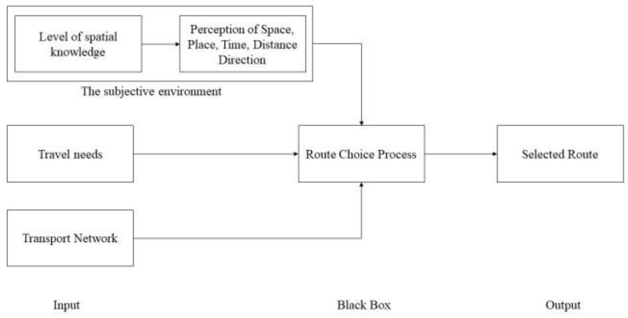

Fig. 1. Route choice process

C. *Walking attractiveness*

The main interest in the field of walkability is the perceived walking attractiveness, which measures how friendly an area is to walk. Walking attractiveness is often assumed to be influenced by the built environment. Therefore, walking attractiveness has been measured by means of qualitatively rating the attractiveness of the factors of the built environment [12]. However, Alfonzo (2005) [13] argues that the reason for people to walk and to choose a route is primarily based on basic walking needs (safety, comfort, pleasantness, accessibility and feasibility). Only if those needs are partially covered, pedestrians consider higher-order needs, such as factors of the built environment. Erath (2016) [14] applied this approach successfully to measure walking attractiveness.

D. *Syntheses*

Research tends to focus on factors determining route choice and the influence of the built environment on walkability rather than the role of alternative routes. Most researchers estimate choice models based on revealed or stated preference data. However, none of them discussed and argued their choice of factors. Therefore, the results of meta-analyses like the one of Urech (2017) [11] are useful to continue with. Many papers conclude that minimizing distance is the main factor determining route choice. But what factors are relevant if the routes have the same length? This question remains unanswered. Furthermore, to the best of my knowledge, the specific role of alternative routes has not been addressed so far. Therefore, one question that needs to be answered is if alternative routes themselves do influence walking attractiveness of the chosen route and influence route choice.

III. Theoretical Framework

Little knowledge about an area could lead to the choice of a worse alternative over better ones [4]. According to Golledge and Garling (2001) [15], spatial knowledge can be measured as the number of alternative routes known to a traveller. This leads to the first hypothesis:

- The number of individually known alternative routes is positively correlated with walking attractiveness. (H1)

Based on the mentioned arguments for the first hypothesis, and considering that preferences change with trip purpose, the assumption is that people who use more routs have a higher overall satisfaction because they have a higher overall utility. This leads to the second hypothesis:

- The number of individually used alternative routes is positively correlated with walking attractiveness. (H2)

In order to assess the role of alternative routes, it is key to know which routes are actually chosen. Sever papers agree that pedestrians tend to take the shortest route. However, it is of great interest to find out which routes will be chosen if several alternatives with similar length exist or if the chosen route is actually the chosen route. Armeni and Chorianopulos (2013) [10] argue that pedestrians tend to take similar route alternatives, because they rate the same urban factors as important. This finding can also be combined with the theory of bounded rationality. Pedestrian usually have limited knowledge about an area and obtaining information is costly. Therefore, pedestrians try to reduce their information cost, for example by just following other people in assumption that they have more information. The relatively more people take this route the more likely that this assumption is the best option becomes true. Therefore, one can expect that even though multiple alternatives exists, one route alternative is used significantly more than others.

- Within a given demand of pedestrians, one alternative is used significantly more than other equally long route alternatives. (H3)

According to Helbing et al. (2001) [16], pedestrians tend to take the route where they can go straight as long as possible and turn as late as possible. This effect leads to the proposed hysteresis effect, which explains why pedestrians take a certain route to a destination but another way back.

- Pedestrians choose a different route to a certain destination than on their way back. (H4)

To find the factors that determine the choice between multiple alternatives, the results of the meta-analysis of Urech (2017) [11] will be empirically tested. To validate those factors, just eh most important ones have been considered.

- Basic walking infrastructure, greenery, social comfort and obstacles are the factors determining route choice. (H5)

IV. Approach

To research the phenomena of alternative routes, three case studies have been identified. To assess the importance of alternative routes and to identify the chosen routes a survey was conducted. The factors determining route choice have been identified base on previous literature. These factors are validated with revealed preference data measured in the case study areas.

A. Case studies

The locations for the case study need to fulfil the following requirements:

- Obvious origin and destination / attractor for pedestrians;
- Presence of multiple, equal long alternative routes;
- High frequency and large number of pedestrians during the day;
- Route length shorter than 600 m.

Around railway stations in urban areas, high pedestrian traffic is common. The more trains per hour arrive at the stations, the higher the pedestrian frequency. Furthermore, most people who arrive at the railway station will either walk, take a tram or a bus to travel to their final destination. Based on the requirements described above and the finding that railway stations are suitable for this case study, the railway stations Zurich Stadelhofen, Zurich main station (Zurich HB) and Zurich Oerlikon were selected. All of them are in the top 8 of the most important railway stations in Switzerland according to the number of passengers [17]. Between Zurich Sadelhofen and Bellevue, there are a lot of pedestrians en route. Oerlikon has also a high share of pedestrians walking from the station to the Albert-Näf-Platz, where several bus and tram stations are located. Zurich HB is selected because of the knowledge that many pedestrians are walking at the Bahnhofstrasse and the streets around this area. While there is no obvious single destination or attractor where a lot of pedestrians would be walking towards, however, the whole area around the Bahnhofstrasse is an attractor for people. Therefore, an intersection where a high number of pedestrians are passing by is chosen as the observed destination

B. Survey

The survey collects revealed preference data and was designed as a web-based survey with the tool Qualtrics. The purpose of the survey was to get an insight into the following:

- The chosen route of pedestrians in the case study areas;
- General route choice behaviour of pedestrians in the study area;
- Individual characteristics of pedestrians;
- Walking attractiveness;
- Spatial knowledge.

An anonymous link and a QR-Code leading to the survey have been printed on a flyer. The flyer was distributed at all case study areas on two weekdays per week, three times a day, to get cross-sectional data of all pedestrians. To increase the response rate, an incentive in form of a lottery to win 50 Swiss francs was included in the survey.

To collect the data about the chosen route, pedestrians needed to have the opportunity to choose between all available route alternatives. Therefore, the choice set was defined beforehand. In order to have a straightforward and clearly laid out design of the survey, the question was split up and implemented in the form of a decision tree diagram. This means that a separate question for each decision node has been established. A decision node is defined as an intersection where pedestrians need to decide which path to take. Because pedestrians are normally not willing to make detours, only the paths in direction of the destinations where possible to choose. To implement those questions, each path was numbered beforehand.

C. Network audit

The purpose of the network audit was to collect data of the built environment to validate the findings from the literature review. The determined eight factors measured in the network audit and the operationalization are presented in Table I. Those factors have been measured for all route segments of the choice set.

TABLE I. OPERATIONALIZATION

Factors	*Measurement Method*
Distance	Measure route form A to B
Presence of cars	0 = no car, 1 = car
Separation from traffic	0 = not separated, 1 = separated
Separation from bicycle lanes	0 = not separated, 1 = separated, 2 = separated on sidewalk
Sidewalk width	Average sidewalk width per segment. Maximum 5 meters.
Trees / Green	Number of trees per segment / Length of green area per segment.
Social comfort	Recording of average number of people present in a streetscape. Count two times a day.
Obstacles	Recording number of obstacles per segment.
Crossings	Identify the total width of crossings per segment.

D. Procedure of data collection

The flyers were distributed in November 2017 each on a Tuesday and Thursday for all three case study areas. In order to get a cross-sectional sample of pedestrians per area, the flyers were distributed during three different time slots per day: One in the morning during rush-hour (around 7:30 to 8:30 pm), one during noon (around 12:00 am and 1:00 pm) and the last one in the evening during rush-hour (around 5:00 and 6:00 pm). The flyer distribution was performed at Bellevue, the Albert-Näf-Platz and the intersection Usteristrasse/Lintheschergasse for the case study Zurich HB. To ensure that pedestrians from all directions are reached, the flyers have been distrusted randomly to waiting people but as well to pedestrians passing by.

In total, 1’614 flyers have been distributed, whereas the average response rate is about 23.8%[1], calculated as the average of all individual response rates. In the case study Stadelhofen 663 flyers have been distributed, in Oerlikon 538 flyers and in Zurich HB 307 flyers. In general, the flyer distribution method worked well, and the response rate is like

[1] Calculated as the number of pedestrians participated divided by the total sample size.

expected [18]. An interesting finding is, however, that almost on every day the response rate from the morning flyer distribution is the highest, whereas the distribution in the evenings performed worst. This might be because in the evening pedestrians are rushing to leisure activities and forget about the survey or they are tired. In contrast to the morning, people are going to work and participate when they need a break from work or on their way to work in the tram.

V. Results

In total, 303 participants completed the survey. In the case study Stadelhofen, 166 pedestrians participated, in Oerlikon 76 and in Zurich HB 61. The respondents are evenly distributed among gender. Younger and higher educated people are somewhat over-represented compared to the population of Zurich [19][20]. However, the population of Zurich does not correspond to the population of the sample. In all three case studies, work is the dominant activity. Work as activity is mainly represented in the morning sample. Education is the second most represented activity, mainly in the case study Stadelhofen. In the afternoon and evening sample, leisure and shopping activities are mentioned more.

A. Walking attractivenss

Walking attractiveness is assumed to be correlated with the number of known routes and the number of used routs. To test those correlations, multiple regression models are estimated.

TABLE II. Linear Regression Results

	Model Nr. Of known routes		**Model Nr. Of used routes**	
Mean Satisfaction	***Value***	***Stdv.***	***Value***	***Stdv.***
Intercept	44.96****[1]	0.15	0.95****	0.14
Nr. Of known routes	0.14	0.64		
Nr. Of used routes			-0.28	0.72
Oerlikon	-0.30**	0.15	-0.25	0.14
Zurich	0.19	0.22	0.36	0.21
Work & Education	0.13	0.16	0.17	0.16
Known routes: W&E	0.15	0.62	0.16	0.74
Adj. R^2	0.03		0.02	

[1]Indicators of statistical significant: **** >99.9%, ***>99%, ** >95%, *>90%

The results in Table II show a positive correlation between the number of known routes and satisfaction. Furthermore, the results show that pedestrians in Oerlikon are significant less satisfied than in the reference area Stadelhofen. The results also present that satisfaction seems to be influenced by trip purpose. Pedestrian which are going to work or school are more satisfied than pedestrian performing a leisure activity. This can be explained due to the assumption that pedestrian going to work or school have lower individual requirements on a route than pedestrians performing a leisure activity. Therefore, their requirements are satisfied faster. The correlation between the number of used routes and satisfaction has rather a negative correlation. However, in other models also positive correlations have been observed.

The variability in the parameters found in the model results lead to the conclusion that the correlation of the number of used routes respectively in the number of known routes with satisfaction depend on the context. It has been revealed that satisfaction has been rated different in each case study area. Furthermore, the results depend also on trip purpose.

B. Distribution between equal long route options

Fig. 2. Show the results of the routes pedestrian have chosen in the different case study areas.

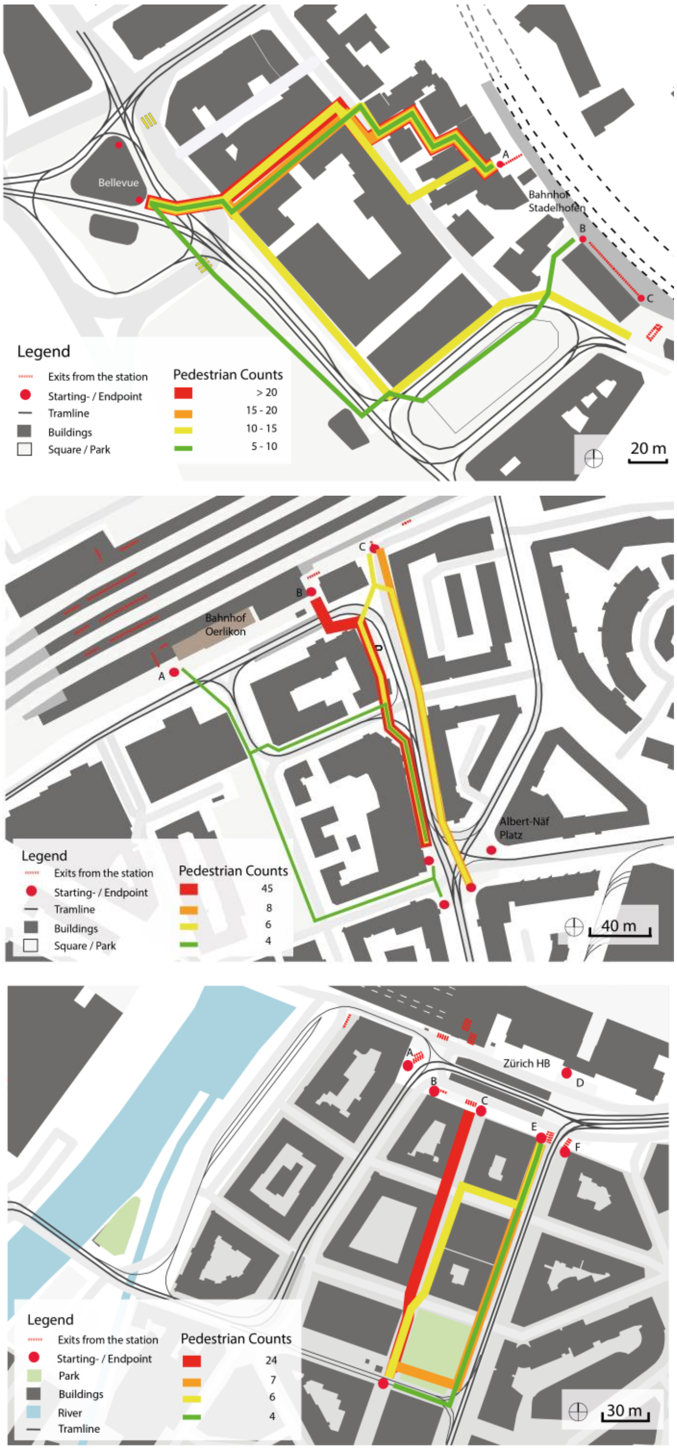

Fig. 2. Chosen routes in case studies

The results of the survey revealed that different routes between a given origin and destination are used. However, one route is often preferred Furthermore, it has been revealed that "shortest route" and "habit" are the most important reason for choosing a route. Even though if pedestrian think they have chosen the shortest route it is most often not the shortest. This leads to the conclusion that route choice strongly depend on the individual perception. Moreover, the result that one route is chosen most often could be explained due to the theory of bounded rationality. Because obtaining information is costly and therefore, pedestrian try to reduce their information cost. This could lead for example to the fact, that pedestrian follow other pedestrians by the assumption that they have more information.

C. Factors determining route choice

The factors revealed from literature have been measured in the case study areas. In order to validate those measurements multinomial logit (MNL) models have been estimated.

TABLE III. MNL MODEL RESULTS

	Model Stadelhofen		**Model Zurich HB**	
Parameter	***Value***	***Stdv.***	***Value***	***Stdv.***
Crossing	22.3***[1]	2.61	1.96	1.53
Green	-0.363**	0.15	0.098*	0.05
Length	-0.0179***	0.005	-1.16***	0.04
Obstruction	0.258***	0.04	0.78***	0.19
Presence of cars	2.41***	0.49	0.662	1.56
Sidewalk width	2.90***	0.37	-0.93***	0.31
Separation from bicycles	0	0	0	0
Social comfort	1.44***	0.43	-0.643*	0.47
Tree	-0.178***	0.05	0.362***	0.11
Adjusted R^2	0.312		0.194	

[1]Indicators of statistical significant: **** >99.9%, ***>99%, ** >95%, *>90%

The model results in Table III show that most factors are statistically significant to influence route choice. Only separation from bicycles was not. This is due to the homogeneity of the chosen routes corresponding this factor. Furthermore, some significant coefficients in the MNL model do not always have the same sign for the different case studies and are in general not always like expected. Those findings lead to the conclusion that the importance of the factors of the built environment depend on the context. However, it could be also a result of the small sample size and the small variance n the route attributes.

VI. CONCLUSIONS

The main purpose of this thesis was to get an insight into pedestrians walking behaviour, their distribution over equal long route options and the role of alternative routes in terms of walking attractiveness.

The main finding of this thesis is that results of waking attractiveness and factors determining the choice between alternatives depend strongly on the context. This could be observed in the analysis testing the correlation of satisfaction with the number of known respectively the number of used routes. Not all models showed a significant correlation, however, in general the correlation between the number of known routes and satisfaction is positive. For the correlation between the number of used routes and satisfaction the correlation seems to be rather negative. Furthermore, this study reveals that between a given origin and destination several routes are used. However, one route is often preferred. The finding that one route is preferred could be due to bounded rationality. In general, route choice depends strongly on pedestrians' perception. However, there is still a lot of factors unclear regarding pedestrians' behaviour. Therefore, further research should investigate pedestrians' perception especially regarding distance.

ACKNOWLEDGMENT

I thank Prof. Dr. Francesco Corman for the possibility to write this thesis, for his critical reviews and helpful inputs. Furthermore, I am grateful to my supervisor Mark Meeder for his valuable and supportive advices. I also want to thank Ernst Bosina for his helpful inputs during the presentations. Moreover, I gratefully acknowledge the help and support of my fellow students, my friends and family.

REFERENCES

[1] Lindelöw, D., Å. Svensson, C. Sternudd and M. Johansson (2014) What limits the pedestrian? exploring perceptions of walking in the built environment and in the context of every-day life, Journal of Transport & Health, 1 (4) 223–231.

[2] Hoogendoorn, S. P. and P. H. Bovy (2004a) Dynamic user-optimal assignment in continuous time and space, Transportation Research Part B: Methodological, 38 (7) 571–592.

[3] Muraleetharan, T. and T. Hagiwara (2007) Overall level of service of urban walking environment and its influence on pedestrian route choice behavior: analysis of pedestrian travel in sapporo, japan, Transportation Research Record: Journal of the Transportation Research Board, 2002, 7–17.

[4] Stern, E. and D. Leiser (1988) Levels of spatial knowledge and urban travel modeling, Geographical Analysis, 20 (2) 140–155.

[5] Broach, J. and J. Dill (2015) Pedestrian route choice model estimated from revealed preference gps data, paper presented at the Transportation Research Board 94th Annual Meeting, vol. 15-3669.

[6] Guo, Z. and B. P. Loo (2013) Pedestrian environment and route choice: evidence from new york city and hong kong, Journal of transport geography, 28, 124–136.

[7] Antonini, G., M. Bierlaire and M. Weber (2006) Discrete choice models of pedestrian walking behavior, Transportation Research Part B: Methodological, 40 (8) 667–687.

[8] Daamen,W., P. Bovy and S. Hoogendoorn (2005) Influence of changes in level on passenger route choice in railway stations, Transportation Research Record: Journal of the Transportation Research Board, 1930, 12–20.

[9] Papinski, D., D. M. Scott and S. T. Doherty (2009) Exploring the route choice decision-making process: A comparison of planned and observed routes obtained using person-based gps, Transportation research part F: traffic psychology and behaviour, 12 (4) 347–358.

[10] Armeni, I. and K. Chorianopoulos (2013) Pedestrian navigation and shortest path: Preference versus distance., paper presented at the Intelligent environments (workshops), 647–652.

[11] Urech, S. (2017) Parameters of walkability: A meta-analysis of their perception by pedestrians, Master Thesis, IVT, ETH Zurich, Zurich.

[12] de Cambra, P. J. M. (2012) Pedestrian accessibility and attractiveness indicators for walkability assessment, Ph.D. Thesis, Thesis for the Master Degree (MSc) in Urban Studies and Territorial Management.

[13] Alfonzo, M. A. (2005) To walk or not to walk? the hierarchy of walking needs, Environment and behavior, 37 (6) 808–836.

[14] Erath, A. (2016) Walkability and pedestrian route choice, Arbeitsberichte Verkehrs-und Raumplanung, 1161.

[15] Golledge, R. G. and T. Garling (2001) Spatial behavior in transportation modeling and planning, CRC Pres.

[16] Helbing, D., P. Molnár, I. J. Farkas and K. Bolay (2001) Self-organizing pedestrian movement, Environment and planning B: planning and design, 28 (3) 361–383.

[17] SBB (2016). Passagierfrequenz, webpage, https://data.sbb.ch/explore/dataset/passagierfrequenz/?flg=de

[18] Axhausen, K. W. (2008). Social networks, mobility biographies, and travel: survey challenges. Environment and Planning B: Planning and design, 35(6), 981-996.

[19] Stadt Zürich (2012) Bildungsstand der stadtzürcher bevölkerung, webpage, https://www.stadt-zuerich.ch/prd/de/index/statistik/publikationen-angebote/publikationen/webartikel/2012-11-21_Bildungsstand-der-Stadtzuercher-Bevoelkerung.html.

[20] Stadt Zürich Amt für Statistik (2016) Bevölkerung nach 5-jahres-altersklassen und geschlecht 2016, webpage, https://statistik.zh.ch/internet/justiz_inneres/statistik/de/daten/daten_bevoelkerung_soziales/bevoelkerung.html.