Pedestrian Access to Public Transport

University of Stavanger

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by

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1 INTRODUCTION

The invention of the private car changed urban life by providing the freedom to travel where ever desired, at any time, within a so far unimaginable radius. Architects and urban planners enthusiastically picked up the new opportunities and the car rose to become the dominant mode of transport in many Western cities during the 20^{th} century. The new mobility options allowed the design of cities that were no longer characterised by spatial confinement but required the car for urban transport. As a consequence, providing access for cars became a necessity.

The apparent freedom of the private car came not without a price. The oil crises during the 1970s demonstrated the vulnerability of cities that depend exclusively on individual motorised transport. Cars consume high amounts of energy ineffectively. Rising fears on climate change in the early 1990s incited further criticism of emissions from fuel driven individual mobility. Following undesirable effects on the global scale, numerous negative impacts on the local level came into focus. Traffic emissions increase smog and noise in cities, posing a health threat. Cars occupy valuable space and require costly infrastructure. Motorised vehicle traffic threatens safety for non-motorised street users. Compromised safety limits independent mobility for the elderly, disabled, and children. Planning for cars propels urban sprawl and eats up green land. Furthermore, car mobility is increasingly seen as one reason for inactive lifestyles and a threat to societal health. The opportunities offered by individual motorised transport in cities are increasingly questioned as a source of societal, local and global challenges.

The three main alternatives to the car are public transport, cycling and walking in Western cities. Public transport requires high investments in technical infrastructure and receives a high level of professional attention. Cycling needs less personal and public investment but still requires a vehicle. Next to the public and some associations, the cycle industry also welcomes an increase in cycling. Walking enables mobility under environmental conditions that remain impassable for any wheeled form of transport, and it does not require a vehicle. Deeply integrated in daily life, walking often therefore remains unrecognised as a transport option. Despite constantly dispersing cities and rising travel distances, walking remained chronically underestimated as a form of urban mobility in its own right.

This research targets the relationship between walking and public transport. To understand that public transport does not provide mobility from door to door poses not an intellectual challenge. Using a public transport vehicle includes in most cases two walking trips before and after the ride. Along these two sections of the journey, travellers are exposed directly to the urban environment. The quality of the physical context for walking influences this part of the journey. This research questions how urban environments can improve the convenience and pleasantness of pedestrian access to public transport.

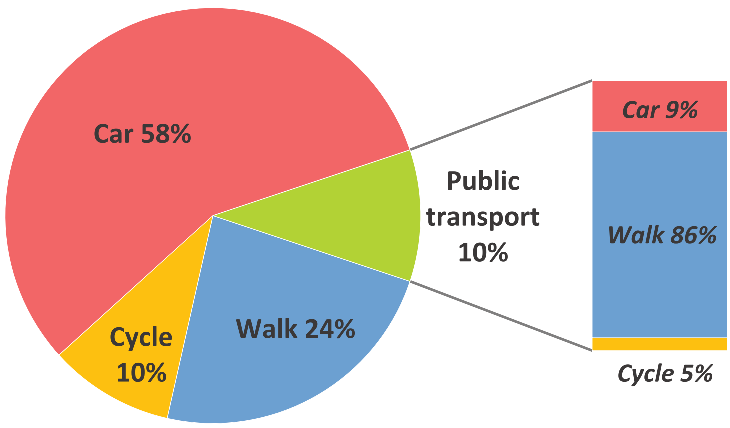
Having worked as architect and urban planner in a number of countries, I was always interested how urban residents make use of the environments we design and built. Would these children with balloons in my architectural illustrations enjoy what was about to become a built reality? How would people behave when they are confronted with all the ideas, manifested in physical structure? My interest in the relationship between behaviour and environment certainly establish the background for about 1500 video observations that lay the basis for most of the analyses presented in Chapter 5, 6 and 7.

The rising debate on urban sustainability shifted not only my focus towards mobility in cities. Urban densification was often uncritically sold as all-round strategy to shorten travel distances for the benefit of walking, cycling, and public transport. I understood that of these three mobility options, pedestrians are mostly exposed to the physical manifestations that result from urban design, architecture and planning. The question for this research triggered an emotional debate on the public transport system in the town I currently live in. Appears our town attractive for walking to reach the costly public transport infrastructure that many fancied? The question of pedestrian access to public transport appeared so logic to me that I was surprised to find so little literature on the topic in 2011. The following years of intensive research supported my impression of the supplementary coexistence between walking and public transport in cities.

Little data was available on walking trips to and from public transport stops at the start of this research in 2011. The German National Travel Survey[1] shows that 86 percent access public transport by walking (Figure 1). In cities, the percentage even rises to 91 percent. However, the authors of the report were more interested in the minority that accessed public transport not as pedestrian. With regard to the high percentage of walking, the lack of interest surprised.

[1] Mobilität in Deutschland (MiD), published by Folmer et al. (2010)

Figure 1: Access to public transport in cities and rural areas in Germany (Folmer et al. 2010, p. 102)



Meeting Werner Brög and the researchers of his institute Socialdata in Munich resulted in an inspiring cooperation. Their data from numerous surveys on three continents during the last three decades show a recurrent picture. Public transport users spend about half of the travel time from door to door not inside public transport vehicles. The part of the journey undertaken on feet outside in the city influences the impression of the total journey more than the duration spent driving with a public transport vehicle. Chapter 2 provides more details on these interesting studies.

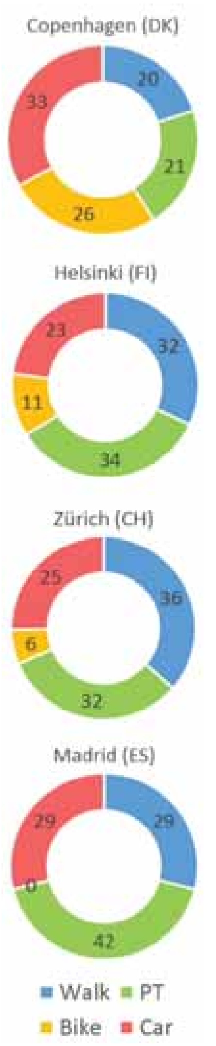
Walther (1973) was among those that questioned early the subjective time experience of time spent walking and waiting as compared to *in vehicle time* along public transport journeys. He finds the subjective experience of walking and waiting to appear 75 percent longer the time spend inside the public transport vehicle (p. 58). The study of Wardman (2001) finds the subjective perception of walking and waiting even to double in comparison to in vehicle time.

All these findings demonstrate impressively the importance of walking for the impression of journeys that include public transport. The understanding we gain cast an interesting light on so called modal split data[2]. Figure 2 shows the modal

[2] Modal split data of European cities shows the percentage of walking, cycling, public transport, and car driving for all trips made. Further transport modes may be specified. The data shows a simplified picture of urban journeys and displays only the mode of transport used for the longest distance of a journey.

share of four European cities. Helsinki, Zürich and Madrid are of unequal size[3] and alter between a warm south European and a cooler Scandinavian climate. All three cities show a high share of public transport, but the share of walking remains equally high. Remembering the amount of walking that is hidden in the percentage of public transport, we understand the central role of walking. Interestingly, also in Copenhagen dominate 'walking-modes' (including public transport), even though the modal split reflects the cities' successful cycling policy.

Figure 2: Modal split of European cities



The presented data shows how effectively the synergetic effect of walking and public transport can reduce car traffic in cities. Further, associating pedestrians with expensive public transport infrastructure provides a monetary dimension to walking. Unattractive conditions for walking reduce the value of costly public transport. Attractive pedestrian access not only completes a high quality public transport service, it also supports walking in general. The apparently narrow field of research – *pedestrian access to public transport* – has played a so-far underestimated role in promoting alternative transport to cars in cities.

That urban environments influence walking substantially is most commonly agreed among researchers in this field. How the physical environment can support walking to and from public transport stops poses the central question for this research. After describing some fundamental characteristics of walking, Chapter 2 reviews the discourse around pedestrian access to public transport. Researchers attend to questions of detoured footpaths, street crossings, or access to shops and services. Of central interest remains the question of how far pedestrians are willing to walk to public transport stops. One of the most interesting studies finds that pedestrian-friendly environments increase accepted walking

[3] Helsinki, 613.000 inhabitants, data source: EPOMM ; Zürich, 373.000 inh., source: Stadt Basel et al. (2012); Madrid, 3.234.000 inh., source: EPOMM ; Copenhagen, 559.000 inh., source: EPOMM

distances to stops by up to 70 percent. In the light of such extensive effects, I was surprised to find that only a few researchers have attempted to measure the environmental effect on accepted walking distances. The reviewed literature provides the background for a first set of research questions. To understand how urban environments influence the experience of walking and distances requires the consultation of further literature.

Publications from the field of physiology demonstrate in Chapter 3 that pedestrians' step frequencies reflect reactions to walking environments. The question for the investigation is, where do step frequencies uncover reactions? In the next step, psychological literature shows how pedestrians experience time and distance. These findings explain theoretically how urban environments influence acceptable walking distances. Two aspects are relevant: firstly, the amount of stimulation that pedestrians receive from walking environments; secondly, the perceived pleasantness of the received stimuli. The central question remains, do walking environments influence pedestrians' stimulation and their impression of pleasantness? Further literature explains how to measure the amount of stimuli that pedestrians receive from walking environments.

Chapter 4 discusses at first the methodological challenges of studies that aim to understand the relationship between urban environments and walking. The text presents three different methodologies for the empirical investigation. Firstly, 597 interviews question how urban environments influence the pleasantness of walking to tram stops. Secondly, 892 observations measure pedestrians' visual stimulation in 18 urban surroundings. Through the data from the first two investigations, we can study whether walking environments influence emotions. Thirdly, 444 pedestrians are observed along walking routes, while accessing public transport stops. All methods quantify pedestrians' behaviour and experiences but also enable qualitative analyses.

Chapter 5 investigates the characteristics of pedestrian access to stops. Walking to stops differs from departing after alighting. Step frequency analyses uncover differences in sensed time pressure and show that approaching pedestrians behave differently from those who walk away from stops. In the same way, preferred walking routes and locations for street crossings differ. The analysis uncovers from where and why pedestrians run to stops and identifies a hot spot for accidents. Chosen walking routes show the detouring effect of public space layouts and carriageways for vehicles. Railings along streets do not prevent pedestrians from taking shortcuts but increase accident risks. The data analysis determines average waiting times before street crossings. Finally, the text studies access to additional destinations such as shops or supermarkets along walking routes to and from stops. The incentive to save an extra journey seems to compensate for inconveniences. The analysis identifies conditions that may encourage more multipurpose journeys in order to lower travel demand in cities. Additionally, easily accessible facilities lengthen acceptable walking distances to stops.

Chapter 6 investigates the sensory experience of walking. The first analysis uncovers significantly different step frequencies in different characterised walking environments. Many people perform activities, while walking, and turn their senses away from environmental stimuli. Further analyses quantify the effect of urban environments on pedestrians' stimulation and the pleasantness of the walking experience. As expected, the walking environment influences how stimulated pedestrians are and also how pleasant walking appears. On the basis of these findings, the text estimates the environmental influence on acceptable walking distances and shows how the character of urban surroundings affects pedestrians' emotions. The conclusion in Chapter 7 summarises, reflects on the main findings, and identifies questions for future research.

2 PEDESTRIAN ACCESS TO PUBLIC TRANSPORT

The search for literature found only 24 scientific texts that focus on pedestrian access to public transport, published between the late 1960s and 2015. Eleven publications target practitioners with advice, while six publications question the effect of walking to public transport on health. Thirteen publications investigate questions at the fringe of this research, not all are cited.

Hass-Klau (2003) discusses the relationship between walking and public transport. She points out that, when urban politicians decide to invest in high quality public transport infrastructure (light rail), the political confidence is strong enough to further implement measures that support walking (pp. 194–195).

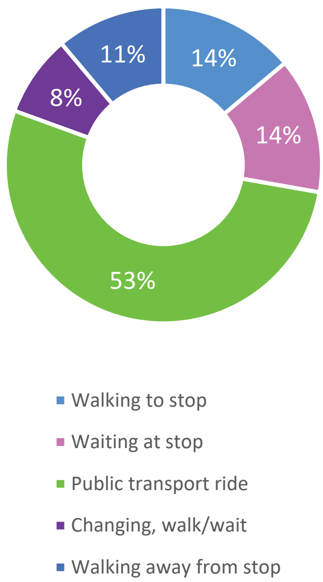
She considers that attractive public transport systems possibly reduce walking as a single mode, but the total amount of walking is likely to increase with the many walking trips that occur with the use of public transport (pp. 193–194). She investigates 20 European cities of similar size. With high quality public transport systems (light rail) pedestrian streets in cities are on average of 6.6 kilometres long. In cities with less attractive public transport infrastructure, the average length of pedestrianised streets drops to 3.7 km (pp. 195–196).

Hass-Klau finds the share of walking to exceed the percentage of public transport in most European cities under 200,000 inhabitants for two reasons: firstly, public transport services are not as good as in larger cities; secondly, walking distances are shorter in these minor cities (p. 194).

Brög (2014) reports on a study that highlights further the importance of walking for public transport. The author and his Socialdata institute interviewed 75,000 public transport users in the four German cities, Halle, Fürth, Augsburg, and Nuremberg. The institute has conducted surveys continuously over several years by in-depth interviews on recently undertaken journeys by bus, tram, and underground. The methodology allows the distinction to be made between five different sections of a public transport journey: (1) walking to the stop, (2) waiting at the stop, (3) the ride on the means of public transport, (4) changing, and (5) the walk to the final destination. Of all public transport users, 96 percent walk towards stops before the ride, and 95 percent do so after having alighted the means of transport (p. 15).

During the survey, interviewees estimate the duration of each part of their journey[4]. In the four investigated German cities, a public transport journey lasted on average 36 minutes from door to door. Interestingly, the ride on the means of transport itself comprises only 53 percent of the total travel time. Forty-seven percent of the journey takes place on foot outside in the city, as Figure 3 illustrates. Any public transport journey involves a substantial amount of time spent walking.

Figure 3: Travel time for sections of a journey that includes the use of public transport, according to Brög (2014, p. 16).



During an explorative part of the survey, interviewees report freely on the remembered impression of the undertaken public transport journey. Researchers subdivide these oral reports into comments that they allocate to one of the five journey sections (as defined above). The so-collected data shows that 73 percent of all comments refer to the time spent on foot outside in the city (walking and waiting), while only 28 percent of all comments speak of the time spent travelling on public transport vehicles (p. 17). The time spent walking and waiting clearly dominates the remembered impression of a public transport journey in the four investigated German cities. Having conducted similar investigations in numerous European, North American, and Australian cities, Brög finds these characteristics of public transport journeys to remain surprisingly stable across cities (p. 17).

Brög (2015) reports on a further mobility survey in the city of Vienna (Austria). The study applies an equivalent methodology to that used in the survey in the four German cities. Only 210 in-depth interviews were conducted (p. 15)[5]. Of all investigated journeys, 28 percent are undertaken by walking and 38 percent by

[4] Interviewers recheck the time estimates with maps and public transport service timetables during extended interviews, as Kehnscherper (2015) from the institute explains in an email conversation.

[5] The data was reflected on a larger data set that derived from investigations between 1993 and 2009 with comparative methods.

public transport. Walking trips that do not include the use of public transport are on average 800 meters long and last 12 minutes. The total travel time of a public transport journey is on average 36 minutes, reports Brög. Interestingly last the walking trips before and after the public transport ride with 14 minutes longer than walking trips that do not include a ride on a public transport vehicle (p. 18).

Differentiating the five earlier defined sections of a public transport journey shows, driving on the means of transport accounts for 17 minutes of the total travel time, and walking before and after the ride for 14 minutes, and waiting at stops last on average 5 minutes (p. 18). Accordingly consumes driving 47 percent, walking 39 percent, and waiting 14 percent of the total travel time in Vienna. Interesting appears to the author that public transport related walking trips are even longer than journeys undertaken solely by walking. These results support again the above reported impression of Hass-Klau. Public transport generates a substantial amount of walking in cities.

A number of publications question the relationship between walking and public transport with regard to societal health (Morency et al. 2011, Freeland et al. 2013, Saelens et al. 2014, Yu and Lin 2015). These studies question the effect of walking trips to and from public transport stops on physical activity levels. More walking has a positive influence on health. The discourse shows that public transport holds the potential to improve societal health through increased physical activity. This research branch follows mostly a strict quantitative methodology and touches the question of walking environments often only at the periphery.

The text in this section demonstrates the importance of walking for public transport and illustrates the synergetic coexistence of both modes. Understanding the character of a public transport journey, as Brög explains, shows the limitation of simplified modal split data that hides a substantial amount of walking. Before turning to the specific question of pedestrian access to public transport, the following section provides a background by discussing some general characteristics of walking.

2.1 Characteristics of walking

Walking is not uniform. Reid (2008) notices that almost everyone can be a pedestrian at some point (p. 106). Defining typical characteristics of walking is therefore difficult (p. 111). Different from any wheeled traffic, pedestrians can cope with terrain (p. 105), with steps, cobbles, surface defects, and can even climb over barriers (p. 106), provided that their physical constitution allows them to. These diverse capabilities of pedestrians also limit generalisations on what appears to be a convenient walking environment. Inconvenient environments challenge the capabilities of pedestrians.

Whyte (1988) describes the *'skilled pedestrian'* that uses all available space, veers from one side of the path to the other and is difficult to follow. Pedestrians adjust their own moves to others. To avoid collisions they slow down within one fifth of a second and observe neighbouring encounters (pp. 57–59). Also these statements describe walking as a diverse and individual form of behaviour, enabled by numerous capabilities.

The attractiveness of walking sees R. Monheim (1977) in the ability to spontaneously change speed and direction, to stop and continue, to talk with others, to look around or to engage with deep thoughts (pp. 30–31). Differently from any wheeled traffic, pedestrians have no turning radius or braking distance. Without having to lock a cycle or to park a car, they can spontaneously enter a shop or a building without losing time. To suppress the flexibility and spontaneity of walking through rules and unsuitable environments disrespects the characteristics of walking and makes walking unattractive, find H. Monheim and Monheim-Dandorfer (1990, p. 189).

How fast do pedestrians walk? Walking speeds can vary with the purpose of the trip, fitness, the quality of the walking surface, and certainly with numerous further conditions. Also the pedestrian environment influences walking speeds. Whyte (1988) reports that in the centre of larger cities, men walk between 88 and 91 meters per minute. When walking fast, people can walk with 107 meter per minute. In passing situations, speed can increase to 134 meters per minute for shorter periods (p. 64). Fast walkers seem not to be more harried than other pedestrians, observed White (p. 65). Garbrecht (1984) reports on comparable walking speeds in Zürich (Switzerland). Pedestrians walk with 83 to 120 meter per minute around the railway station *Stadelhofen*. The study shows that the density of the pedestrian flow influences walking speeds. More crowding restricts fast walking speeds. The research of Fruin (1979) quantifies this effect (p. 193). The extent of the effect depends again on the individual capability of each pedestrian.

How far do pedestrians walk? Also this question depends on the constitution, the purpose of walking, if people carry something, and many other conditions. R. Monheim (1977) considers the characteristics of cities and city centres to influence how long pedestrians walk (p. 22). He found surprisingly high walking distances between 1200 and 1550 meters in city centres (p. 21). The German national travel survey conducted in 2008 (Folmer et al. 2010) finds average walking distances of 1400 metres (p. 89). R. Monheim (1977) reminds us that considering average walking distances can be problematic if we do not know who walks and where (p. 21).

For H. Monheim and Monheim-Dandorfer (1990), walking always comprises an experience of the environment (p. 187). Compared to a car driver, pedestrians are not separated from their surroundings by an enclosure of glass, metal and plastic – the car (p. 188). Fruin (1979) understands walking as the only means of transport "*by which we can dramatically experience the sensory gradients of sight, sound, and smell that define a place*" (p. 188). The low speed of walking results in a highly detailed environmental impression, considers Garbrecht (1984). The resulting multisensory stimulation fires imagination, and encourages association (p. 74).

Lynch (1960) considers the ability to identify the character and structure of an environment as vital for mobility and orientation (p. 3). Orientation relies on visual and other sensory information. Whyte (1988) observes that the blind can orientate by hearing, feeling the pavement, and smelling, if the surroundings provide enough non-visual stimuli (p. 80). Hearing and seeing enable us to recognise and evaluate the dangers of wheeled traffic, suggests Garbrecht (1984, p. 71). Walking not only results in a sensory experience, it requires stimuli for orientation and safe navigation.

Garbrecht highlights pedestrians' ability to get in touch with their surroundings (pp. 70–71). Sauter and Wedderburn (2008) find that pedestrians constantly switch between mobile and stationary activities. They see the ability to quickly switch between walking and staying as an important feature of walking (p. 7). Distinguishing between both states of walking may often be difficult. Gehl (2010b) understands walking not just as a form of transport. Pedestrians take part in the social life of streets and represent the core of urban life (p. 19).

Apart from being social, walking allows us to perform various activities. Middleton (2009) describes activities as phoning, spending time with family, and planning the working day ahead. Walking generally enables thinking. She considers these abilities as a key resource for daily life (p. 1958). In a later publication, Middleton (2010) describes an autopilot mode of walking. Trying to maintain an unbroken stride, the mental experience of walking appears nearly detached from the physical activity of the legs. Being in autopilot modus, pedestrians travel from A to B without consciously making decisions for street crossings, turns, and circumnavigation of obstacles (p. 583). Walking along known routes allows a deep engagement with their own thoughts. Autopilot walking represents in that sense a strategy to turn away from undesired environmental stimuli, as Middleton explains (p. 585).

The experience of walking certainly differs with weather and climate. Interestingly, Zweibrücken et al. (2005) find that weather has only a minor effect on pedestrian flows in Switzerland (p. 27). Weather seems not to influence the choice of walking but certainly the experience of walking. Gehl (2010b) describes the unpleasant effect of traffic noise for pedestrians. Along noisy streets, conversations are only possible by shouting at each other. Street noise overrides all other acoustic information that can stimulate potentially pleasant emotions such as listening to music, conversations, birds, footsteps and so on (pp. 151–154). Additionally, topography influences the experience of walking. Weidmann (1993) finds the energy consumption of walking to double with inclines around 10 to 12 percent. With rising exhaustion, the pleasantness of walking decreases.

Garbrecht (1984) considers that environments influence pedestrians' moods (p. 70). He finds different walking styles express a pedestrian's mood but likewise their personality (p. 63). Middleton (2010) finds clothing, shoes, but also carried items such as mobile phones, to mediate the relationship between pedestrians and their physical surroundings (p. 587). She reminds us that pedestrians' multisensory experience of the walking environment remains individual (p. 582). The experience of walking derives from both, the individual context for walking and the walking environment. Both elements interact. The walking environment can have an effect on an individual's mood, but the emotional status can influence how a pedestrian perceives an environment.

What are attractive walking environments in cities? Urban planners have been paying attention to pedestrians for longer that we might think. The research of Hass-Klau (2014) uncovers planning approaches that were already targeting walking in 1888. With some national differences, pedestrians receive increasing attention from the mid-1920s onward in Europe (p. 269). The early discourse aimed to improve the safety of walking that was threatened by more car traffic in cities. With the rising establishment of the car in in Europe during the 1960s, the discourse on walking increasingly questioned the attractiveness of walking as a result of the urban environment. The earliest publication of interest for this research was published by Gehl (1968) in the city of Copenhagen (Denmark).

The professional context that grew up around Jan Gehl over the last four decades produced one of the most complete and concise summaries on urban environmental characteristics to support walking. Lars Gemzøe and Sia Kirknæs at *Gehl Architects APS* (2009) prepared a report for the pedestrian strategy in the City of Copenhagen. The text discusses features of an attractive pedestrian environment, organises them in a logical manner, and distinguishes between *necessary* and *optional* features (p. 5):

Necessary features:

- A continuous and complete pedestrian network
- Sense of safety, protection from motorised traffic
- Sense of security through social surveillance and activity, especially in darkness
- Direct pedestrian routes with sufficient space and free from obstacles
- Barrier-free paths, smooth surfaces, clearly marked, also convenient for the disabled.

Optional features:

- A fine meshed pedestrian network
- Stimulating and detailed facades, transparent on the ground floor, services and facilities facing the pedestrian environment
- Increased comfort through low noise, good air quality, cleanliness, weather protection, and pedestrian facilities such as drinking fountains, toilets, and so on
- Formal and informal, public and commercial seating places
- Features that invite leisure activities and play
- Art that creates an identity for locations
- Greenery, such as trees, grass areas, flower pots and so on
- Historical elements such as old buildings and facades, sculptures, and other historic features that tell a story about the history of a place

While the necessary features enable one to walk safely and to travel effectively from A to B, the optional features enhance the emotional experience of walking. Possibly, we do not need a distinction between necessary and optional features. If the goal is to encourage urban inhabitants to walk more, we should consider all available opportunities for improvements. However, the distinction between necessary and optional features remains interesting. Optional features of the environment improve the *sensory experience* of walking. Environments can appear pleasing or repulsive. Conversely, necessary features increase the *convenience* and practicality of walking. The dense provision of shops and services that increase the number of potential destinations for pedestrians belongs equally in this category.

The following subchapter shows that most authors focus on the convenience of walking to or from public transport stops. Few authors pay attention to how walking environments influence the emotional experience of walking, and which consequences the sensory impression of the urban surroundings has for access to public transport stops.

2.2 Accessing shops and services while walking to or away from public transport stops

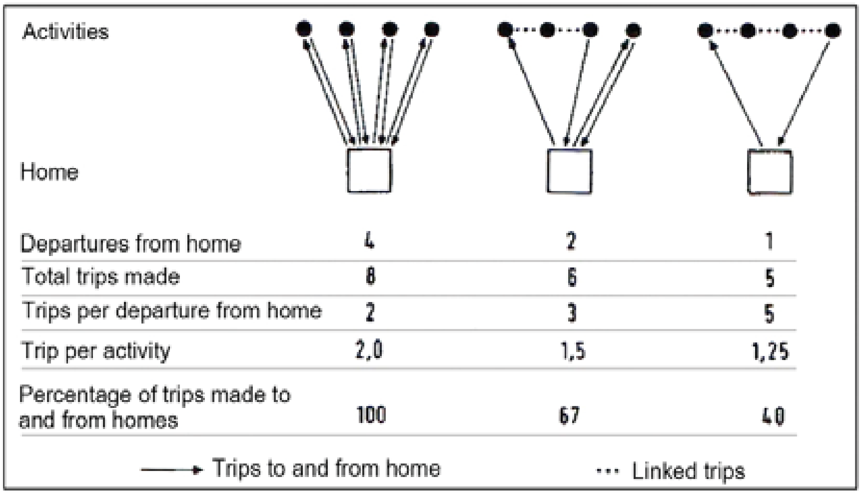
As the previous section illustrated, walking is the most flexible form of mobility, providing fast and convenient access to destinations such as shops along walking routes. Carrying purchased items may appear unpleasant, but Whyte (1988) observed that people carrying bags or suitcases walk as fast as others (p. 57). The possibility of saving an extra journey might compensate for the disadvantage of increased weight to carry. Schmitz (1991b) highlights the possibility of accessing further destinations along walks to and from stops (p. 140).

Textbox 1
Definition: Travel chain

A ***travel chain*** describes a journey, along which more than one destination is accessed. Such journeys can serve more than one purpose. Travel chains combine a number of trips between destinations and are also described as *combined trips*.

The study of R. Monheim (1985a) demonstrates the importance of *travel chains* in reducing the total travel demand in cities. He investigates the number of accessed destinations (which he describes as *activities*) along journeys in the city of Bayreuth (DE). The author shows how accessing more destinations along one journey can decrease trips between homes and travel destinations, as Figure 4 illustrates. For example, travelling from work directly to a sports activity, and afterwards purchasing groceries before turning home, will reduce the number of trips between homes and destinations by 33 percent as compared to accessing these three destinations with separate journeys (the example is shown in the middle of Figure 4).

Figure 4: The influence of travel chains on the total travel demand in cities, translated from R. Monheim (1985a, p. 268)

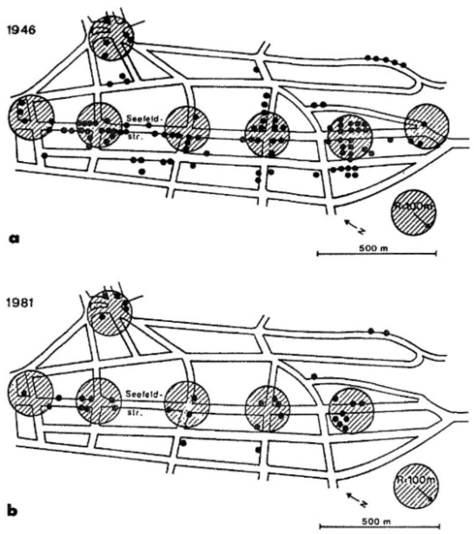


The author finds 66 percent of all accessed destinations in the city of Bayreuth are part of a travel chain (p. 268). The majority of these travel chains are undertaken by walking, according to R. Monheim (1985b, p. 325). Pedestrians can most easily enter a number of destinations if these are clustered within walking distance. The study demonstrates how travel chains reduce the total travel demand in cities.

Hillman and Whalley (1979) analyse data from the British National Travel Survey 1972/73 and 1975/76. They do not focus on pedestrian access to public transport. The analysis shows that one in six shopping trips is part of a travel chain. Nearly half of these multipurpose journeys are made on foot (p. 81). Comparing the surveys showed a sharp decline in walking to shops in 1975/76. The authors consider the phenomenon to derive from reduced shopping facilities in low density urban areas (p. 82). Monheim's study also showed that low urban density disables travel chains.

Hillman and Whalley see a relationship between public transport and shopping facilities. In urban areas with poorer bus services, the number of facilities in reach for pedestrians declines (p. 81). Low urban density is likely to reduce in parallel the quality of public transport and destinations within walking distance. Boesch and Huber (1986) also investigate the relationship between retail and public transport. They find that the number of shops in Zürich Seefeld (CH) decreased from 108 to 36 between 1946 and 1981. The remaining shops in 1981 clustered around public transport stops, as Figure 5 displays (pp. 39–40). More pedestrian

Figure 5: Decline of retail and shops (black dots) between 1946 and 1981 in Zürich Seefeld. In 1981, the remaining facilities appear clustered around tram stops (round shaded areas) (Boesch and Huber 1986, p. 40).



activity around public transport stops presents a locational advantage for shops, according to Boesch and Huber.

Weinstein Agrawal et al. (2008) discover that, of those who access light rail stations in the morning, 87 percent do not stop along the walking route. Of those that stop, about 50 percent purchase food or drinks. Others buy newspapers, talk to somebody, or stop for other reasons. Halts last on average around three minutes (p. 89). Purchasing items other than coffee to go and newspapers does not seem very practical when goods need to be carried to work or education places in the morning and homewards in the afternoon.

Lachapelle et al. (2011) investigate the travel behaviour of 1237 inhabitants in 32 urban neighbourhoods in Seattle and Baltimore (US). Frequent use of public transport and attractive walking environments around homes increase the amount of walking to all destinations near workplace locations. Only food stores are not accessed on the work side of the public transport journey. Carrying groceries on public transport vehicles may appear unattractive, assume the authors. Public transport users walk more often than non-users to retail stores, restaurants, and cafes around their homes (p. 78). Walking to shops and services increases among those that use public transport. The inquiry does not specify whether people access these destinations along walks to or from public transport stops.

Accessing public transport by walking easily allows an extra journey to be saved when shops and other facilities are located close to stops. This option can increase the utility of journeys that include the use of public transport. People might even accept longer walking distances when being able to access additional destinations. The following sections turn to the most central question: how far do people walk to access stops?

2.3 How far do people walk to public transport stops?

Determining walking distances to stops represents a central question of the discourse around pedestrian access to public transport. According to Fruin (1979), the accepted walking distance determines the effective service area of a public transport system (pp. 202–203). Walking distances to stops define the urban area, from where walking to public transport stops appears an acceptable option. Accordingly, acceptable walking distances determine the potential of the public transport infrastructure.

Schmitz (1991b) lists numerous factors that can influence walking distances such as climate, the quality of the public transport service, available information on the public transport service, purpose of the journey, individual fitness, or available transport alternatives (p. 142). The length of accepted distances depends on many factors that often remain difficult to detangle. Schmitz illustrates the complexity of the question on walking distances.

Peperna (1982) investigates walking distances to 13 bus and tram stops in Vienna (Austria) (p. 54). Conducted at stops between six and nine, and ten and twelve o'clock during the summer season (pp. 56–58), 1179 interviews serve as a database (p. 86). The author differentiates between three travel purposes (work, education, sporadic journeys), available transport alternatives, and the travel time on the means of public transport (p. 36). At all chosen stops for the survey, the public transport service frequency remains stable at between five and seven minutes, and distances between stops along the line are between 400 and 500 metres. The choice of stops considers the level of education and age of inhabitants residing around stops, as well as the land use density (pp. 46–48).

With a statistical regression analysis, Peperna separates the effect of the registered contextual conditions on accepted walking distances to public transport stops. Sporadic public transport users walk on average 245 metres to stops this distance increases by 29 percent for travels to work, and by 41 percent to education facilities[6]. The latter result is influenced by unavailable transport options. C*aptive rides* have no other transport options, and accepted walking distances increase when walks to stops exceed 360 metres (p. 60). At walking distances of 550 metres, captive riders walk about 20[7] percent longer distances. The time spent travelling

[6] These values are read from Figure 12, which Peperna presents in the Appendix
[7] These values are read from Figure 12, which Peperna presents in the Appendix

on the means of public transport has no effect on accepted walking distances to stops (p. 63). Peperna investigates further the effect of environmental characteristics on walking distances, as Section 2.8 reports later on. Not many of the further reported studies filter out in such detail the effect of contextual factors on acceptable walking distances.

Walther (1973) measures the length of 2952 walking trips to 42 bus stops along five public transport lines in the city of Bielefeld in Germany (pp. 55–56). The data derives from 37,000 interviews collected in the city of Bielefeld (Germany) in 1967. Each registration covers the accessed stop together with the address from where travellers walked. Researchers measure on maps the shortest possible walking route with regard to the existing footpath network. Walter can show that 75 percent of the walking distances to stops are shorter than 300 metres (p. 103). He separates the effect of residential and workplace density (pp. 33–40). Longer rides on public transport vehicles do not influence accepted walking distances (p. 43)[8]. Walther does not investigate the influence of environmental characteristics on walking distances as he considers such difficult to measure (p. 31).

Fruin (1979) finds 400 metres to be the most applied distance, without specifying the quality of the accessed public transport service. In downtown Boston, 60 percent of walking trips are over 400 metres; only 18 percent are longer than 800 metres. In Manhattan, average walking distances are 534 metres with a median at 326 metres (pp. 196–197).

Fruin reports on a survey that questions the origin and destination of travellers at a major bus terminal in New York. Most people accessed the terminal by walking. At 1050 metres, the average walking distance to the terminal was surprisingly high. At a distance of 300 metres, everybody walks to the terminal. At distances up to 1600 metres, 50 percent still prefer to walk. Over distances of 3200 metres, the terminal is no longer accessed by walking.

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[8] Assuming an average walking speed of 83.3 metres per minute, Walther recalculated measured walking distance to a time value. The travel time from door to door consisted of 32 percent of time spent walking, excluding waiting times at the stop. Walther's results do not differ strongly from Brög's reported study, presented in the introduction. Here, the walk to the stop, and from the stop after alighting, accounted for 26 percent of the total travel time. The difference between the data of Walther and Brög derives from different investigation methods. Walther's focus is solely on bus users and his data contains less detail.

High walking distances to the terminal are surprising as travellers could have easily accessed the terminal by the well-established public transport system around the terminal. Many accept longer walks to avoid changing. Fruin finds that walking to the hub appears reliable and enables good time estimates to reach the bus terminal. Inversely, accessing the terminal by public transport seems more complex and less reliable (p. 197), reducing the attractiveness of this option.

Most persons in the study are commuters and assumed largely to be healthy and not handicapped, considers Fruin (pp. 196–197). He assumes that accepted walking distances are more situation-related and less dependent on exhaustion with longer distances (p. 197). His text only discusses a few factors that might influence accepted walking distances such as weather, street layout, or familiarity with the walking environment. We have to remember that the study investigates walking access to a large hub in a very dense and large city with a complex public transport system. Obviously, people accept quite long walking distances in the busy streets of Manhattan.

Brändli et al. (1978) investigate the influence of walking distances to stops on the use of public transport. The researchers use data from 4396 interviews, collected in Zürich in 1969. The data comprises the accessed public transport stop, and the address from where travellers walk to the stop. The walked routes to the stop are not questioned. For the enquiry, researchers draw up the shortest possible route with regard to the existing footpath network. On average, pedestrians walked 400 metres to bus and tram stops in Zürich (p. 27). The total length of the journey (p. 50), age, and the purpose of the journey (p. 72) do not influence the length of the walking trip. Having to change the means of transport does not vary accepted walking distances (p. 45). Sloping terrain shortened the length of walking routes by 32 to 43 percent (p. 43). About 20 percent do not access the nearest stop and accept longer walks to more distant stops (p. 64).

O'Sulivan and J. Morrall (1996) investigate the walking distance guidelines used by public transport operators in Canadian and American cities. They focus on pedestrian access to light rail stops. Table 1 summarises their findings. The applied walking distances range between 300 and 900 metres. In cities such as Sacramento and San Jose, public transport operators have established their own guidelines based on local investigations. Others apply maximal walking distances of 305 metres suggested by the American Association of State Highway and

Table 1: Walking distance guidelines for access to light rail stops used by public transport operators in Canadian and American cities (O'Sulivan and J. Morrall 1996, p. 20)

CANADIAN CITIES	WALKING DISTANCE GUIDELINES
Calgary Transit, Calgary	General Guideline is 400 m
B.C. Transit, Vancouver	Guideline For LRT is 900 m
Societe de Transport de la Communaute Urbaine de Montreal, Montreal	General Guideline is 400 - 500 m
Ottawa - Carleton Regional Transit Commission, Ottawa	General Guideline is 400 - 600 m
Toronto Transit Commission, Toronto	General Guideline for Surface Transit is 300 m
Edmonton Transportation, Edmonton	General Guideline is 400 m

AMERICAN CITIES	WALKING DISTANCE GUIDELINES
Maryland Mass Transit Administration, Baltimore	Use Guidelines of the American Association of State Highway and Transportation Officials
Niagara Frontier Transportation Authority, Buffalo	General Guideline is 457 m
Regional Transportation District, Denver	General Guideline is 536 m
New Jersey Transit, Newark	General Guideline is 804 m
Southern Pennsylvania Transportation Authority, Philadelphia	An area is considered 'well served' if a stop is less than 402 m from a passenger's origin and is considered 'served' if a stop is less than 804 m from a passenger's origin.
Port Authority of Allegheny County, Pittsburgh	No Guidelines Available
Sacramento Regional Transit District, Sacramento	A 1992 Study found that 64% of transit riders walk less than 403 m and 90% walk less than 804 m. Regional Transit's Guideline is 609 m.
Bi-State Development Agency, St. Louis	No Guidelines Available
Metropolitan Transit Development Board, San Diego	General Guideline is 538 m
San Jose Trolley Corp., San Jose	Average walking distance from LRT to a commercial destination is 30 - 60 m. A one block walk is necessary for 42% of LRT passengers in the five block long core area.
Greater Cleveland Regional Transit Authority, Cleveland	No Guidelines Available

Transportation Officials. Numerous operators use general guidelines based on their own estimates or assumptions (p. 20).

Hoback et al. (2008) present a method for calculating walking distances at both ends of a public transport ride and when changing the means of public transport. The analysis uses spatial data and does not investigate undertaken journeys. The main purpose of the publication is to present an advanced data analysis methodology. The statistical analysis performed with Geographic Information Systems (GIS) software (pp. 682–686) calculates an average total walked distance of 634 metres for each public transport ride (p. 689). Similarly, the publications of Garcia-Palomares et al. (2013) and El-Geneidy et al. (2014) underline the importance of GIS based methods as a performance feature to analyse walking distances to the public transport systems.

How far the majority of pedestrians are willing to walk to reach public transport stops remains a difficult question. As Schmitz illustrated, a row of factors influence the length of walking distances to stops. A number of researchers discuss the role of footpath networks around stops, as the following section highlights.

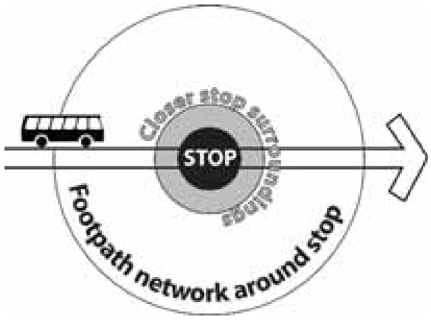
2.4 Catchment areas, footpath networks, detoured walking routes

The urban area around public transport stops is often considered as a *catchment area*. Most common is the catchment area understood as a circular area with a specific radius around the stops. The radius represents the distance, at which walking to the stop is considered reasonable. Catchment areas are often considered in a simplified way as a homogenous spatial area around public transport stops. Together with data on the density of workplaces and residential units, the catchment area provides an estimate of the number of persons that are serviced by public transport. However, urban realities are usually more complex.

Schmitz (1991a, 1991b) differentiates between two parts of the catchment area in which walking differs:

1. The longer section of the walk leading through the ***footpath network*** between the public transport stop and the start/destination point of the journey (1991b)
2. The shorter section of the route in the ***closer stop surroundings*** (1991a)

Figure 6: Closer stop surroundings and footpath network



The experience of walking in the footpath network varies with the pleasantness of the environmental experience. Conversely, street crossings and interactions with cyclists, buses, and other pedestrians characterise the part of the walking route close to the stop, explains Schmitz (1991b, p. 140). Figure 6 illustrates the differentiation of Schmitz. The definition in Textbox 2 derives from the experience gained

Textbox 2
Definition: **1. Closer stop surroundings**
2. Footpath network

The closer stop surroundings represent the area up to a distance of 30 metres around the public transport stop. From here, approaching buses and trams are visible, the stop is quickly accessible, and more shops and services can be available. In the closer stop surroundings, pedestrians have to interact increasingly with vehicles, cyclists, and other pedestrians.

The footpath network comprises all footpaths outside he closer stop surroundings. This network links the surrounding urban area with the closer stop environment. Footpaths can be pavements along the public transport corridor, side streets, pedestrian streets, walking paths through parks, but also informal walking routes.

Appendix 1 presents a more detailed description.

during this current research. Accordingly, Berg (1988) understands the public transport stop as a focal point of mobility, where pedestrians interact with cars, public transport vehicles, cyclists and other pedestrians. The text elaborates the influence of street crossing facilities on time delays and detours along walking routes to public transport stops (pp. 23–28).

Berg (1988) illustrates how the character of the footpath network influences the size of the catchment area. A footpath network with straight, radial footpaths (Figure 7) around the stop appears theoretical and unrealistic. The orthogonal network covers only 64 percent of the area of a radial network, with equal maximum walking distances. A missing orthogonal link at the stop reduces the

Figure 7: Variation of the catchment area according to the footpath network (Berg 1988, p. 60)

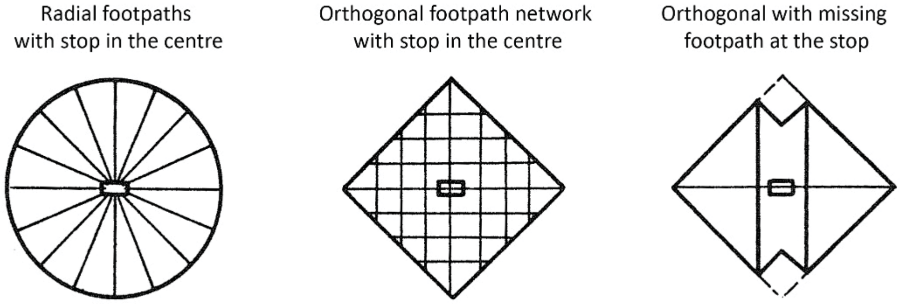
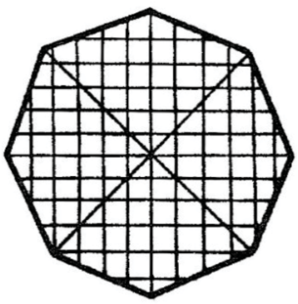


Figure 8: Optimised orthogonal network with added diagonals (Berg 1988, p. 60)



catchment area further. Figure 8 shows an orthogonal network with added diagonals that cross at the stop in the centre. The diagonals increase the area to 90 percent of a theoretical catchment area with radial footpaths, as Berg explains (p. 60). The analysis shows how the character of the footpath network and missing links influence the catchment area.

Textbox 3
Definition: Detour factor

A walking route between A and B in an urban environment most likely does not equal the shortest, linear distance between A and B. The ***detour factor*** is calculated by dividing the nonlinear distance between A and B through the linear distance between A and B.

Yang et al. (2012) investigate *detour factors* in different characterised urban areas around stops in the city of Jinan (China). The detour factor increases to 1.59 around stops at arterial roads. Large super blocks characterise these urban areas. Stops are located at some distance from major traffic junctions. The stop position increases detours as most people approach the stop from adjacent street junctions. Further, the large arterials are impossible to cross informally and so restrict any shortcuts. Streets and city structure are the main factors for detours, according to the authors (p. 8). In urban areas with smaller block size and narrower carriageways, detour factors decreased to 1.33. Section 2.8 presents further details and results from this interesting study.

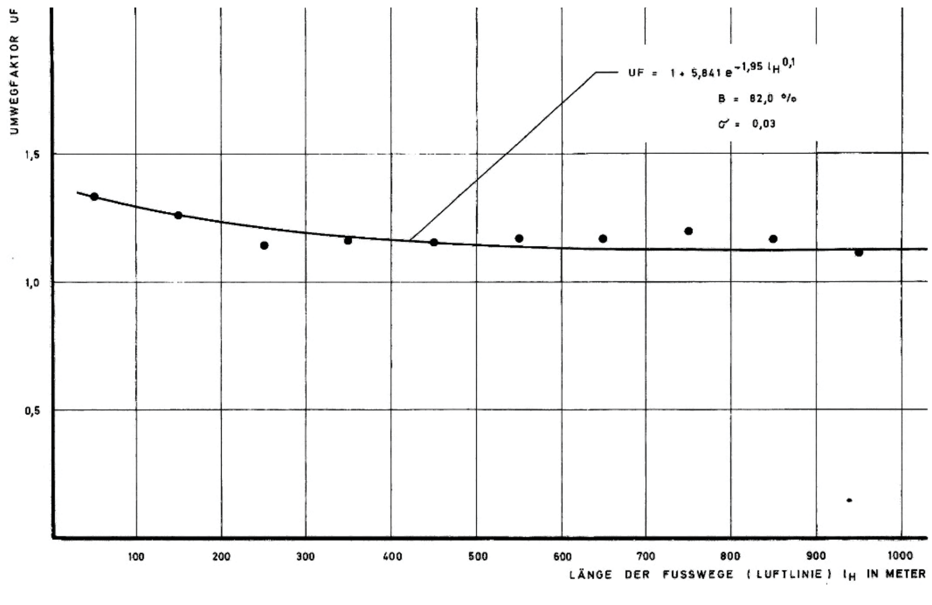
Lam and J. F. Morrall (1982) found average detour factors in the city of Calgary (Canada) of 1.24.

Around suburban bus stops the factor was 1.25, at stops in central urban areas 1.22, and in industrial areas 1.13[9]. The lower detour factor in industrial areas caused walking routes via parking lots and fields (p. 419). Detour factors exceeded 1.41 for nearly all pedestrians that had to cross a railway line in the central business district. Inversely, detours decrease with longer walking routes to stops (p. 420).

Congruent with Lam and Morrall, Walther (1973) finds rising detour factors with shorter walking distances to stops in Bielefeld (Germany). Average detour factors decrease from 1.33 along routes under 100 metres to 1.11 along routes between 900 and 1000 metres in length (p. 121), as Figure 9 shows. The results of Walther, as well as the findings of Lam and Morrall, indicate that detours increase close to the stop. The footpath network has, surprisingly, a lower influence on detours. Missing links in the network seem not to be an issue around the investigated stops in Bielefeld and Calgary.

Schmitz (1991b) points out that, when the stop is already in sight, obvious detours and required stops become increasingly unacceptable (p. 140). O'Sulivan and J. Morrall (1996) consider detour factors up to 1.2 as preferable and over 1.4 as

Figure 9: Detour factor increases with shorter walking distances to stops, X-axis: length of walking trip in metres; Y axis: detour factor (Walther 1973, p. 121)

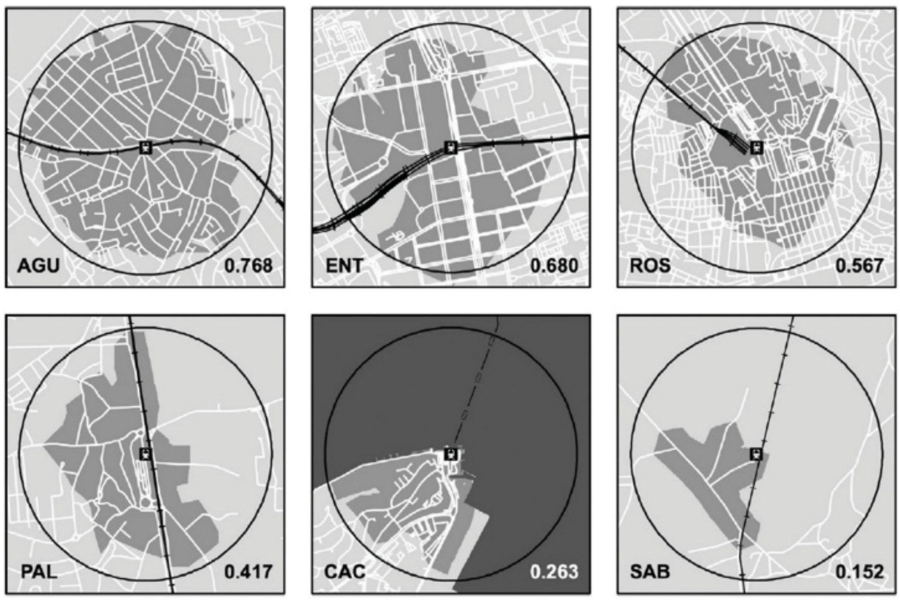


[9] Lam and Morrell differentiated detour factors between summer and winter. The values shown in the text above represent the arithmetic mean for winter and summer.

unacceptable (p. 19). Berg (1988) evaluates detour factors under 1.1 as very good, around 1.25 as good to tolerable, and factors over 1.4 as unreasonable (p. 62). Whether, and under which conditions, pedestrians experience detours as inconvenient remains unclear. It is likely that the diverse characteristics of walking results in very different experiences of detours.

The catchment area around a public transport stop is often considered simplified, as a homogenous circular urban area, from which the stop is equally accessible. In reality though, the accessibility of the stop depends on the character of the city within the area around a stop. An increasing number of researchers criticise the fact that pedestrian access to public transport stops is often only considered in this simplified manner (Hoback et al. 2008, S. Biba et al. 2010, Steven Biba 2014). Authors urge the use of Geographic Information Systems for more precise evaluations of the existing footpath network around stops. Vale (2015) suggests improving the *node-place model* by including the existing footpath network. The model evaluates the quality of a public transport service according to two

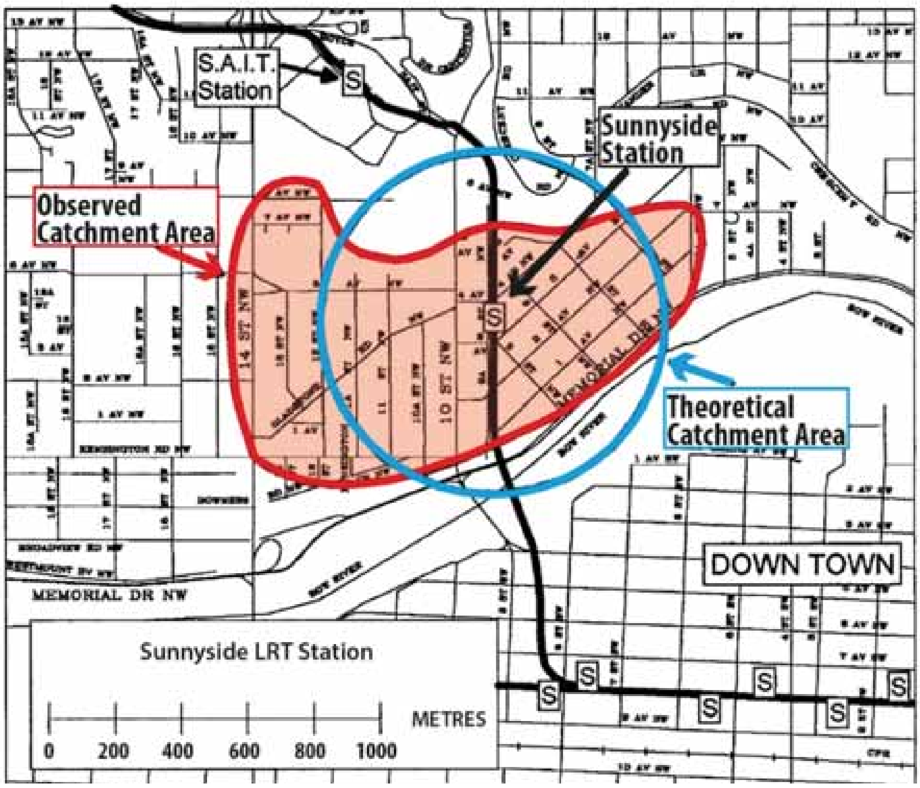
Figure 10: Theoretical area within a 700-metre radius around stops and actual accessible area though the footpath network around train and ferryboat stations in the Lisbon Metropolitan Area (Vale 2015, p. 76)



attributes: firstly, the quality of the public transport service available at a public transport hub (node-attribute), and, secondly, the environmental characteristics within a circular area around a public transport hub (place-attribute) (p. 71).

Vale studies 83 station areas in the Lisbon metropolitan area with the help of an advanced node-place model. He calculates a factor from two variables. The first variable represents the area of a *theoretical* 700-metre radius around each public transport node. The second factor represents the *actual accessible* area though the footpath network up to a distance of 700 metres from the hub (p. 73). Vale calculates a factor by dividing the area of the 700-metre radius through the area accessible by footpaths. Figure 10 shows the variation of the calculated factors from 0.147 to 0.768. In the worst case, the urban area accessible via the footpath network was only 15 percent of the radial catchment area.

Figure 11: Theoretical and observed catchment areas around Sunnyside light rail stop in Calgary

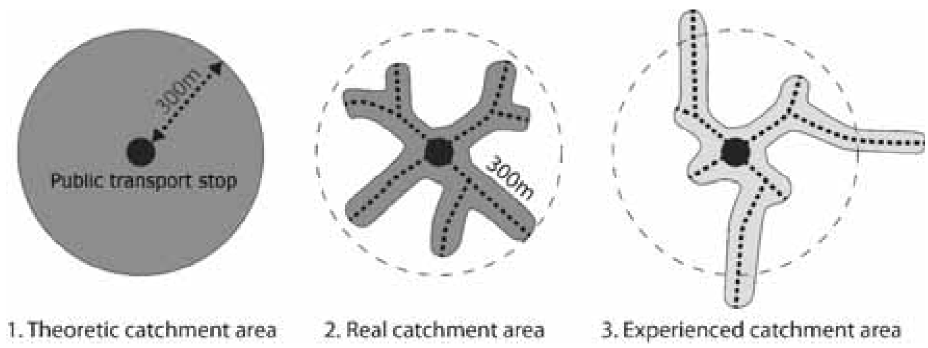


By adding this relatively simple indicator to the node-place model, Vale showed that dense and diverse urban environments can be very different built realities for pedestrian access to public transport (p. 76). Land use density and diversity are not the only relevant factors for convenient access.

O'Sulivan and Morrall (1996) interview light rail users in the city of Calgary (Canada). They collect data on the departure and origin of all trip legs of the public transport journey from door to door. They calculate the average walking distance to the light rail stop *Sunnyside*. They correct distance by the average *detour factor* (as defined in Textbox 3) of the registered walking routes. On a map, they draw a circle around the stop with the radius of the average walking distance. Figure 11 compares this *circular catchment* area (blue) with the *observed catchment* area. The observed area derives from actually walked routes (red). This simple analysis shows that the circular and observed catchment areas do not correspond very well. Characteristics of the footpath network and probably other environmental conditions influence chosen walking routes to the stop, and accordingly deform the catchment area.

Molster and Schuit (2012) consider circular shaped catchment areas as theoretical (1. in Figure 12). Realistically, streets and footpaths around the stop determine access. These footpaths do not always allow access to the stop in a direct line but may require detours. The *real catchment area* derives from the existing footpath network (2. in Figure 12), as Molster and Schuit define. Further, the individual experienced distance is not an objective measure. The individual perception of distance can vary, as the authors highlight. The real catchment area deforms

Figure 12: Catchment area around public transport stops according to Molster and Schuit (2012)



further with the individual experience of distance to an *experienced catchment area* (3. in Figure 12) (p.18-19). How pedestrians experience walking distances to stops can depend on the convenience but equally on the sensory experience of the walking environment. Having to cross trafficked streets certainly appears inconvenient, as the following section discusses.

2.5 Crossing streets

Schmitz (1991a) discusses unsuitable street crossing facilities. He reports on an investigation around the tram stop *Hegelstrasse* in Kassel (Germany), conducted in 1990 by the German Pedestrian Organization. Two carriageways on both sides (with 35,000 cars per day) separate the stop from pavements. A pedestrian underpass provides access to pavements on both street sides (p. 237).

Of pedestrians that do not access the tram stop, 70 percent choose a surface crossing closer than 30 metres to the underpass. The percentage rises to 82 percent when walking to or from the public transport stops. Approaching or departing the stop shows no difference. Schmitz does not find it far-fetched for approaching pedestrians to experience time pressure. Against such a background, the equal behaviour of approaching and departing pedestrians surprises him. Schmitz concludes that public transport users are more sensitive to detours than other pedestrians (p. 237).

Berg (1988) discusses street crossings for pedestrian access to public transport. He refers to data that does not specifically consider pedestrian access to public transport. He defines the five most important types of street crossings: (1) unregulated or informal (2) zebra crossings, (3) traffic lights, (4) underpasses, and (5) overpasses or pedestrian bridges. He poses three questions regarding convenient access to public transport (p. 23). Which of the crossing facilities appears most suitable for pedestrians? How do detours and waiting times that occur at the crossing facilities influence the total access time to stops? How safe are the four crossing options?

Time delays appear significantly lower at zebra crossings as compared to traffic lights. With high traffic volumes on streets, Berg considers that traffic lights allow pedestrians to better enforce their right of way (p. 24). If car drivers accept the traffic rules, this is, however, not the case when pedestrians have the right of way at zebra crossings. For children, elderly or disabled pedestrians, it seems that more strict regulations of traffic lights may be safer (p. 23). The advantages of shorter time delays at zebra crossings are of central importance for adults and young pedestrians.

The author presents calculated time delays only for overpasses and underpasses. Underpasses appear preferable as time delays remains shorter due to lower height differences. (p. 26). Underpasses only provide an advantage over traffic lights with longer red phases when they do not require detours (p. 27). Walking down and up again in an underpass increases the energy consumption by a factor of 5 as compared to a surface crossing, reports Berg. He also reminds us that pedestrians can experience underpasses as unpleasant or unsafe. Underpasses and overpasses are only a preferable option if the topographical conditions do not increase the height differences that pedestrians need to overcome, concludes Berg (p. 28). Similarly, the investigation of Schmitz demonstrates the unattractiveness of underpasses.

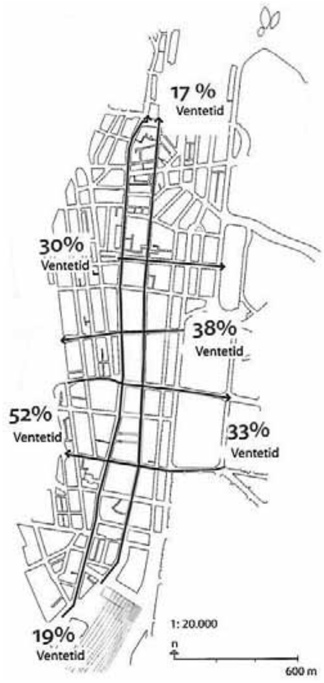
2.5.1 Waiting times

Brunsing (1988) differentiated rightly between average walking speeds and the time consumption of forced halts (p. 110). Based on walking speeds and halts, he defines a '*travel factor*' that describes how fast pedestrians get from A to B.

Gehl and Svarre (2013) present a simple method to investigate waiting times at street crossings as a percentage of the total time walked. They describe the method as *test walks*. During this inquiry, the researcher walks a defined distance in an urban area to investigate the duration of forced halts. The test walker keeps the time he has to stop, for example at traffic lights, together with the total time walked (p. 44). This procedure allows the duration of forced stops to be presented as a percentage of the total time walked. Figure 13 illustrates very different effects of street crossings on the time needed to get from A to B.

H. Monheim and Monheim-Dandorfer (1990) report on a study in Munich (Germany). Thirty-

Figure 13: The percentage of time spent waiting differs between different walked routes (Gehl and Svarre, 2013, p. 44)

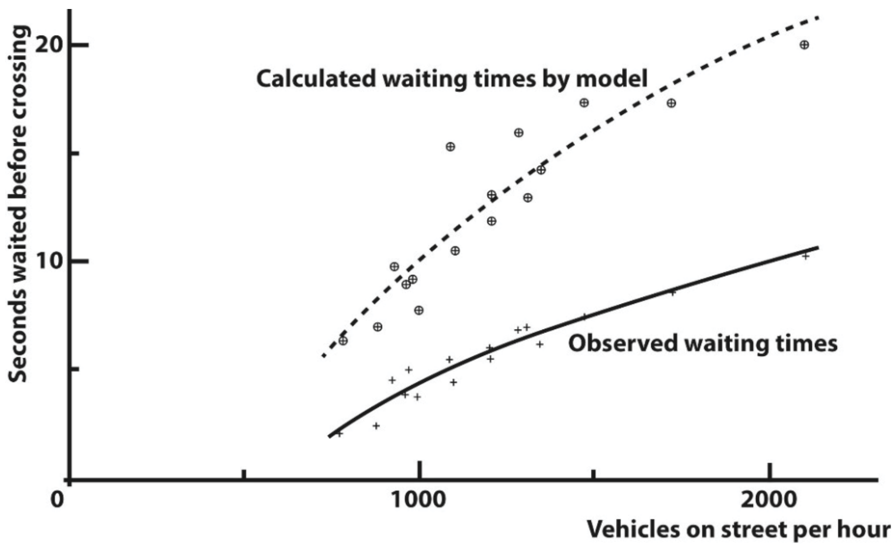


eight percent cross pedestrian traffic lights during red phases of between 40 to 60 seconds. Phases lasting over 60 seconds increase red-walking to 43 percent. At less than 40 seconds, only 19 percent walk on a red light. Waiting times at traffic lights caused a time loss of 30 percent for a one-kilometre-long walk in Munich (p. 193). The results fit well to the findings that Gehl and Svarre present (Figure 13).

Maier (1986) reports on pedestrian behaviour at informal street crossings. Pedestrians cross side streets at any preferred location and they walk diagonally over carriageways, with little haste. Some stop briefly to check for approaching cars. Pedestrians also react when they notice approaching cars acoustically (p. 156). Crossing carriageways with less than 300 vehicles per hour causes no noticeable waiting times, finds Maier (p. 157).

Streets with higher traffic volumes disable unobstructed street crossings. Stopping and waiting at pedestrian traffic lights appears undesirable for Maier. Instead, pedestrians continue walking along the kerb and look out for a gap in the traffic flow that allows them to cross. When crossing separated carriageways, only 5 percent of pedestrians stop on central reservations. Most pedestrians continue walking along the reservation until traffic allows them to cross the second carriageway, as Maier (1986, p. 156) describes.

Figure 14: Average waiting times at street crossings dependent on vehicles on crossed street, difference between modelled and observed waiting times, 1300 observations, 800 – 2000 vehicles per hour on crossed street, according to Maier (1986, p 157)



His text presents a commonly used model to calculate waiting times that occur at street crossings. The model uses street width, walking speeds, and the randomness of gaps in the traffic flow (which depends on the number of vehicles on streets) to calculate the expected waiting time (p. 155). However, Maier observes shorter time delays than the model predicts, as Figure 14 presents. He suggests that his observed waiting times, rather than the model's suggestions, should be considered in planning.

Knoflacher (1989) comments on the study of Maier. He objects to the consideration that observations do not show what pedestrians prefer (p. 182), He reminds that the model calculates waiting times for relaxed and safe street crossings with sufficient distance between driving vehicles. Knoflacher interprets the observed behaviour to show an increasingly unpleasant walking experience with more than 500 to 580 vehicles per hour on crossed streets. He considers the study rather to show the influence of vehicle traffic on walking routes (p. 183).

There is another way to interpret Maier's findings. We can also consider the waiting period to start at the moment when pedestrians reach the street they need to cross. The observed behaviour shows that pedestrians continue to proceed towards their destination while they wait to cross. People walk while they wait. However, when continuing walking along the curb does not bring pedestrians closer to their destination, they can just wait.

The difference between observed and calculated waiting times is important for access to public transport. When approaching the stop, pedestrians want to catch a public transport vehicle. Ensuring arrival at the stop in time requires accounting for the maximum possible time delay at street crossings. Ignoring potential delays increases the risk of missing the means of transport. Time pressure rises, and dangerous street manoeuvres can remain the only option. When walking trips are part of a travel chain with fixed timetables, the barrier effect of trafficked streets is likely to increase.

2.6 Preferred walking routes to reach stops

The study of Brändli et al. (1978) defines four *access sectors* around public transport stops (pp. 42–44), as Figure 15 shows and Textbox 4 explains. These four sectors depend on the driving direction of the servicing means of transport at the stop. The researchers observed that the number of pedestrians walking towards the stop varies in the four sectors, as Figure 16 shows. Brändli et al. consider stops located

Figure 15: Four sectors for pedestrian access to stops dependent on the driving direction of the public transport service:

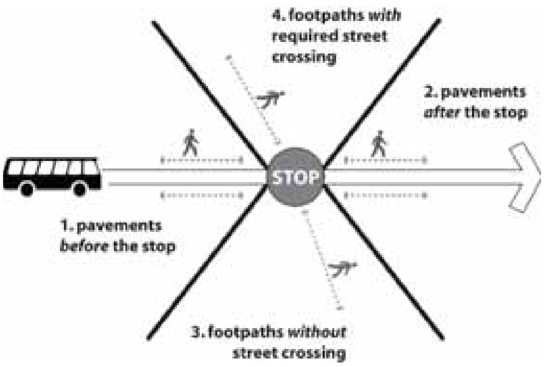


Figure 16: Percentage of approaching pedestrians in four sectors around the stop, according to Brändli et al. (1978, p. 44)

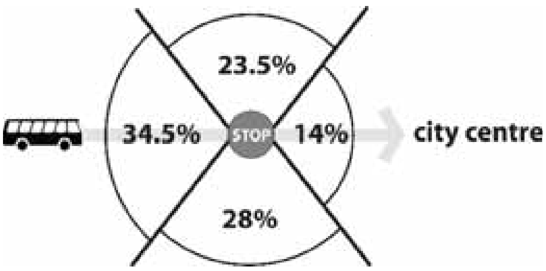
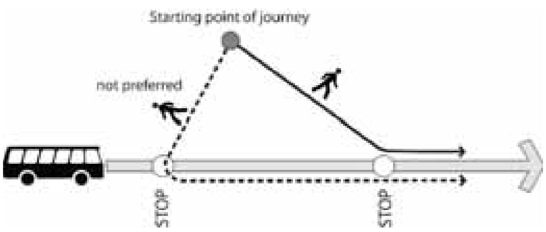


Figure 17: Pedestrians prefer to access stops in the driving direction of the public transport service, even if this stop requires a longer walk



along the main direction of the journey as more attractive. They explain the phenomenon with the desire to shorten the total travel time (p. 44).

Textbox 4
Definition: Four access corridors around public transport stop

1. The ***pavements before the stop*** along the public transport corridor from where the means of transport approaches the stop. Access routes in this sector run in longer or shorter sections along the *pavements before the stop*.

2. The ***pavements after the stop*** along the public transport corridor through which the means of transport departs the stop. Longer or shorter sections of access routes run along the *pavements after the stop*.

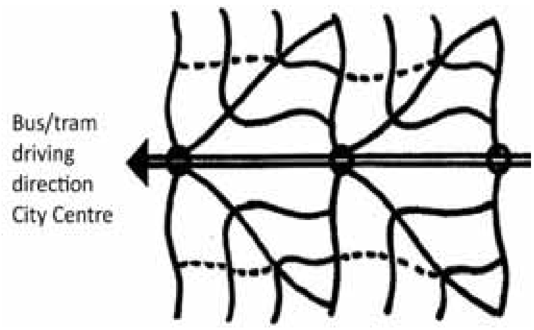
3. ***Directly linked footpaths*** that do *not* require crossing the public transport corridor. These routes do not require walking along pavements of the public transport corridor.

4. ***Linked footpaths with crossings*** that *do* require crossing the public transport corridor. These routes do not require walking along pavements of the public transport corridor.

See Appendix 1 for a more detailed description

Walking against the driving direction of the public transport service represents a detour for the total journey, as Figure 17 illustrates. To avoid such detours, pedestrians accept longer walking routes to stops. The stop along the detoured route is serviced slightly earlier by the means of transport. The time difference compensates for a longer walk to the stop. Walther (1973) finds that, with increasing distance from stops, more people do not access the closest stop (p. 124). About 20 percent access a more distant public transport stop in Bielefeld (p. 55). The effect illustrated in Figure 17 explains partly why people do not always access the closest stop.

Figure 18: Optimal pedestrian network around public transport stops in residential urban areas (Brändli et al. 1978, p. 68)



On the basis of their findings presented in Figure 16, Brändli et al. (1978) suggest an optimised footpath network around stops (Figure 18). In suburban areas, travellers predominantly accesses stops from homes. On the way back, they are likely to use the same route. Accordingly, the suggested footpath network in Figure 18 fits for arriving and departing pedestrians. The suggested network may not fit access routes in more central urban areas. Here, people probably approach and depart stops from many directions.

Marchand (1974) analysed over 100 walking routes to a subway stop in Paris. From minor side streets and footpaths, pedestrians first access the closest main axis that leads straight to the underground stop. Walking routes through side streets appear undesirable, even when shorter. The main axes are busy, partly congested, contain more driving vehicles and pavements are narrow. Illegally parked cars and trees obscure walking. Despite these inconveniences, many pedestrians prefer these busy routes. Manchand concludes that pedestrians choose the straightest walking path to stops. Frequent direction changes appear undesired (p. 504).

Whyte (1988) tracks pedestrians but does not focus on access to public transport. Along with Manchand, Whyte observes that pedestrians prefer busy pavements, even though these paths appear shabby and are crowded (p. 79). Conversely, he understands that a lively and stimulating environment determines route preferences. Whyte considers the concepts of *carrying capacity* or *overload* as sloppy for walking (p. 66). He urges us to understand pedestrians not only as transportation units but also as social beings (p. 77). Boesch (1989) highlights accordingly the importance of socially active axes for pedestrian access to public transport (pp. 22–27). Convenience does not seem to be the only dominant factor for route choice. The sensory perception of the walking environment also appears important.

Weinstein Agrawal et al. (2008) investigated the route choice of pedestrians walking to five light rail stops in California and Oregon during the morning peak hour. Of 727 distributed surveys at stops, 328 were returned. They survey asked participants to estimate the time and distance walked to stops, factors that influenced route choice, and requested they drew out the walking route on a map (p. 83). The inquiry showed that pedestrians choose the most direct route to access stops. The quality of the walking environment did not influence route choice, concluded the authors (p. 94). Results appear reasonable but are likely to be influenced by the interview method. These findings seem to support the conclusion of Schmitz. Direct and fast access is important for route choices (p. 91). Their results apply only for those approaching stops and might differ when departing from stops.

However, pedestrians are likely to experience their environment unconsciously. Findings in Section 3.1 show how walking speeds can vary with environmental characteristics. This research also finds numerous unconscious reactions to environments. Accordingly, interviewees in the study of Weinstein Agrawal et al. are not necessarily aware of the environmental influence on their route choice. Consequently, people are not able to explain the reasons for their route choice to the full extent. Chapter 4 discusses methodological challenges for interviews. Nevertheless, it is likely that the importance of a direct walking route to the stop increases as soon as the stop comes in sight.

Guo (2009) focuses on the effect of the walking environment on the choice of two route options. The study investigated the behaviour of 2748 travellers, who accessed Boston downtown by underground. Route option one involves a longer ride on the means of transport, one change, and an average walk of 3.2 minutes to the final destination. For the second option, travellers alight the underground earlier without changing, and arrive at the final destination by a longer walking route of approximately 10 minutes (p. 346). The analysis uncovers five features of the walking environment that increase the attractiveness of a route option (p. 347):

1. Higher density of route sections with retail facilities
2. Higher density of street intersections
3. Wider average pavement width
4. Walking through the park (Park Boston Common)
5. Not walking in hilly urban quarter with slopes (residential area Beacon Hill) – pedestrians prefer flat terrain

While the first four features increase the probability of choosing a route, the fifth is unattractive (p. 349).

Pedestrians avoid detours when accessing stops. Interestingly, it appears that pedestrians are well aware of the main direction of their journey and choose walking routes to stops accordingly. However, not only the convenience of access routes influences the choice of the walking route to the stop. Equally, the sensory experience of walking environments influences the path pedestrians prefer, as the study of Guo already indicates.

2.7 Walking environments around public transport stops

Numerous authors discuss environmental characteristics to support pedestrian access to public transport. The influence of the walking environment appears clear to the many protagonists of the discourse. Suggestions pay attention to both, the sensory experience of walking environments, and the convenience of access to stops.

Fruin (1979) discusses the density of pedestrian flows and the effect of stairs, escalators, and elevators (pp. 192–204). His *level of service concept* describes the convenience of walking as a function of available space. The concept is highly relevant for busy large-scale public transport hubs, which Fruin investigates in New York. Conversely, available space appears less important for pedestrian access to the majority of public transport stops that are not located in the centre of a global metropolis.

Boesch and Huber (1982) published a guideline for the planning of pedestrian-friendly urban settlements. One chapter focuses on access to public transport stops (pp. 73–82). In the book, *The pedestrian as passenger*[10], Boesch (1989) focuses solely on pedestrian access to bus and tram stops, as well as train stations. He

[10] Translated from the German title *Der Fussgänger als Passagier*

discusses the quality of urban residential areas for walking access to stops (pp. 14–21) and points to the lack of knowledge on the role of architecture and aesthetics for pedestrian access to public transport (p. 13). The publication is one of the first to provide a broader overview on the topic of pedestrian access to public transport.

Authors from the German pedestrian organisation, *FUSS e.V.* (2000), consider the walking environment to influence the perceived walking distance to public transport stops. The authors find monotonous and unpleasant environments but also waiting at traffic lights lengthen individually perceived walking distance to public transport (p. 1). The Swiss pedestrian organisation *Fussverkehr Schweiz* picks up the question of walking and public transport. Schweizer (2005) highlights the lack of data (p. 6). Regli (2010) discusses the influence of the walking environment. He understands the overall experience of ambience, design and light to influence the experience of walking to and from stops (p. 4).

Textbox 5
Definition: trip leg

A ***trip leg*** refers to a section of a journey between two points. The walk between home and a public transport stop is usually the first trip leg of a journey that includes a ride on a public transport vehicle.

The work of Altvater (2001) provides an overview of relevant topics when considering all *trip legs* to improve the quality of a public transport journey. The author investigates the influence of the walking environment around public transport stops. This work uncovers the complexity of such investigations, as the author concludes. Altvater finds his literature review to show numerous concepts and ideas that require further research (p. 135).

Givoni and Rietveld (2007) investigate access and egress trips before and after train rides. Their criticism is that research on these access and egress trips focus mainly on distance or time use. The authors find little research on the qualitative aspects of the journey and consider such to influence the overall experience of travelling (p. 358). Their own analysis of 2542 questionnaires uncovered that, surprisingly, the pricing and the quality of the train service did not have the strongest influence on overall satisfaction. The quality of the station showed an effect that was still half as strong as the quality of the train service itself (pp. 362–363). Investigating in more detail travellers' perception of the train station exceeded the scope of this interesting study.

Gehl Architects (2007) produced a brochure for a future perspective of public transport in the city of Gothenburg (Sweden). The richly illustrated report focuses on public transport hubs and establishes ideas and concepts that are equally relevant for pedestrian access to tram and bus stops. They suggest increasing social activity around hubs through multiple shops, services, and generally high urban density. Attractive public spaces should taking into account the microclimate and human scale; urban design should be convenient for all users and age groups. Aesthetics should create a strong identity for an urban area around public transport hubs. These suggestions rest on long experience in research and practice that grew around Jan Gehl. The proposed measures facilitate the discourse on a more general level but do not increase the understanding of public transport related walking in specific.

In 2009, the public transport industry also started to show some interest in the urban fabric around their transport infrastructure. The International Organization for Public Transport (UITP) (2009) published a positioning paper that suggests (1) mixed land uses and high density urban quarters with attractive public spaces and attractive ground floor facades, (2) high quality public transport infrastructure that functions as a design feature in streets and public spaces, and (3) measures to limit car use (p. 5). These suggestions remain very general. Interestingly, the paper does not mention pedestrians, even though the suggested strategies have a strong impact on pedestrian access to public transport. Are public transport providers still not aware that their clients are also pedestrians? Nevertheless, the publication represents a welcome understanding of the need to consider public transport planning not solely as a question of technical infrastructure.

While authors are aware of the environmental effect on the sensory experience and the convenience of walking to public transport stops, few attempt to measure the effect. The following section presents the few publications that do so.

2.8 Accepted walking distances and environmental characteristics

Section 2.3 in this chapter illustrates the importance of walking distances to stops. Next to population densities, the acceptable walking distance is an important factor that determines the potential of public transport infrastructure[11]. The

[11] There are numerous factors that influence the use of public transport infrastructure, such as pricing, the frequency of the transport service, the quality of the public transport system in a city, and more.

literature in this section investigates how the character of the urban walking environment around stops influences acceptable walking distances to stops.

The study of Peperna (1982) was previously presented at the beginning of Section 2.3. The author was one of the first researchers to measure the substantial effect of environmental characteristics on accepted walking distances to stops. His methodology allowed to measure the environmental effect separately from some previously described contextual conditions such as the travel purpose, available transport options, and the quality of the public transport service.

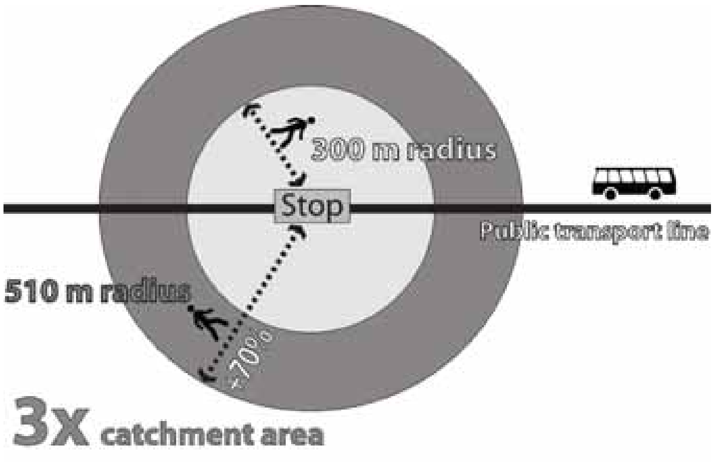
Peperna uses four indicators to determine the quality of the urban surroundings for walking trips to public transport stops: firstly, the typology of the footpath network, such as existing of radials, a grid-like network or specific typologies; secondly, the quality of footpaths by accounting for the amount of car traffic along pavements, greening, and traffic calming measures; thirdly, the visual appearance of the urban surroundings, comprising building types and styles, facades, and the design of the public space; fourthly, the existence of shops, schools, and workplaces around public transport stops. From these four indicators, the researcher defines walking environments that are either ***pedestrian-oriented*** or ***car-dominated*** (pp. 50–52).

Sporadic travellers walk 216 metres to stops in unattractive car-dominated environments. Accepted walking distances increase in the same group by 20 percent in pedestrian-oriented surroundings[12]. Most interesting appear results for journeys to work. Fifty percent accept walking distances over 376 metres in pedestrian-oriented environments, decreasing to 218 metres in car-dominated urban areas. Walking distances in attractive urban surroundings remain 73 percent longer after the effect of available transport alternatives is filtered out (p. 65). On the basis of these findings, Peperna suggests not generalising on accepted walking distances to public transport stops without considering the influence of the urban environment (p. 65).

Knoflacher (1996) points to the substantial effect, which the study of Peperna indicates, for the potential of public transport. With a 70 percent increased walking distance, the spatial size of the (theoretical) radial catchment area around stops would triple in size. Figure 19 illustrates this effect graphically. Pedestrian-oriented

[12] Due to limitations of the data set, the analysis did not filter out the effect of available travel options.

Figure 19: Tripled size of the catchment area with 70 percent longer walking distances



urban environments hence triple the number of urban inhabitants within acceptable walking distances to public transport systems[13], at least theoretically.

Lam and J. F. Morrall (1982) analyse data from 2400 interviews on walking routes to bus stops in Calgary (Canada). The study questions the difference between summer and winter seasons. Public transport hubs and stops where passengers change are excluded. The researchers use detailed maps to trace accurate walking routes to stops, including detours. Table 2 shows the average length of routes to stops in three different urban areas. Distances vary with season but more extensively with the environmental characteristics, as the reduction in industrial areas shows. Accepted walking distances decrease here by 46-48 percent as

Table 2: Average walking distance dependent on season, frequency of bus service, and type of urban environment (Lam and J. F. Morrall 1982, p. 416)

Stop environment	Frequency bus service, minutes	Walking distance summer, metres	Walking distance winter, metres
Central business district	5-8 min	292 m	355 m
Suburban residential	5-8 min	373 m	348 m
Industrial area	30 min	173 m	211 m

[13] Factors such as the density of stops along a public transport line, the density of the public transport network, and further factors influence such a simplified theoretical consideration.

compared to suburban stops, and by 39 – 42 percent compared to stops in the centre (p. 411). To what extent lower bus service frequencies in industrial areas influence walking distances remains unclear.

The shorter walking distances in the central business district is somewhat surprising. That walking environments in suburban areas are more pedestrian orientated than the central business district of Calgary appears to be a scarcely convincing explanation. Further, walking distances drop unexpectedly during the summer. The authors explain the phenomenon with the possibility of reduced reliability of car transport with snow and ice on the streets during the cold winter in Calgary (p. 416). The effect of these non-investigated factors remains unclear though. The study demonstrates that there are a number of factors involved when measuring walking distances.

In the previously reported study of O'Sulivan and Morrall (1996), researchers asked interviewees to estimate the time they spent walking to and from light rail stops. The researchers calculated the time spent walking from the measured distance of walking trips (assuming an average walking speed of 80 metres per minute). Walking distances are with 651 meters at suburban stops longer as in the central business district with 326 metres (p. 25). Comparing the calculated duration for the walk to the stop with peoples' time estimates uncovers a difference. Walking trips to and from suburban stops are on average underestimated. The quality of the walking environment could cause the effect, the authors assume (p. 25).

Faster walking speeds in suburban environments would also explain the phenomenon. Differences in average waiting times for street crossings may provide further explanations. Without more detailed knowledge on the background of the study that O'Sulivan and Morrall report, the difference between calculated distance and time estimates remains unknown. Similarly, longer walking distances to suburban stops are difficult to explain with the character of the walking environment.

Maghelal (2009) investigates whether the percentage of public transport users that walk to light rail stops varies with the features of the built environment. Even though this is not a direct investigation of accepted walking distances, varying percentages indicate changing accepted walking distances to light rail. With the help of Geographic Information Systems (GIS), the author analyses four features of the pedestrian environment around 20 light rail stops in Dallas county: (1)

vehicle oriented design, (2) residential density, (3) land use diversity, and (4) walking oriented design (p. 48). Only density had a significant effect (p. 58). Unexpectedly, higher densities decreased the percentage of walking trips to stops (p. 61). The study does not provide a convincing explanation for the found effect. Chapter 4 discusses the challenges of the applied methodology of the study, Maghelal reports.

The previously presented study of Guo (2009) identifies five environmental features that influence the travel route of public transport users. These features also influence the time spent walking to final destinations after the public transport ride and, accordingly, the walking distance:

1. One more parcel with shops and services per 100-metre walking route increases walking time by 5 percent
2. One more footpath intersection per 100-metre route increases walking time by 3 percent
3. Pavements widened by 1.8 meters (6 feet) increases walking time by 5 percent
4. Walking routes through the park, Boston Common, increase walking time by 29 percent
5. Walking routes through the hilly area of Beacon Hill decrease walking time by 35 percent

The five presented environmental conditions can vary in parallel with other non-included factors. For example, wider pavements and more shops can correspond with generally more pleasant and stimulating surroundings. I assume that it is not the pavement width alone that caused the observed effect but the environmental conditions that correspond with wider pavements.

The influence of topography appears extensive in Guo's study. We have to remember that the enquiry shows the effect of an urban area with noticeable topography. Here, investigated pedestrians walk up- and downhill. Weidmann (1993) finds walking uphill on a 10 to 12 percent incline to increase the energy consumption by about 80 percent (p. 24). The data of the previously discussed research of Brändli et al. (1978) uncovers sloping terrain to reduce acceptable walking distances by 32 to 43 percent (p. 43). The findings of Guo appear plausible.

The decision to depart from the subway stop through a park is likely to be a conscious decision. Such depends on individual preferences, as Guo (p. 350) admits. I consider results not to show that parks generally increase accepted walking distances. However, the investigation shows that the environment can influence route choice and the time travellers accept to walk after the public transport ride. This is an important contribution to the discourse.

One of the most interesting studies was present by Yang et al. (2012). The authors investigate factors that influence the accepted walking distance to 19 *rapid bus transit*[14] stations in the City of Jinan in China. They use data from 1233 interviews regarding the walking trip to the stop (p. 6). The study defines three rough characteristics for the pedestrian environment.

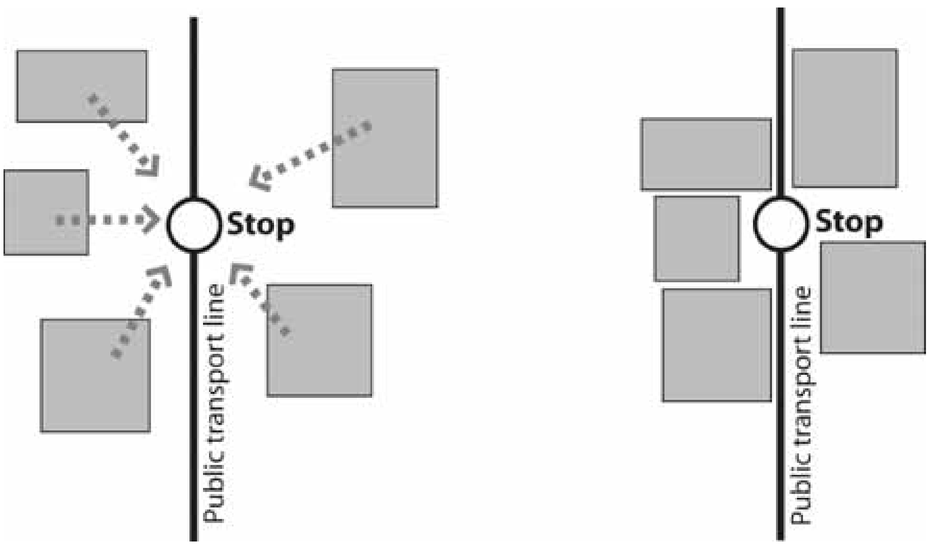
An ordinary least square regression isolates the effect of the urban environment on accepted walking distances from other factors. Variables such as income, occupation, age, and travel purpose have a very low influence on accepted walking distances. Conversely, all environmental variables remain significant (p. 11). The average walking distance is 600 metres. More shops, smaller block sizes and trees along pavements increase accepted walking distances by about 25 percent. At terminal stations (at the end of lines) the average walking distance increases by 67 percent (p. 13). With high land-use densities, the average walking distance decreases by 25 percent (p. 13). The authors explain the reduction with higher density by the lower number of people that have to walk far to reach the stop. Further, the distance between the stop and the city centre influences how far people are willing to walk to the stop. With each kilometre increased distance between city centre and stop, the accepted walking distance to stops rises by 75 metres (p. 12). According to these results, the average walking distance of 600 metres doubles at stops of eight kilometres distance from city centres. This appears to be a very extensive effect.

The authors point to some shortcomings of their study. First, they could only measure the land use density very roughly. Second, they investigate only walking trips to reach stops before the ride on the means of transport. As they point out, the walking route after the ride on the bus could also influence accepted walking distances. Third, they do not investigate the character of the walking environment along each individual walking route. Instead, they use the characteristics of the public transport corridor as a proxy for the urban environment along the walking route (p. 13). Despite these shortcomings, the study shows well the potential of the environment to increase accepted walking distances to public transport stops.

[14] Rapid bus transit public transport systems consist of buses that drive on dedicated carriageways with priority over other vehicles on street.

This research focuses on the effect of urban environments on pedestrian access to public transport stops. How well do the six presented studies explain the environmental influence on pedestrian access to stops? The findings of Lam and J. F. Morrall (1982), O'Sulivan and J. Morrall (1996), and Maghelal (2009) remain somewhat ambivalent. It is likely that the results of these studies are influenced by the combined effect of (1) the population density around stops, and (2) the applied methodology to derive average walking distances. All three studies measure walking distances of a random number of pedestrians that access stops. With high population densities directly around the stop, the data sample must contain more observations from pedestrians who only have to walk short distances to the stop. Inversely, a highly dense residential development at 250 metres distance from the stop would increase the average walking distance, as more public transport users arrive from the dense development at some distance from the stop. Average measured walking distances are influenced by the spatial distribution of population densities around stops, as Figure 20 illustrates. The described phenomenon influences the average walking distance (in a random data sample) to stops independently from environmental characteristics.

Figure 20: Different average walking distances as result of dissimilar spatial locations of urban density (indicated by grey fields)



The described effect of the spatial urban density distribution on the results of average walking distances could well explain longer walking distances to stops in less dense suburban areas in the studies of Lam and J.F. Morrall and O'Sulivan and J. Morrall. Similarly, the phenomenon in Figure 20 explains shorter walking distances with high urban densities in the study of Maghelal. The survey of Peperna (1982) is less likely to be influenced by the described effect[15]. Yang et al. (2012) recognise the effect of density and filter it out. Density distributions remains irrelevant for the methodology Guo (2009) applies. Walther (1973) was the first author who described and accounted for the density effect (p. 53), but his study does not investigate the influence of environmental characteristics on walking distances to stops.

The study of Peperna (1982) provides a good orientation on the extent of the environmental effect. However, the investigated environmental characteristics remain rough and still do not provide detailed information for planning and designing pedestrian-friendly environments around stops.

Guo (2009) presents applicable findings. Attractive parks increase accepted walking distances. The general effect may, however, remain lower than the reported 30 percent increase. The average effect of topography appears valid, reducing accepted walking distances by 35 percent. The unit chosen for the density of shops and footpath intersections requires a detailed measure for a specific walking route. Both variables describe features of an attractive walking environment. More shops and a denser footpath network with more intersections are likely to increase accepted walking distances.

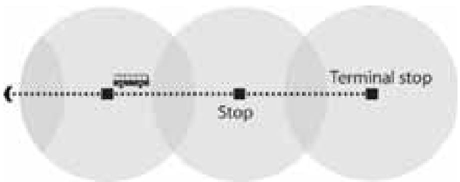
Congruent with Guo, Yang et al. also find that more shops and smaller street block sizes (resulting in a denser footpath network with more footpath intersections) increase accepted walking distances by 25 percent. These results do not appear unreasonable but may depend on further environmental features. More shops and a denser footpath network are also likely to increase social activity, possibly the design of footpaths, the size of buildings, and so on. Environmental characteristics that vary together with the footpath network and the number of shops may jointly influence the uncovered effect.

Yang et al. find longer accepted walking distances at terminal stops. The effect may result from overlapping catchment areas, as Figure 21 shows. The terminal stop overlaps 50 percent less with other catchment areas. Eclipses close to the

[15] The maps that Peperna provides for the urban areas around the studied public transport stops indicate an evenly distributed dense city structure around stops.

radial borders of the catchment area can reduce the number of people that have to walk longer distances to stops. Additionally, the previously discussed phenomenon of different density distributions may be another reason for longer walking distances at terminal stops.

Figure 21: Different size of catchment area at terminal stops due to unequal overlapping



Possibly terminal stops are more important as local centres in suburban parts of the city. This centrality effect may decline around stops along the public transport line. When public transport stops play a role as local centres, more shops and services are pleasant and convenient for walking, and accepted distances are likely to increase.

2.9 Conclusion on the discourse around pedestrian access to public transport

Boesch (1989) finds the question of pedestrian access to public transport to be neglected for three reasons. Firstly, walking as a form of transport appears underestimated. Secondly, there is a lack of cooperation between urban planning and building departments in city councils, road infrastructure departments, local public transport operators, and railway authorities. Thirdly, these institutions are characterised by very different professions, depending on differing legal rules, and receiving funding from different sources (p. 8). The International Organization of Public Transport (UITP) (2009) was urging an integrated approach for public transport and urban planning in 2009. Congruent with Boesch, the paper calls for cooperation between politics, public administrations and infrastructure provision, as well as urban planning and design professionals (p. 2). Difficult collaboration across institutions and professions possibly explains why the relationship between walking and public transport has remained neglected for decades.

The research of Brög (2014) and his institute *Socialdata* underlines impressively the importance of walking for the use of public transport. No other form of urban mobility is of such multimodal character as journeys that include the use of public transport. The findings of Brög demonstrate the incompleteness of strategies that support public transport without considering pedestrian access to stops.

How far pedestrians are willing to walk to stops is of central interest. Walking distances to stops allow us to estimate the potential use of public transport infrastructure. Additionally, the population density along a public transport corridor determines the number of potential passengers. Data on residential densities are available in most Western cities. Conversely, the question of an acceptable walking distance to stops remains complex. A number of studies on acceptable walking distances aim only to evaluate the potential of public transport infrastructure. These studies do not explain why public transport users accept long or short walks to stops.

R. Monheim (1977) points to the difficulty of determining acceptable walking distances without knowing who walks. When travellers have no other transport option, they may be forced to walk longer distances. Questioning acceptable walking distances to stops remains complex as there are numerous mediating factors involved, some of which have been discussed by the literature. Little attention is paid to the effect of the public transport system itself. The distances between stops and the density of the public transport network determine walking distances to the nearest stop. People are likely to accept longer walking distances when they find a fast, inexpensive, and convenient public transport service at the stop. The study of Fruin (1979) shows that travellers accept longer walks to public transport hubs. That people accept walking longer distances to train stops than to bus stops is commonly understood.

Further, a good public transport system in a city provides better access to more locations throughout the city, probably encouraging longer walks to stops. Transport policies do not only influence the quality of the public transport system but also the attractiveness of other available travel options, such as cycling or car driving. These factors remain complex to compare across cities. Accordingly, finite measures of average walking distances to stops in different cities remain somewhat incomparable.

As the effect, the transport system in a city remains difficult to determine and average measured walking distances in a specific city remain somewhat limited regarding generalisations. More promising appear studies that focus on factors that vary acceptable walking distances within a city context. Such approaches ease generalisations and provide more relevant information to plan and design urban areas for convenient pedestrian access to sops.

Numerous authors provide suggestions on suitable walking environments for access to stops on the basis of data and knowledge on walking in general. What we know about walking in general is certainly relevant for the specific conditions of access to public transport. However, such literature does not advance our understanding of the specific character of walking trips associated with a public transport journey.

A number of authors discuss questions such as detours that result from footpath networks, the possibilities to access additional destinations along walks to stops, and the influence of required street crossings. Not all authors provide empirical data for their considerations on these topics. All these questions influence the convenience of access to stops and possibly how far people are willing to walk to stops.

Most interesting remain some of the investigations reported in Section 2.8. The studies of Peperna (1982), Guo (2009), and Yang et al. (2012) demonstrate that the quality of the walking environment influences substantially how far people walk to stops. These studies measure the environmental effect on acceptable walking distances, but the authors do not question why the urban surroundings influence walking distances to stops. Investigating walking as a psychological question may explain the mechanisms behind the effect that Peperna, Guo, and Yang et al. measure. Chapter 3 consults further literature from the field of physiology and psychology to formulate a second set of questions for the empirical investigation.

2.10 Research questions – part one

The first part of the questions for research refers to the convenience of walking environments around public transport stops. The reviewed literature in this chapter defines the first set of three research questions:

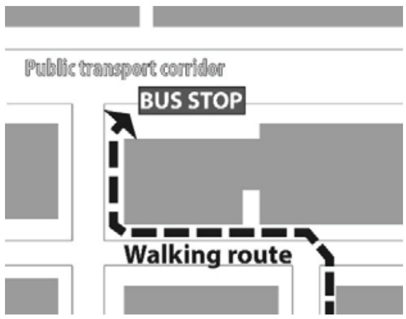
1) **Access to facilities along walking routes to and from public transport stops**

   The presented discourse shows that additional destinations are easily accessed by pedestrians, stops are focal points for the provision of shops and services, and how combined trips can reduce the travel demand in cities. Which facilities are accessed and where? Do individual conditions such as car availability influence the utility of facilities? Can we observe differences between approaching and departing pedestrians? Do possibilities to combine trips increase accepted walking distances to public transport stops? Does the location of shops and services in relationship to the stop influence access to these facilities?

2) **Detours**
The literature review shows that any pedestrian network causes detours. Property borders that pedestrians cannot step over, as well as any large built structures, such as railway lines and buildings, detour walking routes. These factors appear well understood.

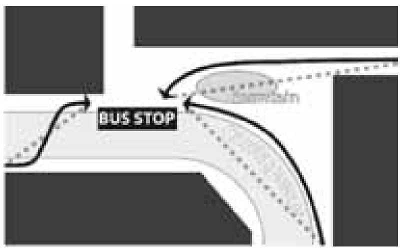
Walther (1973) finds increasing detour factors with walking distances of less than 100 metres to stops. Why increase detours in close vicinity around public transport stops? Schmitz (1991b) highlights the importance of this question. He finds that unobstructed and direct access to the stop becomes most important when pedestrians get close to stops and even more so when the stop comes in sight. To answer the question, the investigation in this research differentiates between three reasons for detours.

Figure 22: Detour caused by the city structure



The ***city structure*** derives from property boundaries, buildings and street blocks that all cannot be walked over, as Figure 22 illustrates. How extensive is the effect of the city structure on the detour factor?

Figure 23: Detours caused by the public space layout



Equally, the ***layout of the public urban space*** influences detours. Streets and street crossings, trees, planted beds, fountains, chairs of cafes and other seating facilities can become obstacles for pedestrians, as Figure 23 shows. How does the public urban space influence the detour factor? An important issue related to the layout of the public urban space is street crossings. Street crossings substantially increase detours. How extensive is the effect of street crossings?

Are there ***other reasons*** for detours, for example when pedestrians choose to access cash machines, post boxes, bins, and so on? These facilities are not necessarily located along the most direct walking route to public transport stops. People may also take detours according do disorientation. To what extent do such conditions increase detours around public transport stops?

3) Street crossings

Well-located crossing facilities increase the convenience and safety of access to public transport. The question remains, can we identify where street crossing facilities appear most suitable? Where do pedestrians that walk towards or away from stops cross streets? Can we identify a pattern?

A further important issue is time delays that can occur when pedestrians cross trafficked streets. Waiting times before crossing carriageways may account for a substantial duration of three to five minutes. The barrier effect of large streets is likely to influence accepted walking distances to stops. How long do pedestrians wait before they can cross streets? How do traffic volumes on streets and the different forms of street crossings, such as traffic lights, zebra crossings and informal crossings, influence waiting times?

3 EXPLAINING THE RELATIONSHIP BETWEEN WALKING AND URBAN ENVIRONMENTS

Knoflacher (1996) considers addressing the convenience of walking to be relatively simple in practice. Providing obstacle free and direct walking routes, or suitable street crossing facilities, does not represent a major technical challenge. Improving the emotional experience of walking appears more complex (p. 138). The literature in Chapter 2 mostly questions the convenience of the urban environment for pedestrian access to stops. Only some researchers demonstrate that the important question of accepted walking distances depends also on the sensory experience that pedestrians receive from their urban surroundings.

This chapter discusses findings from the field of psychology and physiology for two purposes. Firstly, to establish a theoretical basis to investigate how urban environments influence the sensory experience of walking. Secondly, to explain how the sensory experience of the walking environment can possibly influence how far pedestrians are willing to walk. This theoretical background allows a second set of research questions to be defined that target the environmental influence on the sensory walking experience.

3.1 Walking speeds indicate reactions to the walking environment

A central challenge of the discourse around walking remains to explain the relationship between the sensory experience of walking and the urban environment. Knoflacher (1996) points to the difficulty of quantifying the quality of the urban environments (p. 133). He objects, however, to the assumption that human behaviour reflects the character of the walking environment (p. 137). Equally, Garbrecht (1984) considers the character of the walking environment to trigger reactions that reflect the environmental experience (p. 70).

Psychologists, Maderthaner and Szynkariuk (1999), point out that up to 50 percent of human behaviour is determined by the environment and up to 50 percent by the individual background (p. 239). The individual background can be the purpose of the journey but also a persons' attitude, specific experiences, physical health and so on. Borson Fich et al. (2011) find the environmental experience to activate emotions. The emotional experience derives from conscious and unconscious environmental perceptions. People react to their perception of an environment. These reactions intend to improve the emotional experience. The authors understand that human behaviour targets positive emotions (p. 93). Accordingly, pedestrian behaviour seeks to enhance the sensory walking experience. Therefore, Borson Fich et al. hypothesise that the environment influences objectively observable behaviour (p. 97). Accordingly, Maderthaner (2008) considers emotions to determine behaviour (p. 300). On this basis, walking speed and alterations to it represent reactions to an emotional experience of walking. This experience derives in equal parts from (1) the environment in which people walk, and (2) the individual context in which walking takes place.

When Whyte (1988) describes pedestrians' behaviour, he mostly refers to their walking speed. During the morning rush, people walk fast; people really want to get from A to B (p. 66). Walking in the evening rush hour is more relaxed but still an efficient flow. Pedestrians are more social, more spontaneous, people drop into shops and stop to talk or to watch something when returning from work (p. 67). Observing fast pedestrians, Whyte gained the impression that those are not more harried or tense than others. Fast-walking people appear less responsive to their surroundings. By ignoring their social context, fast walkers appear arrogant (p. 65). Whyte's observations uncover a relationship between walking speeds, speed variations, and the urban environment.

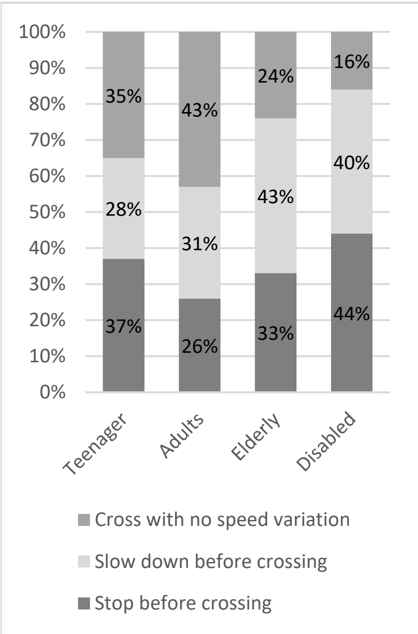
Many researchers investigate the influence of the environment on walking speeds. Varying walking speeds indicate a reaction to environmental characteristics. Pailhous et al. (1990) describe the relationship between walking speed and the environment. What surrounds pedestrians influences pedestrians' step length, frequency and speed (p. 275). The speed of movements influences the perception of the environment. The other way round, the character of the environment can also influence walking behaviour and speed.

Whyte (1988) observed that sensory offers draw pedestrians' attention and result in more speed alterations and stops. Pedestrians react to shop windows, special price offers, illuminated displays, shows, activities, light effects, sound, noises, music, and to possibilities to touch goods to gain a haptic experience (p. 85). When passing a shop window of interest, pedestrians can slow down from a brisk speed of 90 metres per minute to 60 metres per minute[16]. They may even stop for a short moment. Speeding up again, people continue at 105 metres per minute, as if they

[16] Whyte uses feet per minute and miles per hour as units for walking speed

want to make up for the delay. In contrast, '*dull blocks* [with little stimulating facades] *are fast traversed*' observes Whyte (p. 66).

Figure 24: Walking speed variations at zebra crossings, according to Schweizer et al. 2009, p. 35)



Whyte's observations uncover an informative logic. Pedestrians react to more and diverse environmental stimuli with speed alterations and slower walking speeds. These environments seem to attract attention. Lower levels of attention in boring surroundings let speeds increase with less variations.

Schweizer et al. (2009) observed the behaviour of 1500 pedestrians at ten different zebra crossings in six cities in Switzerland (pp. 28–29). From video footage, researchers roughly estimated pedestrians' walking speed while crossing. Of teenagers, adults, and elderly people, about 90 percent walked at an average speed of between 60 and 90 metres per minute. Eighty to 89 percent of disabled pedestrians walked across zebra crossings at speeds slower than 60 metres per minute.

On average, 70 percent of all observed pedestrians alter their speed when stepping over the carriageway, as Figure 24 shows. They either slow down before the zebra crossing or they stop[17]. This is interesting, as pedestrians have the right of way at zebra crossings in Switzerland. Most pedestrians are certainly aware of the dangers of driving vehicles. The fear of accidents increases attention, and the walking speed varies – also when having the right of way. These speed variations indicate the experience of compromised safety.

Gehl and Svarre (2013) report on an investigation of walking speeds on the *Amagertorv* square and the adjacent pedestrian street *Strøget* in Copenhagen (DK)[18].

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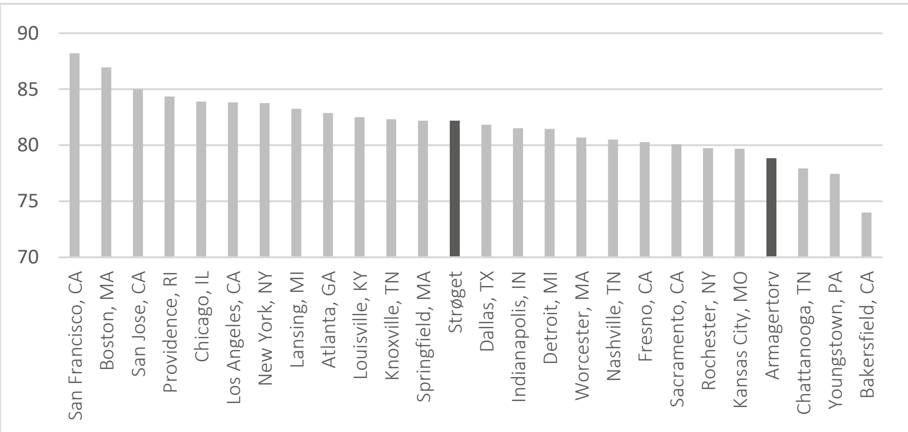
[17] Not surprisingly, the observed behaviour differs between elderly and disabled pedestrians and younger age groups.
[18] They timed every third pedestrian that crossed a starting line, in total 200 pedestrians. The temperature was mostly about 5 degrees Celsius on a grey winter day

Researchers expected lower walking speeds on the square as the environment invites more diverse and stationary activities. Apart from the dimensions of the open space, the characteristics of the buildings and facades are similar at both studied locations (p. 123). In the pedestrian street, people walk at an average speed of 82 m/min and at 79 m/min on the square[19], a difference of about 4 percent. The speed alteration appears slight and invisible to the naked eye. The researchers consider warmer summer weather may have been more inviting for stationary activities and could have increased the difference between the two locations (p. 123).

Levine et al. (2007) measure walking speeds in central areas of 24 US cities. The study finds a 35 percent increased average walking speed in the largest city (San Francisco) as compared to the smallest (Bakersfield) (p. 473). Whyte (1988) also finds faster walking in larger cities (p. 65).

Figure 25 presents the speed measures from the study that Gehl and Svarre reported on (dark grey bars) together with the study of Levine et al. from the 24 American cities (light grey bars). The light grey bars in Figure 25 indicate higher speeds in larger cities. Most interestingly, it appears that the walking speed from the two locations in Copenhagen differ as much as the walking speeds between nine American cities. Does the environment influence walking speeds more

Figure 25: Average walking speed in metres per minute at 26 locations. Light grey: Levine's US study. Dark grey: The study in Copenhagen reported on by Gehl and Svarre



[19] The authors reported walking speed in kilometres per hour, 4.93 km/h in the pedestrian street, 4.73 km/h on the square.

extensively than city size? We learn from both studies that averages of walking speeds do not vary to a great extent.

The text so far shows that researchers use the walking speed and its variation to show how pedestrians react to urban environments. Observable speed variations work well for this purpose, but alteration of averages seems more difficult to observe. The following text describes the possibility of using the frequency of pedestrians' steps as a substitute for walking speeds. Step frequencies have so far received little attention but appear as an even better indicator to uncover pedestrians' reactions to urban environments.

3.2 The step frequency as substitute for the walking speed

Measuring walking speeds requires information on distance and the time needed to walk between A and B. For the kind of observations that Whyte carried out, such information is not so easy to derive. Without knowing the length of steps, the frequency does not provide an exact measure of the walking speed. While the walking speed is a definite measure, the combination of step length and frequency can vary for the same walking speed. Egerton et al. (2011) find very few publications that investigate the relationship between these three features of walking (p. 178). The same impression arises in this current research. Of interest are two questions:

1. Does the stop frequency represent a suitable measure to investigate the experience of walking?
2. How exact do averages of step frequencies[20] reflect averages of walking speeds?

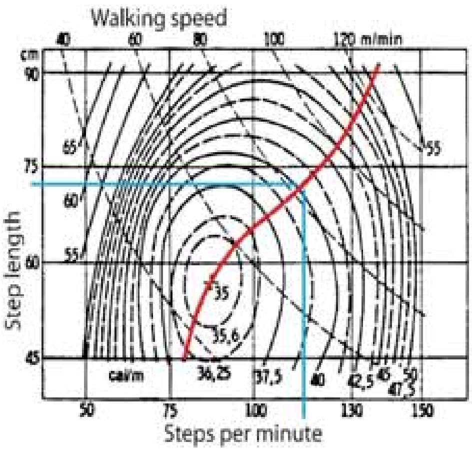
The following text focuses on the first question. Psychologists and physicians are interested in step length and frequency, as those measures describe in more detail walking behaviour. They conduct studies predominantly in experimental settings. Zatsiorky at al. (1994) describe the relationship between step length and frequency as a pattern of walking. Pedestrians choose a walking pattern to optimise body

[20] Step length and frequency results in the distance and time between two heel strikes. Researchers use two different methods to derive step length and frequency: Firstly, they measure distance and time between the heel strike of the right foot and the next heel strike of the left foot; secondly, investigators measure distance and time between two successive heel strikes from the same foot. The first method results in a doubled frequency and halved step length in comparison to the first method. I will adjust all presented results to the step length and frequency that results from both feet (first method). Some authors even mix measuring methods for frequency and distance without clearly pointing out the difference.

stability or to prevent the feet from slipping at the heel strike (pp. 117–118). On a slippery walking surface, people prefer shorter steps combined with higher frequency. Walking patterns under real-world conditions probably depend on many more factors, as walking speeds equally do.

Zatsiorky et al. (1994) find, not surprisingly, that a short-legged pedestrian increases the step frequency to retain the same walking speed as people with longer legs (p. 112). Leg length influences the energetic effort to walk at a specific speed. Weidmann (1993) reports that the energy consumption of walking results from raising/lowering and acceleration/deceleration of the body mass with each step. Pedestrians choose intuitively the step frequency that minimises the energy consumption and maximises comfort. Not the step length, but the frequency, is the main factor for the energy consumption of walking (p. 21).

Figure 26: Relationship between walking speed (metres per minute), step length (centimetre), step frequency (steps per minute), and energy consumption (calories per minute), presented by Weidmann (1993, p. 22) according to Rohmert and Rutefranz (1983)



Weidmann finds average step frequencies alter between 108 and 120 steps per minute (p. 19) and a minimum energy consumption of walking at a speed of 83.4 metres per minute (p. 22). He presents a diagram from Rohmert and Rutefranz (1983), as Figure 26 shows. According to Rohmert and Rutefranz, a walking speed of 83.4 metres per minute is most energy efficient with step frequencies slightly below 120 steps per minute and a step length of between 70 and 75 centimetres (blue lines in Figure 26). Holt et al. (1995) find the most effective step frequency at 110.4 steps per minute (p. 172)[21].

The most effective step frequencies for fast walking generally range from between 100 and 118 to 120 steps per minute. The frequency emerges as a better indicator for the experience of walking than walking speeds. Firstly, step frequencies indicate the energy consumption of walking better than walking speeds. Secondly,

[21] This frequency also minimizes head movements, and Egerton et al. consider the step frequency as a compromise between head stability and energy consumption.

the frequency filters out the effect of leg length. Thirdly, the frequency allows real-time speed variations to be investigated.

The second question remains. Can averages of step frequencies serve as indicators for average walking speeds? Or, does the variation of the step length disable a linear relationship between speed and frequency? Egerton et al. (2011) conduct an experiment with 63 healthy participants[22]. When people choose their own preferred combination of step length and frequency, the relationship between step length and frequency remains linear for 84 percent of participants[23] (pp. 180–182). Variations between age groups are insignificant (p. 181). The study of Danion et al. (2003) shows comparable findings. Frequency and speed increase in parallel with a low variation of three percent (p. 76).

Weidmann (1993) also finds a parallel increase of step length, frequency, and speed. When the leg length limits to increase the step length, raising the frequency remains the only option to walk faster (p. 18). Hence, the step frequency can serve as an indicator for the walking speed, but with some limitations for higher speeds. At what speed the relationship between step length and frequency starts to vary depends on leg length but remains unclear. Weidmann considers shoes to influence the frequency (p. 16). High heels, for example, are likely to reduce the step length, which may result in higher frequencies. Clothes and the walking surface can have an effect. The influence of such factors remains equally unclear so far.

The search for relevant literature uncovers only one study that investigated the relation between walking speed, step frequency and step length under real-world conditions. Molen et al. (1972) observe 533 pedestrians at three locations:

1. Lane though a park
2. Passage underneath a museum
3. Pavement of a thoroughfare

[22] Egerton et al. divided participants into three age groups. The average body size, weight and leg length remained constant between age groups. The authors controlled for variations of the leg length (that caused differing step lengths) by dividing the step length of participants by the leg length.
[23] when controlled for variations of the leg length

The authors describe the park as pleasant and the other two locations as a dull walking environment (p. 216). The researchers measure the time pedestrians need to walk a fixed distance and count the number of steps. From this data, they derive the walking speed, the step frequency and length. They also collect data on gender, estimated age and body size. The study comprises only single walkers and seemingly healthy pedestrians. Investigators exclude strollers. Observations take place during daytime but not during the morning and evening rush hour.

Results (pp. 217–220):

1. Daytime does not affect the relationship between step length, frequency, and walking speed
2. Males walk on average at 83.4 metres per minute and female pedestrians walk on average 76.1 metres per minute.
3. Increasing body size increases step length
4. With increasing speed, the ratio between step length and frequency remains stable
5. Age does not affect the ratio between step length and frequency
6. The ratio between step length and frequency differs significantly (p value < 0.000) between male and female pedestrians. Woman can reach the same speed as men with a combination of higher step frequency and shorter steps (average ratio for male: 0.72 (n=309) and for female pedestrians 0.60 (n=224)).
7. Walking speeds and patterns vary with environmental characteristics. In the dull walking environments, speed, frequency, and step length of male and female pedestrians exceed the measures taken in the park environment.

Table 3: Characteristics of gait of observed pedestrians, classified according to the criterion location, as found by different authors (Molen et al. 1972, p. 221)

Authors	Location	No. of subjects	Step frequency (st/min)	Mean velocity (m/min)	Mean step length (cm)
Finley and Cody (1970)	Shopping centre	112 ♂ 168 ♀	113.5	74.2	65.5
	Small commercial area	113 ♂ 167 ♀	113.4	76.1	66.8
	Residential area	147 ♂ 119 ♀	112.8	79.3	70.1
	Business area	162 ♂ 118 ♀	114.3	81.9	71.8
	Men (total)	534	110.5	82.1	74.1
	Women (total)	572	116.5	74.0	63.4
Molen (1964) (A+B)	Covered passage and sidewalk of thoroughfare	147 ♂ 93 ♀	113.1 122.8	92.1 86.8	81.4 70.8
Rozendal (1968) (C)	Lane in park	162 ♂ 131 ♀	102.2 106.6	75.6 68.6	73.7 64.5

The authors present and compare their own data with data from another study, conducted by Finley and Cody (1970). Table 3 presents these results[24]. Results in Table 3 show that differentiating between male and female pedestrians uncovers different walking speeds in dissimilar environments. Finley and Cody did not

Table 4: Relationship between the dimensions of walking (Molen et al. 1972, p. 221)

	Male			Female		
Average speed (metres/min)	Step frequency (steps/min)	Ratio step length/frequency	Number of subjects	Step frequency (steps/min)	Ratio step length/frequency	Number of observations
70-80	103,1	0,71	80	111,3	0,61	62
80-90	107,5	0,74	75	122,9	0,57	49
90-100	114,2	0,73	62	126,7	0,59	28
100-110	123,2	0,72	35	132,6	0,58	9

24 In the table presented by Molen et al., step frequency represents the time interval between the heel strike of the left and the right foot.

Figure 27: Relationship between step frequency and walking speed according to Molen et al. (1972)

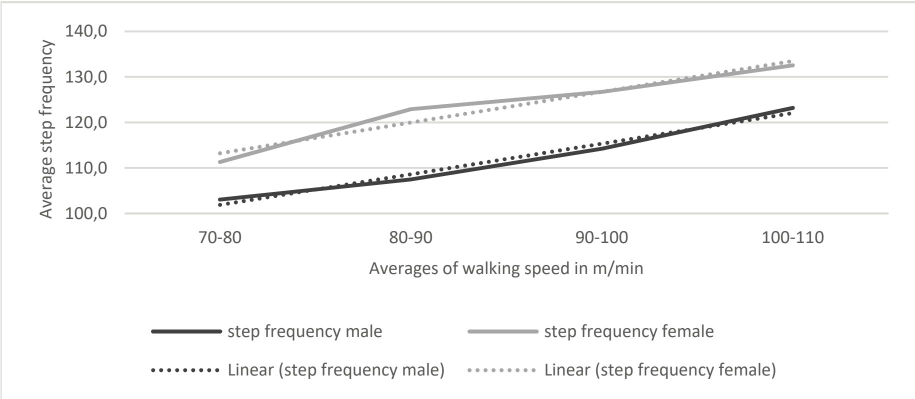
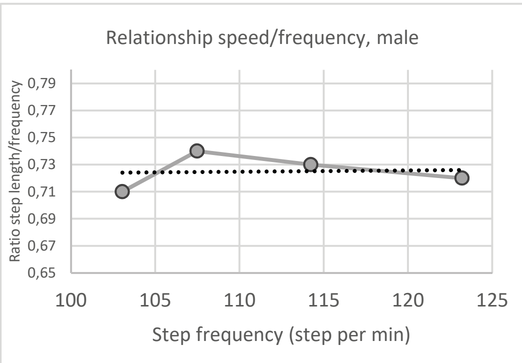
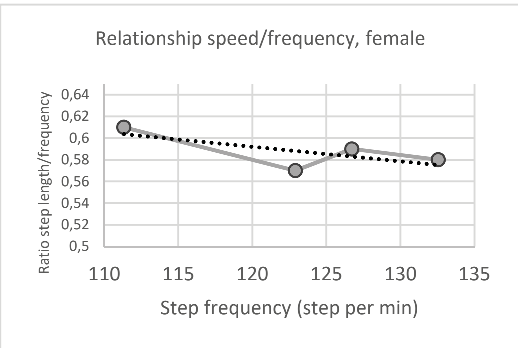


Figure 28: Relationship between ratio step length/frequency and step frequency for male and female pedestrians according to the data of Molen et al. (1972)





distinguish between male and female pedestrians. Molen et al. consider the lacking differentiation to blur the results, and the environmental difference becomes invisible (Table 3).

Table 4 presents the ratio step *length/frequency* for different walking speeds according to the data of Molen et al. Figure 27 represents graphically the data from Table 4 and shows again the nearly linear relationship between step frequency and walking speed for women and man. Variations do not exceed three steps per minute, equalling a speed difference of about five metres per minute.

The decreasing ratio clearly reflects that woman have to increase the step frequency at higher walking speeds as woman's shorter legs limit their ability to increase the step length at higher walking speeds.

We can conclude that the step frequency serves well as a substitute for walking speed and appears even more suitable for investigating the subjective walking experience. Averages of step frequencies reflect averages of walking speeds with some limitations for higher walking speeds. Against the background of the text in the first part of this subchapter, step frequencies enable the investigation of reactions to environmental characteristics. The metronome method would even allow speed variations to be uncovered at the second they occur.

3.2.1 Investigating sensed time pressure by observing steps

Altering walking speeds close to the stop can indicate sensed time pressure. An uncomfortably high walking speed before the slowdown derives from a high sense of haste. Step frequencies allow us to investigate whether pedestrians sense time pressure on the basis of some simple assumptions.

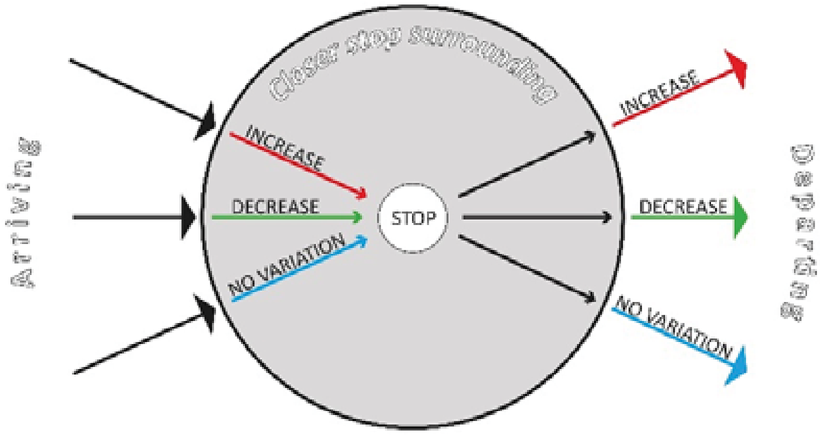
Lam and J. F. Morrall (1982) observe that approaching pedestrians decrease their walking speed when the public transport stop comes in sight (p. 410). When getting close to stops, pedestrians are able to board any vehicle at the stop after a few fast steps. People seem to relax when the stop comes within close reach. Walking speeds and alterations of walking speeds can possibly indicate whether pedestrians approach stops under time pressure.

As we have seen in the previous section, step frequencies indicate walking speeds. The energy efficiency of walking drops with step frequencies over 118 steps per minute. Averages of frequencies over 118 steps per minute likely indicate sensed time pressure. This might not be the case for one single person. However, when the average frequencies of, for example, all approaching pedestrians exceed 118 steps per minute, many pedestrians in this group walk uncomfortably fast, probably due to time pressure. Hence, the height of the step frequency, together with its alteration close to public transport stops, can indicate time pressure.

We can, therefore, investigate whether pedestrians, who walk towards or away from public transport stops, sense time pressure on the basis of four simple assumptions:

1. A sudden increase in the step frequency indicates a rise in time pressure
2. A rapid decrease in the frequency indicates a decline in time pressure
3. Unvaried step frequencies indicate no change in sensed time pressure

Figure 29: Step frequency variations for approaching pedestrians that arrive at the stop and pedestrians that depart the stop. Frequency variations occur when pedestrians enter or depart the closer stop surroundings



4. Unvaried high average frequencies over 118 steps per minute indicate higher time pressure than lower frequencies

The third and fourth assumptions are linked. If pedestrian's steps remains unchanged at high frequencies, they may well experience time pressure. On the basis of the four formulated assumptions, Figure 29 defines three conditions for pedestrians approaching the stop and three for those that depart. Frequencies can rise, drop, or remain unchanged when entering or departing the closer stop surroundings. The two step frequency measures around public transport stops, as explained in the previous subchapter, allow us to investigate the sensed time pressure of observed pedestrians around public transport stops.

Does the step frequency of pedestrians vary for other reasons? Of course; Section 2.1 describes numerous reasons for frequency alterations. However, these adjustments of steps are optional and are unlikely to occur when pedestrians are in haste. Risking missing the bus at the stop, as a trade-off for a shop window inspection, does not appear very reasonable. Another reason for speed decline can be exhaustion. Again, such may occur rather as a gradual reduction and not as sudden drop in the walking speed close to the stop. For the specific condition of walking trips to public transport stops, sudden step frequency variations most likely indicate an alteration in sensed time pressure. Lower haste provides more freedom for optional speed variations.

3.3 Walking and the environment – stimulation, emotions, and the experience of time and distance

Walther (1973) reminds us that the subjective experience, of a) walking and b) riding on the means of public transport, can differ but remains interlinked. (p. 58). He cites the study of Handke (1970). He found that with increasing walking distances to underground stops in Berlin, fewer public transport users consider the means of transport as 'fast'. The length of walking trips to stops influences the impression of the overall travel speed. The impression of the travel speed derives from all trip legs of a public transport journey, independent of the distance travelled.

The meta study of Wardman (2001) covers literature that investigated differences in time experiences of walking, waiting, changing and riding on the means of public transport. The author finds public transport users experience the time spent walking as being twice as long as the time spent riding on public transport vehicles (p. 42). Wardman considers the experience of time spent walking to vary strongly with the local environment, weather, and daytime (p. 4). To account for this unequal time experience, Walther multiplied time spent walking with the factor 1.75. As result, in his study, the perceived time for walking increases to 47.5 percent of the total travel time from door to door (p. 61).

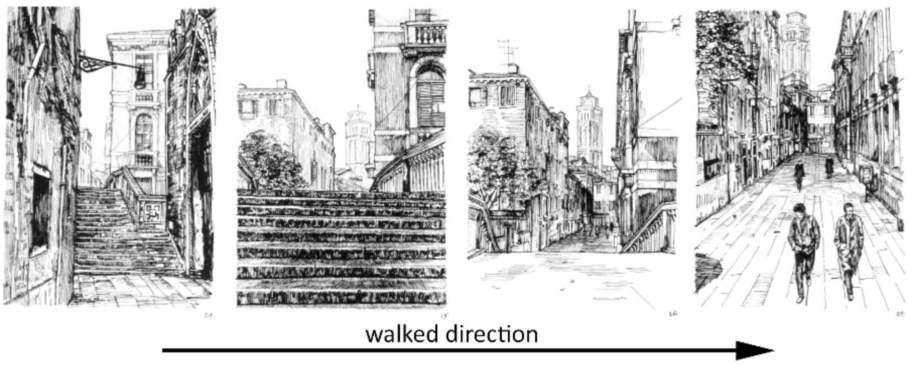
The studies of Wardman and Walther indicate that the sensory experience of travelling influences the perception of time and distance. However, their research does not explain the observed phenomenon. Travelling inside a comfortable public transport vehicle, without any physical effort, may appear pleasant. Walking and waiting outside is likely to be uncomfortable without weather protection and in noisy streets that require frequent attention. The sensory experience of walking and the subjective perception of time and travel distance are likely to influence how far pedestrians are willing to walk.

Gehl Architects APS (2009) consider that characteristics of the walking environment influence the subjective experience of walked distances (p. 13). Bosselmann (1998) describes his subjective experience of time and distance during 14 walks, each of which lasts four minutes and is approximately 350 metres long (pp. 62–91). The environment of the 14 walks varies, as the examples in Figure 30 illustrate. The subjective experience of walked distance and time seems to change with environmental characteristics. This effect surprises Bosselmann (p. 90).

Figure 30: Maps of Bosselmann's walk in Venice (left), Piazza Navona in Rome (centre), Stanfort Shopping Center in Palo Alto (right) (Bosselmann 1998, pp. 53–89)

According to his descriptions, the 14 walking routes alter in complexity and visual stimuli. Thirty-nine drawings are necessary to describe the visual experience of the walk in Venice (Figure 31). In all other environments, fewer pictures are sufficient to reflect the impression of the walked path (pp. 53–60). Bosselmann remembers the stimulating walk in Venice as long (p. 61). In contrast, there was little of interest to report from a walk over a car park in front of the *Stanfort Shopping Centre*. Here, pedestrians "*might not get very far at all*" comments Bosselmann (p. 88). His descriptions refer alternately to time and distance. Sometimes even the dimension to which he is referring remains unclear. Time and space appear as an interrelated impression that is difficult to detangle.

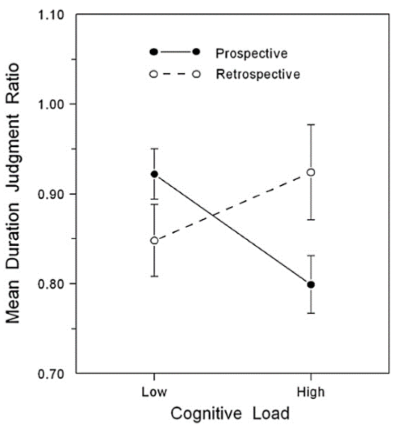
Figure 31: Successive impressions from Bosselmann's walk in Venice, from Bosselmann (1998, p. 57)



The observations of Bosselmann show that the subjective experience of duration can vary. A watch does not necessarily reflect the individual impression of time. When walking, fast-passing time corresponds with the impression of fast progress in getting from A to B. The apparent distance seems to shrink.

Psychologists have examined the experience of time since the first half of the 20th century through experiments. This literature explains some of Bosselmann's impressions, although the experiments of psychologists are not always comparable with the real-world conditions of walking in cities. The perception of time alters with the amount and complexity of sensory stimulation that our minds need to process[25], explains Ornstein (1977, pp. 106–108). A more recent meta study by Block et al. (2010) differentiates between

Figure 32: Mean duration judgment ratio for prospective and retrospective experience of time as function of the level of stimulation (cognitive load) Block et al. (2010, p. 336)



1. the perception of time while it is passing, as the *prospective* experience of time, and
2. the remembered duration of a passed moment, as the *retrospective* experience of time.

Prospective and retrospective time experiences appear to result in contradicting time evaluations (Figure 32):

1. prospective time experience:
   a. **high stimulation → shorter**
   b. *low stimulation → longer*

2. retrospective, remembered duration:
   a. **high stimulation →** *longer*
   b. *low stimulation* **→ shorter**

The difference between prospective and retrospective experience is important for walking. The prospective experience of time appears relevant for the perceived walking speed while walking. This time experience directly influences the experience of walking. How we remember the duration of a walk, the retrospective

[25] Ornstein refers to the amount and complexity of our mental stimulation as the amount of cognitive load (1977, pp. 106–108). Two factors determine the cognitive load our mind has to process: firstly, external information and stimulation that our body experiences through sense organs, and secondly, the complexity of mental processing when we act on or react to external stimulation.

time experience, can influence our choice of whether to walk again. According to the results of Block et al., walking trips in stimulating environments appear prospectively as shorter, but we remember the walked duration as longer. Figure 32 illustrates this contradiction.

What appears as contradiction still contains a logic. The impression of fast walking (in highly stimulating environments) can be likely to lengthen the memory of the apparent distance walked. When time runs fast while walking, the remembered starting point of the trip must appear further away, in dimension, distance and time. This relationship between speed and distance also reflects Bosselmann's descriptions of walking. The walks in Venice and in front of the Stanfort Shopping Centre equally lasted four minutes. In Venice, many direction changes and multiple different visual impressions generate a memory of a long distance walked. In contrast, Bosselmann remembered the distance walked in front of the shopping centre as short. As a logical consequence, the walking speed must have appeared fast in Venice but slow in front of the shopping centre. The walking speed reflects the prospective impression of time, while Bosselmann was walking. The above presented illustration from Block et al. (Figure 32) indicates that the prospective time experience drops by about 15 percent from low to high stimulation.

It is unlikely that pedestrians remember a walk solely as a temporal duration or distance. The memory of a walk must appear more holistically, influenced by emotions that rise during walking. Emotions can be pleasant or unpleasant. Similarly to stimulation, the emotional experience of walking influences the subjective experience of the time and distance walked.

Harton (1939) finds that the pleasant emotion of success shortens the remembered estimation of duration. He asks participants to solve a maze in a given time. Positive emotions associated with success result in shorter duration estimates (p.

Table 5: Difference between objective and subjective duration estimates (seconds), and difference between estimates for success or failure in solving the maze, according to Harton 1939, p. 60)

Objective duration		Subjective duration				
Objective duration in seconds	%	Duration estimate success	Variation objective time	Duration estimate failure	Variation objective time	% variation of time estimate between failure (100%) and success
210	100 %	188	-10,5 %	222	5,7 %	-15,3 %
165	100 %	154	-6,7 %	180	9,1 %	-14,4 %
255	100 %	210	-17,6 %	245	-3,9 %	-14,3 %

61)[26], Table 5 present the results of the study. The temporal periods in Harton's experiments fit well to the duration of a short urban walk of between 2 and 4.5 minutes.

Bosselmann did not report on the emotional experience of his 14 walks in different environments. The reader might guess for himself. Would the walk across the large car park in front of the shopping centre be more pleasurable than walking in Venice? Guessing that the walk in Venice appeared more pleasant is not far-fetched. Berlyne (1971) explains that (1) the level of stimulation and (2) the emotional impression that derives from stimuli together influence the perception of time. Pleasant events mostly increase attention (p. 81). Higher attention increases sensory stimulation. Accordingly, pleasant experiences shorten the perception of passing time. Stimulation can also rise to unpleasant levels, resulting in stress (pp. 86–95). Middleton (2010) notes that urban environments can provide too much stimuli; such surroundings are unpleasant, and people 'shut down' their senses (pp. 584–585).

Schirmer (2011) discusses how fear and sensed insecurity increase attention (p. 4). Intensive but unpleasant stimuli are likely to lengthen the subjective time impression. Levine (1997) points to an example: for a parent with an injured child, the trip to the hospital appears endless (p. 39). In Levine's example, the pain of one's own child increases worries and fears that are likely to increase attention. Such a high level of attention combined with an unpleasant emotion stretches time.

We can summarise four points that are relevant for the subjective perception of passing time:

1. The amount of stimulation; high stimulation shortens time
2. The pleasantness of stimulation; pleasant stimulation shortens time
3. Too low stimulation is boring and lengthens time
4. Too high stimulation is unpleasant and lengthens time

Maderthaner (2008) presents the *circumplex model of emotions* (p. 299), as Figure 34 illustrates[27]. The model shows an interesting analogy to the relevant factors for the

[26]Harton understands our minds as storing positive memories in a better-ordered manner than negative ones. Positive memories occupy less "storage space", resulting in a shortened memory of duration.

[27] Russell et al. (1989) showed that the model proved valid in cross-cultural tests (p. 849).

Figure 34: Circumplex model of emotions according to Maderthaner (2008, p. 299) and Russell et al. (1989, p. 849)

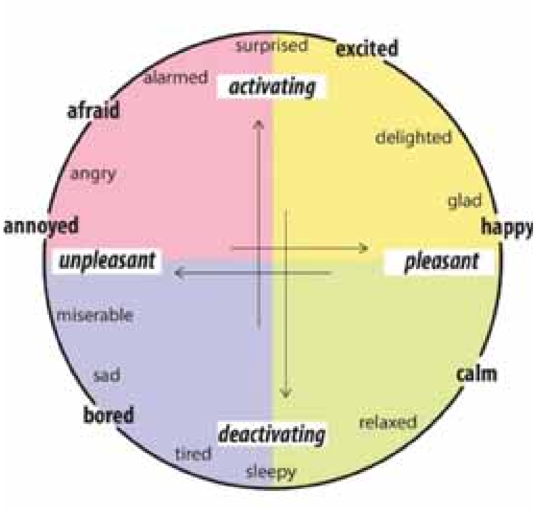
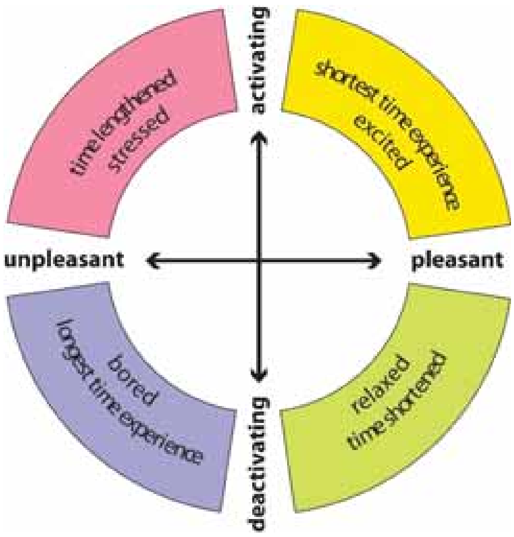


Figure 33: Circumplex model of pedestrians' time experience



experience of time. The circumplex model structures emotions with help of the two dimensions:

1. ***Activation***[28] - defining the amount of stimulation

2. ***Pleasantness*** - describing the emotional experience of stimuli

Emotions can be activating (alarmed, excited) or deactivating (relaxed, bored). At the same time, emotions can be pleasant (excited, relaxed) or unpleasant (alarmed, bored). These four mental states do not just differentiate emotions in general. They also serve well to differentiate the experience of walking.

The circumplex model of emotions structures emotions with the same dimensions that are relevant for the time experience. The four emotional conditions defined by the circumplex model (excitement, relaxation, boredom, and stress) include a temporal component. Stress is characterised by too little time and boredom by too much time. Both conditions are unpleasant. Relaxation typifies a welcome amount of available

[28] Russell et al. (1989) also refer to *activation* as the *level of arousal*. I found Maderthaner's (2008, p. 300) German expression *Aktivierung* more suitable for the context in this chapter and translated the German expression *Aktivierung* with the English word *activation*.

time. Excitement may be characterised by a lost sense of time, resulting in time gaps. Excitement describes a pleasant emotion. The link between emotions and time allows the transfer of the circumplex model of emotions to a *circumplex model of pedestrians' time experience*, as Figure 33 displays. The equivalence of the relevant dimensions in both models uncovers a theoretical relationship between the perception of time spent walking and the emotional walking experience. The previously described literature on the experience of time supports the *circumplex model of time experience.*

The emotional and temporal experience is highly relevant for walking. Especially under time pressure, the perception of a fast walking speed is welcome and can lower sensed haste. The impression of speed rises when time appears to run faster. High and pleasant stimulation accelerates the (prospective) time experience, and pedestrians perceive getting from A to B fast. The perception of quick access is pleasant when intending to get from A to B. This experience results later in a positive memory of walking. The way in which walking is recalled influences the future choice to walk again.

The so-far somewhat theoretical link between time experience and emotions raises two important questions for an empirical investigation: firstly, which environments do pedestrians experience as pleasant? Section 4.2 presents a survey method to question how environments influence the pleasantness of walking to public transport. Secondly, do changing environmental characteristics result in a variation of pedestrians' visual stimulation? Answering the second question appears more complex. How can we measure the amount of stimulation that pedestrians receive from their environment? The following section provides a background to answering the second question.

3.4 Measuring the amount of visual stimulation pedestrians receive from walking environments

How can we investigate the amount of sensory stimuli that pedestrians receive from their surroundings? Maderthaner (2008) explains that the human sense organs establish a link between our mind and the surrounding reality (p. 133). Five different sense organs supply information. We can see, hear, receive haptic stimuli, and we can smell and taste. Whyte (1988) observes pedestrians and describes their reactions to received stimuli in a busy urban street (pp. 79–102). Shop windows, special price offers, displays, living displays and shows, activities (p. 85), possibilities to touch goods (p. 100), light effects, sound, noises (p. 86), and so on can draw pedestrians' attention.

However, the human brain receives unequal amounts of information from the five sense organs. Maderthaner (2008) considers 80 percent of the total sensory information to be visual (p. 133). Accordingly, the visual walking environment substantially influences the amount of stimuli pedestrians receive from urban surroundings.

Gibson (1982) explains the process of visual perception during movement. While walking in the direction of the visual field, objects constantly transform in a flowing movement from the centre to the sides of our visual field (pp. 222–223). Appleyard et al. (1964) consider the experience of velocity to rest on the apparent movement of visible objects[29]. We interpret our motion in relationship to the enclosing urban form, as they explain (p. 8). Appleyard et al. consider the experience of space to depend on the speed of a movement (p. 12). The faster we move, the fewer details we see. When driving a car, speed limits visual information on the surroundings. Slower walking speeds result in a detailed sensory experience of the environment, dominated by visual information.

How do pedestrians gain a visual impression from their surroundings? Gibson (1982) describes our body as a hierarchical system that steers what we can see. Eyes can move and sit inside the head. The head can turn independently from eyes, and rests on the body. The body can bend and is carried by legs, which stand on the ground (p. 221). Legs enable us to experience the environment through locomotion. The head determines the direction of the visual field by turning. Our eyes focus on the detectable details within our visual field through eye movements (p. 235). Body, head and eyes move together dependent on the visual environment.

Our visual field spans over 180 degree to the sides and 140 degrees in an up/down direction, explains Gibson. The centre of our visual field is in focus but more blurred to the edges (p. 222). What eyes can see is neither microscopically small nor an endless galaxy (p. 9,10). Head turns let the visual field 'sweep' over the visual surroundings, tilting of the head results in a 'rolling' of the visual field. Head movements result in a vanishing and reappearing of objects in the visual field (p. 127). Our mind assembles this visual information as a collage of overlapping images into a panoramic picture, as described by Gibson (1950, pp. 157–158) in an earlier publication.

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[29] Obviously, gravitational forces that occur with acceleration and deceleration also inform our brain on movement. For relatively low speeds of pedestrians, these gravitational forces remain low and certainly less relevant for the sensory experience of movement.

The collection of visual information requires and results in frequent eye and head movements (Gibson 1982, p. 221)[30]. Long fixations on one point are a rarity in daily life and indicate rather that we are lost in our thoughts. In such moments, we do not see what we look at (p. 228). The centre of clear vision can change 100 times per minute, uncovers Gibson (1950, p. 155). In complex situations, which require extra attention, the rate of visual fixations may even increase.

Hass-Klau et al. (1999) investigate 'streets as living space'. She finds 'things to look at' as an important feature of an attractive urban environment (p. 128). For Jacobs (1993), an attractive street provides visual stimuli and results in many head movements (p. 282). In his understanding, the visual stimuli of the walking environment trigger head movements.

Gehl et al. (2004) study the effect of building façades on pedestrians' head movements. While walking along visually stimulating buildings, 75 percent turn their face towards the façade. Only 21 percent look at large-scale, monotonous and closed façades (p. 9). The amount of stimuli a façade provides determines how often pedestrians look at it. These results may not appear surprising. Why should pedestrians turn their head when there is nothing to see? However, the investigation shows that the amount of visual stimuli varies with environmental characteristics.

The presented literature indicates that head movements reflect the amount of visual stimuli that pedestrians receive from the walking environment. This answers the last question asked in the former subchapter. Counting head movements seems to provide a measure for the amount of visual stimulation that pedestrians receive from the environment they walk through. Head movements do not measure stimuli from non-visual sense organs, but they seem to provide a good approximation for the total stimulation.

3.4.1 Looking down to the pavement – turning away from visual stimuli

Apart from head movements, initial observations found another behavioural pattern that indicates the environmental influence on visual stimulation. While

[30] Whether a relationship exists between eye and head movements remains unclear in Gibson's text. The scale of the pedestrian environment may affect the ratio between head and eye movements. In large-scale environments, visual objects are further away. Hence, the visual field covers more visual stimuli, though less detailed. As visual objects are further away, more objects become visible. Such environments may result in fewer head movements while the rate of eye movements can remain stable or increase.

walking, people look down to a point on the walking surface three to five metres in front of them. Pedestrians look down more or less recurrently and for shorter or longer periods. Middelton's previously described *autopilot modus* of walking (Middleton 2010, p. 583) can explain why pedestrians tilt their head downwards while walking. While looking down, pedestrians turn away from their visual environment. With minimal visual effort, they ensure a clear path ahead. Pedestrians may not just detach themselves from their visible environment due to a sensory overload. Looking down can indicate that people do not desire to look at something, or there is nothing to look at. In environments with little stimulation, engaging with one's own thoughts becomes a strategy to overcome unpleasant boredom.

Negatively perceived stimulation may result in looking down. The strategy still exposes pedestrians to traffic emissions such as noises and smells. Not having to look at these sources of unpleasant stimuli may, nevertheless, improve the walking experience. Tilting the head down represents a reaction to an unpleasant emotion, triggered by the pedestrian environment.

Similarly to head movements, the time pedestrians look down appears quantifiable. As looking down has not been investigated, the extent of the observed phenomenon remains unknown. Do pedestrians look down for longer periods in less stimulating environments? Would such an investigation also enable us to interpret which stimuli pedestrians perceive as negative?

Figure 35: Pedestrians look down while walking, especially in boring and noisy environments

3.4.2 *Doing things while walking – increasing stimulation*

Figure 36: Eating while walking on Strøget in Copenhagen

The ability to perform additional activities while moving constitutes an important characteristic of walking. Pedestrians perform very different activities. Block et al. (2010) find that performing tasks increases stimulation and shortens the subjective time experience. The more complex such activities are, the stronger the effect (pp. 330–331)[31]. Simple straight-ahead navigation at four kilometres per hour leaves room for a wealth of physical and mental capabilities, especially in boring environments. Here, performing activities appears as a welcome entertainment. Focusing on something else also allows us to turn away from negative perceived stimuli.

Initial investigations showed that pedestrians do many things. This aspect of walking has found little attention in the literature so far. People rummage in bags, purses, or in jacket pockets. They sort their clothes while walking. People eat: sometimes just an apple, others even manage to eat burgers or fork in pots containing fast food. Such can almost appear as artistic performances while walking and require many to walk slower. Pedestrians smoke, women put on lipstick and manage their make up in portable mirrors. People count money, look

[31] The study of Block et al. (2010, pp. 330–331) showed that subjective time shortens with the following conditions:
when we are required to respond to stimulation,
when we have to attend and decide between different sources of stimulation,
when we are engaged in complex tasks.
Levine considers that activities, which engage "right-hemisphere modes of thinking" (R-mode), also subjectively shorten sensed time (Levine (1997, pp. 46–47). He refers to the work of Roger Sperry, who found differences between the left and right hemisphere of the human brain. R-mode of thinking is non-verbal, intuitive, subjective, relational, holistic, and time free. In contrast, the left hemisphere operates the verbal, analytical and rational, and is best at counting, planning and marking time. I consider an intense visual experience of an environment to be an R-mode activity. However, instead of stretching time, R-modes of thinking result in a time-free experience, or even in a sensed time warp.

at their watches, fiddle with sunglasses or sort their hair. Not all activities have an entertaining character, but many do.

Smart phones are attractive gadgets and enable a range of activities while walking. Pedestrians even manage to type text or perform other actions that require focusing on phone screens for extended periods. Smart phones have become the 'car radios' for pedestrians. Whenever walking becomes boring, the phone offers entertainment that certainly enhances and shortens the walking experience.

The ability to perform an activity while walking may depend on the complexity of the path ahead. If navigation requires full attention, the surplus of pedestrians' capabilities may decrease. Street crossings and walking along busy pavements may require full attention. Complex walking environments may hence decrease the number of pedestrians that keep themselves busy with something else. Conditions that require pedestrians' attention do not suit the previously discussed characteristics of walking and can be inconvenient for pedestrians. Not having the freedom to make a phone call, sort out bags, listen to music, and so on, is likely to reduce the pleasantness of walking. Further, familiar environments along frequently used walking routes may influence the ability and motivation for further entertainment while walking. The performance of activities on the way may represent an interesting indicator for the pleasantness of the walking environment and, equally, for its visual attractiveness.

3.5 Research questions - part two

Having explained the possibilities of step frequency investigations and how urban environments influence the subjective experience of walking distances and emotions, we can define further questions for the empirical investigation.

1) **Investigating bodily reactions to walking environments**

   The literature presented in this chapter demonstrates a relationship between walking environments and pedestrian behaviour. Step frequencies are an important feature of behaviour while walking. The literature underpins the idea that frequencies might reflect emotions that derive from walking environments. Step frequency investigations can hence establish a relationship between the experience of walking and the urban environment around public transport stops. Do pedestrians react to environmental characteristics along walking routes to public transport stops? Do frequencies indicate reactions to inconveniences such as street crossings or detours?

2) Difference between walking to approach stops and walking to depart

Walking takes place at both ends of the public transport ride, but the difference between both walking trips remains so far unstudied. When walking to catch a means of public transport, travellers are likely to experience time pressure. It is probable that the walking experience changes when departing from stops. Section 3.2.1 in this chapter explains how step frequencies reflect time pressure. How many approaching pedestrians experience time pressure as compared to departing ones? Do approaching pedestrians behave differently from those who depart? Do approaching and departing pedestrians react differently to walking environments?

3) The influence of walking environments on walked distances

The discussed literature in Section 2.8 showed how urban environments influence walking distances to stops. Section 3.3 in this chapter explains how the (1) amount and (2) pleasantness of stimuli that pedestrians receive from walking environments is likely to influence the perception of walking distances. Section 3.4 develops a basis to investigate pedestrians' stimulation. On the basis of the literature in this chapter, we can formulate two questions for the empirical enquiry: Firstly, how do different walking environments influence the level of pedestrians' visual stimulation? Secondly, how do pedestrians evaluate the stimuli that they receive from walking environments? The next chapter presents an interview method to investigate the reported pleasantness of stimuli from different walking environments.

4) The emotional perception of the walking environment

On the basis of the *circumplex model of emotions* (Section 3.3), the inquiry into stimulation and pleasantness also allows us to determine how walking environments influence the emotional experience of walking. To understand the environmental effect on pedestrians' emotions, we need to investigate two questions: Do walking environments influence pedestrians' stimulation? Do some kinds of stimuli appear more pleasant than others? Both questions are equally relevant for the subjective experience of time spent walking. Section 4.4 describes the procedure to investigate whether and how urban environments influence pedestrians' emotions.

4 METHODOLOGY FOR THE EMPIRICAL INVESTIGATION

This chapter describes the methodologies for empirical investigation of the questions posed at the end of Chapters 2 and 3. The text focuses first on the advantages and shortcomings of applied research methods to investigate the relationship between walking and urban environments, illustrated by examples. The first section identifies difficulties, which the investigative methodologies in the following sections seek to circumnavigate as well as possible.

4.1 Applied methods to study the relationship between walking and urban environments

Numerous researchers from the fields of health, urban transport and planning have investigated the effect of the urban environment on physical activity and walking. Scientists apply very different methodologies. Two meta studies of Ewing and Cervero (2001, 2010) summarise the development of one specific methodological approach between 2001 and 2010. The applied methods compare the character of urban neighbourhoods with, for example, residents' mode choice for urban journeys or the time spent walking. Researchers apply a number of procedures to quantify walking or travel behaviour. Interviews are most commonly used. Comparing behaviour and environment further requires characterising the neighbourhoods in which people live and act.

Several tools are available to establish data on the physical appearance of urban neighbourhoods (Saelens 2002, Millington et al. 2009, Carr et al. 2010, Belohlavek et al. 2011). For statistical investigations, environmental characteristics need to be quantified. Geographic information systems can facilitate data collection, or data is readily available. Researchers also register environmental features also, for example by site visits. Satellite photos, maps and other aids support registrations.

The meta study of Ewing and Cervero (2010) comprises publications that quantify environmental characteristics such as land used density and diversity, the number of street intersections, the total length of available pavements and footpaths, retail floor area ratio, street block size, distances to public transport stops or shops and service facilities, and other factors (pp. 282–294). Academics use statistical multiple regression analyses to separate the influence of environmental characteristics (as independent variables) on travel choices or the amount of walking (as dependent variable) (pp. 270–271).

The described methodological procedure allows one theoretically to identify the influence of the environment on walking or travel choices. Statistical analyses are expected to show, for example, the influence of land use diversity on the number of minutes that residents walk per day. Unfortunately, the approach appears less promising in practice than in theory. Ewing and Cervero admitted that single environmental features explain only a small proportion of behaviour variations in the publications the authors investigated (p. 265). Many environmental variables remain insignificant for travel choices and walking.

The previously presented study of Maghelal (2009) shows an example of the difficulties of the described research approach. The author investigates catchment areas around 20 public transport stops. Results revealed that higher land-use densities surprisingly reduced the percentage of people who walked to public transport (p. 61). Other environmental characteristics had no effect. One problem of statistics is that the mathematical procedure cannot explain the results. The researcher can only guess at the reasons behind the numerical outcome. Better explanations require a detailed investigation of the urban quarters around light rail stops and possibly of the societies that reside in these areas. The 20 investigated catchment areas extend over more than 20 square kilometres. A closer focus on urban areas of such dimension appears difficult.

What are the challenges of the described research approach? First, Mees (2009) considers methods to establish the amount of walking within an urban area as critical. He finds asking people how often and how long they walk to involve a moral aspect. Such enquiries expose interviewees' fitness as well as their attitudes towards environmental questions. Therefore, the enquiry guarantees incorrect results. With positive attitudes towards walking, physical activity and environmental questions, interviewees wish to support the enquiry by giving 'the right answers', is a criticism levied by Mees (pp. 185–186). As a result, the collected data insufficiently reflects the reality. This problem may vary with the design of questionnaires and the context for interviews.

Second, researchers use spatial data to characterise whole urban neighbourhoods. This procedure can only describe urban areas as homogenous environmental settings – which is unlikely to be the case. From a pedestrian perspective, urban quarters seldom appear as a homogenous structure. Diverse walking routes within urban neighbourhoods may result in very dissimilar environmental impressions. Admittedly, the diversity of environmental characteristics in urban neighbourhoods may vary between American, European, and other cities.

Nevertheless, considering an urban area as a homogenous walking environment remains critical.

Third, the elements that create an environment, for example housing types, streets, footpaths, green elements and so on, can be repeatedly found in cities. The arrangement of these elements, however, most probably varies. Different configurations can create unique urban environments with similar environmental features. J. Jacobs (1961) already urged that the detail of a specific environmental context should be accounted for when studying the use of, for example, an urban park (p. 433). Data from geographic information systems do not provide such detail. As a consequence, these systems provide only a very limited presentation of an urban reality. Quantifications of environmental characteristics are complex. This is already true for one specific urban area that we can capture visually when we stand still somewhere in the city. Quantifications remain even less sufficient when they cover whole urban neighbourhoods from the perspective of a pedestrian. I doubt that the aim to establish a “universal” or “average” presentation of an urban area makes much sense. Such a perspective does not exist for pedestrians.

The explanations in the previous sections lead to a fourth challenge. Quantitative descriptions of urban surroundings are not objective, even though a number of researchers claim differently. Quantifications require us to determine what to count, as numeric presentations of a built environment can never include all the elements that create the urban reality. Therefore, quantitative presentations remain subjective, perhaps even more than detailed qualitative descriptions. These shortcomings are limited somewhat when we a) focus on one specific urban environment, and b) do not restrict environmental registrations to a few features, just because these are conveniently countable.

Fifth, the problem of complexity also exists for the social character of urban neighbourhoods. As Guo (2009) reminds us, it is not only the environmental characteristics that vary between neighbourhoods. It is likely that very diverse societies reside in these urban areas (p. 344). Manaugh and El-Geneidy (2011) are surprised by the extent of the effect that Guo describes. They find individual household characteristics to drastically influence travel choices (p. 315). The qualitative investigations of Pooley et al. (2011) illustrate the complexity of travel decisions at the household level. Available transport options, attitudes, accessible clothes and weather gear, behaviour and mood of children, the need to access more than one destination along journeys, and many more conditions influence how people travel in cities (pp. 5–6). So many factors create nearly a unique context for each household. Comparing the travel choices of many households remains therefore a complex task. Such diverse societal factors are difficult to collect for a database and challenge statistical models that seek to analyse travel behaviour.

Sixth, many study designs cannot connect performed walking trips with the environment along walked routes. Studies compare data from geographical information systems with data from interviews. When comparing the general behaviour of residents with a vague average characteristic of their residential neighbourhood, the investigation of the relationship between both elements of interest becomes difficult. The used data on environmental characteristics and walking (or travel behaviour) remain somewhat detached. A weak relationship between behaviour and environment in the data restricts a better identification of the environmental influence.

The described challenges may not apply equally to all studies that use the described methodological approach. Chapter 2 presents some studies that circumnavigate some of the discussed weaknesses. The six described shortcomings highlight general difficulties. We need to remember these challenges when designing methods to investigate how environments influence pedestrian behaviour or the experience of walking.

Flyvbjerg (2001) discusses critically investigation methods in social science. He urges closeness to the object of research (p. 132). In the above described research approach, the urban residents and their behaviour are the objects of interest. According to Flyvbjerg, closeness seems to be an important condition to derive the necessary detail that explains an observed phenomenon (pp. 133–134). The applied tactics of the presented discourse often seem to lack this closeness and detail. Aside from the context that determines travellers' choice and behaviour, numerous unconsidered factors influence the results of statistical inquiries. Lacking closeness and detail disable the explanation of statistical results, especially when they do not reflect the researchers' expectations.

The research design presented in the following sections seeks to enable investigations under conditions that minimise the distance between urban environments and walking. Interviewees report on just-performed walking trips. Observations uncover a direct relationship between walking and the environment. However, the general limitation of statistics that Flyvbjerg describes also remains relevant for this research. Asking more simple questions, maintaining a close relationship between walking and urban environments, and the combination of qualitative and quantitative investigations can relieve the shortcomings Flyvbjerg highlights.

4.2 Interviews – walking trips to tram stops in Zürich

The data collected from interviewing tram passengers in Zürich target one central question. Does the remembered character of the walking environment influence the evaluated pleasantness of a walking trip to tram stops? The collected data allows us to study the first dimension of the circumplex model – the pleasantness of the environmental stimulation, as explained in Section 3.3. Interviews allow further investigation of the use of shops and services along walking trips to public transport stops, discussed in Section 2.2.

The design of the questionnaire comprises three groups of questions:

1. walking, such as, for example, the duration of the trip, street crossings, access to additional destinations, and so on
2. the individual context for walking, such as travel purpose, age, frequency of undertaken journey, attitudes, and so on
3. reported environmental descriptions

The combination of these three question groups maintains a relationship between walking, the individual context of walking, and the environment for walking. The relationship between walking and environments remains closest when surveys question one specific performed walking trip instead of walking in general. We interviewed tram passengers on the walking trip to the stop before entering the tram.

It remains difficult to question the relationship between the environment and walking. In the previously described inquiry, Weinstein Agrawal et al. (2008) question whether the walking environment influences pedestrians' route choice to public transport stops. Most pedestrians report directness as the main reason for their choice. The results do not appear unreasonable. However, Walther (1973) finds that about 20 percent do not access the stops in the shortest walking distance. Also Brändli et al. (1978) uncover this phenomenon. These results raise the assumption that pedestrians are not always aware how environments influence their walking behaviour. Unawareness can disable interviewees from reporting on how environments influence their behaviour.

An alternative survey design may overcome the challenge of pedestrians' unconscious environmental experience. Not asking directly after environmental effects appears more promising. Questioning the characteristics of an environment that people walked through appears feasible. People can also evaluate their walking experience. This evaluation should be requested independently of environment descriptions. The analysis can then investigate whether environmental presentations influence the evaluation of walking. Separating evaluations from questions on environmental characteristics appears to be a feasible approach to studying the unconscious experiences of the walking environments.

4.2.1 Context of the survey

With the support of the public transport operator in Zürich (VBZ)[32] and *Fussverkehr Schweiz*[33], four to five persons interviewed 596 tram passengers between 9.00 and 16.00h, on five week days between the 19th and the 23rd August 2013 in Zürich (Swizerland). Conducting interviews during rush hours in the morning and afternoon was difficult in crowded trams.

Interviewers were instructed to read the exact text of each question in the questionnaire. The use of tablet PCs for registrations enabled them to show lists of possible answers to the interviewees. Each interview lasted about four to five minutes. Interviewees were randomly chosen on the driving tram, preferably shortly after boarding.

The interviews were conducted on tramline 10 between stops *Zentral* and *Zürich Stern Oerlikon*, and on tramline 4 between stops *Bellevue* and *Bahnhof Altstedten Nord*. The section of line 4 leads, via 18 stops from the railway station 4.5 kilometres northwest of Zürich Main Station, to the northern corner of *Lake Zürichsee*. The north-western part of the line runs through an urban area that is characterised by large-scale industry, storage, and office buildings. North from Zürich Main Station, line 4 drives through a lively, mixed-use urban quarter with a street block building structure. South from the main station, the tram line runs along the river *Limmat* though a central urban area until it reaches the busy public transport hub *Bellevue* close to the lake.

Line 10 links the main station in Zürich with an important sub centre, Zürich *Oerlikon*, about four kilometres northeast of the main station. From the city centre,

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[32] Verkehrsbetriebe Zürich (VBZ)
[33] Swiss Pedestrian Association

Line 10 drives first along busy commercial streets. Larger multi-family housing units, with shops and services on the ground floor, characterise the environment. The tram continues in the direction of *Oerlikon* through still densely built residential areas with predominantly four- to five-storey buildings, but with fewer shops and services on ground floors. Getting closer to *Zürich Oerlikon*, the number of shops and services increases until line 4 reaches a busy commercial street at the stop *Zürich Stern Oerlikon*, close to the railway station *Zürich Oerlikon*.

4.2.2 The questionnaire design

The questionnaire contained 16 questions and consisted of three parts. The first questions focused on the context for the walked trip to the stop.

- Do passengers walk to the stop?
- How regularly do passengers perform the journey?
- Purpose of the travel?
- Are travellers on the way to the destination or are they heading back home?
- The estimated duration of the walk to the tram stop?
- The course of the journey before boarding the tram?

To define the course of the journey before boarding the tram, interviewers presented a printed illustration with three options (Figure 37): (1) walking to the tram stop before boarding the tram, (2) walking to the stop, boarding the tram or bus and changing to the current tram, (3) travelling by train and changing to the tram at a railway station. Interviewers explained to the interviewees that the following questions relate to the walking trip indicated in yellow and red colours on the card in Figure 37.

Figure 37: Card, mode of journey before boarding the tram, three options

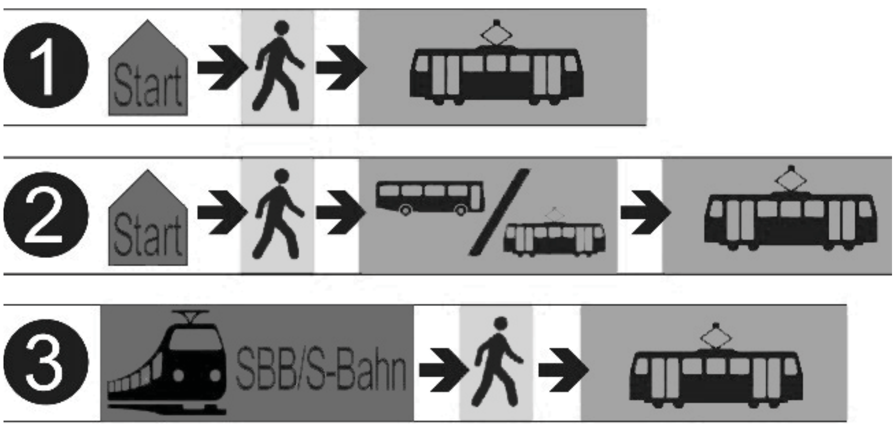


Figure 38: Card to describe the characteristics of the walking environment

Next, interviewees should characterise the remembered environment along the walk to the stop. Interviewers showed a printed card, displaying eight photographs (Figure 38), which illustrated eight environmental characteristics, from top left to bottom right:

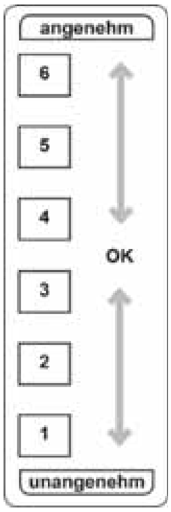
1. Car traffic, street
2. People, activity
3. Interesting buildings
4. Crowding
5. Unattractive, boring
6. Trees, greenery
7. Shop windows
8. Waiting

Interviewees choose as many pictures as they like to describe their remembered impression of the urban surroundings they walked through to reach the stop.

The following questions focus on further details along the walk to tram stops:

- Performed activities while walking, such as listening to music, eating and so on
- Accessed shops and services along the walk to the stop, and type of accessed facility
- Crossing of trafficked streets along the walk; if yes, people were asked to specify (traffic light, zebra crossing, underpass/bridge, other)
- Sensed time pressure
- Impression of safety; whether interviewees considered the walked route safe enough for a seven-year-old child walking alone

Figure 39: Rating scale used to evaluate the overall impression of the walk to the stop



As a next step, the tram passengers should evaluate their overall impression of the walk to the stop with a rating scale that interviewers presented in printed form (Figure 39). The scale ranged from 1 (unpleasant) to 6 (pleasant).

The last part of the interview concentrated on personal information.

- The attitude towards walking, how often interviewees walked for longer than 10 minutes during the last seven days
- Car availability and whether the car appeared an impractical option for the current journey
- Age
- Occupation

Interviewers noted whether they experienced the communication as difficult and registered the gender of interviewees. Section 9.1 in Appendix 2 presents the original questionnaire together with an English translation.

Section 6.5 presents the results from the analysis of all factors that influence the evaluated pleasantness of the walk to tram stops in Zürich. Section 6.6 analyses the survey data regarding access to additional destinations such as shops along walking trips to stops.

4.2.3 Shortcomings

The environmental descriptions with the help of pictures remain relatively sketchy. It is likely that most pedestrians walked through changing environmental contexts. Such variations appeared too complex to question in the short time available. Previously presented research reports also face this shortcoming.

Asking interviewees to evaluate overall impressions implies several difficulties. Numerous individual factors influence interviewees' moods and certainly their experience of the walk to the stop. The survey results do not show, therefore, how pleasant walking routes to tram stops in Zürich are. The data analysis can investigate which factors influence the evaluation of pleasantness. Available statistical methods can separate the extent of unknown factors that influence the reported walking experience. These techniques will be applied in the analysis.

General attitudes towards walking influence interviewees' evaluations. People may not disregard the positive impact of walking on climate, environment, and health with negative evaluations. However, by focusing solely on factors that varied the evaluated walking experience, this shortcoming also vanishes to some extent. If interviewees' attitude towards walking influences the evaluation of pleasantness, the question on the attitude in the last part of the interview can uncover this effect.

Interviews can only uncover pedestrians' individual impressions of a walking environment. This perception may vary between individuals. However, this may not appear to be a major shortcoming, as the inquiry is not interested in an objective environmental characterisation. The focus lies on the influence of the environmental impression on the pleasantness of walking. If pedestrians experience their walking route as dominated by green, the analysis investigates the effect of this reported impression. Whether trees or park-like surroundings along walking routes result in a 'green' environmental impression is not investigated.

The context for the enquiry allowed only closed questions with predefined answers. This questionnaire design limits a deeper insight into the context of walking. The design does not reveal to what extent the predefined answers appeared relevant. Neither does the survey show whether aspects other than those questioned are important for walking. Accordingly, the context of this survey limits the 'closeness' and 'detail' that Flyvbjerg (2001) finds important, as discussed previously. The following Section presents a very different method, which overcomes some of the herein described shortcomings.

4.3 Pedestrian observations – measuring visual stimulation

Whyte (1988) charts behaviour in urban squares, undertakes counts and interviews, but predominantly he watches people (p. 105). His descriptions demonstrate the capability of observational methods to uncover a relationship between behaviour and environments. Whyte observes, for example, the use of benches on a minor urban square. If there are many empty benches, people choose not to share a bench with a stranger. Sharing a bench becomes acceptable when a square becomes crowded. The seating capacity of a square appears, hence, to some extent self-levelling. People's acceptance of sitting close to each other changes with the number of people around, explains Whyte (pp. 165–173).

Whyte uses video cameras to capture pedestrians' behaviour. This method uncovers details that often remain invisible to the naked eye. He describes the collision avoidance abilities of two pedestrians that walk towards each other. At a distance of six metres from each other, they seek eye contact to convey their intentions, sometimes underlined by a pointing motion of one hand. Getting closer, they change their course slightly, which is only sufficient if both perform a comparable move. Then, they look down to avoid direct eye contact and lift their head first at the moment they pass each other, describes Whyte (pp. 57–59). The detail of this observation illustrates nicely how walking differs from any other form of mobility on wheels.

In a sense, Whyte observes directly how people make use, or react to their direct surroundings. Observations enable Whyte to define behavioural patterns. Rich details uncover logical behaviour in a specific context. The observed behaviour can vary with the urban surroundings. With this experience, Whyte can foresee with some certainty how people will behave under certain circumstances, as he states (p. 342). The ability to predict derives from an understood logical relationship between behaviour and environment.

R. Monheim (1980) describes a method that he calls quantitative counts. These inquiries advance simple pedestrian counts with additional observable information, such as, for example, estimated age, carried items, whether people walk alone or with others, and so on (pp. 145–152). In the same manner, pedestrians' behaviour appears quantifiable. Prior to such quantifications, the researcher needs to identify behavioural patterns, Whyte reminds us (Whyte 1980, p. 110). This initial understanding defines what observations need to look for. The explorative observations that Whyte describes are well suited for such a purpose.

Observations have some advantages when compared to interviews. Interviewees can only report on something that they are aware of. This limitation creates difficulties when we are interested in behaviour that is deeply integrated in daily life, as walking is. Observations can uncover behavioural patterns that pedestrians perform unconsciously. Further, the process of any interview influences answers. When the observer remains invisible to the observed, the data collection procedure does not influence the derived data. These are important advantages of the observational method.

On the other hand, not everything is observable. The individual context for walking remains hidden such as, for example, the purpose of travelling, the available travel options, and further personal information. This background, however, remains possibly not the dominant factor for the relationship between behaviour and environments. According to psychologists, Maderthaner and Szynkariuk (1999), observable behaviour results up to about 50 percent from the environment, at least theoretically.

Knoflacher (1989) reminds us that observable walking behaviour does not necessarily show what people desire (p. 182). This is true as pedestrians react to an existing environment and not to conditions they might prefer. However, keeping in mind some basic characteristics of walking, as Section 2.1 describes, observations show well where walking is restricted. Unsuitable walking environments often trigger untypical behaviour or reactions.

The following text presents two very different observation methods. The methodology in Section 4.3.1 aims to study the influence of walking environments on visual stimulation. The observational approach in Section 4.3.2 targets walking behaviour along routes to and from public transport stops.

4.3.1 Investigating visual simulation

The interviews described in Section 4.2 aim to investigate how walking environments influence the *pleasantness* of walking. Pleasantness is the first dimension of the circumplex model to describe pedestrians' emotions and the subjective experience of time and distance (Section 3.3). To study the environmental effect on pedestrians' emotions and distance perception, we require a second measure, the *amount of stimulation* pedestrians receive from the urban surroundings. The methodology described in this section aims to measure pedestrians' visual stimulation in different urban surroundings. Section 3.4 describes how head movements indicate the amount of pedestrians' visual stimulation.

The inquiry systematically observes 892 pedestrians in 18 different urban environments in the cities of Copenhagen (DK), Zürich (CH), Biel[34] (CH), and Brighton (UK) with the help of a video camera[35]. Initial explorative observations in Copenhagen show five behavioural patterns that the collected video clips allow to be quantified.

1. Head movements
2. Time people look down to the pavement
3. Step frequency
4. Whether performed activities while walking
5. Walking alone, in pairs, or in groups

Head movements become visible and countable on video clips. Movements of the head when pedestrians directed their field of vision downwards were not counted. The time pedestrians looked down was measured with a stop watch. The length of time pedestrians performed activities while walking was not measured. Some activities require visual attention, such as, for example, looking at a mobile phone. This attention was counted as time looked down.

A metronome[36] enabled the number of steps per minute to be measured during direct observations. Initial studies show that this method is feasible with little practice. Differently from speed measures, the *metronome method* uncovers speed variations at the second they occur. This real-time indicator for the walking speed makes it significantly easier to observe spontaneous reactions to walking environments. As all observed pedestrians could walk unhampered, frequency variations occurred rarely.

The video clips derive from a position with a good view on a section of a pedestrian path of 50 to 150 metres length. The length of clips varies between 10 and 30 seconds, at a minimum of 8 seconds and a maximum of 2 minutes. Forty

[34] The city of Biel is bilingual, the French name is Bienne

[35] Camera type: Sony HDR-PJ740

[36] Musicians use metronomes to receive exact measures for beats per minute. I simply considered a step as one beat per minute. This enabled me to adjust the rhythm of the metronome to the rhythm of steps, which appear quite stable when pedestrians can walk unhampered. The metronome then shows the step frequency in the unit *steps per minute*. The frequency derives from heel strikes of both feet.

to sixty observations (maximum 87 and minimum 29) were conducted at each of the 18 different locations.

Approaching pedestrians often recognise that that they are being filmed when getting closer to the camera. Filming is stopped early enough that reactions to the camera are not captured[37]. The feet, legs, hands and faces of each observed pedestrian are visible on film clips. Of all filmed pedestrians, only one person expresses the desire not to be captured by the camera. The video clip is deleted on site.

Pedestrians are selected randomly on site for observations. Clips show only fast-walking pedestrians with frequencies over 100 steps per minute. If more pedestrians approach the camera, the one that is best to observe and that walks fastest is filmed. The study excludes children and the disabled. Tourists are recognisable by their clothes and carried items and are not captured.

At all observation locations, the walking surface is smooth, dry, not or only slightly sloping, and free of steps or other obstacles. The number of pedestrians varies between the studied environments. The density of the pedestrian flow is not measured, but crowding does not occur. All observed pedestrians can walk unhampered at the highest preferred speed.

Observations take place on weekdays either before lunchtime, between 10 and 12.30, or during the afternoon between 15.30 and 17.30. The weather varies with the seasons of the year. The different climate in Copenhagen, Zurich/Biel and Brighton can cause variations. However, the weather is mostly sunny with comfortable temperatures between 16 and 24 degree Celsius. Only two case studies in Brighton are conducted with overcast weather. Wind does not discomfort walking during the observations.

Table 6 presents an overview of all 18 investigated urban surroundings and provides a short description of the environment. Table 6 also indicates the *total environment score* for each observation location. Scores range from values 1 (unattractive) to 3 (attractive) and derive from the *environment matrix* that Section 4.3.2 describes in detail. Section 9.3 Appendix 2 shows the detailed environmental evaluations through the environment matrix for the 18 investigated environments

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[37] From all film sessions, I recall only two incidents where people asked me about my filming. I was able to delete a video clip on site if a person felt uncomfortable about being part of my study, but nobody insisted on that.

together with a short description of each studied area. Table 6 distinguishes further three groups of locations. This distinction derives from the *circumplex model of the walking environment*, as Section 4.4 presents.

Group 1 – boring and exciting environments. Pleasant walking environments are in most cases pedestrian streets (or streets with restricted car access) and facades with shops and catering facilities. Boring walking environments are footpaths along trafficked streets, or in monotonous environments with closed large-scale facades. At all 12 locations, people did not need to pay attention to car traffic.

Group 2 – street crossings, stressing environments. The second group consists of three locations where pedestrians cross carriageways and tram rails. The conditions for street and tram rail crossings differ in complexity.

Group 3 – specific environmental conditions. The third group investigates specific conditions for walking in an indoor shopping centre (exciting environment), in an underpass (boring environment), and in an environment with a particular scenic view over the city of Zürich (relaxing environment). More detailed descriptions of the observation locations are provided in Appendix 2.

Time restrictions require that the registrations are simplified as much as possible. The number of cars on direct adjacent streets (in the cases where there were streets) remains uncounted. Counts would have provided a statistical measure that may influence behaviour. Measuring the duration of performed activities is too time-consuming. Counting steps within a time interval is more precise than the metronome method but also more time-consuming.

The purpose for walking can differ between lunch and afternoon observations. Too high or too low pedestrian flows prohibit filming during some days. A choice of locations that allows observations at the same time of day is more time-consuming. For the same reasons, the sample size differs between the observation locations as well as the duration of each single observation. Some locations enable longer but fewer observations. The length of the observation does not influence the data, as an initial analysis shows.

The results of the investigation of visual stimulation are presented in Section 7.3.

Table 6: Overview of all locations for observations, place and city; short description of environmental characteristics according to circumplex model of the walking environment, as explained in Section 4.4; the environment score is explained in Section 4.3.2

Number, Place, City CPH – Copenhagen Z – Zürich BR – Brighton BI – Biel	Short description	Environmental characteristic	Environment score	n Observations
Group 1 – pleasant or unpleasant walking environment				
01 Bernstoffgade, CPH	Car traffic, dead façades, wide street	boring	1,1	54
02 Gloucester Pl., BR	Car traffic, dead facades, fenced in	boring	1,2	58
03 Niels Juels Gd., CPH	Car traffic, dead façade, trees	boring	1,3	23
04 John Str., BR	Closed façades, technical street design, few cars	boring	1,3	53
05 Pfingstweidstr., Z	Wide street, dead facades, car parking	boring	1,4	49
06 Carsten Nieburs G., CPH	Designed new street, dead facades	boring	1,5	29
07 Fiolstræde, CPH	Shopping street, old unpretentious facades	exciting	2,7	63
08 Garner Street, BR	Many small shops, few cars, narrow street	exciting	2,8	87
09 New Road, BR	Shared space, benches, cafes, old facades, trees	exciting	2,8	66
10 Østregæde, CPH	Central shopping street, no green	exciting	2,9	68
11 Rennweg, Z	Central shopping street, benches and cafes	exciting	2,9	48
12 Amagertorv, CPH	Central square, interesting facades	exciting	3,0	53
Group 2 – Street crossings				
13 Str. cr. Zürich Station, Z	Street and tram crossing with light signal	stressing	1,2	45
14 Str. cr. Public transport stop Zentral, Z.	Zebra crossing, many tram tracks	stressing /exciting	1,2	71
15 Str. cr. Zentralplatz, BI	Central square, car traffic, shared space	exciting	2,5	54
Group 3 – Specific environments				
16 Underpass Z. Oerlikon, Z	Pedestrian underpass, building site	boring	1,2	29
17 Indoor shopping C., Z	Corridor in underground shopping centre	exciting	2,4	30
18 Limmatquai, Z	Simple pavement along river, interesting view	relaxing	1,9	44

4.3.2 *Describing walking environments to investigate pedestrians' stimulation*

To investigate statistically the amount of head movement in different environments, we need a systematic approach to describe the urban surroundings. A statistical analysis requires some form of a quantitative description of walking environments. However, I do not consider a quantitative representation of walking environments as objective and suggest abandoning the idea that we can describe urban surroundings "objectively" by counting objects. To circumnavigate as well as possible the shortcomings described in the introduction of this chapter, registrations remain limited to the visual environment from pedestrians' perspectives in one specific location.

Registrations require the analytical ability to define the environmental features that a) create the character of an urban location, and b) are relevant for pedestrians. Trees, pavements, buildings, trafficked streets, and also social activity are complexly interrelated. Counting the physical features of a walking environment does not sufficiently reflect the urban reality. Any numerical description needs to account more holistically for the elements that create an urban space and how these elements together generate a sense of a place. Registrations require, therefore, a qualitative understanding of the urban context for walking.

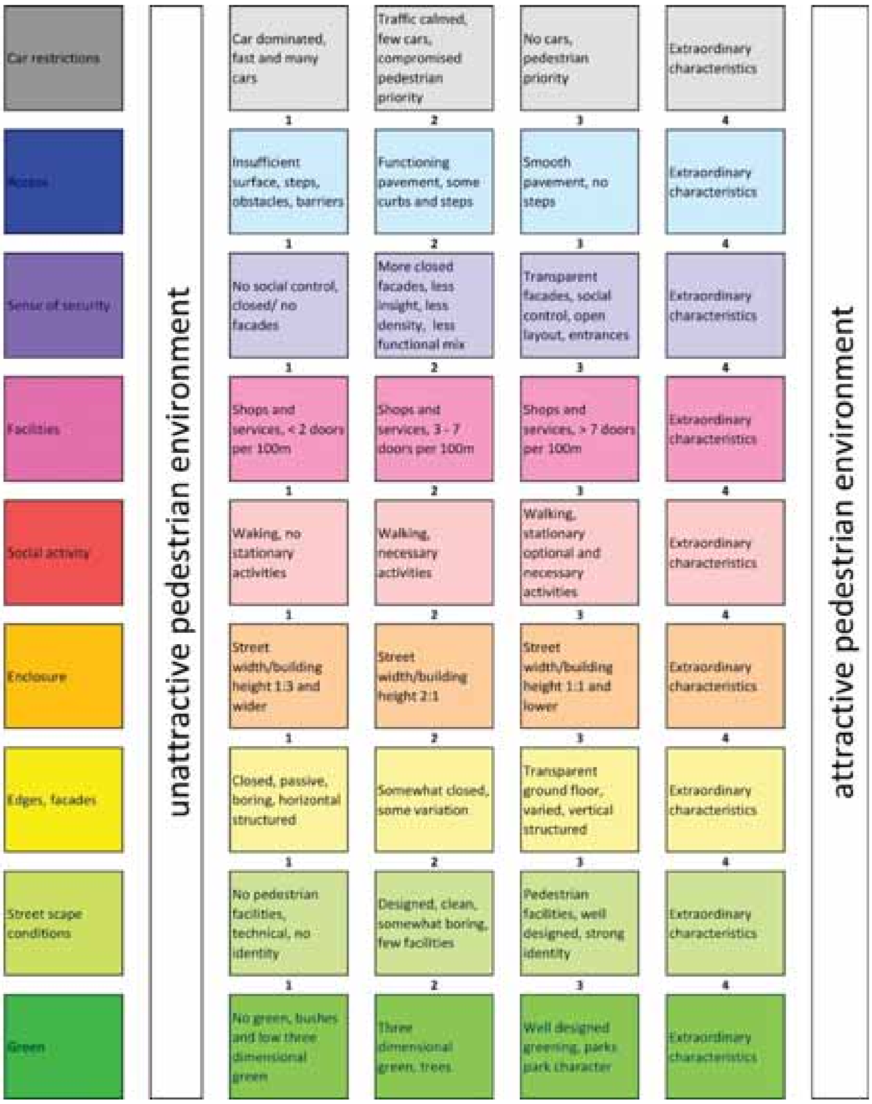
Figure 40 represents the ***matrix for the pedestrian environment***, which defines nine categories of the walking environment. Gehl Architects APS (2009) summarise what constitutes a convenient and attractive walking environment, as presented at the end of Section 2.1. This text provides the basis for the matrix. As the matrix focuses on the visible walking environment from a pedestrian's perspective, not all the elements that Gehl Architects APS describe are included.

The matrix defines nine *environmental categories* to describe the character of the visual urban surroundings for pedestrians. For reasons explained in the introduction of this chapter, the investigation does not cover whole urban areas. Pedestrian networks remain irrelevant for the research design. As the influence of darkness will not be investigated in the current research, the matrix covers only peripherally street lighting and other features of relevance for walking during dark daytimes only. Figure 40 presents the matrix that defines nine environmental categories to describe the 18 investigated walking environments during the pedestrian observations.

The matrix defines four *grades* for each environmental category:

- Grade 1 - unpleasant and inconvenient – unattractive
- Grade 2 - acceptable
- Grade 3 - pleasant and convenient – attractive
- Grade 4 - extraordinary

Figure 40: Matrix for the classification, description, and evaluation of characteristics of the pedestrian environment



The following text defines the environmental conditions for grades 1 – 3 along the seven categories of the matrix. An example explains the meaning of the fourth grade *extraordinary* later on.

The category, **car restrictions**, describes the number of moving cars, to what extent they receive right of way, and the driving speed of vehicles. The amount and speed of the motorised traffic influences pedestrians' experience of safety. Vehicle traffic threatens especially children and disabled people. Crossing busy streets can also be time-consuming, difficult and dangerous for any other pedestrian. Noise and exhausts make walking uncomfortable (grade 1). In streets with fewer cars and traffic-calming measures, walking becomes more attractive and safer (grade 2). Most attractive is walking in pedestrian-designated areas where cars have no access (grade 3).

Uneven and damaged surfaces, steps, high curbs, and other obstacles on pedestrian paths, such as lightning posts, traffic signs and so on, reduce the **ease of access** (grade 1). Smooth surfaces for walking improve conditions but may still require stepping over curbs and steps (grade 2). Most attractive are footpaths without steps and curbs or, where necessary, with ramps and slopes (grade 3). Ease of access is increasingly important for elderly and disabled pedestrians but also for children, people pushing prams and so on.

The sense of **security** represents a central feature. If people do not feel secure, they will not dare to walk. Darkness and insufficient social control such as the consequence of absent social activity reduces individually sensed security (grade 1). A well-illuminated environment that pedestrians can easily survey supports sensed security (grade 2). Socially active environments with social surveillance from buildings with windows or transparent facades facing the pedestrian environment increase personal security (grade 3). Buildings must be active at all times of the day. Empty office blocks do not support a sense of security at night.

Facilities represent shops and other services in buildings, addressed to pedestrians and visible from the pedestrian environment. These facilities can be supermarkets and shops, restaurants, cafes, post offices, or banks; but they can also be sport clubs, health services, and so on. Pedestrians should receive direct and easy access to these offerings. A pedestrian environment without facilities (grade 1) may not be unattractive, but services and facilities along pedestrian paths can easily cater for pedestrians' needs (grade 2). Densely provided facilities (grade 3) increase the visual diversity of environments, are practical for pedestrians, and generally increase social activity and the number of pedestrians.

Social activity describes the amount of human activity in an urban area[38]. Chosen stationary activities remain rare in unpleasant environments and pedestrians traverse these environments fast (grade 1). In less unpleasant environments, more walking takes place and more necessary social activities such as delivery of goods, short conversations and so on (grade 2). In pleasant environments, more people walk, and the number of chosen stationary activities increases (grade 3) such as sitting on benches, eating, chatting, street performances, and so on. Pleasant urban environments often function as recreation areas.

Buildings or walls represent the edges of the public urban space in which walking takes place. Edges thereby define the spatial dimensions of the pedestrian environment. *Building height* divided by *street width* describes the **enclosure** of a walking environment. This category in the matrix describes a very fundamental characteristic of the urban surroundings. Enclosure alone does not describe the dimensions of a walking environment. The distance to edges becomes especially important when these edges are attractive. Only when edges are close, as in narrow pedestrian streets below 15 metres in width, all details become visible and increase the amount of visible sensory stimuli (grade 3). In large-scale urban environments such as broad streets over 40 metres wide, or very large squares, the amount of stimuli from edges such as facades decreases (grade 1). With distance to facades at between 15 and 40 metres, more details become visible (grade 2)[39].

Unattractive **edges** are blank walls or large-scale and long facades with little variation and restricted views into buildings (grade 1). More interesting and stimulating facades may have a vertical structure and are more detailed, (grade 2). Transparency on the ground floor establishes a relationship between the inside of buildings and the pedestrian environment outside (grade 3). Visible details of shop interiors are highly stimulating. Few features within the public space may provide such high amounts of visual detail as attractive edges.

The **streetscape** represents the surface pedestrians walk on with all sited objects such as street furniture, sculptures, fountains, railings, and so on. Greening also influences the character of the streetscape, but the matrix treats greening as a separate category. An unattractive streetscape contains no benches and can appear technical, has no identity, and may be dirty and insufficiently maintained (grade 1).

[38] Gehl (2010a, pp. 81–83) provides a useful differentiation for the duration, quantity and quality of social activity that is used for the differentiation between the three grades.
[39] Gehl Architects APS (2009) do not mention enclosure, but Hass-Klau discusses enclosure as a relevant environmental characteristic for walking (2014, pp. 280–294). Gehl discusses the dimension of urban spaces (2010b, pp. 33–38).

A more attractive streetscape contains some pedestrian facilities, is clean and properly maintained, but remains somewhat boring and technical in its appearance (grade 2). An attractive streetscape contains formal and informal[40] possibilities for seating and supports or creates the identity of a location through good design (grade 3).

Green vegetation such as trees, grass plains, or flower pots can increase the attractiveness of the pedestrian environment. Greenery can provide a counterweight against motorised traffic. Greening can help to increase pleasant stimulation and hence increase the pleasure of walking. No greening constitutes grade 1 in the matrix. Trees (grade 2) provide shade in summer, can reduce wind velocity, filter fine dust, and generally have a positive effect on the microclimate[41]. Trees with further green elements such as grass plains, planted pots and so on can improve the visual appearance of the pedestrian environment (grade 3). Greening in cities can also be inappropriate, as the example of the *Amagertorv Square* illustrates in the following text section.

The matrix defines nine categories and grades these in four steps. Figure 42 shows an example of a graded environment derived from the matrix for the *Amagertorv Square* in Copenhagen (DK). From the nine grades, a total score can be calculated.

Figure 42: Environment chart for Amagertorv Square, Copenhagen

Figure 41: Picture of the Amagertorv Square in the old city centre of Copenhagen

[40] Formal sitting facilities are benches and everything that is provided with the intention to be sat on; informal sitting facilities can be steps and any other objects that allow seating, even though these are not designed for seating.
[41] Boesch highlights these advances of trees and green for the microclimate (1989, p. 22).

Section 9.2 in Appendix 2 represents how the nine grades are used to calculate a total score for the walking environment, as Figure 42 shows.

The fourth grade of the matrix *extraordinary characteristics* allows environmental categories that are central for the identity of an urban location to be accounted for. Thereby, the grade can also compensate for categories with lower grading, if these do not lower the attractiveness of the environment for walking.

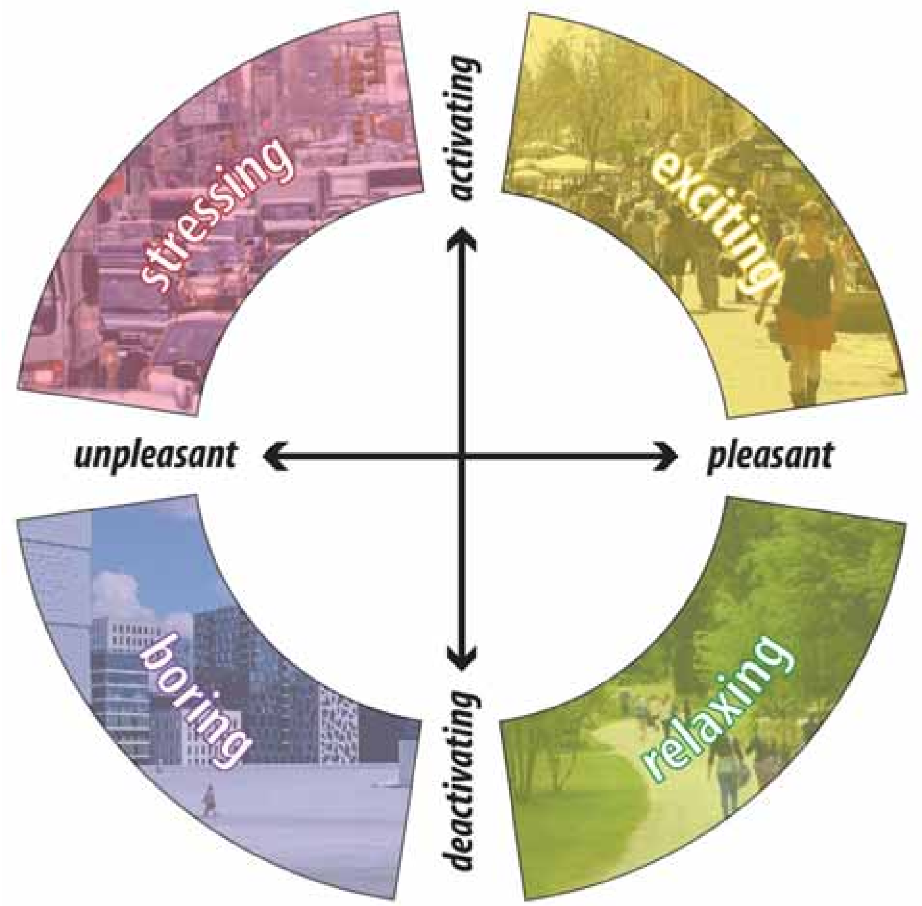
The *Amagertorv Square* in Copenhagen presents an example with extraordinary graded categories. The square is located in the centre of Copenhagen's inner city centre and receives its unique character from the surrounding facades and a vibrant social life (Figure 41). Accordingly, the categories *activity* and *edges* are graded as extraordinary in the matrix (Figure 42). Green features are absent, but trees would not increase the quality and the identity of the square. Trees would even block the view of these facades. The two extraordinary rated categories, *activity* and *edges*, compensate for the lack of green.

4.4 The circumplex model of the walking environment – questioning the emotional walking experience

The methodology described in this section seeks to answer whether walking environments influence pedestrians' emotions, as Section 3.5 questions. The investigation rests on the ***circumplex model of emotions***, which Section 3.3 describes. The model distinguishes between four different emotional statuses, excitement, relaxation, boredom, and stress. These emotions are described by the two dimensions of *stimulation* and *pleasantness*. By anticipating which environments are high or low in stimulation and where walking appears pleasant or unpleasant, the circumplex model allows us to hypothesise what kind of emotions walking environments trigger. On this basis, I suggest a transformation of the *circumplex model of emotions* to a ***circumplex model for the walking environment***, as Figure 43 illustrates.

The model in Figure 43 defines four fundamentally different walking environments that potentially trigger emotions such as excitement, relaxation, boredom, and stress. The data from the survey described in Section 4.2 questions the *pleasantness* of walking environments. The observational methodology in the previous Section 4.3 investigates how environments influence pedestrians' *stimulation*. On the basis of the *circumplex model of emotions* (Section 3.3), both inquiries together can answer question four in Section 3.5. Do walking environments influence pedestrians' emotions?

Figure 43: The circumplex model for the walking environment



The following text describes the relationship between the characteristics of walking environments and pedestrians' emotions that my suggested model in Figure 43 anticipates. ***Exciting*** environments are pleasantly activating and provide many pleasant stimuli. A suitable example would be a pedestrian street with detailed facades, shop windows and entrances, outside seating and an amount of social activity that does not hinder walking. The busy surroundings increase stimulation. Pedestrian streets further offer many practical functions. Doors of shops and other services invite pedestrians to enter. Goods presented outside shops intend to catch people's attention. All these stimuli appeal to pedestrians and do not require attention. Many facilities provide options but do not require one to choose. The freedom to attend to or ignore the surroundings represents an important difference from environments of unpleasant and activating characters.

Stressful environments are unpleasantly activating. Walking along or crossing trafficked streets and large junctions can be stressing. High noise levels represent a permanent stress factor for pedestrians. Together with exhaust emissions from motor vehicles, such surroundings are highly stimulating but in an unpleasant manner. Knowing the fatal dangers of the wheeled traffic, pedestrians are hopefully attentive. Emotions such as fear and insecurity increase attention. Turning away from the intensive and unpleasant stimuli of vehicle traffic is not an option.

Relaxing environments stimulate less but pleasantly. Parks or urban areas dominated by green and landscape features are likely to result in a relaxing walking experience. Sounds are muffled and of lower volume. Likewise, the visual surroundings appear less garish in more uniform colours. Compared to stimulation in pedestrian streets, parks may appear less 'pungent' or provoking. The parks and green surroundings encourage attention but allow pedestrians to turn away from stimuli.

Boring environments provide unpleasantly little stimulation. Nothing catches pedestrians' attention or triggers any reactions. Examples of boring walking environments are industrial areas or footpaths outside large-scale office buildings or introverted shopping centres. Boredom is unpleasant. Large-scale buildings with little variety in facades bore the slow-moving pedestrians. Levine (1997) even considers boredom to increase physical exhaustion (p. 36). As such, boring environments are not suitable for muscle-propelled pedestrians.

Section 6.7 shows how walking environments influence the emotional experience of walking by combining the results from (1) the investigation of stimulation (Section 4.3), and (2) the investigation of evaluated pleasantness (Section 4.2).

4.5 Public transport stop investigations – observations along walking routes

The data collection method described in this subchapter aims to study access to facilities, reasons for detoured walking routes, the effect of street crossings, and preferred walking routes. These research questions are formulated in Section 2.10. The methodology also allows step frequencies to be measured. Of interest are differences between pedestrians that approach or depart from stops and whether step frequencies show reactions to walking environments, as questions one and

Figure 44: Screen shots of six wide-angle cameras for the case study at the public transport stop Strøget in Copenhagen

two in Sections 3.5 ask. The research design described in this section also uses observations.

To observe people along walking routes to and from public transport stops, six to eight cameras[42] capture pedestrians along the routes to and from the 14 investigated public transport stops. Cameras are mounted against lamp posts, traffic lights and traffic signs, as well as facades. The captured video films show movements on all footpaths linked to the studied public transport stops. Figure 44 presents six screen-shots of the cameras used around the public transport stop *Strøget* in Copenhagen.

[42] I used six wide-angle cameras with focal length of between 30 – 60mm (according to 35mm film format) and two normal camcorders.

The video footage enables observation of walking routes around stops up to a distance of between 40 and 250 metres[43]. In total, 444 pedestrians are observed, on average for one minute and 10 seconds. Filming takes place between 15.30h and 18.00h. The afternoon rush produces high pedestrian flows and appears more informative than the morning rush[44]. The data is collected between spring and autumn 2013. The weather remains most comfortable during filming, with temperatures between 16 and 25 degrees Celsius and low wind speeds. Further details on the data collection process are provided in Section 9.4 in Appendix 2.

Public transport stops are investigated in three cities, *Copenhagen* (DK), Zürich (CH), and *Brighton* (UK). Bus stops are studied in Copenhagen and Brighton, and tram stops in Zürich. Hubs and stops where many travellers change the means of public transport are excluded. Most public transport stops consist of two stops on opposing sides of the public transport corridor. Only one of these stops is studied.

The walking routes of all observed pedestrians are drawn out on digital maps. Section 9.6 in Appendix 2 presents maps of the urban areas around the 14 investigated stops with the registered walked routes. About 30 registrations for each of the 444 observations are formulated into a data set on six main topics:

1. General data, such as approaching or departing from stops, estimated age, carried items, and further information
2. Behaviour along each individual walking route, such as step frequencies, chosen stops, single walking or in groups, performed activities, reactions to other pedestrians and vehicles
3. Environmental characteristics along walking routes close to and distant from stops
4. Walked distances during observations, detours, and observation time
5. Access to or from different types of buildings and facilities
6. Behaviour at street crossings, used crossing facility, numbers of cars per hour on crossed streets

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[43] The average distance at which I could observe pedestrians was 80 metres, maximum distance 250 metres; when pedestrians accessed shops and facilities close to the stop, distances dropped to between 40 to 20 metres.

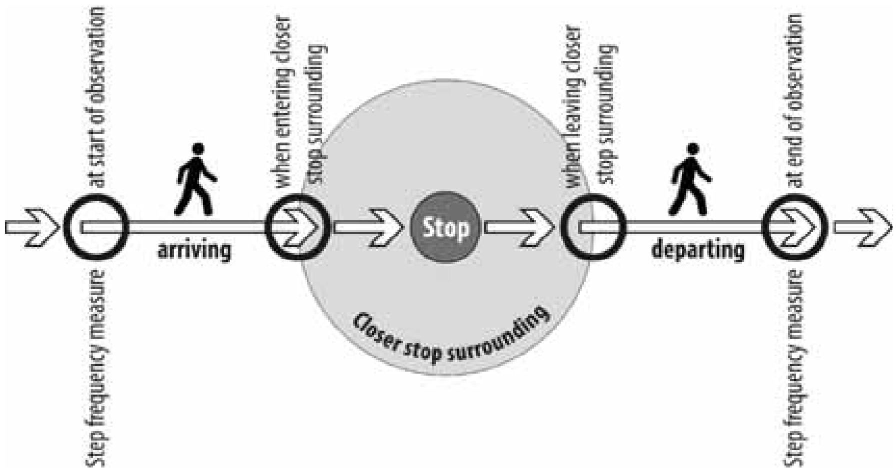
[44] Whyte (1988, p. 67) describes walking during the afternoon rush hour as brisk, but most social (Whyte (1988, p. 67). I expected more people to access shops and other facilities while travelling home in the afternoon.

Ninety variables are calculated from the 30 registrations for a statistical analysis. The data also enables qualitative analyses. Section 9.4 in Appendix 2 represents a detailed description of all registrations

4.5.1 Measuring step frequencies

Step frequencies were measured with the *metronome method* (explained in Section 4.3) at two locations, as Figure 45 illustrates: firstly, when pedestrians enter or exit the closer stop surroundings, and secondly, at the maximum distance from the stop that cameras can capture, either at the start (for approaching pedestrians) or at the end (for departing pedestrians) of each observation. The second frequency measurement takes place mostly in the footpath network around stops or along pavements in the public transport corridor and is referred to as the *distant measured step frequency*. Only 351 of the total 444 observations allowed the step frequency to be registered at two locations.

Figure 45: Locations for two separate step frequency measures for arriving and departing pedestrians



4.5.2 The choice of investigated public transport stops

Categorising pedestrian networks around stops is complex. Footpath networks are often a collage of very different conditions. The most basic environmental differentiation that guides the choice of public transport stops for the inquiry are stops in *car-dominated* or in *pedestrian-orientated* environments. The following characteristics additionally guide the choice:

1. The built urban structure consisting either of free standing buildings (Figure 47) or of a street block structure with buildings along edges of streets and public spaces (Figure 46)
2. The location of the public transport stop within the pedestrian network
3. The existence of facilities and services, such as shops, supermarkets, and other facilities close to the stop.

Figure 46: More enclosed public space with urban street block structure around public transport stop Strøget in Copenhagen; map: Københavns Kommune (2013)

Figure 47: More open urban landscape with freestanding buildings around stop Randkløve Alle in Copenhagen; map: Københavns Kommune (2013)

Table 7 at the end of this section shows an overview on the 14 investigated public transport stops together with some information on the urban context and the driving direction of the servicing public transport vehicles. Appendix 2 provides a short description of each investigated public transport stop.

The variety of footpaths around stops limits direct comparisons of stops, but rough trends remain observable. The available time and the complexity of the observation method determine the total number of observations. More observations can advance statistical analyses. The data set comprises only two stop investigations from the city of Brighton due to a data loss. A limited time budget does not allow for compensating for the data loss[45].

[45] I investigated 23 public transport stops with the described methodology. Due to a data loss of video material, only 14 stops could be used for the analysis.

Some measuring methods are not exact, such as, for example, length of the walks during observations. Walked routes are drawn on maps as they appear in the video material, but inaccuracies are not substantial. The lower optical quality of the employed wide-angle cameras only allows to recognise faces up to a distance of five to eight metres between camera and observed pedestrians. As cameras are mounted at some height, faces remained mostly invisible when people crossed the area underneath the camera. The video footage does not enable the exclusive observation of pedestrians from the front. Sometimes objects such as large vehicles are located between cameras and the observed pedestrians. For these reasons, some details of pedestrians' behaviour remain invisible. Low camera resolution sometimes prevents minor details such as in-ear headphones from being seen. Section 9.4 in Appendix 2 describes some further technical challenges of the data collection.

Results from the analysis of step frequencies are presented in Sections 5.1, 5.2, and 6.1. Section 5.3 analyses most preferred walking routes; Section 5.4 shows how detours lengthen walking routes to and from stops. Section 5.5 determines time delays that occur at street crossings. All these analyses are conducted on the basis of the data collection described in this section.

Table 7: Overview of investigated public transport stops; a short description of each 14 stop surroundings provides Section 10.5 in Appendix 2.

	Investigated public transport stop	Location of public transport stop in the city	Predominant land use around stops	Built urban structure	Driving direction public transport vehicle
Pedestrian-oriented	01 Rathaus	City centre	Shopping, service, leisure	City block	North to south through centre
	02 Strøget	City centre	Shopping, service, work, leisure	City block	North to south through centre
	03 Elmgade	Sub centre	Shopping, work, service, residential	City block	From centre
	04 Kreuzstrasse	Sub centre	Shopping, catering, residential	City block	From centre
	05 Bülowsvej	Sub centre	Shopping, catering, work, residential	City block	To centre
	06 Englischv. St.	Urban	Residential, some services and catering	Multiple dwellings, free standing buildings	From centre
	07 Palmiera Sq.	Urban	Residential, park, few shops and catering	Large terrace houses, functioning as multiple dwellings	From centre
	08 Hölderlin St.	Urban	Residential, catering	Multiple dwellings, free standing villas	To centre
Car-dominated	09 Bernina Pl.	Sub centre	Residential, work, commercial centre	Big box, multiple dwellings, villa	From centre
	10 The Level	Urban	Residential, shops, park	Terrace houses, multiple dwellings	To centre
	11 Sølvtorvet	Urban	Residential, few shops, park	City block	From centre
	12 Randkløve A.	Suburban local centre	Residential, shops	Multiple dwellings, single houses	From centre
	13 Technopark	Suburban	Work, hotel	Large freestanding units	To centre
	14 Holmens K.	Urban	Work, hotel	City block, large units	To centre

5 CHARACTERISTICS OF PEDESTRIAN ACCESS TO PUBLIC TRANSPORT STOPS

This chapter presents findings from the 14 public transport stop investigations and the interviews of tram passengers in Zürich. The analysis of step frequencies uncovers important differences between pedestrians that approach stops and those who depart after alighting (Section 5.1 and 5.2). Section 5.3 shows that approaching and departing pedestrians prefer different walking routes. Detours can lengthen walking distances to stops unnecessarily (Section 5.4), and trafficked streets are barriers for all that access stops (Section 5.5). The circumstances, under which pedestrians access shops and other additional destinations when accessing stops, are discussed in Section 5.6

5.1 Time pressure – differences between walking towards and away from public transport stops

Do more pedestrians that walk towards stops experience time pressure than those who depart after alighting? From a psychological perspective, time pressure is likely to influence how pedestrians experience the walking environment and how they behave. Section 3.2.1 describes the basic assumptions that enable us to investigate time pressure by step frequencies.

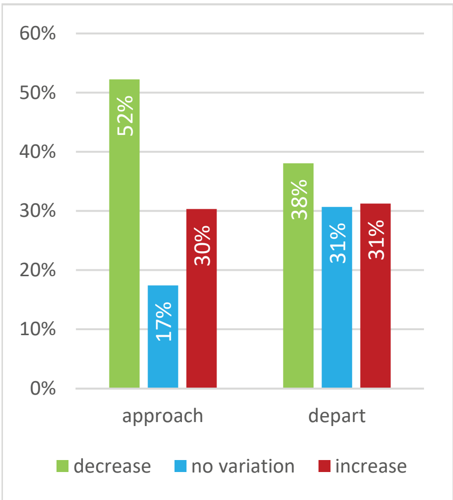
Before turning to the analysis of time pressure, the following two paragraphs provide an impression of the character of the unit *step frequency*. Strollers mostly walk at a step frequency of under 100 steps per minute. The lowest step frequencies observed were around 70 steps per minute. From 100 steps per minute upwards, walking appears more determined. Performing activities with both hands is possible with step frequencies under 100 steps per minute, but it becomes increasingly difficult with frequencies over 115 steps per minute. Frequencies over 120 to 125 steps per minute give the impression of haste. More than 130 steps per minute look hectic. The highest observed frequency was around 140 steps per minute. With such high frequencies, the leg movements no longer look like the harmonic swing of a pendulum. Legs and arms seem to stop abruptly before swinging again hectically in the opposite direction. This inharmonious movement requires frequent physical effort to force a fast leg swing.

One of the fastest observed pedestrians is a young woman on the pedestrian street *Strøget* in Copenhagen (Figure 48). She walks at 132 steps per minute and does not move her head at all. She directs her field of view straightforward in the walking

Figure 48: Fast-walking woman on Strøget

direction. Only her eyes move between a point on the pavement five metres in front of her and the horizontal axis in her walking direction. Without a head turn, her eyes sometimes move quickly to take a glimpse of objects located to the left and right of her straight course. The pedestrian street is full of visual stimuli that she attends to only through eye movements. Her long and fast steps cause her whole body to move slightly up and down. Her fast walking speed is certainly neither energetically efficient nor pleasant. The will or need to get from A to B fast certainly dominates her experience of walking.

Figure 49: Percentages of approaching and departing pedestrians for variations of the step frequency



The following analysis uses the two step frequency measures from the public transport stop investigations, as explained in Section 4.5.1. Whether pedestrians' frequencies alter along the walking route to or from the public transport stop, as Figure 29 in Section 3.2.1 illustrates, is of central interest for the following analysis. Figure 49 shows how many arriving and departing pedestrians decreased, increased, or walked with unchanged step frequency. Figure 51 presents the average step frequency before and after the frequency change of arriving pedestrians; Figure 50 shows the same for those that departed the stop.

During the observations, I gained the impression that approaching pedestrians mostly walk in a determined manner, with a steady fast step. When people first get close to the stop they reduce their step frequency to a more comfortable level. When reaching the closer stop surroundings, pedestrians know they will reach the stop in time. At this moment, time pressure decreases. Accordingly, Figure 49 shows that 52 percent (green bar on the left) of approaching pedestrians slow down close to the stop. Before the frequency decrease, these approaching

Figure 50: Step frequencies (steps per minute) approaching pedestrians before and after the frequency variation

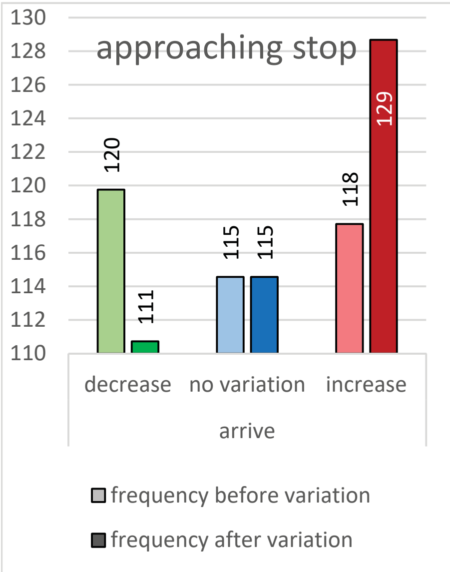
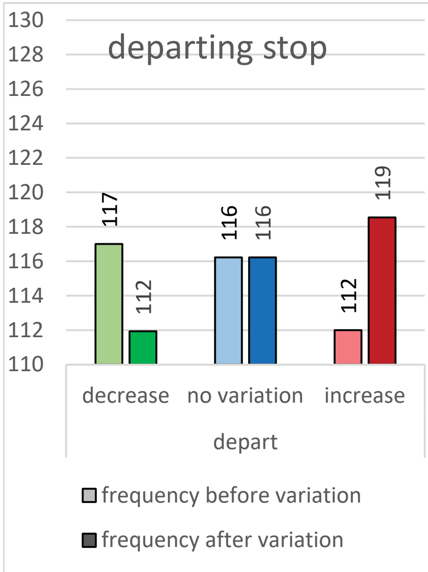


Figure 51: Step frequencies (steps per minute) of departing pedestrians before and after the frequency variation



pedestrians walk very fast, at nearly 120 steps per minute (light green column Figure 50). Remembering that frequencies over 118 - 120 are not energetically efficient, this means that these 52 percent of all the approaching pedestrians walk uncomfortably fast, most likely due to time pressure. They want to catch the bus or tram. When first reaching the closer stop surroundings, time pressure decreases and the frequency drops to 111 steps per minute (dark green column in Figure 50).

Of departing pedestrians, only 38 percent reduce their frequency at some distance from the stop (right green column in Figure 49). Before the frequency reduction, departing pedestrians walk at 117 steps per minute (light green column in Figure 51). After the frequency decreases, departing pedestrians continue at a relaxed pace of 112 steps per minute towards their final destination. The frequency before the reduction, at 117 steps per minute, does not exceed 118 steps per minute. Haste does not seem to influence those 38 percent of departing pedestrians.

Only 17 percent of approaching pedestrians do not vary their step frequency (blue column left in Figure 49). These people are not in a hurry. They know they will reach the stop in time. They walk at about 115 steps per minute, relatively slowly (blue columns Figure 50). Of departing pedestrians, nearly twice as many walk at an unchanged frequency (31 percent). The lack of time pressure provides even fewer reasons to vary the speed of steps. These people walk at 116 steps per minute (blue columns Figure 51). Their frequency optimises energy consumption combined with a satisfying walking speed.

Figure 49 shows an about equal number of approaching and departing pedestrians that increase their step frequency (red columns in Figure 49). The difference in sensed time pressure is revealed in Figure 50 and Figure 51. Approaching pedestrians walk fast at nearly 118 steps per minute before they increase their frequency significantly to 128 steps per minute (red columns in Figure 50). Many of these pedestrians run and are certainly in a hurry.

Conversely, for departing pedestrians, before the frequency increase, they walk slowly at 112 steps per minute in the closer stop surroundings, after alighting from the means of transport (light red column in Figure 51). There are two reasons for this slow walking speed of departing pedestrians. Firstly, the closer stop surroundings are often busy. Pedestrians circumnavigate other people, react to cyclists, but also surround bins, benches, posts, and bus shelters. If they head towards the other side of the public transport corridor, many wait at the crossing. These conditions slow them down. Secondly, numerous passengers orientate themselves, or sort their clothes and bags right after alighting. Observing these people illustrates that they transfer mentally and physically from one mode of transport to another. These two reasons result in low average frequencies of 112 steps per minute close to the stop (light red column in Figure 51). After a slow start, 31 percent (red column in Figure 49) increase their speed to 118 steps per minute (dark red column in Figure 51). Some, but not necessarily all, of these pedestrians may be in a hurry. A proportion may simply desire to make up for the delay in the closer stop surroundings. The latter interpretation fits well to Whyte's observations of changing walking speeds when passing shop windows, as Section 3.1 presents.

We can summarise two central results: firstly, the step frequency variations of 82 percent of approaching pedestrians (green and red columns on the left in Figure 49) indicate time pressure. Secondly, only the frequency increase of the 31 percent of departing pedestrians could derive from haste (red column on the right in Figure 49). However, this increase could equally result from slow walking speeds in the busy closer stop environment.

Sensed haste certainly increases the inconvenience of street crossings, forced stops, detours or crowding. When considering time pressure as a negative emotion, walking trips towards the stop are also less pleasant. To improve the experience along walking trips towards the stop, an environment that shortens the subjective experience of distance appears increasingly important. Section 6.6 shows how walking environments influence the apparent walking distance. Further, convenient walking routes with no forced stops and detours can lower time pressure. An analysis of step frequencies in the next section uncovers conditions that influence the sense of haste among approaching pedestrians.

In the course of this research, I did not find literature that investigates the difference between walking for the purpose of approaching or departing from public transport stops. Lam and J. F. Morrall (1982) observed that approaching pedestrians slow down when they get close to the stop (p. 410). The investigated data set reflects well their findings.

The relationship between (1) headways[46] of public transport vehicles, (2) waiting times at the stop, and (3) time pressure to reach the stop is not an uncommon issue in the public transport sector. Limited resources meant that I was not able to investigate the effect of headways on the experience of time pressure when walking to stops. Short headways can decrease time pressure as the consequence of missing a public transport vehicle is only a short waiting time until the next one. A high level of public transport services at a stop increases the sensory experience of walking trips towards stops.

The following section illustrates behavioural differences between approaching and departing pedestrians, and indicates that walking environments have an influence on haste while walking to stops.

5.2 Different behaviour of approaching and departing pedestrians

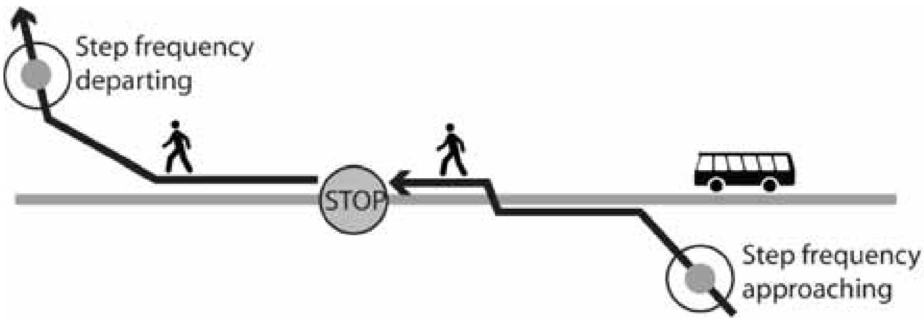
The analysis in this section aims (1) to uncover step frequency reactions to conditions along walking routes, and (2) to investigate behavioural differences between approaching and departing pedestrians. Interesting appears again, under which circumstances frequencies exceed 119 - 120 steps per minute. Such high frequencies are an energetically inefficient walking behaviour, indicating haste or

[46] Headways define the time interval between public transport vehicles that service the stop. In other words, headways define the service frequency along a public transport line.

an unpleasant walking experience. The analysis uses the step frequency measures from the public transport stop investigation (Section 4.5).

Two separate analyses for approaching and departing pedestrians are performed. Two *multiple linear regression statistics* separate the influence of numerous factors that are relevant for the step frequencies of approaching and departing pedestrians. Details of the statistics are discussed in Section 10.2 in Appendix 3. The two data sets comprise 154 observations for approaching pedestrians and 187 observations of departing ones. For approaching pedestrians, the frequency variations uncover a reaction to the remaining part of the walking route to the stop. Step frequency alterations of departing pedestrians show reactions to the part of the route they just walked after departing the stop. Figure 52 illustrates the locations for step frequency measures. Frequencies were measured at an average distance of 80 metres from the stop[47].

Figure 52: Locations for the step frequency measures of approaching and departing pedestrians



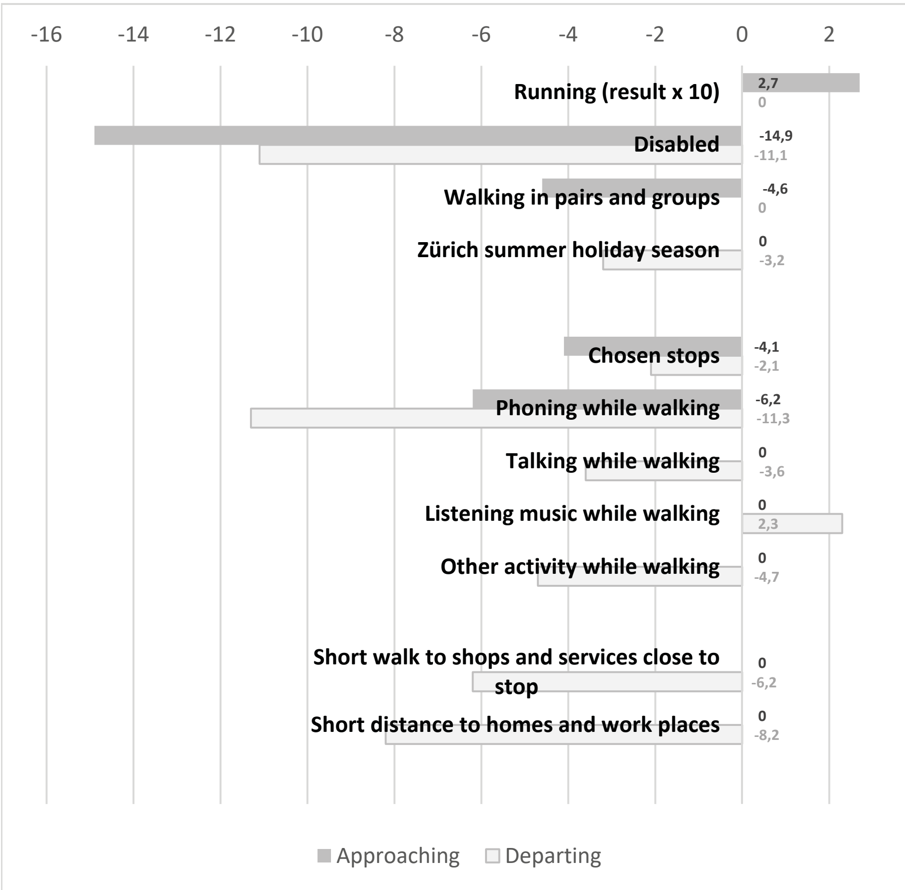
The average frequency of non-disabled and single walking approaching pedestrians is 118.4 steps per minute, and for departing pedestrians 114.8 steps per minute. Figure 53 shows 12 conditions that result in a significant variation in the average frequency. The running approaching pedestrians do so at a 27-steps-per minute higher frequency than average[48]. Departing pedestrians do not run. All disabled pedestrians in the data set walk slower. Pairs and groups walk slower when departing, but not when approaching the stop. People walk at 3.2 steps per minute reduced frequency during the holiday season in Zürich but not when

[47] The average distance varied by about plus/minus 40 metres.
[48] None of the observed pedestrians ran from the start to the end of the observation. The frequency increase does not show a generalizable difference between running and walking but serves to filter out higher frequencies of those who run.

approaching the stop. These results show that approaching pedestrians reduce their frequency only when they have to.

When pedestrians choose to stop, they are not in a hurry and frequencies reduce independently of approaching or departing the stop. The few pedestrians that use phones are forced to slow down, but the frequency reduces substantially more without time pressure when leaving the stop. Departing pedestrians reduce frequencies when they perform activities while walking; only those who listen to

Figure 53: Variation of average step frequency of approaching and departing pedestrians for 12 different conditions



music walk, surprisingly, walk with a slightly increased frequency[49]. The analysis in Section 6.2 shows that approaching and departing pedestrians equally often perform an activity while walking, but only approaching ones maintain a fast step. Short walking distances result in significantly lower step frequencies, but only when departing from stops. These results show again that departing pedestrians often react with a lower frequency in the environmental and individual conditions of their walk. Conversely, approaching pedestrians mostly maintain an unchanged fast step.

As Figure 54 shows, detours increase the frequencies of approaching pedestrians to an energetically inefficient level of over 120 steps per minute. On the way to the stop, detours increase time pressure and stress. On the contrary, frequencies of departing pedestrians drop slightly with a rising detour factor[50]. More complex walking routes can slow pedestrians down, but the effect remains minor. Differently, when very obvious obstacles or street crossings require them to take annoying detours, the frequencies of departing pedestrians rise, and equally so when accessing post boxes or cash machines. While only obvious detours seem to bother those who depart from the stop, any detours discomfort pedestrians on the way to the stop.

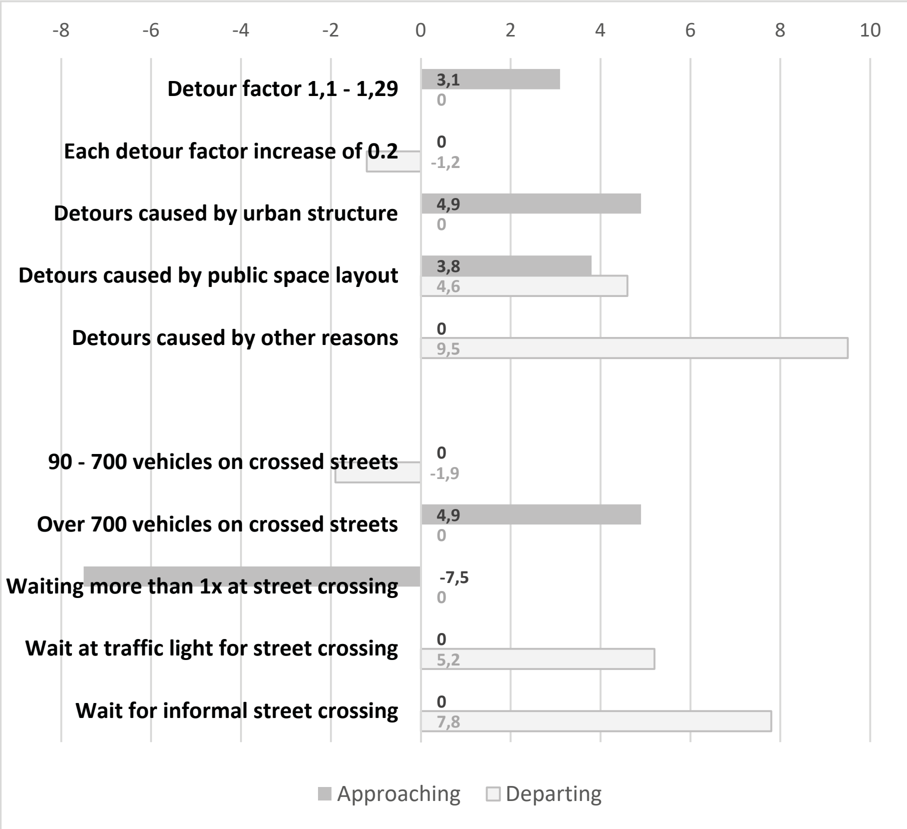
Street crossings do not vary the frequencies of departing pedestrians substantially. However, when having to wait before traffic allows them to cross, increased frequencies of 5.2 and 7.8 steps per minute indicate that forced stops are not welcome. The frequencies of approaching pedestrians rise to an average of 123.3[51] steps per minute whenever they have to cross a busy street (with more than 700 cars per hour). When large streets separate approaching pedestrians from the stop, the risk of unpredictable waiting times increases stress. When approaching pedestrians wait patiently two or more times at street crossings, they walk in a relaxed manner. They may have plenty of time to reach the stop, as a 7.5-steps-per-minute reduced average frequency indicates.

[49] The frequency variations with activities performed while walking remain insignificant in the statistical analysis. More varied frequency reactions very likely cause insignificant results.

[50] Each detour factor increase with the value 0.2 results in a drop of the frequency (of departing pedestrians) by 1.2 steps per minute. As detour factors vary mostly between 1.0 and 1.4, the effect is minor.

[51] Average frequency of 118.4 steps per minute added to the calculated frequency change of 4.9 steps per minute, as Figure 54 shows.

Figure 54: Variation from the average step frequency (in steps per minute) with detours and street crossings



The analysis uncovers differences between walking to approach the stop and walking to depart from it. Approaching pedestrians maintain a fast stride whenever possible. They focus on reaching the stop in time. Detours and street crossings can result in unpleasant delays, which increase time pressure, as frequencies indicate. Walking can become very unpleasant. Conversely, the varied frequencies of departing pedestrians show a more individual walking behaviour. The lack of time pressure allows them to adjust the swing of their legs according to individual preferences. Departing pedestrians have more freedom to choose the most comfortable frequency, and they do so.

The differences between approaching and departing pedestrians may not appear very surprising and have therefore engendered little interest in transport research. I consider this lack of interest as a shortcoming, especially when we aim to understand the sensory and emotional experience of walking trips towards or away from public transport stops.

The statistics behind the analysis in this chapter do not provide the wealth of detail that direct observations do. Observations enable explanations through a high level of detail that statistics do not provide. My interpretation of the statistical results rests on the experience I gained during countless observations and detailed studies of the collected video material. The numerical results in Figure 53 and Figure 54 should not be used to generalise or predict averages of step frequencies.

5.3 Walking routes and pedestrian behaviour

Walking routes to and from public transport stops have a clearly defined destination or departure point. We can investigate whether chosen walking routes around stops show a recurring pattern. Understanding such patterns, if they exist, may inform planning strategies to enhance walking environments for better pedestrian access to stops. Understanding the circumstances that determine pedestrians' route choice may inform the process to find suitable locations for street crossing facilities, or where dangerous informal street crossings may occur. The differences between approaching and departing pedestrians are again relevant for this analysis.

Figure 55: Footpaths around public transport stops, red sector: walking along the corridor with approaching public transport vehicles; yellow sector: walking routes leading directly to the stop; blue sector: walking along the corridor with vehicles that just left the stop.

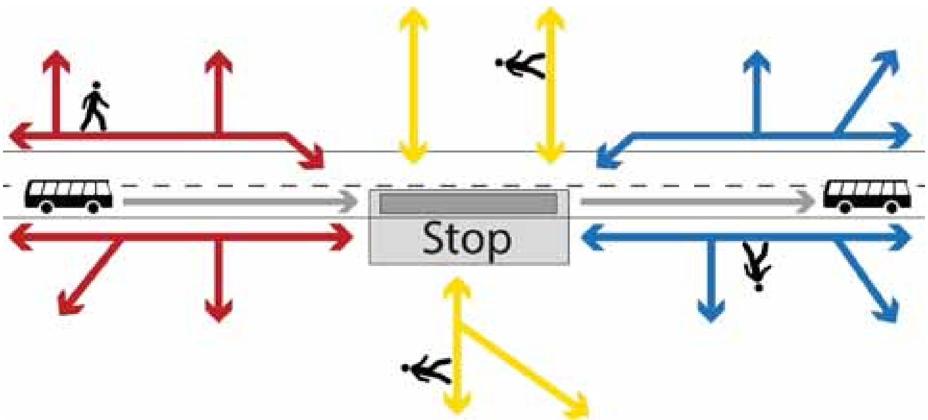
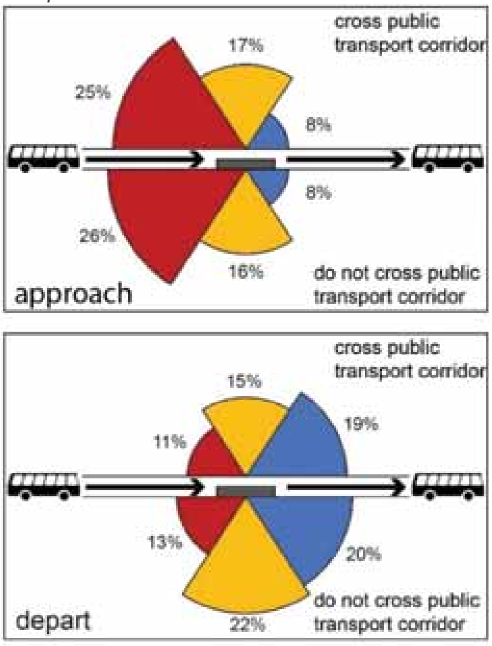


Figure 56: Percentage of approaching/departing pedestrians using footpaths in different sectors; red sector: footpaths with same directions as arriving bus/tram; yellow sector: access directly to stop through footpath network; blue sector: footpaths with same directions as departing public transport vehicle



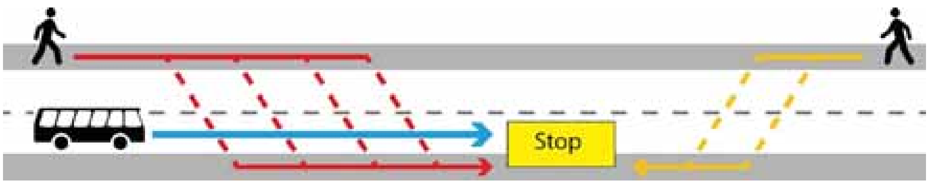
Section 2.6 presents the research of Brändli et al. (1978) who define four sectors around stops. They find approaching pedestrians use different sectors from departing ones. This research defines three sectors for footpaths that are linked to the stop, as the three colours in Figure 55 illustrate. Figure 56 shows the percentage of pedestrians that approach/depart from stops through one of the three sectors. Results in Figure 56 equal the findings of Brändli et al. Fifty-one percent of approaching pedestrians reach stops from the same directions as public transport vehicles do (red sector). Forty-nine percent depart from stops in the same directions as public transport vehicles leave stops (blue sector). Walking against the main travelling direction appears unattractive, as explained in Section 2.6[52]. The observed pattern remains stable at any of the 14 investigated stops and does not change substantially between central and less central or suburban stops.

The need to cross streets can influence the choice of the walking route to the stop. The registrations show that **approaching pedestrians** prefer to cross streets as early as possible, as Figure 58 shows. The analysis of step frequencies in the previous section showed that street crossings increase time pressure. As street crossings can require unpredictably long waiting times, approaching pedestrians

[52] The behavioural pattern also partly explains that not all public transport users access the closest stop, as Walther (1973) finds (Section 2.4).

desire to get over busy streets as early as possible. When remembering that most pedestrians approach stops from the same directions as the public transport vehicle (as Figure 56 shows), most pedestrians will cross the public transport corridor in front of the bus or tram they intend to catch, as the red broken lines in Figure 58 indicate.

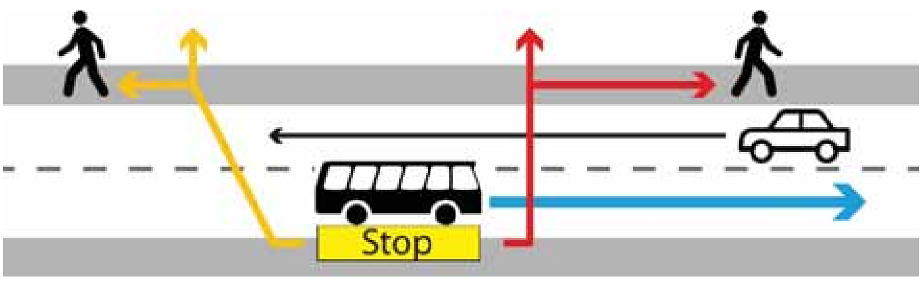
Figure 57: Street crossing behaviour of approaching pedestrians, red = most frequent routes, orange = less frequented routes



Departing pedestrians also prefer to cross the public transport corridor as early as possible after alighting, often close to the stop. When the bus stops on the carriageway, many departing pedestrians cross the public transport corridor right in front of halted buses or trams (red arrow in Figure 57). The logic behind the observed behaviour is simple. The standing public transport vehicle at the stop blocks vehicle traffic on one carriageway. Most pedestrians intuitively use this advantage to cross the public transport corridor right after alighting.

Street crossings behind buses and trams (orange arrow Figure 57) are more dangerous. The vehicles driving on the other side of the street do not see the crossing pedestrians until they suddenly emerge from behind the public transport vehicle. However, the analysis of preferred walking routes (Figure 56) shows that few cross streets behind the halted bus or tram.

Figure 58: Street crossing behaviour of departing pedestrians, red = most frequented route, orange = less frequented route



When buses stop in a bus bay, behaviour differs somewhat. Here, many departing pedestrians cross streets informally at some distance from the stop in front of the bus. As the bus no longer blocks one carriageway of the street, crossing right after alighting is often not possible. As a consequence, pedestrians start walking while waiting. As soon as traffic allows it, pedestrians cross the street informally. Bus bays appear less practical for two reasons. Firstly, pedestrians have to wait longer before they can informally cross both carriageways. Secondly, when having to wait longer to cross, pedestrians are likely interfere with the public transport vehicles from which they just alighted, and which also are leaving the stop. This may also delay the departure of the bus.

The understanding of street crossing behaviour can be advanced by a brief analysis of approaching pedestrians that run. Running pedestrians perform more dangerous street crossings by taking any available shortcut. When running, the focus on reaching the stop rises to the detriment of careful attendance to traffic on the streets. A number of observations at the public transport stop *Holmens Kirke* in Copenhagen show the conditions, under which pedestrians run, as Figure 59 illustrates. Pedestrians leave from an office building, walk in a relaxed manner and wait patiently at street crossings. At the moment they spot the public transport vehicles they intend to catch, they start running.

Figure 59: Running when spotting the public transport vehicle at the stop 'Holmens Kirke' in Copenhagen

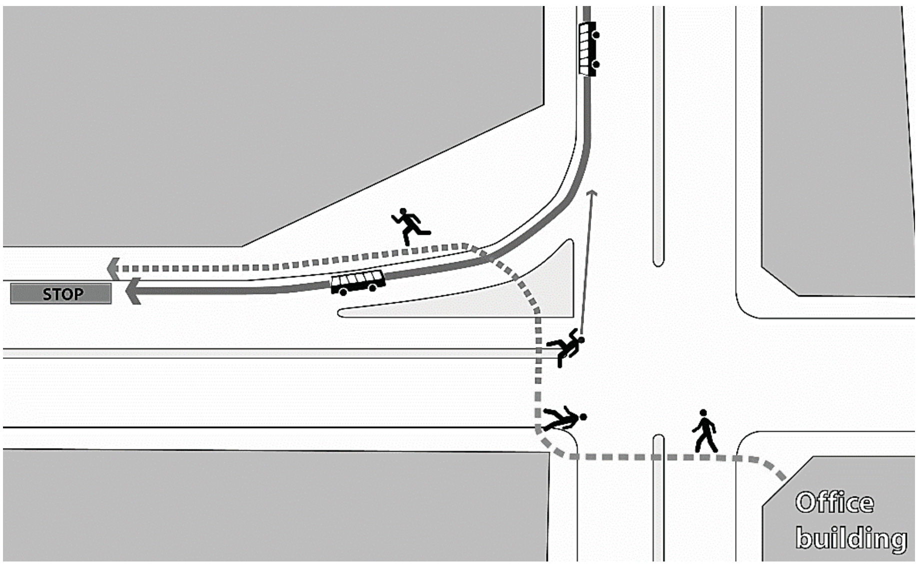
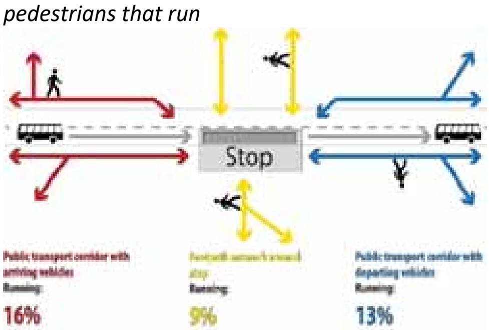


Figure 60: Percentage of all observed approaching pedestrians that run



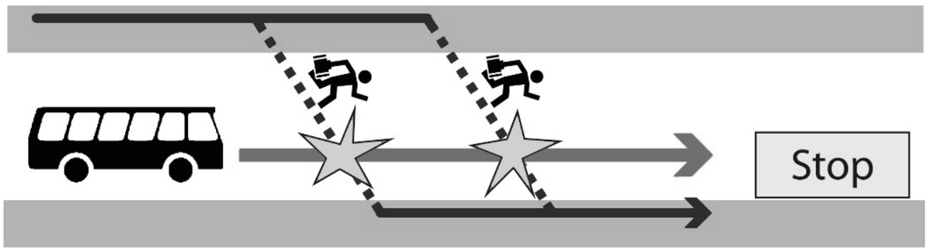
The ability to see the approaching bus or tram increases time pressure and causes more pedestrians to run towards the stop. Figure 60 shows the percentage of all observed approaching pedestrians that run. Along the red indicated footpaths, the driving public transport vehicles are most visible to approaching pedestrians. Accordingly, the percentage of running pedestrians is highest at 16 percent. Even along the blue indicated footpaths, 13 percent run.

Figure 61: Fast crossing of public transport corridor for departing pedestrians in front of tram

From the analysis of (1) preferred walking routes, (2) preferred street crossing locations, and (3) the percentage of running pedestrians along access routes to the stop, we can learn two lessons. Firstly, easing street crossings for departing pedestrians in front of halted public transport vehicles has two advantages. The majority of departing pedestrians can leave the stop safely and quickly. As a result, fewer will cross the public transport corridor informally, reducing disorderly interactions between pedestrians, cars, and public transport vehicles. The street layout at the stop *Englischviertelstrasse* in Zürich presents a good solution, as Figure 53 shows. A zebra crossing in front of the halted tram gives pedestrians the right of way and a traffic isle prevents cars from overtaking the halted tram. Alighted passengers have crossed the street before the tram starts to drive off from the stop.

Secondly, the analyses in this section identify a hotspot for many dangerous street crossings for approaching pedestrians, as Figure 62 shows. Three conditions create this hotspot for possible accidents. (1) Many approaching pedestrians cross the public transport corridor here, and (2) they often do so informally. Further, (3) we find the highest percentage of running at the location indicated in Figure 62. These running pedestrians are late and likely to cross the street right in front of approaching buses and trams.

Figure 62: Accident hotspot for approaching pedestrians that cross the public transport corridor



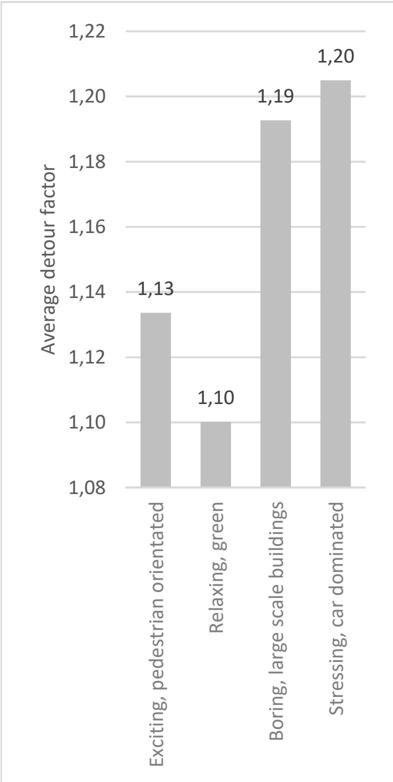
Unfortunately, there is no easy solution to the observed dangerous street crossing pattern that Figure 62 illustrates. Lower driving speeds and reduced vehicle traffic in the public transport corridor can best ease access to the stop for approaching pedestrians. The stops *Kreuzstrasse* and *Rathhaus Platz* in Zürich, as well as *Elmgade* in Copenhagen restrict car access. Pedestrians cross the carriageway safely and quickly, informally at preferred locations, with few stops to wait for cars. At the same time, walking becomes more pleasant with fewer emissions from cars.

5.4 Detoured walking routes

Section 2.4 shows that detours increase in nearly any urban environment as a result of any built structures, barriers such as streets or railway lines, or property borders that pedestrians cannot step over. The average detour factor for all 444 observed pedestrians around the 14 public transport stops was 1.16. The factor remains about equal around stops in Copenhagen and Zürich, at 1.15 and 1.16, but rises in Brighton to 1.22[53]. Detours are equally relevant for approaching and departing pedestrians and the analysis does not differentiate between the two groups.

[53] These detours derive not from the total distance walked to or from stops. The applied method only allowed observation of walking routes to an average distance of 80 metres from stops. Most observations range between 40 to 120 metres in length.

Figure 63: Variations of the detour factor in differently characterised walking environments



Under which environmental conditions do detours increase? The data set differentiates between four environmental typologies according to the *circumplex model of the walking environment* (Chapter 4.4). Figure 66 shows how the average detour factor rises for walking routes in boring and car-dominated environments. Here, walking routes lead along large-scale buildings and wide public transport corridors, often with four carriageways. These surroundings reduce route options. Conversely, pedestrian-oriented environments mostly consist of a fine meshed footpath network. Walking routes are not channelled between buildings and streets and, hence, allow a more direct access to public transport stops. Accordingly, the number of detours decreases. These results reflect a problem discussed by the authors presented in Section 2.4.

Are there other factors of the pedestrian environment that lengthen walking distances to stops? As the second research question in Section 2.10 defines, the data differentiates

Figure 64: Detour factor and the percentage of pedestrians that took detours

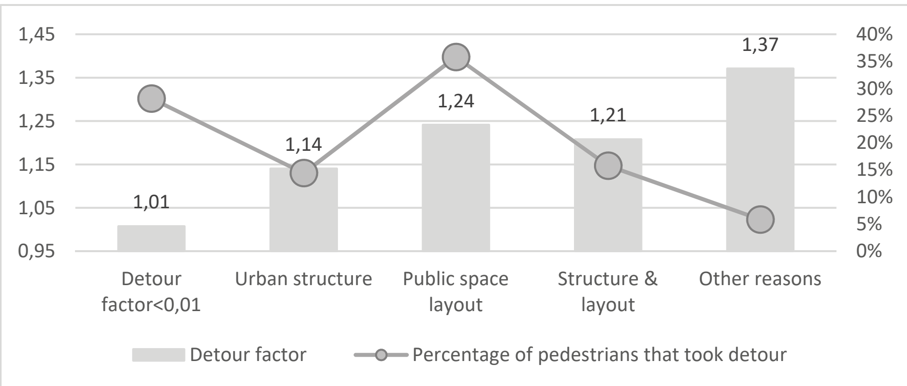


Figure 65: Increase of the average detour factor with more street crossings

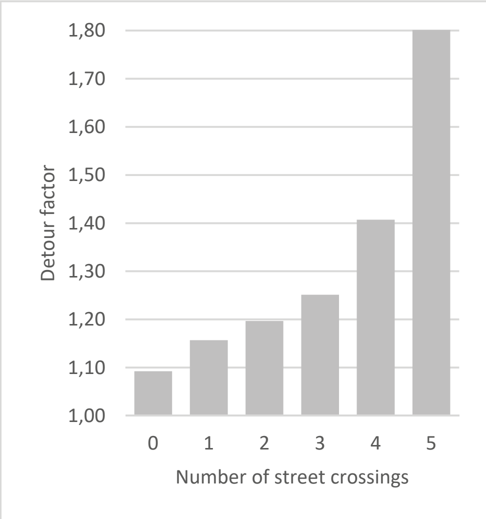
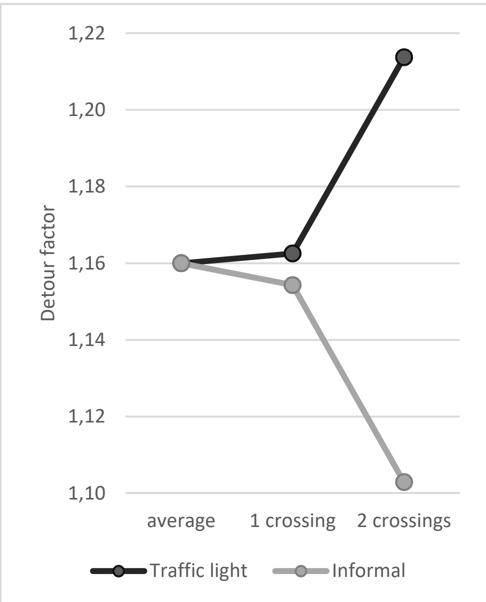


Figure 66: Detour factors with street crossings at traffic lights and informal street crossings



between three reasons for detours: (1) the urban structure, (2) the public space layout, and (3) other reasons. Figure 64 shows how the detour factor varies with these conditions together with the percentage of pedestrians that take detours. About one third approach or depart from the stop in a direct line (detour factor < 0.01). The short observed walking route is likely to influence this result, as the text discusses later.

The longest detours, caused by 'other reasons', increase when people access cash machines, post boxes, or when pedestrians are disorientated. Carriageways of streets, obstacles in the public space, and the layout of footpaths (public space layout) cause more detours than buildings and property boundaries around the stop (urban structure). Literature to date predominantly discusses the urban structure and missing links in the footpath network as the main reasons for detours. On the contrary, the results in Figure 64 suggest that the public space layout has a significant influence on detours.

Investigating further the effect of streets shows increasing detours with more street crossings, as Figure 65 illustrates. Street crossings explain why the number of detours rises in car-dominated environments. Detours at street crossings derive from a zigzag walking route when crossing streets at a right angle and also from unsuitably located traffic lights and zebra crossings. Not all pedestrians accept these detours. Figure 66 shows how the detour factor drops when crossing streets informally as compared to at traffic lights. Informal street crossings are effective shortcuts.

Walther (1973, p. 121) finds a rising detour factor of 1.33 with shorter, 100-metre-long walking distances to bus stops (Section 2.4). At a detour factor of 1.16, the data from this research shows a lower average for the 80-metre-(average)-long walking routes. The difference derives from differences in methodology [54]. The rise in the detour factor with short walking routes to stops, as Walther finds, is likely to derive from inconveniently located street crossing facilities, and a layout of carriageways that prioritises car traffic and not pedestrian access to stops.

The public transport stop investigations did not enable complete walking routes between stops and destinations/departure points to be registered. The methodology reduces the detour factor of the city structure and increases the influence of the street layout. Nevertheless, the data shows the so-far understudied effect of street crossings and the public space layout.

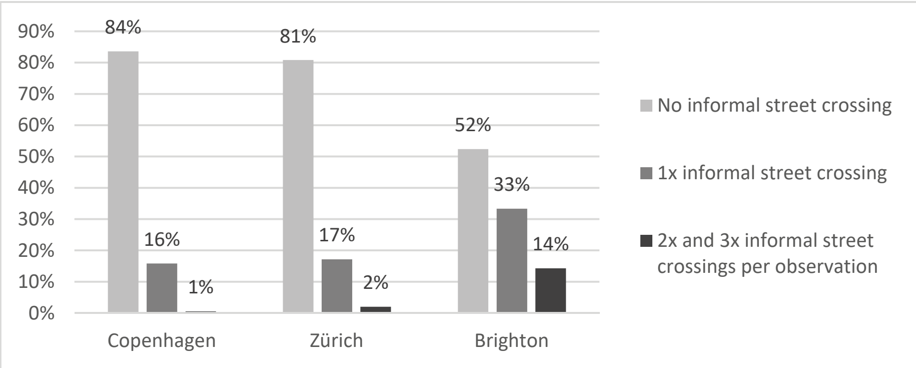
5.4.1 Do railings prevent pedestrians from taking shortcuts?

Around many public transport stops in the UK, railings between pavements and carriageways are meant to prevent informal street crossings. Unfortunately – at least from the perspective of responsible planners, many pedestrians jump over these barriers. People even walk on the 'wrong' side of the railing on the carriageway. High traffic volumes seem not to impress these pedestrians. Walking on the wrong railing side enables them to continue walking and to cross the street when traffic allows. The method of 'walking while waiting to cross' saves, in many instances, a jump over railings. When railings on the other side of crossed streets prevent them from stepping onto the pavement, many continuing walking along the carriageway until the railing ends. When walking along railings represents a detour, pedestrians jump over these barriers.

The observations give the impression that railings cause increasingly more informal street crossings where these barriers end. Railings appear not only to increase informal crossings. These barriers also result in increasingly dangerous

[54] Walter collected information on origins/destinations of walking routes and drew up the most probable walking route to/from stops.

Figure 67: Percentages of informal and potentially dangerous street crossings



crossings. Pedestrians accept high risks to avoid the detours that railings require. Observing how pedestrians behave shows that railings do not reduce accident risks.

In contrast to the investigated stops in Brighton, there are no railings around nearly all investigated stops in Copenhagen and Zürich. This was also the case along trafficked streets and busy junctions. In Brighton, pedestrians perform about twice as many informal street crossings as in the other two cities (Figure 67). The fact that there were only two case studies in Brighton limits generalisations. Nevertheless, the data shows an obvious difference between the three investigated cities. The observed behaviour in Brighton could result from fewer and unsuitable provided street crossing facilities but equally from a different culture. Even if the phenomenon in Figure 67 cannot be fully explained, the comparison shows that more railings in Brighton fail to reduce informal street crossings.

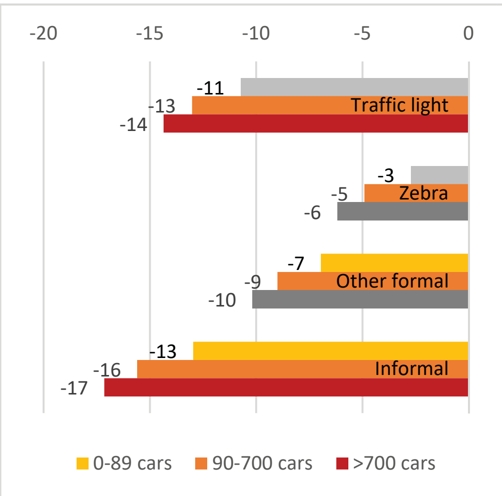
5.5 Barrier effect of streets – waiting at street crossings

Street crossings can require pedestrians to wait until traffic allows them to cross. Waiting times can result in unpredictable time delays when accessing stops. Streets therefore have a barrier effect that rises with the amount of traffic. To estimate the barrier effect of streets, this section asks how long pedestrians wait on average before they can cross streets when accessing public transport stops. The findings allow the calculation of the effect of street crossings on access times to reach stops and help to evaluate acceptable walking distances.

The enquiry again uses the data from the public transport stop investigations. Interestingly, waiting times do not differ significantly between approaching and departing pedestrians. Therefore, both groups are studied together. The analytical principle is the same as the method that Gehl and Svarre (2013) describe for investigating street crossings, as Section 2.5.1 presents. The inquiry in this chapter uses each of the observed walking trips around stops as a *test walk* to study the influence of street crossings on the time pedestrians needed to get from A to B.

Due to limited resources, waiting times at street crossings are not measured during the public transport stop investigations. The data collection registered (a) when street crossings required pedestrians to wait, (b) the duration of each observation, and (c) the distance walked. From time and distance, we can calculate an *access speed*, which describes how fast pedestrians get from A to B. A statistical regression analysis investigates the influence of street crossings, and further factors, on the access speed. In other words, the statistics show how street crossings lengthen/shorten the time pedestrians need to get from A to B. We should not confuse the *access speed* with the *walking speed*. Walking speeds can alter several times along a route. Meanwhile, the access speed describes the duration of the walk between A and B, which is influenced by a number of factors such as waiting times before crossing streets.

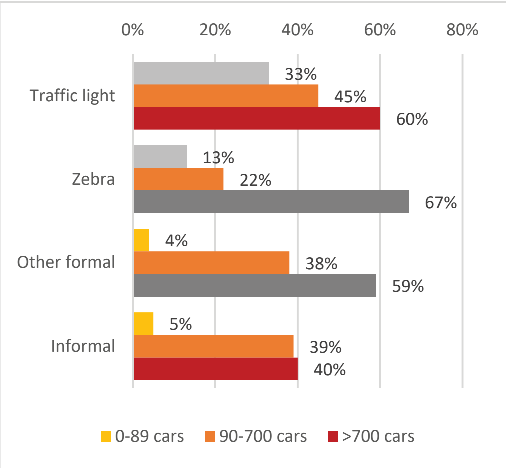
Figure 68: Time delay (seconds) caused by waiting times at street crossings; grey bars indicate conditions that occurred never or rarely



A *multiple linear regression analysis* can show how the average access speed reduces when pedestrians wait at street crossings. As we are interested in the time delay that occurs at street crossings, we can recalculate the access speed reduction to a time value. Dividing the speed reduction by the average walked distance[55] results in the average time delay that occurs with street crossings. To keep the text free from statistical jargon, in Section 10.3, Appendix 3 presents and discusses the statistics behind the presented data in this section.

[55] The data comprises the length of all observed walking routes around stops. The average route length is calculated separately for the groups of pedestrians that crossed streets at

Figure 69: Percentages of pedestrians that had to wait at street crossings, specified according to crossing type and cars on crossed street; grey bars indicate conditions that occurred rarely



The analysis differentiates between street crossings at (1) traffic lights, (2) zebra crossings, (3) other formal crossing facilities[56], and (4) informal street crossings. Further, the number of cars per hour on crossed streets influences waiting times and the percentage of people that have to wait before crossing streets. The data shows significant differences with more than 90 cars on streets, and again with more than 700 vehicles. Figure 68 shows the time delays at street crossings for all pedestrians that wait. Figure 69 indicates the percentages of pedestrians that wait.

When informal street crossings require pedestrians to wait, the time delay appears surprisingly higher than at traffic lights. Informal street crossings allow walking while waiting until traffic on the street allows pedestrians to cross, as Section 2.5 explains. However, when pedestrians reach the pavement on the opposite side of the street from the stop, continuing walking does not get them closer to the stop. Equally, the layout of carriageways, such as, for example, traffic junctions close to stops, restricts the possibility of walking while waiting. As Figure 69 shows, about 40 percent of those that cross streets (with more than 90 cars per hour) informally cannot walk while waiting. These people stop at informal street crossings and wait longer than at traffic lights. With more than 90 cars per hour, the advantages of informal street crossings decline when accessing public transport stops.

Traffic lights require most pedestrians to halt in comparison to other crossing facilities, as Figure 69 displays. By combining waiting times and the percentage of

different street crossing facilities. The average route length is 97.2 metres for all pedestrians that crossed at traffic lights, 101.8 metres for all that walked over zebra crossings, 109.1 metres at other formal crossing facilities, and 84.3 metres at informal street crossings.

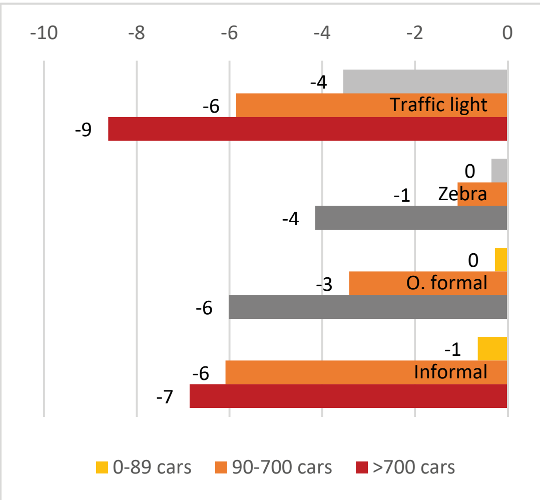
[56] Other formal crossing facilities are mostly continued pavements where side streets intersect with larger streets. These crossing facilities are rarely used, with more than 90 cars per hour on side streets.

those that wait[57], Figure 70 indicates the average barrier effect of street crossings. Time delays in Figure 70 occur on average for all pedestrians that cross streets, including those who do not stop and wait.

Crossing streets informally with more than 700 vehicles per hour shortens the average time delay when compared to traffic lights. However, with more than 1200 cars per hour, informal street crossings become increasingly difficult. The data does not quantify this effect, but the observations provide a clear impression. With over 1500 vehicles on streets to cross, and driving speeds of 50 kilometres per hour, informal crossings no longer present an option for the majority of pedestrians.

When pedestrians have the right of way at zebra crossings and other formal crossing facilities, the barrier effect of streets drops significantly. Waiting times varied at these two types of street crossings[58] more than at other facilities. The average time delays in Figure 70 vary at zebra crossings and other formal crossing facilities by between 3 and 5 seconds with 90 to 700 cars on the street.

Figure 70: Average time delay (seconds) that street crossings caused for all pedestrians; grey bars indicate conditions that occurred rarely



Nevertheless, average time delays (Figure 70) do not matter when approaching public transport stops. Ensuring arrival in time at the stop requires the longest possible time delay at street crossings to be taken into account. However, the time delays that can occur with street crossings remain unpredictable. The delays for those that waited (Figure 68) are only averages, and some individuals can have waited much longer. Hence, the barrier effect of streets remains in reality even more extensive

[57] The barrier effect of street crossings is calculated by multiplying the percentage of pedestrians that waited with the time delays that occurred for those that waited.
[58] These variations caused insignificant results in the statistical analysis.

than the average time delays of those that waited, as Figure 68 indicates.

How extensive do time delays appear when we consider the total walking route to reach or depart from public transport stops? In Zürich, about 50 percent of the 600 interviewed public transport users report walking for three minutes or less to tram stops. With a fast walking speed of 94 metres per minute[59], a 2.5-minute walk equals a 235-metre-long walking distance. Figure 71 shows time delays (calculated from the time delays in Figure 68) as a percentage of a 2.5-minute walk. When pedestrians do not have the right of way, crossing once at traffic lights or informally increases the time to reach the stop by 10 and 11 percent. A second crossing can increase the walking time by 20 to 22 percent. Of the 444 observed pedestrians, 28 percent cross more than one street while accessing the stop. As discussed, approaching stops requires even longer time delays to be taken into account when walking routes lead over trafficked streets.

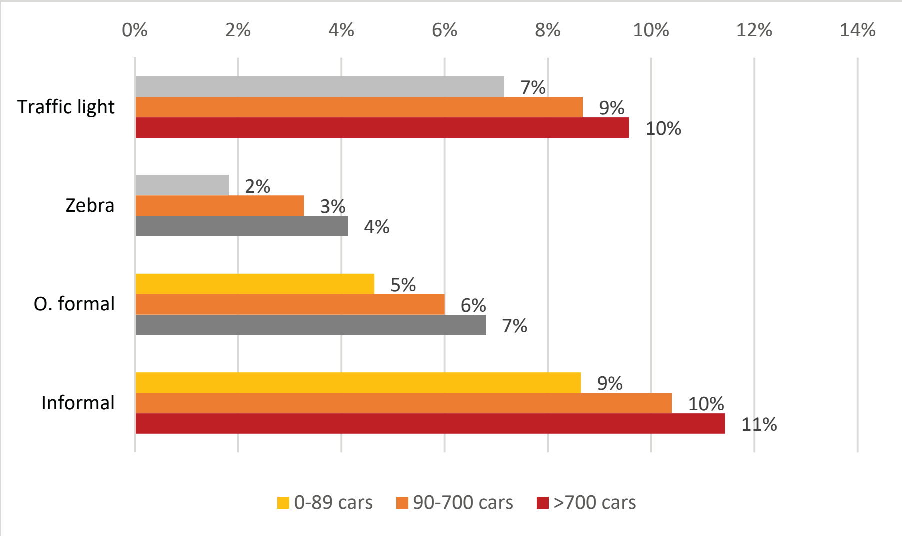
Waiting times remain high at informal street crossings and traffic lights. How convenient are traffic lights as street crossing facilities for pedestrian access to public transport? Delays at traffic lights depend on the length of green intervals for pedestrians. The important question is: are green intervals adjusted to ease pedestrian access to public transport or, rather, according to the amount of car traffic on streets? The analysis shows increasing waiting times at traffic lights with more cars on streets. Traffic lights are adjusted according to vehicle traffic volumes, which is not so surprising. When green phases of pedestrian traffic lights are adjusted to the amount of vehicle traffic on carriageways, they do not enhance pedestrian access to public transport.

How valid are the time delays at street crossings presented in this chapter? We should remember that delays derive not from observed waiting times but from a statistical calculation. The statistics (presented in Appendix 3 Section 10.3) indicate that the presented values for delays can vary by +/- 14 percent[60]. I

[59] Appendix 3, Section 10.4 presents a method to calculate the average walking speed of the observed pedestrians during the public transport stop investigations. This calculation shows a fast average walking speed of 94 metres per minute.

[60] The statistics show an average variation of the calculated access speed of 13.13 metres per minute. For the calculated average walking speed of 94 meter per minute, a variation of 13.12 meter per minute corresponds with a 14 percent alteration. Appendix 3 discusses the statistical details.

Figure 71: Percentage of time increase for a 250-metre-long walk to the stop when adding time delays for average occurred waiting times at street crossings; grey bars indicate conditions that occurred rarely



consider the calculated time delays to be exact enough to evaluate the barrier effect of streets in planning practice. The validity of the statistical calculation is discussed in Section 10.3 of Appendix 3.

How do the findings of the analysis in this section fit with findings of other researchers discussed previously in Section 2.5 and 2.5.1? The average waiting times presented in Figure 68 in this chapter fit well to the model presented by Maier (1986, p. 157), but not to the results of Maier's own observations. He observed shorter delays. Shorter waiting times can result from more possibilities to walk while waiting to cross. Accessing a public transport stop restricts walking while waiting to some degree. When reaching the section of the pavement on the opposite side of the street from the stop, continuing walking would cause a detour.

H. Monheim and Monheim-Dandorfer (1990) find higher percentages for walking on a red light as compared to the analysis in this section. I see two reasons for this difference. Firstly, very long red intervals of around 60 seconds remained an exception at all investigated public transport stops. Secondly, I consider that those who access a public transport stop more often apply strategies to avoid waiting when crossing streets. Keeping these two differences in mind, the findings in this chapter remain comparable with the findings of H. Monheim and Monheim-Dandorfer.

Gehl and Svarre (2013) find that street crossings consume between 17 and 52 percent of walks with differently length and varying numbers of streets to cross in an Australian city (p. 44). This research finds that one street crossing (traffic lights or informal crossings) consumes about 10 percent of a 235-metre-long walk. With more than one street crossing along a 250-meter-long walk, the results of this research correspond with the findings that Gehl and Svarre report.

The attractiveness of informal street crossings depends on the length of the detours they allow pedestrians to avoid. Three conditions influence whether pedestrians are able to cross informally: first, the possibility to continue walking until traffic allows them to cross; second, the physical and mental abilities to perform the necessary manoeuvres; and, third, the amount of traffic on carriageways. More than 1500 cars on crossed streets disable informal crossings for most pedestrians.

Maier (1986, p. 156) finds pedestrians shorten waiting times by walking along streets until traffic allows an informal crossing (Section 2.5, Figure 14). Knoflacher (1989, p. 182) doubts whether pedestrians really desire the behaviour Maier describes. The observations of approaching pedestrians demonstrates that *walking while waiting* is a reaction to rising time pressure when trafficked streets divert pedestrians from public transport stops. The analysis in this section shows that informal street crossings do not shorten average time delays as compared to traffic lights. Additionally, walking while waiting requires a high level of attention to be paid to cars on streets. On the basis of this understanding, informal street crossings do not appear to be a desirable option. With more than 500 cars per hour on crossed streets, informal street crossings become increasingly unpleasant.

Traffic lights ease pedestrian access to public transport when green phases for pedestrians are not solely adjusted to the amount of car traffic on streets. From the observations, I gained the impression that, for the majority of pedestrians, the safety advantage of traffic lights remains lower than we mostly assume. Pedestrians are least attentive at traffic lights. People are more attentive at informal and zebra crossings. This is different for physically and mentally less capable pedestrians such as the disabled, elderly persons, and children. For this group, the more strict regulation of traffic lights remains safer.

Zebra crossings allow pedestrians to cross streets at the second they reach the curb of the carriageway. Having the right of way is most convenient for pedestrians.

Zebra crossings regulate the interaction between cars and pedestrians as equally strictly as traffic lights. Nevertheless, zebra crossings are broadly perceived to be less safe than traffic lights. This impression results in the first instance from thoughtless car drivers. The danger to life from cars is so serious for pedestrians that it takes only a few careless vehicle drivers for zebra crossings to become unsafe. We need to remember that it is not the pedestrian who represents the danger but the weight of a car that moves at 50 kilometres per hour. Disregard for pedestrians' right of way at zebra crossings increasingly threatens children, the elderly and disabled pedestrians.

5.6 Access to shops and services

Walking provides easy access to shops along the way, without having to park a car or lock a bicycle. Catering for daily needs along journeys that include public transport can save an extra trip. On the other hand, purchased items need to be carried. This section investigates how often and under which conditions public transport users access additional destinations along walks to and from stops.

The public transport stop investigations included to some extent instances when pedestrians accessed shops and facilities in buildings along the observed walking route. Of the 444 studied walking trips, only 19 percent led to shops and services in the observed area around investigated stops. As the methodology only allowed observation of pedestrians along a sections of the walk to or from the stop, they may have accessed additional destinations at unobserved locations. The percentage of walkers accessing shops varies between zero and 66 percent between the 14 investigated stops. Supermarkets located close to the stop are most attractive.

The need to carry purchases on public transport vehicles does not lower the percentage of pedestrians that access shops or facilities before the ride. Public transport users access shops where these are available. Saving an extra journey appears to be the most important advantage. Other inconveniences do not dominate this central benefit.

Figure 72: Percentages of different errands from the 24.8% of all pedestrians that performed errands along the walk to the stop

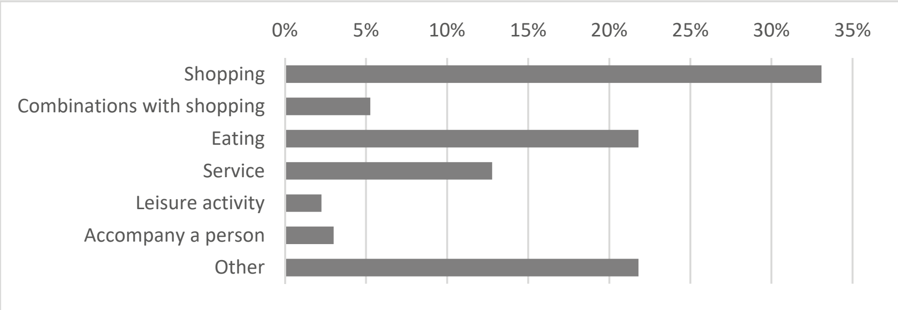


Figure 73: Frequency of undertaken journey with public transport when accessed facilities along the walk to the stop

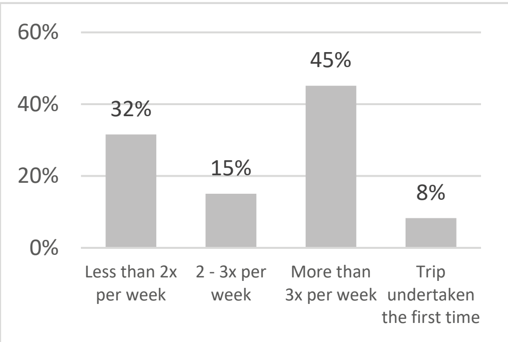
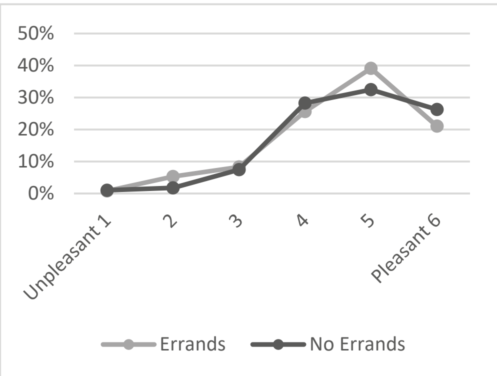


Figure 74: Evaluation of the walked trip of pedestrians that performed errands and those that did not perform errands



The data from the interviews in Zürich allow a more detailed analysis. Twenty-five percent of the interviewed tram passengers indicated that they accessed additional destinations along the walk to the stop. Figure 72 presents an overview of all accessed locations. Purchasing goods and food appears most important.

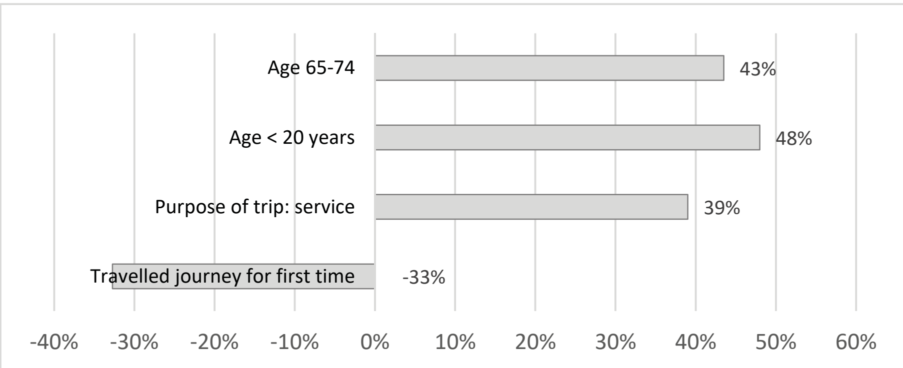
Of those that access further destinations while walking to stops, 45 percent undertake the journey regularly more than three times per week (Figure 73). This group consisted of 84 percent of people travelling either for work or education purposes. Regular use of public transport increases the percentage of access to additional destinations.

Of passengers that accessed services, the second largest group (32 percent) makes the journey less than once a week for various purposes. Interestingly, 73 percent of this group walks four times a week for more than 10 minutes, indicating a positive attitude towards walking. It is to be assumed that a large part of these passengers usually walks but uses public transport once a week when purchasing goods.

Figure 74 shows how pedestrians evaluated the pleasantness of the walking trip to the stop. The figure differentiates between those that accessed facilities and those who did not. Both groups indicate an almost equally pleasant walking experience[61]. Access to services seems not to reduce the pleasantness of public transport related walking trips.

Figure 75 presents various conditions that influence the percentage of errands before the tram ride. Average access to additional destinations increased by over 40 percent among interviewees aged between 65 and 74, and equally among those aged under 20. In the younger group, 82 percent reported having no access to a car. Fewer mobility options increase the use of facilities. Among those aged between 65 and 74, car availability does not appear lower than in other age groups (between 20 and 64), but 79 percent do not have a regular job. With sufficient available time, public transport and walking appears attractive for running errands for people between 65 and 74 in Zürich.

Figure 75: Increase/decrease (in percent) of the average 24.8 percent that accessed facilities. Variation caused by age, the purpose of the trip, and less passengers that travelled the journey the first time accessed services.

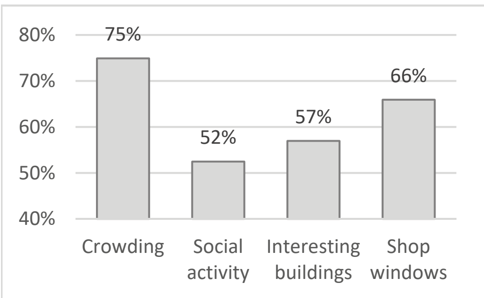


[61] Pedestrians who accessed facilities evaluated the pleasantness of walking at 4.60 on the 6-point Likert scale. The average evaluation of those who did not access further destinations was 4.59 on the scale.

When the main purpose of the travel is to access services such as, for example, doctors, banks, post office, or hairdressers, the average percentage of additional errands along the walk to the stop increases by 39 percent (Figure 75). Among these travellers, 61 percent had no car available. Twenty-three percent consider using a car to be impractical. Rigorous parking restrictions in Zürich clearly show their effect. Independent of these conditions, the main purpose of the journey itself may also increase access to additional destinations. Travelling to doctors, banks, post office, or hairdressers may be necessary, but activities at these locations are less time-consuming than journeys to work, education, or for leisure purposes. Linking further errands to these shorter activities makes leaving the house more rewarding.

When undertaking the journey for the first time, the average amount of travellers that access additional destinations lowers by 33 percent. These people are likely to be less familiar with public transport timetables and routes. Time estimates for the walk to the stop are more difficult with a lack of experience. Accessing additional destinations along these walks appears less attractive. First-time travellers may further have daily routines that exclude the possibilities for errands along walking routes to stops. These people probably cater for their needs along other journeys.

Figure 76: Increase (in percent) of the average 24.8% that accessed facilities with chosen photos that described the environment along the walked trip to the stop



With the help of the eight photographs, interviewees were asked to describe their impression of the environment along the walk to the stop. The chosen pictures illustrate the urban characteristics of the areas where interviewees access facilities before the tram ride. Average access to additional destinations increases by between 52 and 75 percent with pictures that indicate crowding, social activity, interesting buildings, and shop windows (Figure 76).

The pictures describe the character of central urban areas, for example around the Zürich Main Station or the public transport hub *Stadelhofen*. More and diverse available facilities in these urban areas are likely to increase the percentage of access. The results may not appear surprising but again show that providing shops and services around stops caters for a demand. With more options, more people make use of facilities along walking routes to stops.

Figure 77: Percentage of pedestrians that undertook no errands/errands dependent on the length of the walked trip to the stop

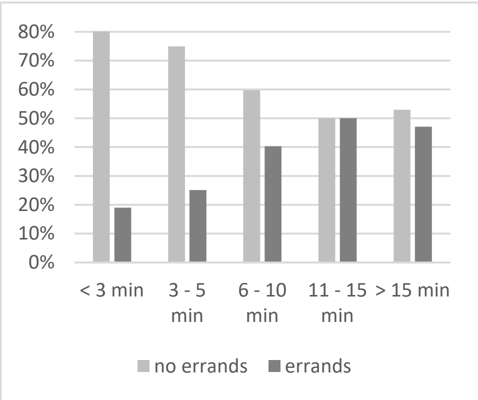


Figure 77 shows how the percentage of errands increases nearly linear with longer walks to the stop. Three reasons can influence this effect. Firstly, accessing additional destinations can require walking a more detoured route to the stop. Secondly, when pedestrians access services such as post boxes, or they purchase food to go, they need to interrupt their walk for a short period. These stops may influence the estimated duration of the walking trip to the stop. Thirdly, those who walk longer distances might pass by more facilities, providing more options to access additional destinations.

Next to the three described factors involved, I consider that the incentive to save an extra journey lengthens acceptable walking distances. Results in Figure 77 appear surprisingly clear. The average estimated time of the walk to the tram stop increased by 30 percent when interviewees accessed additional destinations. I evaluate a rise of between 15 to 25 percent in accepted walking distances as realistic when there is the option to access multiple destinations. Saving an extra trip represents a good compensation for a longer walking distance.

One shortcoming of the interview data was the difficulty of conducting interviews during the rush hour. The analysis shows that 45 percent of regular public transport users access shops and services. There is a high probability that interviews during the afternoon rush hours would have included many more regular travellers. The percentage of those accessing additional destinations would have risen accordingly. The data from interviews shows a bias towards non-rush hour travels. The majority of public transport journeys take place during the rush hour.

Interviews indicate only roughly how the availability of shops influences access to these destinations. The methodology disables detailed analyses of the walking environment along routes to tram stops. Results indicate, however, that the amount and diversity of available facilities influences the percentage of access.

Aggregating the data into groups and sub groups can result in small samples that restrict generalisations. The sub groups discussed in this section contained at least 20 interviews. Despite the low number of interviewees, the data aggregation uncovers explicable phenomena. This logic increases the likelihood that larger data sets would also show comparative results.

Hillman and Whalley (1979) find that 50 percent of journeys that include more than one destination are made by walking (p. 50), as Section 2.2 presents. The data from the interviews in Zürich show a much lower percentage of travel chains, on average only 25 percent. Differences can result from different methodologies. However, travel behaviour may have changed over the last four decades, and it is likely that it differs between the different investigated geographic locations.

Lachapelle et al. (2011) find that frequent public transport users walk more often to destinations close to workplaces and homes (p. 78). The previous section shows, accordingly, a significant increase in accessed facilities to 44 percent among frequent public transport users. The investigation also indicates that those who walk regularly use public transport when purchasing goods.

The analysis of the collected data sheds light on all the questions formulated in Section 2.10. We can summarise seven points for the use of facilities along walking routes to and from public transport stops:

1. More and diverse facilities bear a potential to increase the percentage of multipurpose journeys
2. Quality and type of facilities is likely to influence access; supermarkets are most frequently accessed
3. Accessing more than one destination appears attractive for seniors and those with restricted car availability
4. Pedestrians access additional destinations despite inconvenient detours, street crossings, and increasing walking distances

5. The advantage of catering for additional needs along walking trips exceeds the inconvenience of carrying purchased items on public transport vehicles
6. Regular public transport users access additional destinations more regularly than less frequent travellers
7. Accepted walking distances to stops can increase by between 15 and 25 percent with easy accessible facilities along walking routes to stops

Results indicate a cultural difference in the way people purchase goods and groceries needed daily. People either fill up their fridges by buying larger amounts of food for longer time intervals or they cater for their needs along their daily travels. The first option is only possible by car. The second option reduces the required fridge volume and, more importantly, the total demand for car journeys in cities. How people cater for their daily needs is influenced by available transport options but possibly also by attitudes and the number of accessible destinations along journeys between homes and workplaces.

The analysis in this section supports the impression explained by Böesch and Huber (1986, pp. 39–40) that public transport, walking and shopping facilities are symbiotically interlinked. Public transport stops cluster mobility and increases the amount of potential clients for any retail facility. Attractive and diverse facilities open up convenient options for public transport users and make public transport journeys more rewarding.

6 THE SENSORY EXPERIENCE OF WALKING ENVIRONMENTS

As Section 3.1 points out, the behaviour of pedestrians reflects an environmental experience. This chapter analyses walking behaviour in different urban surroundings and discusses how the experience of walking changes with environmental characteristics. The final two sections estimate the environmental effect on acceptable walking distances and show how environments influence the emotional experience of walking.

6.1 Walking environments and step frequencies

As Section 5.2 illustrated already, step frequencies reflect reactions to the conditions of walking and the walking environment. Observing pedestrians' steps uncovers unconsciously performed reactions to the urban surroundings for walking.

Legs and feet move in a steady rhythm when pedestrians can walk unhampered on an even surface. In busy environments, most of the reasons for frequency variations are obstacles ahead. Impediments rarely cause stops but a slight change of course combined with a step frequency variation. Most common reactions to other pedestrians are alterations of the frequency in order to avoid collisions. Pedestrians return to their preferred frequency whenever possible. Reactions to obstacles that are more than four to six metres away are rare. The flexibility and speed of walking does not require one to pay attention to the environment a long distance ahead.

The frequency can change when people spot something of interest or perform activities while underway, such as taking a puff from a cigarette, eating, sorting clothes and so on. At the second pedestrians direct their attention to whatever they are performing, the steady swing of their legs becomes uneven. Equally, the step frequency varies when the environment attracts pedestrians' attention. These frequency alterations show again that pedestrians react rarely to something more than five to six metres away. Within such short distances, pedestrians also receive non-visual stimuli from their environment. The multi-sensory impression of walking depends substantially on the nearby urban surroundings.

An observation on the pedestrian street *Strøget* illustrates how the swing of legs corresponds with visual information on the walking course ahead (Figure 78). A fast-walking man reduces his step frequency at the moment he spots the red traffic light six metres in front of him. Arriving at the curb of the carriageway, he stops and wanders around. With a green light, he continues walking and reacts with an unstable frequency to oncoming pedestrians on the carriageway. With a clear headway, the pace of steps becomes steady again and he picks up exactly the same frequency as 30 seconds earlier, before the slowdown when spotting the traffic light.

Figure 78: Man walking on Strøget in Copenhagen, the arrow indicates direction of walking

Watching pedestrians' steps also uncovers differences between younger healthy and elderly or disabled pedestrians. Elderly people often walk with less constant step frequency. Even though they appear safe on their feet, controlling their balance requires effort. Their legs do not swing as accurately in a back and forward direction as we can observe for younger pedestrians. Elderly pedestrians often swing their legs slightly out of the walking direction to the sides. As a result, the swinging movement of legs looks less regular. Placing feet slightly out of the walking course counterbalances sideward movements of the torso. Such walking must significantly increase the energetic effort. The ability to walk is not just a question of fitness but requires the abilities to control and balance the body on both feet. If these abilities are compromised, energy consumption rises and walking becomes less pleasant.

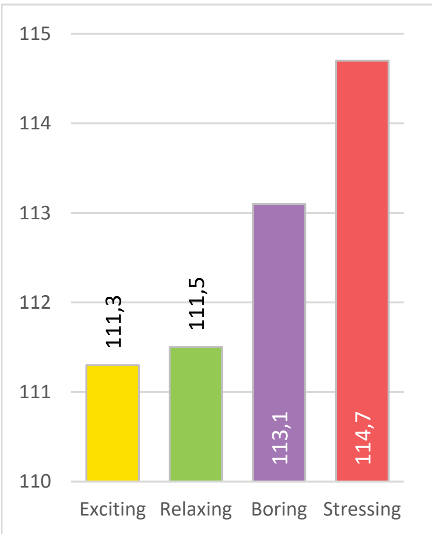
When disabled, the ease of walking depends increasingly on the walking surface. The following two examples illustrate this relationship. The pedestrian street *Strøget* has two gutters, running parallel along the street (Figure 79). The walking surface is very smooth, only the gutter changes to a more uneven material. The level of the gutter is lowered slightly by about half a centimetre. All observed elderly pedestrians avoid stepping on the gutter or its edge. Even many healthy pedestrians take a conscious and distinct step over the gutter. Such apparently

Figure 79: Gutter on Strøget

‘invisible’ obstacles make walking even more exhausting, especially for those who are less safe on their feet.

An observation from Zürich illustrates the importance of walking surfaces. An elderly woman crossed a tram track. She approached with a steady and brisk step and appeared safe on her feet. The impression changed when she stepped onto the street over the curb of the lowered pavement and further over the tram rails. These obstacles required her to direct her sight downwards. She ensured that her feet swung safely over the curb, and she avoid stepping on the rails. As a result, the length of steps and the swinging movement of the legs became unsteady. Her uneven foot movements alone compromised her balance. As if this was not complex enough, watching her step restricted her ability to pay attention to vehicles on the street. Her head moved quickly upwards to catch a glimpse of what was moving on the carriageway she was crossing. Such a walking experience is obviously unpleasant and stressing for the observed woman, who gave otherwise a sprightly impression.

Figure 80: Average step frequencies in four different environment characteristics, the effect of running filtered out



Environments also influence the average step frequencies of pedestrians. At some distance from the public transport stop, most pedestrians can walk unhampered at their preferred step frequency. During the public transport stop investigations, I measured step frequencies at an average distance of 80 metres from public transport stops (as explained in Section 4.5.1) and registered environmental characteristics at these locations (as defined by the *circumplex model for the walking environment* in Section 4.4).

A statistical analysis shows how the average step frequency varies in (1) exciting, (2) relaxing, (3) boring, and (4) stressing environments[62]. The significantly higher step frequency of some observed running pedestrians results from time pressure and not from environmental characteristics[63]. As the data comprises nearly equal amounts of arriving and departing pedestrians, possible differences between both groups do not influence the results.

As Figure 80 shows, average step frequencies vary significantly between exciting and relaxing environments, compared to boring and stressing surroundings. The difference between boring and stressing walking surroundings remains insignificant (even though average frequencies differ)[64]. People pass by slightly faster where environments stress or bore them. I interpret these results to reflect a less pleasant walking experience in urban surroundings that either stress or bore pedestrians.

As discussed in Section 3.2, Molen et al. (1972) find an average step frequency of 113.1 for men, and 122.8 for women along the pavement of a thoroughfare and in an underpass. Women might feel less safe in the underpass and walk faster. The results for male pedestrians in the study of Molen et al. fit better to the findings in Figure 80. Male and female pedestrians walk in unpleasant environments at 114.7 steps per minute. Differentiating between male and female step frequencies may have showed better comparable results.

Figure 80 also shows a 7.1-steps-per-minute higher average frequency in relaxing environments than Molen et al. registered in a park[65]. The difference derives possibly from different observed pedestrians. Public transport users do not walk

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[62] Section 11.2 in Appendix 3 provides the details on the statistical calculations. The analysis filters out the effect of running.
[63] None of the observed pedestrians runs for the whole duration of the observation. People run along sections of the observed walking routes.
[64] Higher variation in the data samples causes statistically insignificant differences between boring and stressing environmental characteristics. The difference between averages can, with a higher probability than 5 percent, derive from random variation in both data sets.
[65] Molen finds 102.2 steps per minute for male pedestrians and 106.6 steps per minute for female pedestrians in a park.

for the enjoyment of walking, and roughly 40 percent experience time pressure. The results show that pedestrians react with their steps to different environmental experiences.

6.2 Turning away from the visual surroundings – performing activities while walking

As Section 3.4.2 discusses, pedestrians are able to perform different kinds of activities while walking. Performing activities while walking increases stimulation while walking in boring environments; it also enables pedestrians to shut off sensory impressions from unpleasant environments. Do more pedestrians entertain themselves in stressful and boring walking environments?

The pedestrian observation studies (Section 4.3) find that on average 52 percent of pedestrians in boring and stressful environments perform activities. In exciting and stimulating environments, only 39 percent of observed pedestrians do so. Unobscured walking in boring environments increases the number of pedestrians

Figure 81: Percentage of pedestrians who perform activities while walking in 12 walking environments; dark grey columns = boring and stressing walking environments, light grey columns = pleasantly stimulating walking environments

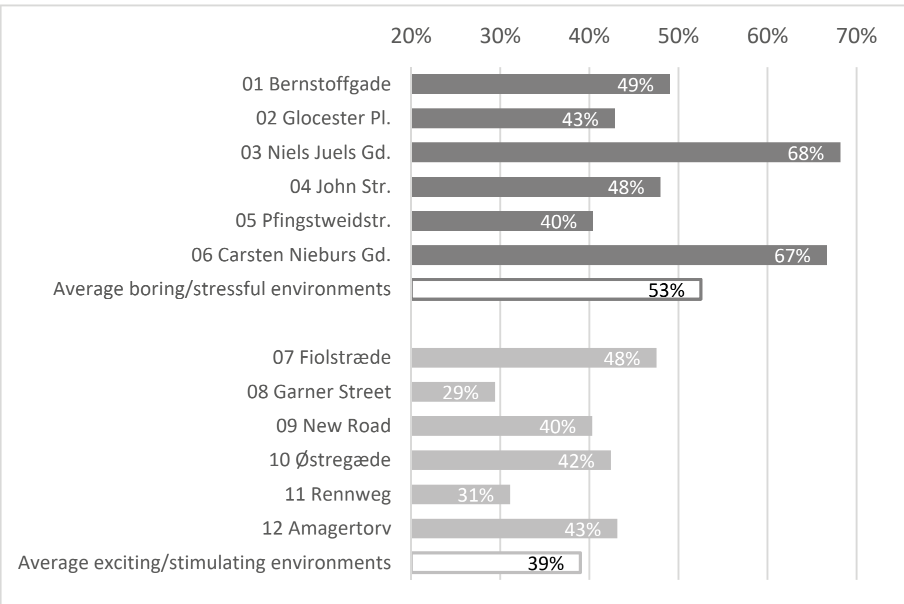

Figure 82: Walking along a boring pavement at Niels Juels gate in Copenhagen

that perform activities. However, the trend shows a relatively high variation, as Figure 81 illustrates.

The streets *03 Niels Juels Gd.* and *06 Carsten Nieburs Gd.* show the highest percentages of people who do something while walking. Both locations comprise straight pavements of between 150 and 250 metres in length. Horizontally structured facades on both sides of the street create an apparently long and unvaried corridor. Long and obstacle free corridors with little stimulation encourage many pedestrians to entertain themselves with additional activities.

The data from the public transport stop investigations show on average lower percentages of performed activities. Only 31 percent of the observed pedestrians do something while they walk. It is likely that the difference results from differing observation methods[66] but possibly also from different walking conditions. The observed pedestrians around public transport stops are either about to arrive at the stop, or they have just departed from it.

Interestingly, the percentage of performed activities does not differ between approaching and departing pedestrians. Figure 83 shows the percentage of

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[66] The video material from the public transport stop investigations shows less detail than the film footage from the pedestrian observations.

Figure 83: Percentage of pedestrians that performed activities in environments at some distance from stops, as defined by the circumplex model for the walking environment

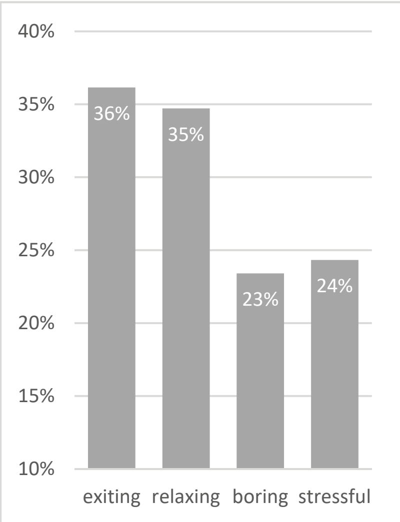
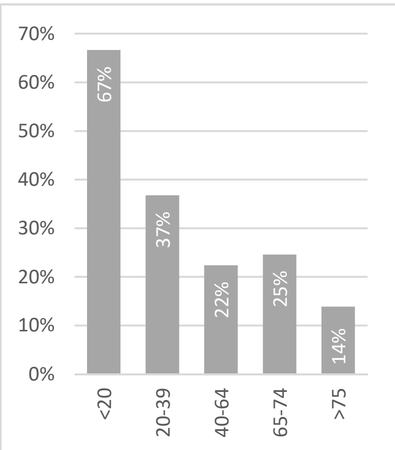


Figure 84: Influence of age on the percentage of pedestrians that perform activities



performed activities in four different walking surroundings[67]. The pedestrian environment along the walking route to stops influences the performance of activities inversely, as the pedestrian observations find. In exciting and relaxing environments, 36 and 35 percent perform activities but the percentage drops to 23 and 24 percent in boring and stressful surroundings.

The contradicting results from both studies show that it is not just the character of the walking environment which influences whether pedestrians entertain themselves by doing something while walking. The total length of the walking trip might have an effect. Trips to stops are usually short, and many pedestrians may just walk. Another possibility might be that fewer perform an activity right after they started walking, or right before arrival. Both reasons would explain the difference between the two data sets. Further, environments must allow pedestrians to focus on something else. This would explain fewer activities when accessing stops in stressful surroundings but not in boring environments.

The interviews in Zürich show that performed activities vary substantially with the age of those who walk (Figure 84). Younger pedestrians perform substantially more activities while walking than older pedestrians. Through mobile phones and other portable data devices, internet and

[67] As defined by the *circumplex model for the walking environment* in Section 4.4.

social media are available on the go. These options may rather attract younger pedestrians.

The analysis shows that walking environments do have an effect on the percentage of pedestrians that entertain themselves while underway. Registering the duration of performed activities, the kind of activity performed might have provided more explicable results. However, the data demonstrates that it is not only the character of walking environments that influences whether people do something while they walk.

6.3 Visually stimulating walking environments – investigating head movements

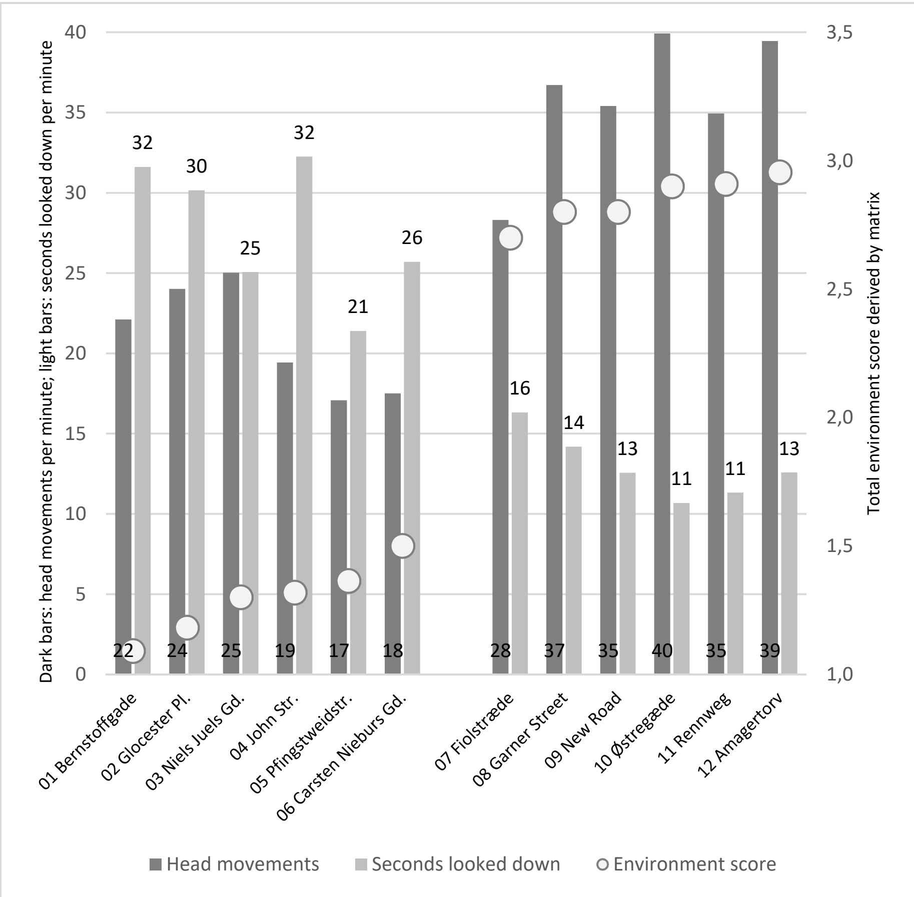
This section investigates whether walking environments influence the amount of visual stimuli that pedestrians receive from the urban surroundings. Do averages of head movements vary with characteristics of the walking environment?

The investigation uses the data from the pedestrian observations (Section 4.3), which provides the necessary detail to count head movements in 18 different urban contexts. The analysis compares head movements with environmental characteristics. The *matrix for the pedestrian environment* (Section 4.3.2) provides the basis to describe and quantify the environmental character of the 18 locations for the observations.

The environment score rises with more social activity, more greenery, more attractive facades, more shop windows and facilities, and with less vehicle traffic. Figure 85 shows that rising environment scores also increase the number of head movements. Inversely, the time pedestrians look down decreases with higher environment scores. The data on head movements demonstrates that environmental characteristics influence the amount of visual stimuli that pedestrians receive from their surroundings. Lower environment scores describe boring environments on the left side of Figure 85. Accordingly, stimulation remains lower than in more stimulating surroundings on the right side of Figure 85.

The descriptive statistics in Figure 85 already support the assumption that walking environments influence the amount of stimulation that pedestrians receive from urban surroundings. The text shows later in Section 6.3.2 that the impression from Results in Figure 85 also remain statistically valid (Section 6.3.2). The next section investigates the effect of street crossings and some more specific walking environments.

Figure 85: Seconds looked down per minute (light grey columns), head movements per minute (dark grey columns), total environment score as derived from the environment matrix (light grey dots)

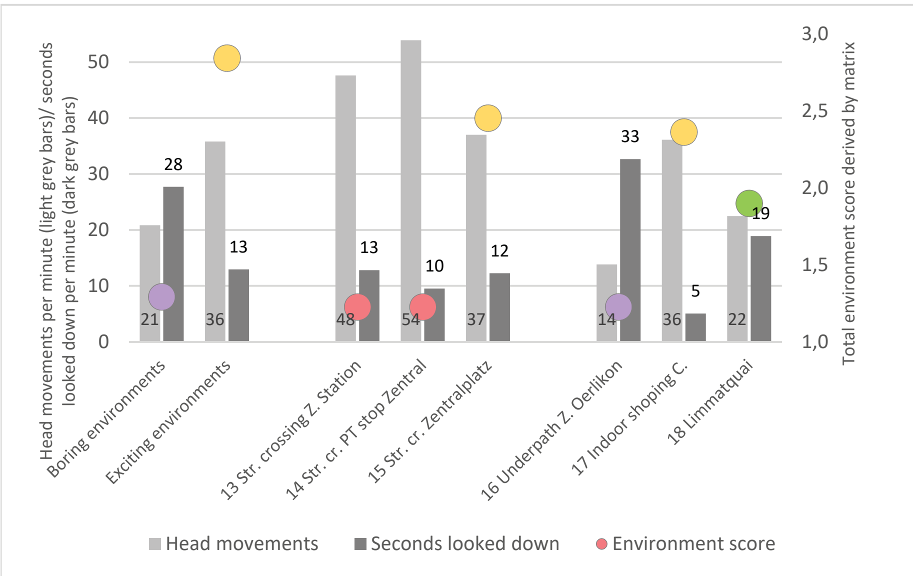


6.3.1 *The influence of street crossings and other environmental characteristics on visual stimulation*

This section examines visual stimulation when crossing streets, in an underpass, in an indoor shopping centre, and along the quay wall of the river Limmat in the centre of Zürich. Figure 86 shows averages of counted head movements and seconds looked down at all locations; for a comparison, it also shows averages in boring and exciting environments[68]. A series of T-tests (Appendix 3 Section 10.5.1) shows significant and insignificant differences for head movements between the studied locations. The colour of the dots in Figure 86 indicates the type of environment, according to the circumplex model of the walking environment (Section 4.4), and the height of the environment score (Section 4.3.2).

At locations 13 – 15 (in Figure 86), the observed pedestrians cross carriageways. The quality of the environment becomes irrelevant when crossing busy streets. Car traffic requires attention. Crossing a street at traffic lights might not necessarily

Figure 86: Head movements in specific urban environments. Seconds looked down per minute (grey columns), head movements per minute (light grey columns), total environment score as derived from the environment matrix indicated by rhombi, colour of rhombi indicate environmental characteristics according to the circumplex model: yellow: exciting, green: relaxing, violet: boring, red: stressing. The first two pairs of columns on the left indicate averages of pleasant and unpleasant environments (studied locations 01 – 12 from the observation studies)



[68] Averages derive from results for head movements and looking down in Figure 85 for boring (location 01 – 06) and exciting (location 07 – 12).

require one to ensure visually that all cars have stopped when the pedestrian lights show green (even though this might be advisable). Less regulated street and tramline crossings require visual information to avoid accidents with vehicles. Paying no visual attention is dangerous and not an option in these locations.

Head movements during street crossings are more distinct. The angle of the head turns is higher than at all other studied locations. With the first step on the carriageway, most people look in the direction of approaching vehicles. The first turn is followed quickly by a second in the opposite direction and often a third in the opposing direction. After the first steps onto the carriageway, behaviour differs. Some just rush over the street, directing their sight in the direction of their brisk walk. Others continue to observe the carriageway to the left and right with further head movements. With increasing complexity, more people continuously turn their head to look for approaching vehicles. Walking appears stressful.

Crossing the carriageways and tramlines at the (14) *public transport stop Zentral* is most complex. Pedestrians walk over a zebra crossing that stretches over two minor trafficked carriageways, and further over three tramlines that meet at exactly the point where the observations took place. No light signal indicates approaching trams. Before crossing the tram rails, pedestrians need to look in three different directions. Some people turn their head so often that I wonder whether they become dizzy. Forty-five head turns per minute equals about one head turn per second – on average. Pedestrians perform so many head turns for only a short period of about 10 seconds while walking over the tram lines. With so many head turns, little time remains to look down. I consider so many head movements, which are not encouraged but necessary, to indicate stress.

Conditions for street crossings at (13) *Zürich Station* are less complex but still require attention. Pedestrians walk over two trafficked carriageways and two tramlines in the centre of the street. A traffic light regulates the street crossing; an orange flashing light indicates approaching trams. The conditions require significantly more head movements than exciting environments encourage (Figure 86). The time pedestrians look down is significantly lower, compared to boring environments. Short periods looked down indicate that attention is required. Crossing the street at the station in Zürich still stresses pedestrians.

Crossing the carriageway on the (15) *Zentralplatz* square in Biel appears very different. The Zentralplatz is a specific form of shared space in Switzerland[69].

[69] Switzerland has specific rules for a form of shared space that is called *Begegnungszone*. The following rules apply: 1.Pedestrians have right of way over vehicles, also on carriageways.

Here, pedestrians have the right of way when crossing the marked carriageway for vehicles on the even surface of the square. Many buses and other vehicles drive over the square. Most people just walk without hesitation onto the area that is marked for cars. Having the right of way does not require them to pay attention to cars, and other environmental stimuli attract pedestrians' attention. Head movements and time looked down in the *Zentralplatz* are equal to those in exciting environments.

The (18) *Limmatquai* in Zürich is a relaxing environment for pedestrians. People walk along a pavement between the river *Limmat* and a street with tram rails[70] and restricted car access. Four-storey buildings with shops on the ground floor are located along the opposite side of the street. Young trees grow along the pavement. A gutter secures the quay wall along the pavement. Characteristic is the scenic view onto the skyline of the older part of the centre. Head movements and time looked down differ significantly from results in exciting and boring environments[71]. The relaxing environment along the river stimulates pleasantly, with a comfortably lower amount of stimuli.

The (16) *underpass Zürich Oerlikon* (Figure 86) is an oval concrete tube, about 25 metres long, with an asphalt walking surface and some lighting in the middle of the ceiling. Here, head movements drop to 14 movements per minute and the time pedestrians looked down increased to 33 seconds per minute. These represent the lowest number of head movements and the longest period pedestrians look down in the least stimulating environment among all the investigated locations[72] [73]. Results demonstrate that underpasses are unpleasant and provide nothing of interest to look at.

Location 16 is an underground shopping centre at the Main Station in Zürich. At no other studied location do pedestrians walk indoors. The passage is about 5

2. Pedestrians should not hinder vehicle traffic intentionally or more than necessary. 3. Driving speeds are limited to 20 kilometres per hour. 4. Car parking is prohibited if not indicated otherwise. 5. Zebra crossings or traffic lights are not allowed (and not necessary) within a *Begegnungszone*.

[70]It is difficult to find relaxing urban environments where enough pedestrians walk at a speed of at least 100 steps per minute. In urban parks the majority of people stroll with lower step frequencies.

[71] According to two tailed t-tests, results for p-value <0.01, except for comparison between *Limmatquai* and unpleasant/deactivating environments, p-value < 0.07

[72] One tailed test assuming unequal variances, p value < 0.00

[73] One tailed test assuming unequal variances, p value < 0.00

metres wide and 3.5 metres high. Several shop windows and entrances are located left and right along the passage. The passage is newly built, with high quality materials in a modern style, and brightly illuminated. Head movements do not differ significantly [74] from those in exciting environments. Interestingly, the average time pedestrians look down in the indoor environment was significantly[75] less (5 seconds per minute) than the average time in exciting environments (13 seconds per minute). The reason for the low values for looking down remains unclear. All pedestrians can walk unhampered but appear in clusters. The majority of pedestrians are likely to be public transport users. Time pressure and a denser pedestrian flow may restrict looking down for longer periods.

The data discussed in this section shows clear differences between stressing, exciting, relaxing and boring environments. Head movements show that street crossings require a high level of attention, despite the unpleasantness of car traffic. Relaxing environments provide lower stimuli. The investigation at the underpass exemplifies the extremes to which stimulation can drop in a boring environment.

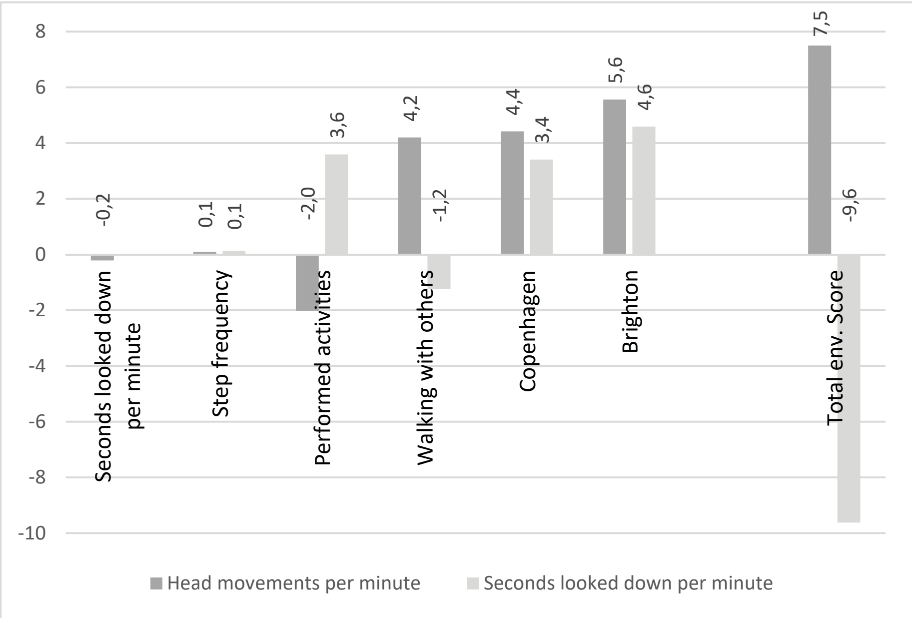
6.3.2 Statistical investigation of head movements and looking down in exciting and boring environments

A statistical analysis can filter out the effect of some non-environmental factors that influence head movements and so determines more precisely the environmental effect on pedestrians' visual stimulation. The *environment score*, as derived from the *environment matrix* (Section 4.3.2), provides a quantitative description of the walking environment. Two *multiple linear regression statistics* investigate the effect of the environment score on head movements and looking down. To keep the text free from statistical jargon, Section 10.5.2 in Appendix 3 presents and discusses the details of the statistics. Figure 87 shows the influence of seven factors on the average number of head movements and on the average number of seconds looked down per minute.

Seconds looked down per minute influence the number of head movements. Looking down for 10 seconds per minute results in two fewer head movements per minute. When pedestrians look down, they cannot focus on the stimuli around them. The variable filters out this effect for the analysis of head movements. The effect of

[74] Two tailed t-test assuming unequal variances, p-value = 0.90
[75] One-tailed t-test assuming unequal variances, p value < 0.00

Figure 87: Influence of the total environment score and other factors on head movements per minute and seconds looked down per minute



looking down on the number of performed head movements remains relatively low.

With a *step frequency* increase from 110 to 120 steps per minute, pedestrians perform one more head movement per minute, and the time looked down increases by 13 seconds per minute. Walking faster requires more visual information to navigate, but fast-walking pedestrians are less interested in their environmental surroundings. Fast pedestrians look down for longer, which requires them to collect more visual information in shorter time intervals[76]. The total effect of the step frequency on head movements and looking down remains small.

When pedestrian *perform activities* while walking, people look down at their phones, their bags, their hands. Whatever they perform receives their visual attention. Accordingly, the number of head movements drops and the time looked down increases. When accompanied, pedestrians look at each other. Exchanging glances increases head movements and reduces time looked down.

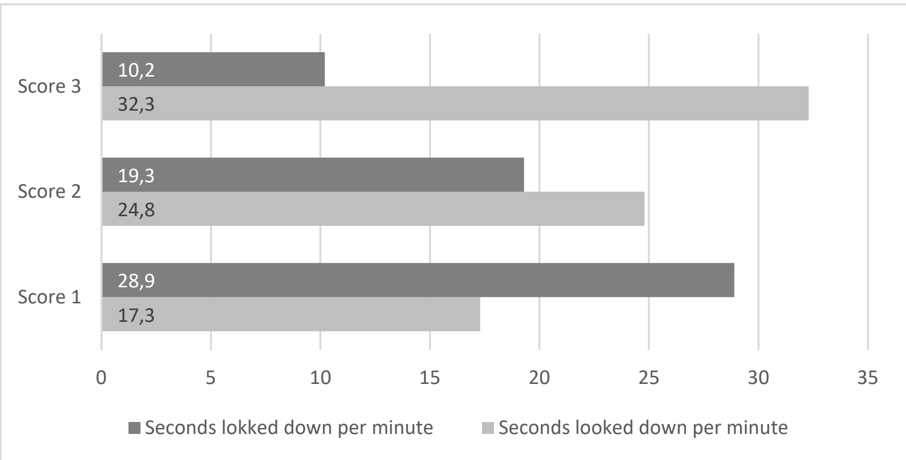
[76] Whyte (1988, p. 65) describes fast-walking pedestrians as appearing arrogant. Paying less attention to the surroundings may well stimulate such an impression.

Further, people seem to perform slightly fewer head movements in the city of Zürich, compared to *Copenhagen* and *Brighton*[77]. As the following Section 6.4 will show, the effect does not derive from differences between cities but from the chosen locations for observations in these cities. When separating the total environment score into more detailed environmental characteristics, the difference between the investigated cities disappears.

The *environment score* remains the most important factor for head movements and looking down. As Figure 87 shows, an increase in the score by the value 1.0 results in 7.5 more head movements per minute and in 9.6 less seconds looked down. Figure 88 shows the variation of head movements and looking down with the environment score for a single walking pedestrian, performing no activity while walking with an average step frequency of 115 steps per minute. We can calculate these values from the results of the statistical analysis (Appendix 3 Section 10.5.2). Head movements increase by 86 percent from a boring (score 1) to an exciting environment (score 3). Seconds looked down decrease by 65 percent.

The results reflect well the impression of the presented data in the introduction of Section 6.3 (Figure 85). Pleasant walking environments, with a higher environment

Figure 88: Variation of head movements per minute and time looked down per minute for a single walking pedestrian with a frequency of 115 steps per minute



[77] Figure 87 shows how head movements differ in Brighton and Copenhagen from Zürich. Zürich serves as a reference and is therefore not listed in Figure 87.

score, increase visual stimulation. The remaining question is: which features of the visual walking environment raise the level of pedestrians' visual attention? This question is tackled in the following section.

6.4 How walking environments raise the level of pedestrians' attention

Which visible features of the walking environments raise pedestrians' levels of visual attention and so increase stimulation? The analysis in this section aims to understand what pedestrians look at when they walk. Appendix 3 presents in Section 10.5.3 the details of the *multiple linear regression statistics* behind the results in Figure 89. Statistics determine the effect of seven environmental and four non-environmental factors on the number of head movements pedestrians perform per minute and the seconds looked down per minute.

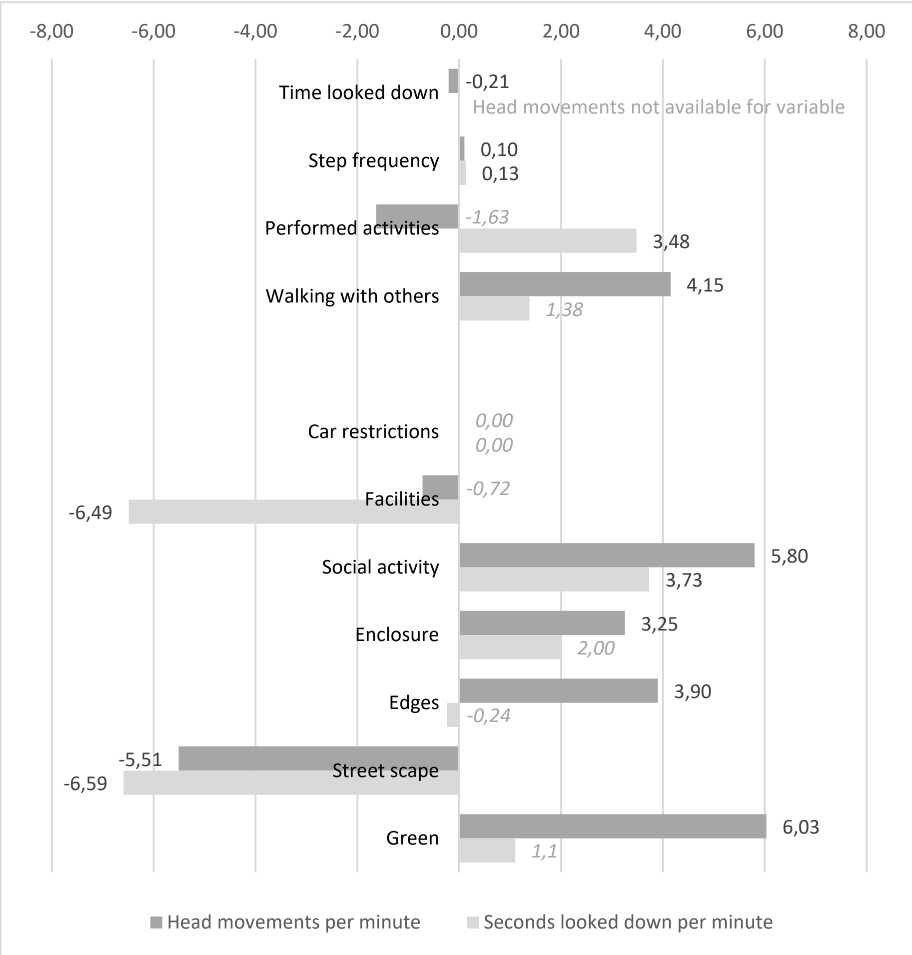
The environment matrix (Section 4.3.2) defines and grades nine environmental categories. From these categories, the following six appear relevant for visual stimulation and are included in the analysis:

- car traffic restrictions
- shop windows
- social activity
- the enclosure of a walking environment
- the attractiveness of facades
- the street scape design
- greening

The statistical analysis also considers the effect of time looked down, the individually chosen step frequency, performed activities, and walking with others. The results for these four conditions in Figure 89 do not vary substantially, compared to the statistics discussed in the previous Section 6.3.2. The differences between the three cities disappear with the more differentiated inclusion of environmental characteristics in the analysis. The walking environment again remains most influential for pedestrians' head movements.

Car restrictions describe the number of cars in the pedestrian environment. Vehicles on streets have only a very low (statistically insignificant) influence on head movements and looking down. Both variables are excluded from the

Figure 89: Variation of head movements per minute and seconds looked down per minute; cursive greyed values indicate insignificant result with limited validity



statistical analysis. When pedestrians do not have to cross a street, cars appear not to attract their visual attention. Car traffic still exposes pedestrians to stimuli such as noise, exhausts, and dust. Such emissions are difficult to ignore and certainly appear unpleasant. The investigation method does not allow a quantification of this effect.

Increasing density of ***facilities*** in the pedestrian environment describes the presence of shops and other services. The variable reflects the presence of shop windows, entrances, or other features that address pedestrians. Facilities do not influence head movements significantly but decrease time looked down. Visual stimuli of facilities catch pedestrians' attention for longer periods. Shop interiors become visible through transparent façades and can stimulate intensively. The visual field of the eyes is large enough to capture numerous stimuli from shop interiors without further head turns.

Social activity describes the number of people in a walking environment and the kind of activities they perform. When pedestrians and other people are present, head movements increase together with looking down. Pedestrians' direction of sight frequently changes in socially busy environments. With many people around, walking requires frequent information on the movement of other individuals. However, prolonged eye contact with strangers appears inappropriate to most pedestrians, at least in the cities where observations took place. Many pedestrians look quickly down to the pavement when they pass other people close by. As a result, increased social activity increases the number of seconds looked down per minute.

Enclosure describes the distance between buildings on both sides of streets in relationship to the building height. In less enclosed environments, facades are more distant from pedestrians' eyes. With increasing distance, the stimulation from facades decreases. There is less to see in close vicinity to the left and right. Three-dimensional objects, as for example buildings, are more remote from the pedestrians' eye and remain visible without head turns. Conversely, in more enclosed walking environments, close visual stimuli to the left and right draw attention, causing more head movements. The effect of enclosure on looking down remains minimal (statistically insignificant).

The variable ***edges*** describes the amount of visual detail that, for example, building facades provide. With increasingly detailed and varied façade designs, head movements increase, but the effect on looking down remains low (insignificant). Facades raise pedestrians' levels of visual attention and increase stimulation.

The variable ***streetscape*** describes the design of the walking surface, lighting, benches, and all the other built and designed visible elements situated on the walking surface. More attractive streetscapes decrease head movements but also the time pedestrians looked down. Pedestrians look at the streetscape design that becomes visible in the direction of their walking course. Paying attention to these stimuli in the direction of walking requires no head turns.

The variable ***green*** significantly increases head movements but has no (significant) influence on looking down. The investigations do not comprise environments of park-like character. Green always represents an additional feature in the investigated environments. Green elements are visually attractive as the substantial increase in head movements indicates.

On the basis of long experience, Gehl Architects APS (2009) specified environmental characteristics for attractive walking environments, as Chapter 2.1 presents. The results in this chapter show that pedestrians indeed pay attention to the environmental attributes that Gehl Architects APS consider as important. The authors define environmental features that increase stimulation, as the analysis in this section demonstrates.

The statistical analyses remain somewhat abstract. The observational method applied does not allow observation of what pedestrians pay attention to visually. First, the statistical analysis shows what pedestrians look at, or not. The results of the statistical calculations (which Appendix 3 presents) show an important shortcoming. The investigated environments that I chose for observations are either of *boring* or *exciting* character, according to the *circumplex model for the walking environment* described in Section 4.4. The six environmental categories vary in relative parallel between exciting and boring environments. Distinguishing the effects of single categories remains therefore difficult. It remains promising that all results are plausible. The described problem arises solely from the statistical methodology, as Section 10.5.3 in Appendix 3 describes in more detail.

Culture may have an influence. The majority of the observed pedestrians in the three investigated cities are certainly socialised in a Western culture. We do not know how cultural differences influence the relationship between walking environments and visual stimulation. However, when we understand head movements as a rather unconscious feature of pedestrian behaviour, the cultural effect may not be too substantial. The experience of fear and social insecurity has not been investigated. According to the previously discussed findings of Schirmer (2011), fear increases attention and stimulation. We do not know how time pressure influences visual stimulation. Haste is an important aspect when approaching public transport stops, as Section 5.1 illustrates. We should also remember that the quantified characteristics of the walking environment derive from a structured process of qualitative evaluations that the matrix in Section 4.3.2 defines. An objective holistic representation of visual walking environments does not exist.

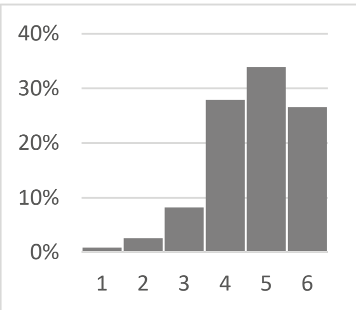
The most important result of this investigation is that visual stimulation varies with the character of environments. The analysis indicates which elements of walking environments increase visual stimulation. This provides a basis to analyse how urban walking environments influence the apparent walking distances. The following section investigates the pleasantness of environmental stimuli.

6.5 The pleasantness of the environment along walks to tram stops in Zürich

Pedestrians' subjective experience of walking distances in cities depends on stimulations and the pleasantness of stimuli (Section 3.3). The previous section 6.3 measures the environmental effect on the visual stimulation of pedestrians. This section investigates the influence of environmental characteristics on the pleasantness of walking. By doing so, this section provides the second element to determine how urban environments influence accepted walking distances.

Two parts from the inquiry in Zürich are central for the analysis: firstly, the pictures that describe the environment along interviewees' walking routes to tram stops; secondly, the evaluation of the pleasantness of the walk to the stop. These two elements allow us to study how the pleasantness of walking varies with reported environmental characteristics.

Figure 90: Frequency distribution (in percent of interviewees) between values 1 to 6 to evaluate the overall experience of the walked trip to the stop



During the survey, interviewers present a six-point Likert scale[78] to tram passengers and ask them to evaluate the pleasantness of the walk to the stop (illustrated in Chapter 4.2.2). The value one indicates an unpleasant walking experience, six a pleasant one. Figure 90 shows the frequency distribution of interviewees' evaluations. Most pedestrians evaluate walking as pleasant with a value of 5 in the scale. The average value is 4.7. Many factors influence these positive results: pleasant weather shortly after the main holiday season but also attitudes towards walking and its positive environmental effect. The bias towards positive evaluations

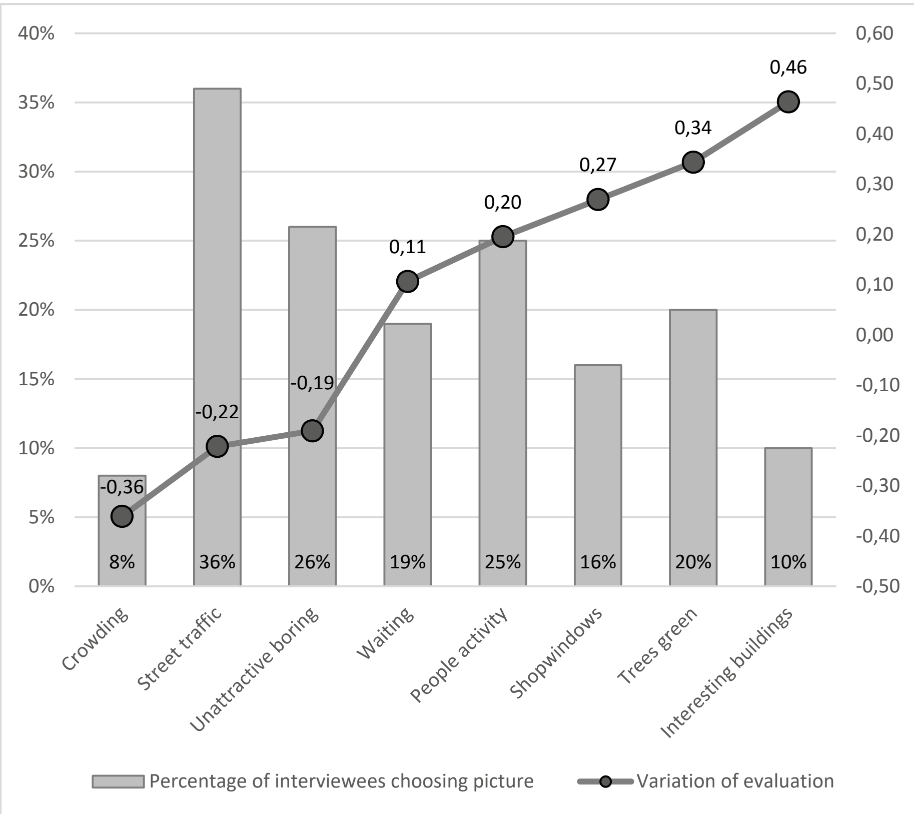
[78] A *Likert scale* is a commonly used rating scale with a set of integers that define a range between, for example, a positive or negative evaluation of a phenomenon or an experience. Section 4.2.2 shows the Likert scale used during the interviews on trams in Zürich.

does not limit the intended analysis, which questions the conditions, under which the average evaluation of pleasantness changes.

Interviewees describe the environment along their walk to the stop with help of eight pictures, as presented in Chapter 4.2.2. Participants choose a suitable amount from the eight photographs to reflect their remembered environmental impression. About 50 percent chose only one photo, 34 percent two, 14 percent three, and 2 percent four photos.

Figure 91 shows how the character of the walking environment alters with interviewees' environmental descriptions. The grey bars indicate the percentage of pedestrians that describe the environment with one of the eight photos. As 50 percent of the interviewees chose more than one photo, the summed up

Figure 91: Evaluated pleasantness of the walk to the stop with indicated environmental characteristic with help of eight pictures. Light grey columns: percentage of interviewees that choose pictures; grey dots indicate the average variation of pleasantness with chosen picture



percentages from all eight photos exceeds 100 percent. The grey dots indicate the increase (+) or decrease (-) of the average Likert scale evaluation when interviewees choose one photo.

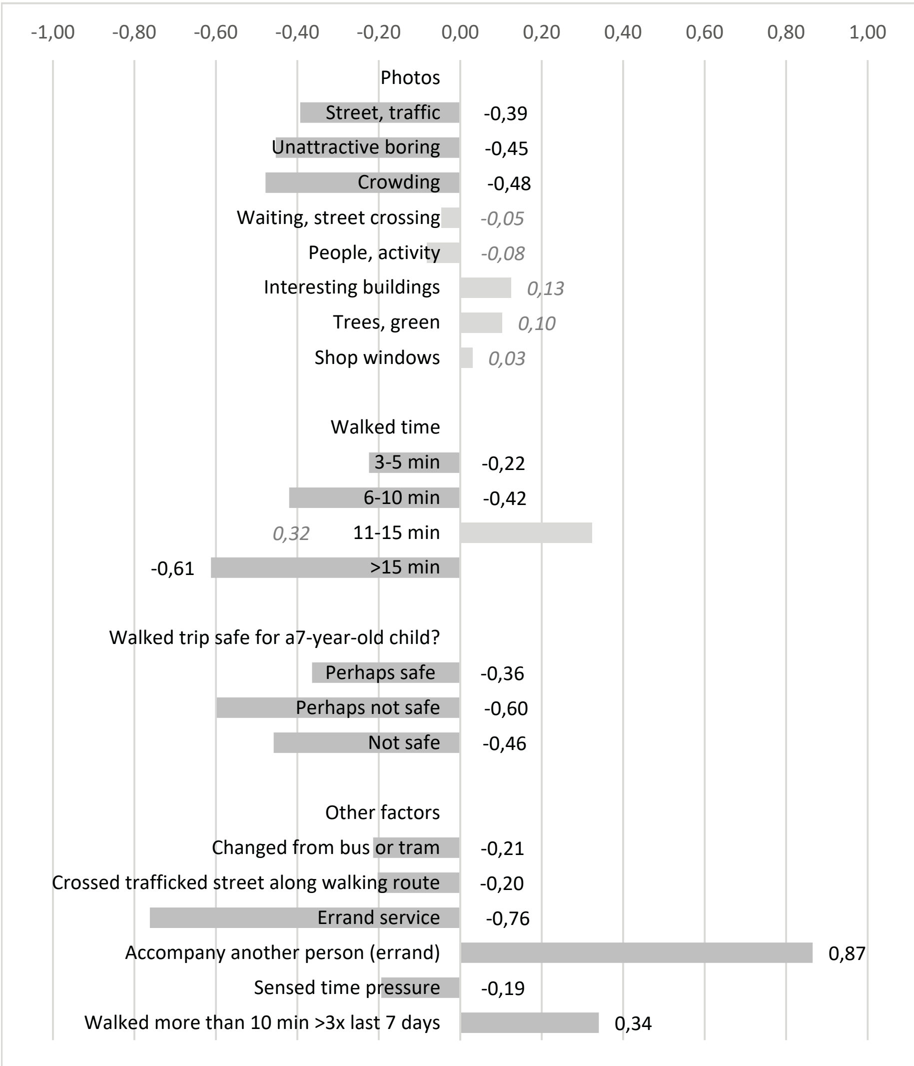
Figure 91 shows a clear trend. Crowded walking routes, trafficked streets, as well as unattractive and boring surroundings decrease the pleasantness of the walk to the tram stop. Social activity, shops and shop windows, trees and greening, as well as interesting buildings, increase the pleasantness of walking. Only positive results for the picture *waiting* appear surprising. Waiting takes place at one or more locations along a walk and does not represent a continuous experience of the environment. Seventy-seven percent chose the picture *waiting* together with other pictures. The impressions of these other pictures are likely to dominate the walking experience. The combination of waiting with other pictures increases the results for waiting.

6.5.1 Results of the statistical data analysis

We can also investigate statistically which factors increase or decrease the pleasantness of walking to tram stops in Zürich. In contrast to the descriptive presentation of the data in Figure 91, the statistical analysis includes other conditions, which influence the reported pleasantness of walking. Appendix 3 presents in Section 10.6 the details of the *multiple liner regression analysis*. Figure 92 shows all factors that had a significant influence on the Likert scale evaluation of the walk to the stop. The values in Figure 92 represent the average increase or decrease of the Likert scale evaluation, which ranges from 1 (unpleasant) to 6 (pleasant).

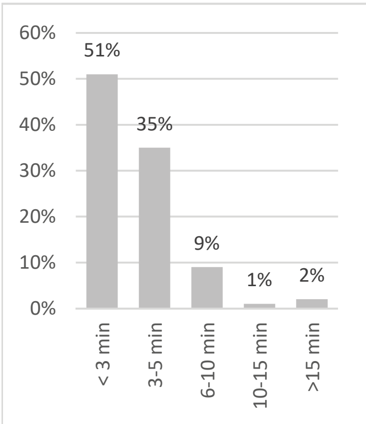
Most factors in Figure 92 result in a reduction of the Likert scale evaluation. The previously presented frequency distribution for the pleasantness evaluation (Figure 90) explains the phenomenon. Most pedestrians evaluated their walk positively with an average score of 4.7. Improvements from the average score range only between score five and six, while factors that reflect unpleasant experiences range between five and one. In the statistical analysis, the narrow range for increased average pleasantness causes few significant results.

Figure 92: Conditions that influenced the evaluation of the walked trip to the stop; cursive light grey values indicate insignificant results for chosen pictures



Chosen pictures that describe an unpleasant walking environment decrease the overall evaluation significantly by 0.39 to 0.48 points on the scale. Three of four pictures that describe a pleasant environment for walking show an improved, but insignificant variation. The pictures *waiting* and *people/activity* point in an unexpected direction and derive from the high average evaluation of pleasantness (causing insignificant results). The reason for a low reduction of pleasantness for *waiting* was explained in the previous section. The difference of evaluated pleasantness between pictures *people/activity*, *interesting buildings*, *trees/green*, and *shop windows* to pictures *street/traffic*, *unattractive/boring*, and *crowding* remains important. In general, the results from the statistical investigation remain congruent with findings in the previous section.

Figure 93: Duration of walking trips to reach tram stops



The analysis uncovers a number of other relevant factors. Pleasantness decreases nearly linearly with an increase in the time spent walking. Surprisingly, there is only a 0.32 point increase in the Likert scale evaluation for longer walking trips of 11 – 15 minutes' length, but this result remains insignificant. Presumably, this unexpected result derives from specific conditions and fewer observations. Except from this outlier, the successive decrease in evaluated pleasantness with longer walks to stops reflects well the findings of the literature discussed in Section 2.3. Walking distances to stops constitute an important factor for access to stops.

Interviewers asked whether the chosen walking path to the stop appeared safe enough for a seven-year-old child walking alone. The impression of unsafe walking routes reduces the overall evaluation of the walk to the stop by 0.36 to 0.6 scores on the Likert scale. The safety impression depends on interactions with vehicle traffic along walking routes[79] and is certainly associated with the negative impression of the variable *crossed trafficked streets*. Traffic dangers are well communicated and presumably all interviewees are aware of the fatal risks.

Having to change public transport vehicles reduces pleasantness. I assume the effect of this variable not to derive from walking but from a generally negative impression of the total journey. Crossing trafficked streets reduces the pleasantness of walking. Those that crossed trafficked streets described the walking environment with the pictures *'street', 'traffic'* and *'waiting'*. Sections 6.2, 6.3 and 6.5 discuss the inconveniences of street crossings and demonstrate how

[79] Interviews were conducted during daylight in relatively central urban areas. It is unlikely that compromised personal security influences the results.

unpleasant walking across trafficked streets appears. Interview results confirm the impression of these previously presented findings.

Accessing facilities such as post boxes, cash machines, and so on, decreases pleasantness by 0.76 scores on the Likert scale. Accessing these necessary, though slightly time-consuming activities requires detours and certainly increases time pressure when walking towards the tram stop. When people accompanied somebody, their evaluation score increased extensively by 0.87 points on the Likert scale. Only one percent indicated having accompanied another person to a destination passed by along the walk to the stop. Walking together likely improves the experience of walking, but the extent shown in Figure 92 certainly reflect only a few specific registrations.

As we would expect, sensed time pressure reduces the evaluation of the walk on average by 0.19 points on the Likert scale. When people indicated that they walked more than three times during the past week, their evaluation increased by 0.34 points. Much walking reflects positive attitudes towards walking. It is likely that these people evaluate walking to stops generally as more pleasant.

How important is the walking environment, compared to other conditions that influence the pleasantness of walking? Walking distances have a clear influence on the pleasantness of the walk to tram stops. We have to remember that over 50 percent of interviewees walk short distances to stops (Figure 93), which does not vary the average pleasantness of walking. For the majority of interviewees, the character of the walking environment exceeds the effect of the walking distance. Section 6.6 shows how environmental characteristics influence the subjective impression of walking distances.

High awareness regarding safety issues certainly increases the measured effect on the pleasantness of walking to the tram stop. The safety question was asked right before passengers were requested to evaluate the pleasantness of the walk. When interviewees describe the walking route as unsafe, a highly pleasant evaluation in the following question certainly appeared illogical to most participants. It is certain that safety significantly influences the evaluation of pleasantness, but the total effect in comparison to other questioned factors is likely to remain slightly lower than Figure 92 shows.

I consider the effect of the walking environment to remain surprisingly obvious in the analysis. Pedestrians are no doubt aware of the negative influence of longer walking distances and compromised safety. Conversely, I consider most pedestrians to be unaware of how the environment influences their individual walking experience. The chosen methodology appears to be a suitable approach for investigating the effect of urban environments on walking. Not asking interviewees directly about their environmental impression appears to me central for identifying the influence of the urban surroundings on walking.

6.5.2 Shortcomings

Understanding how the procedure of the interview itself influences the survey results represents a common challenge of the research method. The discussion of the results for the safety question in the previous section reflects this challenge. In the same manner, the visual presentation of the eight pictures for the environmental classification could influence the evaluation of pleasantness. Pictures may have resulted in a more memorable and stronger impression than orally formulated questions. Accordingly, the choice of pictures may influence the evaluation of pleasantness more strongly than orally asked questions. To minimise this effect, pictures were presented during the first quarter of the interview, while the evaluation of pleasantness was queried in the final quarter.

The description of the walking environment through pictures remains sketchy. The environmental characteristics can alter several times along a walking route. It is to be assumed that only a very few of the 596 interviewees walked the same route to one of the stops along the investigated tram lines. The context of the survey does not allow us to investigate in detail the characteristics of each individual walking route. This inaccuracy causes random variation in the data set.

The design of the Likert scale for the evaluation of the pleasantness limited the statistical analysis somewhat. A scale that would have resulted in an average evaluation of pleasantness closer to the values three or four in the centre of the scale would have eased the statistical calculations. I conducted six minor test surveys to optimise the design of the questionnaire and investigated several options for the Likert scale. Available time limited an extension of this process.

As always, individual attitudes, experiences, and the emotional status of interviewees influence the evaluation of pleasantness. This is a fundamental problem when asking about the overall impression of a walking trip. Interviewees can be in good mood or feel miserable for reasons that have nothing to do with their walk to the stop. We do not know these emotions, but they influence how pleasantly interviewees remember the walk to the stop. As a result, answers vary according to unknown *third factors.* For this reason, the results for the average pleasantness remain relatively abstract. Averages do not provide an objective answer regarding the pleasantness of walking environments along the investigated public transport lines. Due to the impact of unknown third factors, the analysis questions solely how the average evaluation of pleasantness alters with environmental descriptions (through pictures). The statistical analysis filters out some effects that might influence the environmental effect, but certainly not all.

The described shortcomings influence the results of the statistical analysis. The calculated numerical values for the strength of the environmental effect may provide an unrealistic impression of exactness. However, results can be readily explained and I consider them to provide a solid indication for the environmental effect.

Conducting interviews on trams appeared the most promising context for the survey. Interviewees used a tablet PC for the registrations. Nevertheless, we realised during the survey that interviews in more crowded trams during rush hours remained difficult. Therefore, rush hour travellers remain underrepresented in the survey. A more exact cross section of all public transport users over the day would possibly have increased the amount of regular travellers. The context of this research disabled such a survey setup.

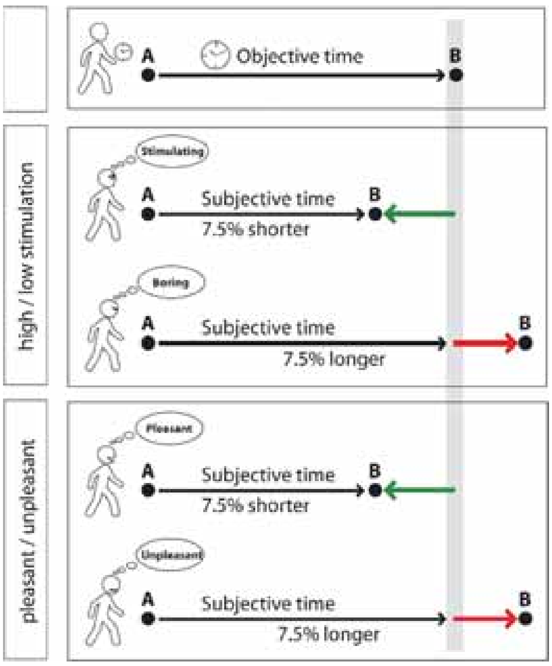
I consider, however, that the influence of the bias through underrepresented rush hour travellers does not threaten the results for the central questions of interest. My fieldwork gained the impression that pedestrians do not experience walking environments consciously. The environmental influence may vary between regular and non-regular travellers, but unlikely to a very extensive degree. We should remember that the data is not a cross section for the characteristics of public transport journeys during week days in Zurich.

I discussed in Section 4.1 the problem of distance between the researcher and the object of interest. The closed interviews can, of course, not derive the individual and environmental context for walking, to a level of detail that can explain how interviewees arrive at their evaluation of walking. This general shortcoming applies to any statistical method. The methodology addresses the problem of closeness on a different level. The survey allows the investigation of the impression of a specific walking trip that interviewees performed just before the interview. The methodology maintains, thereby, a close relationship between the reported impression of walking and the walking environment that shaped this impression. I consider these characteristics of the survey method to address the closeness problem. Telephone interviews and methodologies that question the amount of walking as a function of an urban residential area limit the described closeness between experience and environment, or between behaviour and environment. The methodology for the interviews in Zürich seeks to reduce this limitation.

6.6 The influence of walking environments on pedestrians' perception of time and acceptable walking distances

Can we estimate how walking environments influence pedestrians' perception of time spent walking from A to B? We know that (1) *the amount of stimulation*[80] and (2) *the pleasantness of stimuli* [81] can each vary pedestrians' time perception by about 15 percent, as Figure 94 illustrates.

Figure 94: Varying time/distance experience when walking



The investigation of head movements finds pedestrians to be highly stimulated on socially active squares, while underpasses are the least stimulating. I estimate the time spent walking in the square to shrink by 7.5 percent, while pedestrians experience time as 7.5 percent longer when walking through an underpass. With the help of a linear equation[82], we can calculate further estimates for the percentage variation of apparent time in environments that are less stimulating than a square but

[80] Section 3.3 discusses the meta study of Block et al. (2010), which finds the prospective perception of time to lengthen by about 15 percent with low stimulation as compared to high stimulation.
[81] Section 3.3 presents results from the investigation of Harton (1939) who finds pleasant experiences result in a 15 percent shorter time experience as compared to unpleasant experiences.
[82] For an explanation on the linear equation, see Section 10.7 in Appendix 3.

*Table 8: Percentage variation of perceived time spent walking in different environments as a result of the amount of **stimulation** pedestrians receive from walking environments*

Environmental typology	Variation of perceived time spent walking (%)
Socially active square, shop windows, interesting facades, no green	-7,5%
Busy pedestrian street with shops, narrow, no green	-5,1%
Relaxing environment with scenic view, or park, few people	+2,7%
Boring environment, large scale and closed facades, few pedestrians	+5,1%
Boring footpath along trafficked street	+2,1%
Underpass, few pedestrians, not stimulation	+7,5%
Complex or informal street crossing	+7,5%

more stimulating than an underpass. Results are presented in Table 8[83] and Table 9[84].

The percentage variation of perceived time in Table 9 shows how single attributes of a walking environment influence pedestrians' perception of

Table 9: Percentage variation of perceived time spent walking as a consequence of stimulation that pedestrians receive from environmental attributes

Environmental attribute	Variation of time spent walking (%)
Shops and shop windows, < 2 doors per 100m	0%
3 - 7 doors per 100m	-1,7%
> 7 doors per 100m	-3,4%
Walking, no stationary activities	0%
Walking, necessary activities	-1,3%
Walking, stationary, optional, and necessary activities	-2,5%
Street width/building height 1:3 and wider	0%
Street width/building height 2:1	-0,9%
Street width/building height 1:1 and narrower	-1,7%
Facades closed, passive, boring, and horizontally structured	0%
Facades somewhat closed, some variation	-1%
Transparent ground floor, varied, vertically structured	-2,1%
No pedestrian facilities such as benches, technical, no identity	0%
Designed, clean, somewhat boring, few facilities	-1,6%
Benches, bins, other facilities, well designed, strong identity	-3,2%
No green	0%
Three-dimensional green, trees	-1,6%
Trees and greening, well designed	-3,2%

[83] The basis for results in Table 8 is the investigations of head movements in 18 different walking environments as presented in Section 6.3 and Section 6.3.1.
[84] The results in Table 9 derive from the statistical investigation of head movements in Section 6.4, which shows how specific environmental attributes increase head movements and the time pedestrians look down. For the estimation in Table 9, I added the number of head movements per minute with the seconds looked down per minute, divided by two.

Table 10: Percentage variation of accepted walking distance with altering ***pleasantness*** *of environmental stimulation*

	Environmental attribute	Variation of perceived time spent walking (%)
1	Interesting buildings	4,5%
2	Shop windows	3,1%
3	Trees, green	1,6%
4	People/ activity	4,1%
5	Unattractive/boring	-2,8%
6	Street traffic	-0,1%
7	Crossing trafficked street	-3,9%
8	Compromised safety street crossing	-3,6%
9	Crowding	-4,0%

time[85]. We can use these results to adjust the time estimates in Table 8. For example, pedestrians experience time as 2.5 percentage points shorter when there are no people on the otherwise stimulating square with shop windows and interesting facades.

Complex or informal street crossings (last row in Table 8) are not the least stimulating, but they require high attention and pedestrians are twice as stimulated as on an attractive urban square. High stimulation is, however, not encouraged by the urban surroundings but required to prevent fatal collisions with vehicles. I estimate such high stimulation as a result of required attention to be highly unpleasant and to lengthen the perceived time spent walking by 7.4 percent.

Not only does the level of stimulation influence how pedestrians perceive time while walking from A to B, but so does the pleasantness of the walking experience. Results from the interviews in Zürich (Section 6.5) reveal that boring pavements along busy streets are less pleasant for walking[86]. I estimate here that the apparent time spent walking stretches by 7.5 percent. Conversely, pedestrians evaluate socially active urban surroundings with interesting facades and shop windows as most pleasant[87]. I estimate that such pleasant walking environments shorten the perceived time spent walking by 7.5 percent. With a linear equation, we can again estimate how time shrinks/stretches in surroundings that appear more pleasant

[85] These attributes reflect six (of nine) environmental categories that the matrix for the walking environment defines, as presented in Section 4.3.2.

[86] Pedestrians evaluate boring and insufficiently maintained footpaths as unpleasant. Equally, interviewees remember street traffic as unpleasant. Pavements can be boring and pedestrians are, at the same time, exposed to traffic emissions. Boring pavements along trafficked streets are common walking conditions walking in cities.

[87] Interviewees' evaluation of pleasantness increased when they described their walking environment with pictures that show (1) shop windows, (2) people and activity, and (3) interesting buildings. I evaluate environments that combine all these three attributes as most pleasant.

than pavements along busy streets but less pleasant than socially active squares with shop windows and interesting facades. Table 10 shows how pedestrians' perception of time shrinks/stretches (in reference to objective time) with the pleasantness of walking environments.

Table 11: Estimated variation of the perceived time spent walking with different environmental characteristics

Walking environment	Variation of time spent walking (%)
Socially active square, shop windows, attractive facades, no green	-17 %
Square with attractive facades, no shop windows, greening, few people	-15 %
Busy pedestrian street, shops, narrow, no green	-10 %
Relaxing park environment with social activity	-9 %
Relaxing environment, scenic view or green, few people	-1 %
Boring footpath along trafficked street	8 %
Boring environment, large scale and closed facades, few pedestrians	9 %
Crowded pavement along trafficked street, boring facades, no green	10 %
Underpass, few pedestrians	11 %
Crowded underpass	14 %
Complex or informal street crossing	14 %

Psychologists find (1) *the pleasantness of an experience* and (2) *the level of stimulation* to influence time experience. I suggest adding up the effects of *pleasantness* and *stimulation* to obtain a final estimate of how walking environments influence the time while walking from A to B. Can we just add up the effect of both factors as I suggest? The psychological literature proposes that *the level of stimulation* and *the pleasantness of an experience* are interrelated, but independent experiments find that both influence time perception. We cannot, so far, finally determine whether adding up the effect of stimulation and pleasantness is the most suitable basis for estimation. Nevertheless, the final results of my proposed evaluation procedure fit with the findings of other researchers, as the text will discuss later on.

On the basis of my proposed procedure, Table 11 shows how 11 different walking environments influence pedestrians' perception of time spent walking. Section 10.7 in Appendix 3 shows how the percentages in Table 11 are calculated from results in Table 8, Table 9, and Table 10.

6.6.1 The effect of urban environments on accepted walking distances

Most interesting for pedestrian access to public transport stops is the question of how walking environments influence the distances people are willing to walk to stops. I consider the perception of time, as discussed in the previous section, to reflect the perception of a walking distance. When pedestrians experience the time they need to walk from A to B as long, then the distance between A and B also appears long.

With apparently long walking routes to stops, fewer people are willing to walk to stops, even though the objective distance might be shorter than pedestrians perceive. Relevant for acceptable walking distances to stops is not the objective distance but the perceived distance public transport users have to walk to stops. Figure 95 illustrates the relationship between perceived distance and accepted walking distances.

Figure 95: Relationship between apparent distance to the stop (and apparent time needed to reach the stop) and accepted walking distance to stop

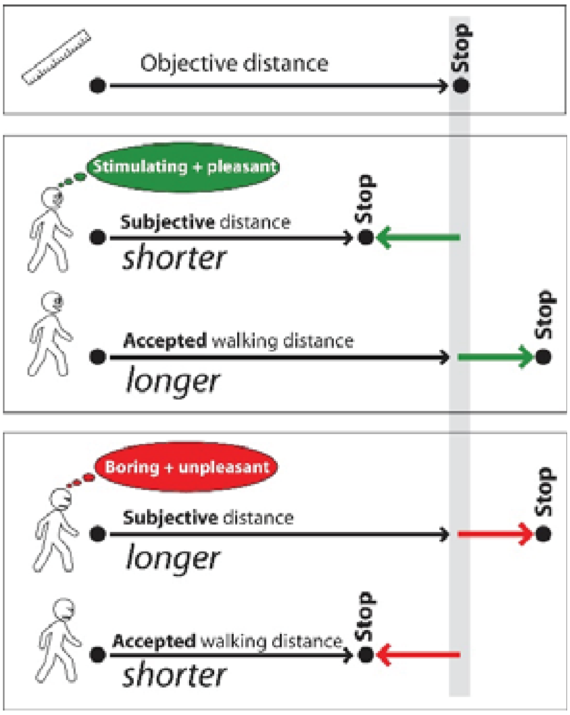
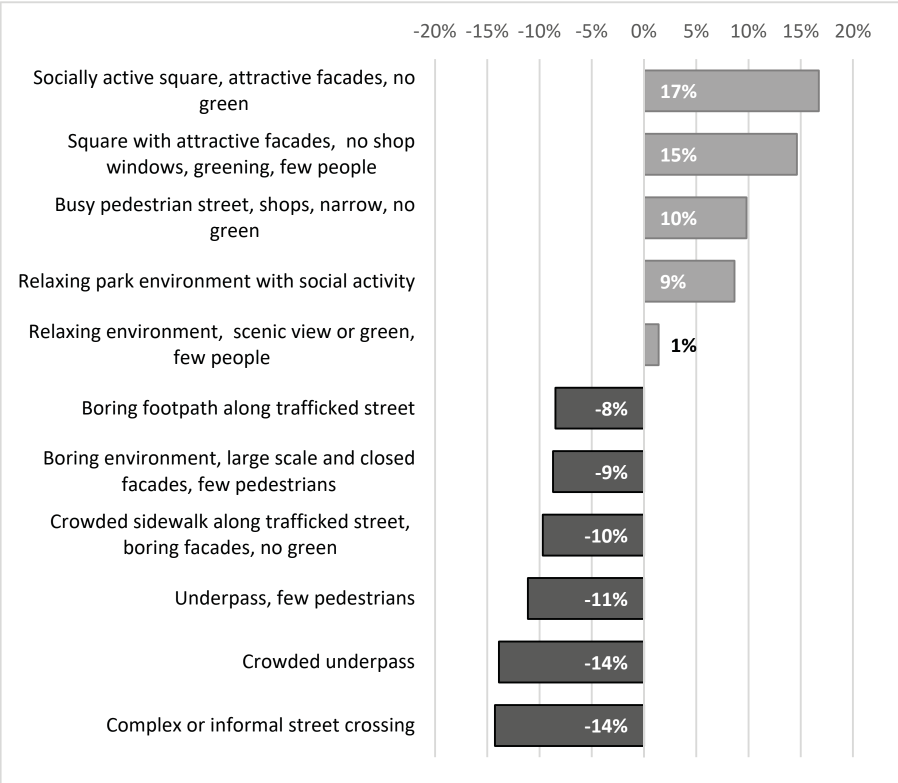


Figure 96 shows how different environmental characteristics influence acceptable walking distances. We need to remember that the percentage variation in walking distances derives from my evaluation of how pedestrians experience time in the previous section. Further, Figure 96 shows only the effect of the sensory experience of walking environments. Waiting times at street crossings and the enticing possibilities to access further destinations along walking routes are not reflected by the result in Figure 96.

Do the estimations in Figure 96 appear realistic compared to the findings of other researchers? Yang et al.

Figure 96: Variation of the accepted walking distance in different urban environments as a result of pedestrians' perception of walking distances



(2012) find 25 percent longer walking distances in areas with minor street blocks, shops and facilities along footpaths, and trees at some sections of the walking route. Urban areas with large-scale buildings, no shops and services, and large arterial roads serve as a counterpart. The authors neither discuss the effect of waiting times at street crossings nor filter out the effect. The estimations in Figure 96 indicate that acceptable walking distances are 19 percent longer in pedestrian streets, compared to a boring environment with large-scale facades (and few pedestrians). When pedestrians have to cross trafficked streets in boring surroundings, the acceptable walking distance can be 29 percent lower than in a pedestrian street without cars[88]. These results do not appear very different from those reported by Yang et al. (2012).

[88] Section 5.5 finds waiting times to consume about 10 percent of a short walking trip to a public transport stop.

Peperna (1982) reveals that regular travellers[89] accept 70 percent longer walking distances in *pedestrian-oriented* surroundings, compared to *car-dominated* urban areas in Vienna. On the basis of my own research, socially active squares with shops and interesting facades (pedestrian-oriented surroundings) result in 26 percent longer walking distances than a boring pavement along a trafficked street. The barrier effect of trafficked streets can easily reduce acceptable walking distances by 10 (one crossing) to 20 percent (two crossings)[90]. Further, this current research finds that 45 percent of regular public transport users access additional destinations, increasing acceptable walking distances by 15 to 25 percent[91]. When we add up the findings on (1) surroundings which are attractive in a sensory way, (2) the barrier effect of trafficked streets, and (3) longer walking distances with accessible additional destinations, the findings of this research can explain the substantial effect Peperna finds.

Comparisons between this current research and other studies are limited due to a somewhat different definition of the environmental features of relevance for pedestrian access to stops. Equally, results are derived from very different research methodologies. Keeping in mind the methodological differences, the findings of Peperna and Yang et al. appear surprisingly compatible with my own study.

We should take into consideration the fact that Figure 96 shows estimations that rest on my own investigation of (1) pedestrians' stimulation and (2) the reported pleasantness of walking environments, but also on (3) the findings of psychologists on the perception of time. Not only are these three elements of different characters, they remain complex to measure, and the units of these measurements are not directly compatible. Even though Figure 96 shows numerical results, these figures remain estimations. We should also remember that the environmental characteristics described in Figure 96 are likely to alter several times along a walking route to a stop. Finally, the subjective experience of walking environments remains an individual experience that can substantially vary from the averages discussed here.

Despite all shortcomings, the results show that the character of an urban environment is important for pedestrian access to public transport stops. Pleasantly stimulating surroundings (1) shorten apparent walking distances, (2)

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[89] Journeys from home to work
[90] These findings are reported and discussed in Section 5.5
[91] These findings are reported in Section 5.6

provide an impression of fast progress while walking towards or away from stops, and can (3) thus reduce the negative experience of time pressure while walking towards the stop. When walking away from stops, pleasant and stimulating environments trigger positive emotions, and walking becomes more pleasurable, as the following section demonstrates.

6.7 Walking environments influence pedestrians' emotions

This final section turns briefly to the question of whether walking environments influence pedestrians' emotions, as the *circumplex model for the walking environment* anticipates in Section 4.4.

The circumplex model of the walking environment differentiates between four pedestrian environments that potentially trigger an (1) exciting, (2) relaxing, (3) boring, or (4) stressing walking experience. Section 4.4 describes (1) pedestrian streets, (2) parks, (3) industrial areas, and (4) street crossing locations that are likely to result in corresponding emotions. The analyses in Sections 6.3, 6.4, and 6.5 measure the environmental effect on stimulation and pleasantness in these four urban environments. We can transform both measures to the unit of the subjective time perception, as the previous Section 6.6 shows. On the basis of the collected and processed data, we can now analyse whether and how walking environments influence pedestrians' emotions. The analysis simply plots the measures for stimulation and pleasantness into a coordinate system with the two axes of the circumplex model, *stimulation* and *pleasantness*[92]. Figure 97 shows the resulting diagram[93].

Numerous pleasant stimuli ***excite*** those who walk in pedestrian streets. With lower social activity in parks or, for example, along rivers with scenic views, the level of stimulation drops, but stimuli remain pleasant and pedestrians ***relax***. Conversely, underpasses offer little stimulation but are also unpleasant. Such

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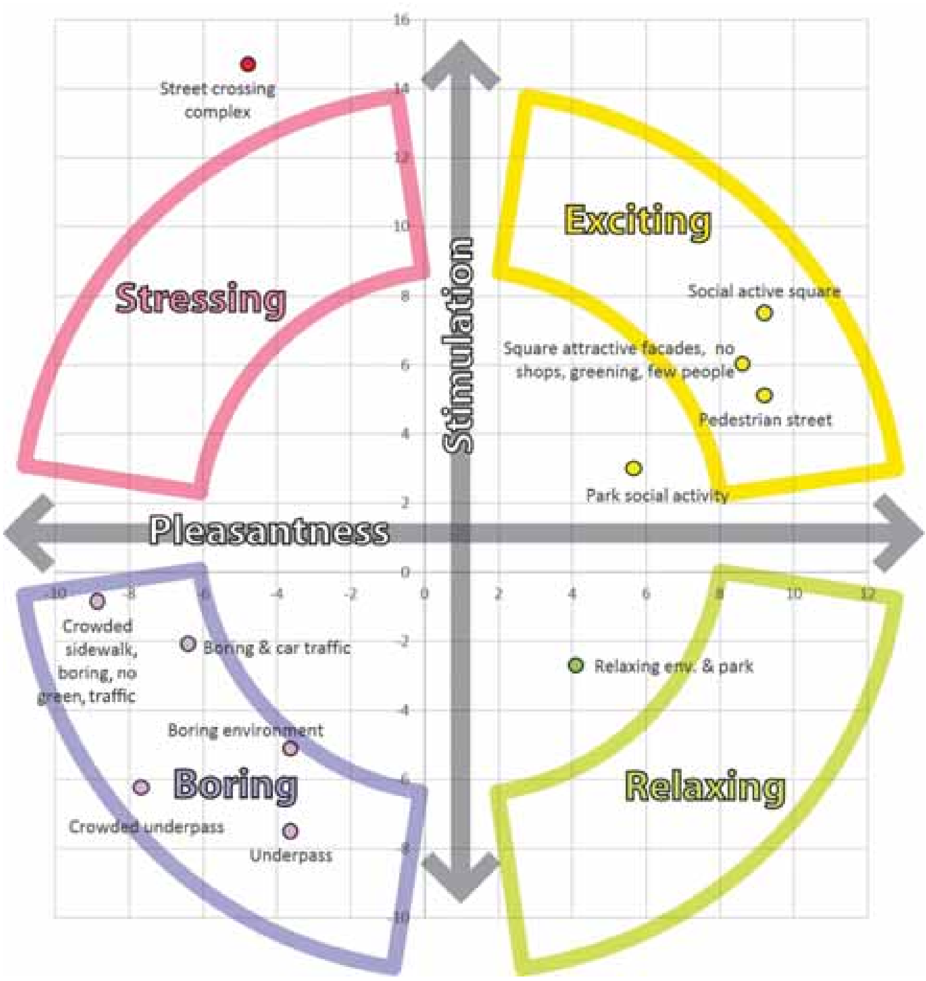
[92] I use the measures for stimulation and pleasantness that have been transformed to the unit, accepted walking distance, as Table 32, Table 33 and Table 34 present in the previous sections.

[93] The unit for stimulation derives from head movements per minute, recalculated into the unit, accepted walking distance (as described in the previous section). The unit for pleasantness reflects the alteration of evaluated pleasantness (on the Likert scale) as the analysis of the interview data showed. The unit for pleasantness in the graph is also recalculated to the unit, accepted variation of walking distance, as discussed in the previous section.

unpleasant walking routes ***bore*** pedestrians. Vehicles on streets do not raise pedestrians' levels of attention. Accordingly, pavements along trafficked streets remain boring. Only when pedestrians have to pay attention to driving vehicles during informal or less regulated street crossings, does stimulation rise to unpleasant levels, and walking becomes ***stressing***, as the red data point in Figure 97 illustrates.

Boring and exciting environments appear most common in urban environments and have been studied most extensively in this research. Around the investigated

Figure 97: Circumplex model of pedestrian emotions with data points for walking environments according to emotion and stimulation



public transport stops, walking routes rarely lead through parks. Nevertheless, greening and trees can substantially improve the sensory experience of walking. Access to public transport stops requires pedestrians to regularly cross streets. The distances that pedestrians walk across carriageways remain short, but the influence of these short sections on pedestrians' emotions remains extensive.

Plotting the investigation results into the circumplex model provides a picture that corresponds with psychologists' application of the model. The results in this section support the hypothesised relationship between environmental characteristics and pedestrians' emotions in Section 3.3. The environments that I considered to be exciting, relaxing, boring, and stressing do trigger corresponding emotions. Admittedly, my suggestions are not far-fetched, and results do not represent a major surprise. However, the analysis in this section shows that we can measure the environmental effect on pedestrians' emotions. These results support the existing experience and leave less room for doubt. Walking environments do influence the emotions of pedestrians, and, accordingly, the experience of walking. The analysis in this chapter demonstrates further that the subjective experience of walking distances is closely interrelated with the emotions that walking environments trigger.

7 CONCLUSION

Walking is deeply integrated into our daily life and offers the easiest possibility for getting from A to B. Mobility on foot is nearly always available without any vehicle or technical aids. Today, walking is also considered to be a healthy physical activity that does not require one to be sporty. Pedestrians move emission free and do not endanger other individuals. Walking is not only a form of mobility but allows social interaction and generates urban life.

Public transport journeys include a substantial amount of walking. Around 90 percent of public transport users walk to stops and spend about 45 percent of the travel time not inside vehicles. The time spent on foot outside in the city shapes the impression of a public transport journey more extensively than the ride itself. Walking appears to be the most convenient option to access stops. Surprisingly, walking is rarely considered as an integral part of a public transport journey. This research questions how the urban surroundings influence walking to stops. Investigations aim to understand how environments can jointly support walking and the use of public transport.

As the literature in Chapter 2 uncovers, the question attracting most attention is how far public transport users walk to stops. This distance determines the urban area from which walking to stops appears acceptable. The number of potential public transport users depends, among some other factors, largely on the distance travellers are willing to walk to stops. Researchers investigate the extent to which property boundaries, large buildings, and footpath networks lengthen distances. For similar reasons, street crossings are of interest as they delay access to stops by requiring pedestrians to wait until car traffic allows them to step across the carriageways. Easily accessible facilities along walking routes appear convenient as they allow several travel purposes to be combined along just one journey.

Few researchers question how the character of the urban environment influences walking distances to stops. Results show that public transport users walk up to 70 percent longer distances in *pedestrian-oriented* urban areas, compared to *car-dominated* surroundings, independent of walked detours. Street crossings and good access to facilities is unlikely to explain such extensive variations. The discourse shows only that urban environments influence walking to stops, but explaining the measured phenomenon remains difficult. How do urban environments influence walking and acceptable walking distances?

Rather than questioning the physical environment itself, I was convinced to find better answers in the behaviour of pedestrians who have to cope with what surrounds them. However, the reviewed literature sheds only little light on how pedestrians make use of their physical surroundings. Urban environments are shaped by designers, architects, planners, engineers and other professions. Are the ideas of all these experts relevant and useful for those who walk in the city? Do pedestrians behave as planners and designers think they will? I consulted more literature to gain a better understanding of walking as human behaviour, rather than a form of transport. The aim was to understand (1) the relationship between pedestrian behaviour and environments, and (2) why some urban surroundings encourage pedestrians to walk longer distances to public transport stops.

As the literature in Chapter 3 emphasises, pedestrians see, hear, smell, and touch what surrounds them. They feel the surface they walk on under their soles. The physical context for walking results in sensory impressions that trigger emotions. Emotions in turn determine behaviour. Pedestrian behaviour seeks to enhance the walking experience and reflects an impression of the walking environment. Studying behaviour may uncover how environments influence the walking experience.

Researchers investigate walking speeds as one central feature of human gait. Physiologists support the idea that the frequency of steps provides an even better measure to investigate reactions to urban environments and the experience of walking. Findings demonstrate that the average step frequency rises nearly linearly with the walking speed. The most energy-efficient frequency ranges between 110 and 120 steps per minute. A metronome allows us to determine precisely where and when the rhythm of steps changes. Studying steps may shed light on how pedestrians experience walking and what surrounds them.

Psychological literature indicates that urban environments are likely to influence a) the amount of stimuli pedestrians receive from their physical surroundings, and b), how pleasant pedestrians evaluate these stimuli. The amount and pleasantness of stimuli affect the subjectively perceived time spent walking, and consequently the apparent distance walked. Furthermore, psychologists use both dimensions as indicators for emotions such as excitement, relaxation, boredom, and stress. Investigating whether and how walking environments influence the amount and pleasantness of pedestrians' stimulation answers two important questions. Firstly, what kind of walking environments shorten apparent walking distances? Secondly, do urban surroundings influence pedestrians' emotions? Long footpaths and negative emotions while walking are unlikely to encourage pedestrians to walk longer distances to stops.

How to measure pedestrians' stimulation? Psychologists consider that visual information constitutes roughly 80 percent of all stimuli. Pedestrians collect visual information from frequent head and eye movements. By looking down at the pavement, pedestrians limit the amount of information to the minimum necessary to navigate. Hence, counting head movements and measuring the time pedestrians look down seems to provide a good indicator for the level of visual stimulation received from urban surroundings. A further indicator is provided by pedestrians' ability to perform activities while walking. By looking at phones, sorting in bags and so on, pedestrians entertain themselves, where little else appeals to their senses and walking becomes boring.

To study the pleasantness of environmental stimuli 596 tram passengers were asked to describe the walking environment along the trip to the stop, with the help of pictures. Further questions focused on behaviour, the length of the walk to the stop, the travel purpose, and further background data. Towards the end of the interview, people rated the pleasantness of their walk to the stop. The survey aims to understand how the evaluated pleasantness varies with environmental descriptions and other factors. The data also shows the conditions under which pedestrians access shops and other facilities along walking routes to stops.

In a second investigation, I captured 892 pedestrians with a video camera to study the influence of 18 different walking environments on pedestrians' head movements and the level of visual stimulation. A third enquiry method, utilising six to eight temporally installed cameras, captured the behaviour of 444 pedestrians while walking towards or away from 14 public transport stops. On the collected video material, I studied whether pedestrians' steps indicate reactions to environments and whether walking to approach stops differs from departing after alighting. The video material further enabled the examination of

- Access to additional destinations such as shops
- Reasons for detoured walking routes
- Preferable walking routes and locations for street crossings
- Time delays that result from waiting to cross streets

While the interviews allow background information on walking to be retrieved, the observational methodologies uncover unconsciously performed behaviour that interviewees cannot report on.

The research uncovers some characteristics for pedestrian access to stops. Step frequencies show differences between (1) walking towards stops and (2) departing from stops after alighting. Eighty-one percent of approaching pedestrians walk under time pressure, but less than 31 percent do so when leaving the stop. Those who walk to stops also behave differently from those who depart. Due to haste, approaching pedestrians ignore their surroundings and walk in a determined manner with a fast step. Conversely, the frequencies of pedestrians who depart reveal numerous reactions. People walk in a relaxed manner during holiday seasons or when the distance to the stop is short. When walking in twos or groups, frequencies incline equally as when pedestrians perform activities. These differences have an implication for the walking environment. While direct and unobscured footpaths reduce time pressure when approaching stops, departing pedestrians prefer surroundings that allow them to behave according to individual moods and preferences. Interestingly, frequencies indicate that crossing trafficked streets and detoured walking routes remain annoying for both approaching and departing pedestrians.

Approaching pedestrians prefer different parts of the footpath network around stops from those who depart. Eighty percent choose walking routes that do not require them to walk against the direction of their ride on a tram or bus. Pedestrians on the way to the stop cross streets as early as possible. Unpredictable time delays before street crossings are stressful, and many start running at the second they spot the bus or tram they intend to catch. Preferable walking routes and time pressure result in dangerous street crossings right in front of public transport vehicles. The majority of alighted pedestrians cross the public transport corridor right at the stop, mostly in front of the halted bus or tram. When the stopped public transport vehicle blocks one carriageway, crossing becomes easier. Where zebra crossings ease street-crossing, most alighted pedestrians reach the pavement on the other side before the halted public transport vehicle drives away from the stop.

Having to walk around large properties or built structures lengthens walking distances to stops. Interestingly, it appears that obstacles in the public space, street crossings, and carriageways detour walking routes to an equal extent as the footpath network around stops. Car-dominated stop surroundings lengthen walking routes on average by 19 to 20 percent. Denser footpath networks in pedestrian-oriented environments increase distances to stops by only 10 to 13 percent. Detours increase with more than one street crossing, while informal crossings are effective shortcuts. Railings do not reduce informal street crossings, but they trigger more dangerous manoeuvres.

Crossing streets can require pedestrians to wait until traffic allows them to walk across the carriageways. Waiting times depend on the kind of street crossing and the amount of traffic on carriageways. With more than 700 vehicles per hour, average waiting times range between 14 (informal crossing) and 17 (traffic lights) seconds. As these delays vary unpredictably, ensuring an in-time arrival at the stop requires pedestrians to take longer time delays into account. Crossing one busy street at traffic lights or informally lengthens the duration of a 2.5-minute walk to the stop on average by 10 to 11 percent. Zebra crossings are more convenient. Having the right of way means that waiting times remain predictable and shrink to an average of only five to six seconds.

Shops and other services along walking routes to stops are valuable additional destinations that pedestrians can access quickly. Inconveniences such as detours, additional street crossings, or having to carry purchased items do not outweigh the advantage of saving an extra journey. Supermarkets and facilities to cater for daily needs appear most useful and are accessed equally before or after the public transport ride. Of regular public transport users, 45 percent access destinations along a public transport journey. Not surprisingly, with more available facilities along walking routes, more pedestrians access these destinations. The incentive to save an extra journey encourages people to walk 15 to 25 percent longer distances to public transport stops.

The investigations also identify how urban environments affect pedestrian behaviour. If uneven walking surfaces or other obstacles do not interrupt the swing of legs, step frequencies do not vary. At the moment pedestrians spot something of interest, the rhythm of steps alters. This is equally so when people do something while walking, for example taking a puff of a cigarette. Where walking appears stressful or boring, people walk faster at higher frequencies. In relaxing surroundings or in pedestrian streets, average frequencies remain lower, indicating a more pleasant walking experience.

The investigation of head movements shows that pedestrians receive unequal amounts of stimuli in different environments. Socially active pedestrian areas with shop windows raise the level of stimulation by about 70 to 90 percent, compared to surroundings with large-scale buildings, monotonous facades, and wide streets. Least stimulating are underpasses, while stimulation in park-like surroundings indicates relaxation. When crossing streets, the required level of attention increases head movements to an unpleasantly high level. Pedestrians pay visual attention to trees and greening, shop windows, attractively designed walking surfaces and street furniture, as well as to other people. Cars driving past are uninteresting.

Interviews show that walking becomes increasingly unpleasant with too little space for walking and along monotonous and badly maintained footpaths. Interacting with cars and enduring traffic emissions is equally unpleasant. Inversely, walking becomes pleasant where people are around, where shops display their goods, in green surroundings, and where buildings and facades appear interesting. Results from interviews demonstrate that not all stimuli are pleasant.

The investigation of head movements and the interviews confirm (1) that urban walking environments influence the amount of stimulation that pedestrians receive from their surroundings, and (2) that the pleasantness of walking varies with environmental characteristics. By comparing the results with the findings of psychologists, we understand that the sensory experience of walking environments determines the apparent walking distances and consequently affects how far travellers are willing to walk to stops. Along pavements of trafficked streets with boring facades, in underpasses, and on crowded footpaths, pedestrians only accept 8 to 11 percent shorter walking distances to stops. Inversely, park-like environments and pedestrian streets lengthen distances by around 10 percent. Lively urban squares with shop windows and attractive facades can even lengthen acceptable distances to stops by 17 percent. The sensory experience of walking environments alters the acceptable walking distance by around 30 percent between extremes. Walking distances to stops depend not only on convenience but equally on the sensory impression of the urban surroundings.

Against the background of psychologists' understanding of emotions, the results for stimulation and pleasantness indicate the kind of emotions that walking environments trigger. Busy urban squares and pedestrian streets appear exciting, parks are relaxing, large-scale buildings along wide streets appear boring, and crossing trafficked streets stresses pedestrians. These results are not very surprising, but they demonstrate again that walking environments measurably influence pedestrians' emotions. Where walking results in negative emotions, people will not walk far, or they may not walk at all.

To summarise, acceptable walking distances vary with the following conditions

1	The incentive of a multipurpose journey with accessible additional destinations, such as shops, along walking routes	+15 to +25%
2	Time delays when crossing a trafficked street	-5 to -15%
3	Sensory experience of urban environments and the resulting impression of a walking distance	up to + 30%
4	Inconvenient public space layouts and street crossings lengthen walking distances	-10 to -20%
5	Increased energy consumption when walking in hilly terrain, depending on the slope	-30 to -50%

Unfortunately, the literature findings on the effect of climate and weather remain ambivalent. We also do not know how time pressure influences the impression of walking distances when approaching stops.

Apart from the quantitative measures and estimations, three fundamental impressions arise from my studies. Firstly, pedestrians predominantly react to stimuli within a radius of four to six metres. Only within such short distances, all sense organs can receive information. The capabilities of pedestrians' sense organs determine the right scale for good walking environments. Urban areas that provide sufficient space for convenient car access mostly exceed the abilities of pedestrians' senses. As a consequence, walking becomes boring and distances appear longer.

Secondly, diversity is a central attribute of an attractive walking environment. Non-monotonous surroundings subdivide the impression of a walking route into shorter sections of different character. Walking becomes more entertaining, and apparent distances shrink. The quality of design appears to me only of subordinate relevance. Design standards can sometimes even create dull surroundings. Trees, greening, the surface for walking, street furniture, and architecture provide an often unexploited potential to avoid monotony.

Thirdly, smoothly paved footpaths enable walking but do not appeal to pedestrians' senses. Providing some form of technical infrastructure insufficiently supports walking. The challenge remains to stimulate pedestrians' senses positively. Only where walking becomes pleasant and enjoyable, will more people walk more and longer distances.

How does this research contribute to the existing discourse? That urban environments influence walking is not a surprisingly new result. Many of my questions have been previously focused on by other authors, and my studies support their findings. Less common are some of the methodologies I applied, and few studies so far quantify the environmental effect on walking and behaviour. The unit *acceptable walking distance* is highly relevant for pedestrian access to public transport stops and for the potential of public transport infrastructure. Results demonstrate that the quality of the walking environment is *not* a "soft" factor with a diffuse effect that remains unmeasurable.

Under some circumstances, quantitative results are easier to understand and to communicate than longer qualitative explanations. Quantifications can be useful for political decision making but also to convince professional groups that are less used to qualitative descriptions. Further, measures are easily applicable in tools and software to facilitate planning and walking. The quantitative results of this research supply, thereby, an existing body of qualitative knowledge.

This research uncovers some specific characteristics of pedestrian access to public transport. To date, the differences between walking to approach or depart from a stop have engendered little attention. Findings have an implication for the design of the walking environment. Pleasantly simulating environments are important for approaching and departing pedestrians, but for different reasons. When walking towards stops, high and pleasantly stimulating environments shorten the apparent distance to the stop and provide an impression of fast progress in reaching the stop. The impression of a quickly accessible stop can ease sensed time pressure. When departing from stops, pleasant and stimulating urban surroundings trigger positive emotions and walking becomes pleasurable.

The findings highlight further that walking mostly does not result in a conscious environmental experience. This is especially true for walking trips to public transport stops. Pedestrians do not question whether the walk to the stop is pleasurable, but the environment influences the emotional impression and memory of the trip. The unconsciousness of the environmental experience poses a methodological challenge.

I dedicated a considerable amount of time to developing methods for the investigation of step frequencies, head movements, and other aspects of walking behaviour. I am convinced that these methodologies can contribute to future research. To date, investigating walking as a psychological issue does not appear to be very common. The results show that such an approach can enhance our understanding of this fundamental form of urban mobility.

As always, answers to research questions pose new questions. Understanding better how clothes, shoes, body size, the surface pedestrians walk on, and other factors influence step frequencies would make frequency investigations more rewarding. Equally, the relationship between walking speeds and frequencies remains somewhat vague. Research that would shed more light on the characteristics of step frequencies can advance the utility of this investigation method.

Counting head movements to investigate pedestrians' visual stimulation appears as a feasible and rewarding approach. I studied head movements at only 18 different locations. Results for some environmental characteristics rest on few observations, such as for example walking in parks. More studies would enlighten the issue of visual stimulation under conditions that this research investigated rarely or not at all. Further, more data on head movements in different environments will enhance the possibilities to determine what pedestrians pay attention to visually. Such studies indicate directly how urban environments can be improved to achieve a better sensory experience of walking and to encourage the use of public transport.

My investigations show only indirectly how environments influence the subjective experience of walking distances. Studies that focus directly on pedestrians' subjective perception of time and distance can be even more rewarding. I assume it will be possible to examine these questions under real-world conditions. The often sterile settings of psychological experiments are unlikely to reflect walking in cities. A secondary question is whether the perception of time spent walking corresponds with the impression of walking distances. My assumption that this is the case is not far-fetched, but how the perception of time and distance mesh remains somewhat unclear.

Numerous existing studies of psychologists and physiologists substantially enhance our understanding of walking. A comprehensive review of this literature can shed more light on the psychology and physiology of walking. Such knowledge bears great potential and will contribute to the development of methodologies to explore walking. Investigating the physiology and psychology of urban walking can result in more and better explanations of the relationship between walking and the built environment.

The results also raise more specific questions regarding pedestrian access to public transport stops. I consider access to additional destinations as important. The convenience of multipurpose trips saves many extra journeys and encourages travellers to walk longer distances to stops. This potential deserves a closer research focus. Do people access additional destinations preliminarily due to their convenient location? How important is the quality of facilities, compared to convenient accessibility? Which further factors influence whether and where people access additional destinations along walking trips to stops? How important are daily routines and the context of individual households in enabling multipurpose journeys? Answers would possibly inform strategies to increase the amount of multipurpose journeys, which can substantially reduce the travel demand in cities.

Enquires do not focus on all challenges of street crossings apart from the time delays and detours they cause. How pedestrians interact with cars is not a new issue. Nearly all public transport users have to cross a more or less trafficked public transport corridor at least once. This research uncovers some new aspects that highlight the importance of street crossings for walking trips to and from stops. Pedestrians' interactions with cars and public transport vehicles deserve a closer focus that bears a high potential to improve access to stops.

This research was propelled by my interest in the planning and design of urban environments but focuses extensively on pedestrians' behaviour. Suggestions for a sound walking environment around public transport stops remain relatively broad. Concrete guidelines can, under some circumstances, hamper a creative search for the best solution in a specific urban context. In my opinion, understanding the character of walking and access to public transport stops is the key to creating environments for convenient and pleasant access. I am convinced that an understanding of walking behaviour enables an engaged designer, planner or engineer to create good physical solutions for pedestrians.

As equally important as research, I see a demand for increased awareness and understanding of walking among all professions and forces that shape our cities. Walking is not only a question of a paved network of footpaths that links A with

B. The work of architects, urban designers, landscape architects, infrastructure engineers, and many other professions influences how attractive walking will be. The protagonists that shape our cities need to understand how their work influences the most fundamental form of mobility – walking. From ten years' planning practice, I gain the impression that appropriate planning and design practices bear a widely unexploited potential to support urban walking and public transport. I consider improvements not primarily as a financial challenge but rather as a question of planning and designing according to the pedestrian perspective.

The urban environment is important for walking, and walking is an integral part of any public transport journey. Pedestrians are flexible but slower, public transport drives faster but is little flexible. These unequal characteristics supplement each other and create a symbiotic coexistence between both modes of mobility. Strategies to support public transport remain incomplete without focusing on walking. Disregarding walking diminishes the return on costly public transport infrastructure. I am still surprised that the public transport industry has, for decades, failed to press the need for good walking environments around stops. The combined support of walking and public transport triggers synergetic effects that bear a great potential to change car-dominated mobility in cities. Further, good cities for walking are good cities for living.

8 APPENDIX 1

8.1 Environmental typologies around public transport stops

The urban area around public transport stops consists of four different typologies that influence walking (Figure 98):

1. The surroundings close to the stop (1)
2. The pavements on both sides of the public transport corridor with the public transport vehicles approaching the stop (2)
3. The pavements on both sides of the public transport corridor with the public transport vehicles departing the stop (3)
4. The footpath network on both sides of the public transport corridor (4).

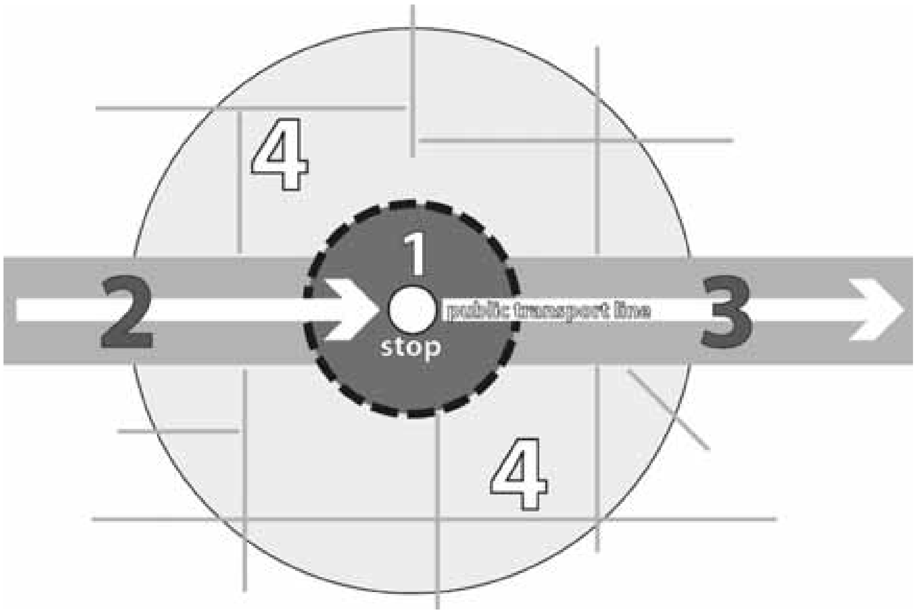
8.1.1 The closer stop surroundings

I see the most fundamental difference between the ***closer stop surroundings*** (inside the dotted line in Figure 98) and all zones outside this (zones 2, 3, and 4). Within the closer zone, the stop is visible and quickly accessible, normally up to a distance of about 30 – 40 metres. High walls, hedges, buildings or other stationary objects hinder the view to the stop. Further, carriageways with high traffic flows obstruct quick access to the stop. Only areas from where (1) the stop remains visible and (2) pedestrians have unhampered access belong to the closer stop surroundings. My definition of the closer stop surroundings is hence not always the area inside a 30 – 40-metre radius around the stop, as the dotted line in the simplified graphic (Figure 98) indicates.

Entering the closer stop surroundings can cause a variation in the walking behaviour of arriving pedestrians, who are often under time pressure. As soon as pedestrians enter the closer stop environment, they relax. Conversely, when pedestrians can see the bus or tram arriving at the stop, many hurry up.

Pedestrians and public transport users convert from one mode to the other within the closer stop environment. Pedestrians become public transport users and public transport users convert to pedestrians. The switch represents a significant change in the sensory experience. Most problematic appears to be the transition from a passive journey in a public transport vehicle to an active form of mobility after alighting. Suddenly, the former passengers need to become physically active, to concentrate on complex movements of people and vehicles, and to actively navigate and decide on directions. After alighting, people sort out carried items and clothes within the closer stop surroundings, mostly while they start walking. These transitions take place in the closer stop environments.

Figure 98: Four types of public transport stop environments: 1. The footpath network, 2. The corridor with the arriving public transport vehicles, 3. The corridor with the departing vehicles, 4. The closer stop surroundings



8.1.2 The public transport corridor

When shops and services were found around stops, they were mostly located along the public transport corridor. Public transport corridors are generally busier than the footpath network (4 in Figure 98) and include more vehicle traffic and higher pedestrian flows (Figure 99). When pedestrians walk to the stop along the **corridor with the public transport vehicles approaching the stop** (2 in Figure 98), they also receive visual information on the position of the public transport vehicle. The effect of this is to influence walking behaviour in the same way as described for the closer stop surroundings, but over a longer distance. Along the **corridor with the public transport vehicles departing the stop**, pedestrians have less information on public transport vehicles but can see whether buses or trams have

Figure 99: Busy public transport corridor in Copenhagen

already arrived at the stop.

8.1.3 Footpath network

The environmental characteristics of the footpath network differ often significantly from the appearance of the public transport corridor. Here, the stop often remains invisible and pedestrians receive no visual information on the position of public transport vehicles. Footpaths are often pavements along narrower side streets (Figure 100) or footpaths through green areas or minor squares. These environments are mostly tranquil with fewer pedestrians and driving cars, but there are often more parked cars along side streets. If the stop is not located in a very central urban area, the number of facilities decreases within the pedestrian network as compared to the public transport corridors. The density and height of buildings can be lower in the pedestrian network, but this is not always the case.

Figure 100: Footpath along a side street in Copenhagen

9 APPENDIX 2

9.1 Questionnaire used for interviewing tram passengers in Zürich

Swiss-German questionnaire from the tablet PCs with English translations in grey colour:

Sind Sie zu Fuss zur Haltestelle gelaufen? (Did you walk to the public transport stop?)

Bei nein Befragung Abbrechen (with no, stop the interview)

- Ja (Yes)
- Nein (No)
- **Wie oft fahren Sie diese Strecke mit der Tram? (How often did you travel this journey by tram?)**
- weniger als 2x pro Woche (less than 2x per week)
- 2 – 3x pro Woche (2 – 3x per week)
- mehr als 3x pro Woche (more than 3x per week)
- zum ersten mal (the first time)

2) Was ist der Hauptzweck dieser Fahrt? (What is the main purpose of this journey?)

Antwortliste kann gezeigt 193arden (List of answers can be shown)

- Arbeit (work)
- Dienstweg (work related trip)
- Ausbildung (education)
- Einkaufen/Shoppen (errands/shopping)
- Dienstleistungen (Arzt, Bank, Post, Frisör ...) (service (doctor, bank, post office, hairdresser …))
- Freizeit (Sport, Besuch, Hobby ...) (leisure (sports, visit, hobby, …))
- Begleitung (Kind abholen ...) (accompany (accompany child …)
- Anderes (other)

3) Sind Sie jetzt auf dem Hin- oder Rückweg? (Are you now on the way towards your destination or are you returning to your home?)

- Hinweg (towards destination)
- Rückweg (travelling homewards)

4) Schauen Sie einmal auf dieser Karte, wie ist Ihre Fahrt bisher verlaufen? (Look at this card; how have you travelled so far?)

Vorlegen: Karte Umsteigen (show: card change)

- Fussweg – Tramfahrt (walking – tram ride)
- Fussweg – Bus/ Tramfahrt – Umsteigen – Tramfahrt (walking – bus/tram ride – change – tram ride)
- Zug/S-Bahn – Fussweg/ Usteigen – Tramfahrt (train ride – walking/change – tram ride)

Ich frage Sie nun einige Fragen zu diesem Fussweg auf der Karte (I will now ask you some further questions on this walking trip on the card)

Auf Karte "Umsteigen" zeigen: Ersten Fussweg für die gewählte Antwort (Point to "change" on the card: the first walking trip for the chosen answer)

5) Wie lange haben Sie für diesen Fussweg zur Haltestelle gebraucht? (How much time did you need to walk to the public transport stop?)

- weniger als 3 min (less than 3 minutes)
- 3 – 5 min
- 6 – 10 min
- 11 – 15 min
- mehr als 15 min (more than 15 min)

6) Welches der 8 Fotos charakterisiert am ehesten die Umgebung Ihres Fusswegs zur Haltestelle? Sie können bis zu 3 Bilder wählen. (Which of the eight photos best characterises the environment you passed through to reach the stop?)

Vorlegen: Karte Bilder (Show: card pictures)

- Strasse/ Verkehr (street/traffic)
- Leute/ Aktivität (people/activity)
- interessante Gebäude (interesting buildings)
- Gedränge (crowding)

- unattraktiv/ langweilig (unattractive/boring)
- Bäume/ Grün (trees/green)
- Schaufenster (shop windows)
- Warten/ Strassenquerung (waiting/street crossing)

7) Haben Sie während dem Gehen telefoniert, Musik gehört, sich unterhalten, oder irgendetwas anderes getan? (Did you perform any activity, such as listening to music, talking to somebody or something else while you walked to the stop?)

- Ja (yes)
- Nein (no)

8) Haben Sie auf dem Fussweg zur Tram noch etwas erledigt? (Did you run an errand along the walk to the public transport stop?)

Antwortliste kann gezeigt 195arden, 1-8 wahlmöglichkeiten (List of answers can be shown, 1 – 8 possible choices)

- Einkaufen (shopping)
- Dienstleistungen (Arzt, Bank, Post, Frisör …) (service (doctor, bank, post office, hairdresser…))
- Freizeitaktivität (leisure activity)
- Etwas gegessen/getrunken (eating/drinking)
- Begleitung (Kind abholen ...) (accompany (accompany a child …)
- Anderes (other)

9) Mussten Sie Strassen mit viel Verkehr queren um zur Haltestelle zu gelangen? (Did you have to cross any trafficked streets to reach the stop?)

- Ja (yes)
- Nein (no)

9a) Haben Sie die Strassen an einer Fussgängerampel, einem Fussgängerstreifen, oder an einer anderen Stelle gequert? (Did you cross the trafficked streets at a pedestrian traffic light, a zebra crossing, or at another location?)

- Fussgängerampel (pedestrian traffic light)
- Fussgängerstreifen (zebra crossing)
- Unterführung/ Fussgängerbrücke (underpass/pedestrian bridge)
- an einer anderen Stelle (at another location)

10) Mussten Sie sich beeilen um rechtzeitig zur Haltestelle zu kommen? (Were you in a hurry to reach the public transport stop?)

- Ja (yes)
- Nein (no)

11) Könnte ein 7 jähriges Kind den Weg den Sie gegangen sind auch sicher alleine gehen? (Could a child aged 7 walk safely alone along the same path you walked to the stop?)

- Ja (yes)
- Ich glaube, ja (perhaps yes)
- Ich glaube, nein (perhaps no)
- Nein (no)

12) Wie würden Sie Ihren Fussweg zur Haltestelle insgesamt Bewerten? (How would you evaluate your walk to the public transport stop overall?)

Vorlegen: Karte Skala (Show: card Likert scale)

- 6 sehr angenehm (very pleasant)
- 5
- 4
- 3
- 2
- 1 sehr unangenehm (very unpleasant)

13) Ich frage Sie nun noch einige generelle Fragen: Wie oft sind Sie in den letzten 7 Tagen eine Strecke zu Fuss gelaufen, die länger als 10 Minuten gedauert hat? (I will now ask you some general questions: How often did you perform a walk that lasted longer than 10 minutes during the last seven days?)

- kein mal (none)
- 1x
- 2-3x
- öfter als 3x (more than 3x)

14) Könnten Sie für diese Fahrt auch ein eigenes Auto nutzen? (Did you have a car available for this journey?)

- Nein (no)

- Ja (yes)
- Ja, aber unpraktisch (yes, but unpractical)

15) In welche Altersgruppe gehören Sie? (What age group do you belong to?)

Antwortliste soll gezeigt 197arden (List of answers can be shown)

- Unter 20 (under 20)
- 20 – 39
- 40-64
- 65-74
- Über 75 (over 75)

16) Was ist ihre aktuelle berufliche Situation? (What is your current occupation?)

Antwortliste soll gezeigt 197arden (List of answers can be shown)

- Schüler/Lehrling/Student (pupil/apprentice/student)
- Angestellt (employed)
- Selbstständig (self-employed)
- Nicht erwerbstätig (unemployed)

Ausfüllen: Geschlecht der Befragten Person (Fill out: gender of interviewee)

Wird vom Befrager eingetragen (to be filled out by the interviewer)

- Männlich (male)
- Weiblich (female)

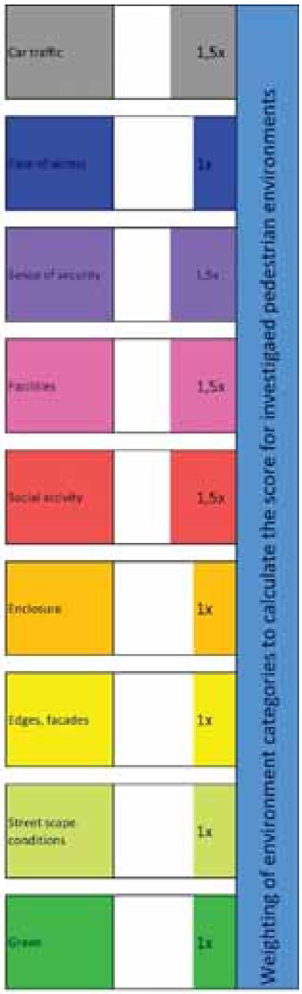
Ausfüllen: Sprachliche Verständigung (Fill out: verbal communication)

Wird vom Befrager eingetragen (to be filled out by the interviewer)

- schlechte Verständigung (difficult communication)

9.2 Calculating a total environment score from the categories of the environment matrix for walking

Figure 101: Summary of grading from the nine categories in the total environment score



Four of the nine categories in the matrix (*green*, *streetscape*, *edges*, and *enclosure*) together describe the visual quality of the built physical environment and the amount of visual stimulation the surroundings provide. Equally, the *access* category describes a feature of the physical designed environment that influences walking in a practical way. Conversely, *facilities* such as shops and other services are built and visible, but they can be destinations for pedestrians. In the same way, the categories, *car restrictions, sense of security*, and *social activity*, describe conditions that influence not just the visual experience of walking but, rather, work on a more complex emotional level. Emissions from car traffic discomfort walking, and streets often require detours; the sense of security strongly influences pedestrians' emotions, while social activity allows interactions but also requires frequent reactions while walking.

I weighted the categories, *car restrictions*, *sense of security*, *facilities*, and *social activity,* higher than the other categories, as presented in Figure 101. I consider that these categories influence walking in strongly emotional and practical way. The total environment score (as the blue bar at the bottom of Figure 42 shows for the *Amagertorv* square) adds up the weighted grades (grade multiplied with weightings) from the environmental categories, divided by the sum of the category weightings. The sum of the category weightings (as shown on the right side in Figure 101) is calculated as:

$$1.5 + 1 + 1.5 + 1.5 + 1.5 + 1 + 1 + 1 + 1 = 11$$

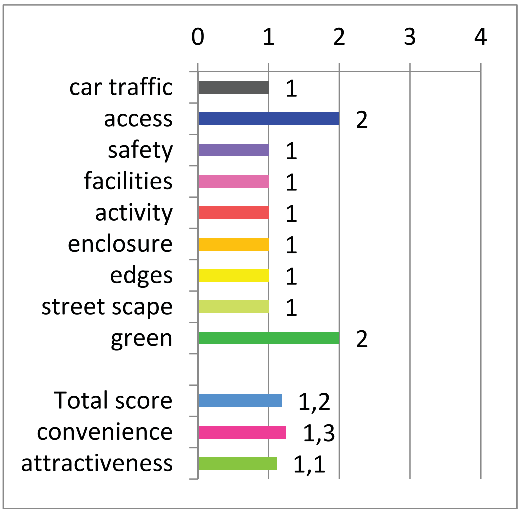
The total environment score for the example of the *Amagertorv* square (Figure 42) is calculated from the weighted category grades as the following:

$(3x1.5 + 3 + 3x1.5 + 3x1.5 + 4x1.5 + 2 + 4 + 3 + 1)/11 = 2.95$

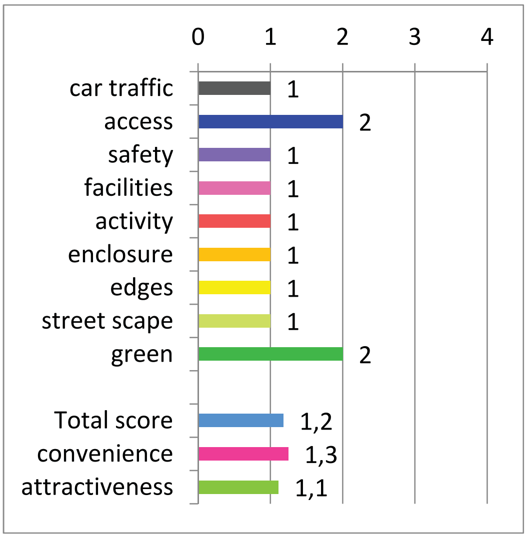
I further limited the total environment score to the value 3.0, as I did not want any *extraordinary* grading (value 4) to cause higher total scores than for environments with no extraordinary graded environment categories. My calculation method for the total environment score increases the total score for the example of the *Amagertorv* in Copenhagen (Figure 42) to the maximum value of 3, despite lacking green features, that does not lower the attractiveness of the square for walking.

9.3 Description of 18 environments for close-up observations

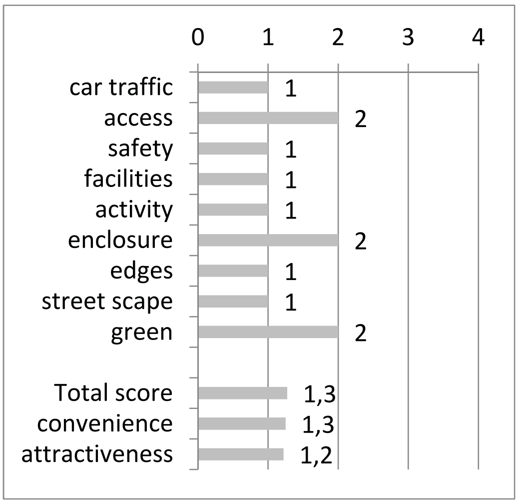
Descriptions of the 18 case study environments with the results of the evaluation by means of the environment matrix follow.



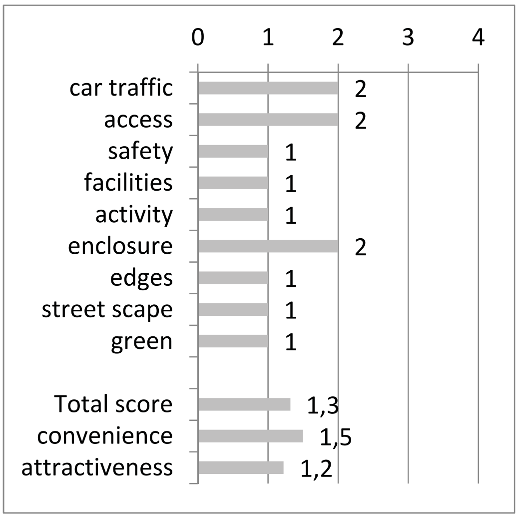
01 Bernstoffgade, Copenhagen, 14.05.2013. Long footpath along a highly trafficked four-lane street, bordered by the large-scale monotonous façade of Copenhagen's central post building. The conditions of the built environment are unpleasant/deactivating.



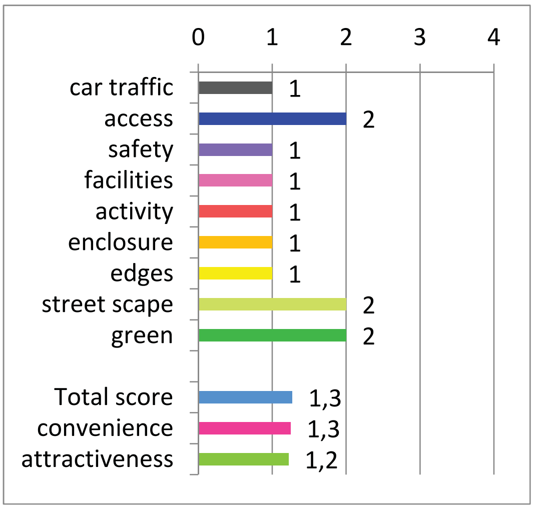
02 Gloucester Place, Brighton, 09.10.2013. The pavement of Brighton's most busy four-lane street corridor, defined by a monotonous façade that does not allow viewing into the postal building. The pavement is bordered by the façade and a fence between the driveway and the pavement. Unpleasant/deactivating.



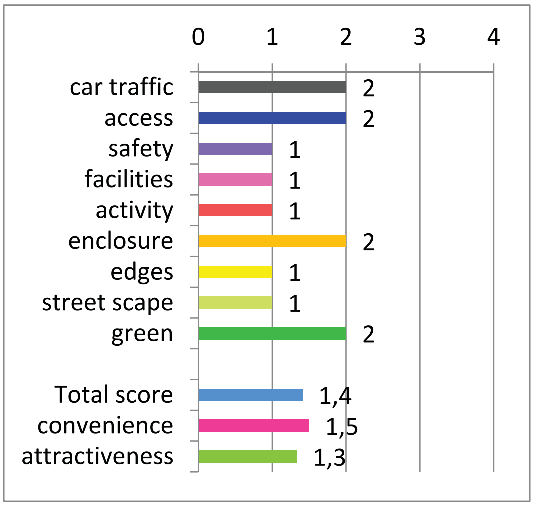
03 Niels Juels Gade, Copenhagen, 25.05.2013. Long footpath along a highly trafficked four-lane street, bordered by a large-scale, closed, ca. 200-metre-long façade. Monotonous row of trees along the pavement. Dominance of car traffic determines categorisation as unpleasant/stimulating. The conditions of the built environment are unpleasant/deactivating.



04 John Street, Brighton, 23.09.2013. Pavement along a side street, slightly sloping, surroundings characterised by various large-scale buildings with monotonous facades. No green, very basic streetscape design, but significantly fewer cars than in case studies 01 CPH, 02 BRT, and 03 BRT. Unpleasant/deactivating.

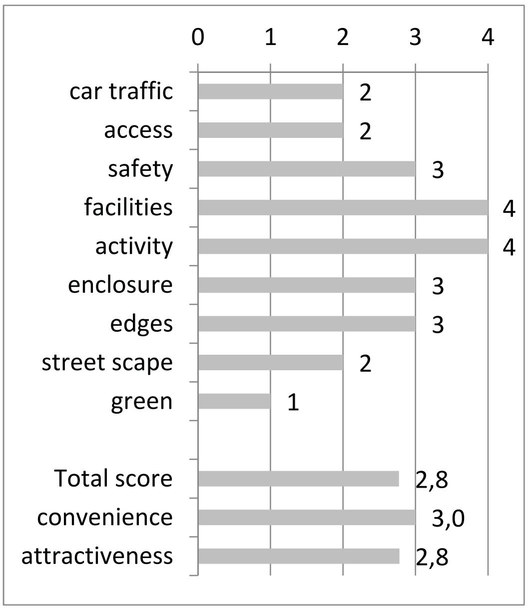


05 Pfingstweidstrasse, Zürich, 21.08.2013. A wide pavement along a newly built four-lane street, some streetscape design elements and trees, very large-scale streetscape, with newer buildings with large-scale, monotonous facades. Fewer cars than in case studies 01 – 03, but more cars than in case study 04. Somewhat unpleasant/deactivating.

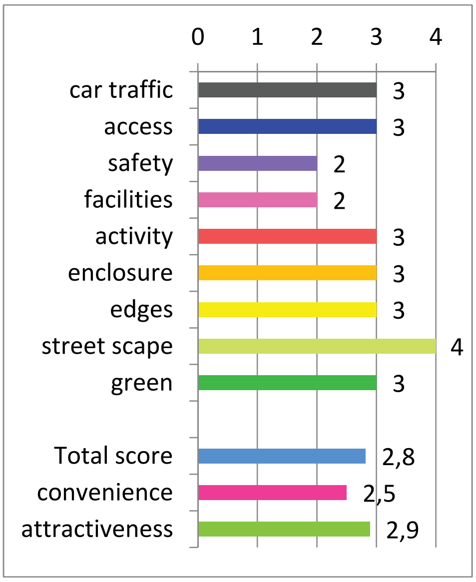


06 Carsten Nieburs Gade, Copenhagen, 14.05.2013. Pavement of a side street with no traffic calming but few cars. A 1:1 relationship between a high façade and wide street results in a well-dimensioned newly built streetscape, some greening along the pavements. The facades are very long, without openings and of a very monotonous design. Unpleasant/deactivating.

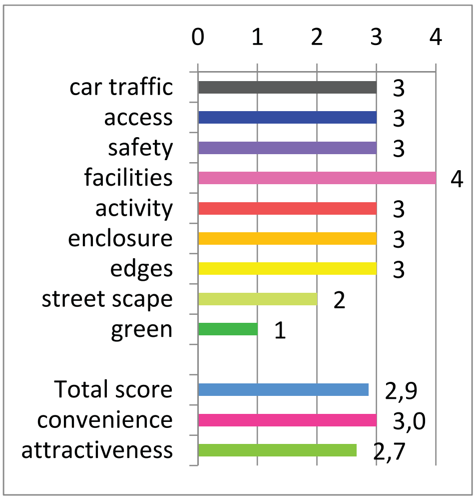
07 Fiolstræde, Copenhagen 23.05.2013. A secondary pedestrian street in Copenhagen's old city centre. Cycling allowed, also access with car for residents, though traffic calmed. No marked pavements, pedestrians use the full width of the street and dominate the cars and cycles. Simple facades with many windows and shop windows and entrances. No green elements and simple streetscape design. Pleasant/activating.



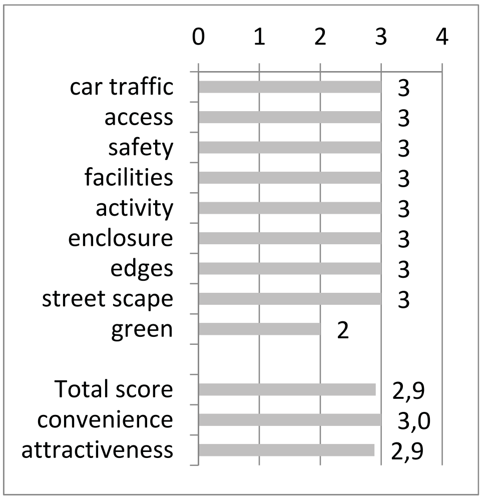
08 Gardner Street, Brighton, 07.10.2013. Although the street has pavements and a one-way driveway for cars, pedestrians dominate the street and use its full width. Along both sides are small shops with shop windows in two-storey buildings, creating a well-dimensioned space for the street. The streetscape design and the facades are basic. The street receives its character from the numerous pedestrians that are attracted by the shops. A pleasant/activating environment for walking.



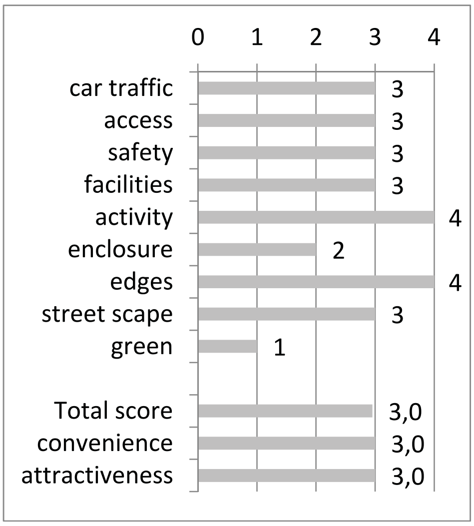
09 New Road, Brighton, 09.10.2013. New Road is a shared space that functions as pedestrian zone. During the observation period, no cars were present. The street has a high quality streetscape designed by Gehl Architects. On the one side, old two-storey buildings contain shops and cafes with outside seating. A long bench establishes the border of the other street side; high trees from an adjacent park behind the bench establish the counterpart to the facades. Pleasant/activating.



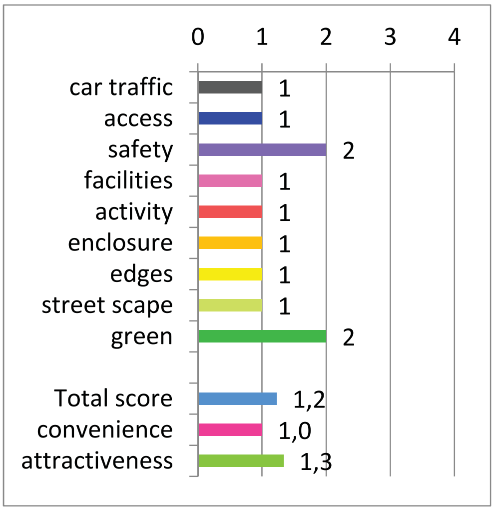
Østregæde, Copenhagen, 30.05.2013. This pedestrian street establishes the eastern extension of Copenhagen's well-known pedestrian street, *Strøget*. Four- to five-storey facades from both newer and older buildings with shop windows establish the borders of the pedestrian street. No facilities and greening. The environment derives its character from the facades and shops and the numerous pedestrians. Pleasant/activating.



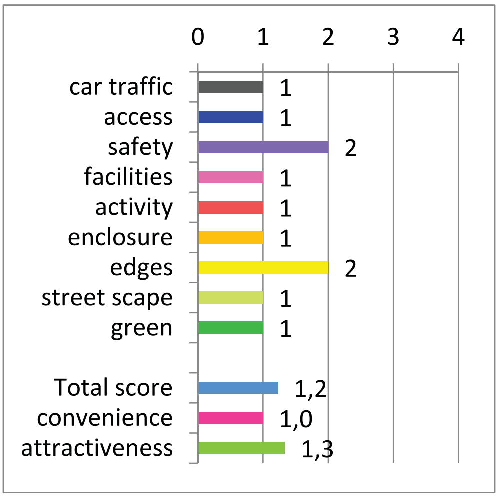
11 Rennweg, Zürich, 26.08.2013. The pedestrian street is bordered by five-storey, unpretentious buildings that create a vertically structured pattern. Characteristic of the street are the shops and cafes on the ground floor with outside seating. Some street furniture and greening elements and many pedestrians. Pleasant/activating.



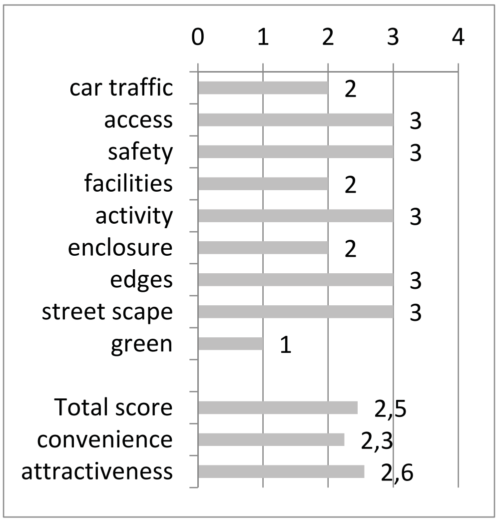
12 Amagertorv, Copenhagen, 30.05.2013. This square is one of Copenhagen's most central at the eastern end of the pedestrian street, *Strøget*. It has a distinct, high quality pavement, benches, a fountain, and public toilets. Street artists use the square as an arena. With no trees and green elements, the square receives its unique character from the old four- to five-storey high facades. Stores and cafes with outside seating attract many people. Pleasant/activating.



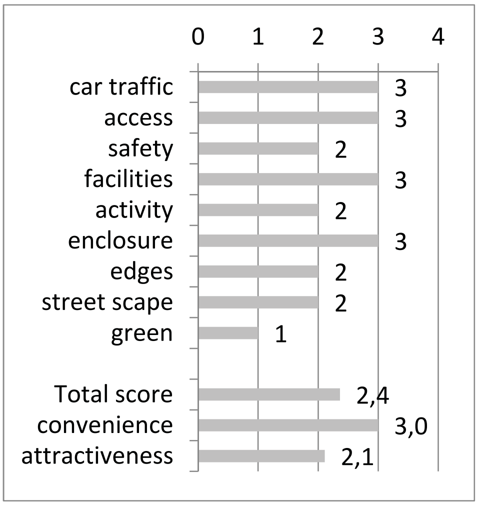
13 Street crossing near Main Railway Station in Zürich, 22.08.2013. The crossing traverses two carriageways for cars and two tram lines. Traffic lights regulate pedestrians crossing the car lanes; a yellow blinking signal light warns pedestrians of approaching trams. Hence, pedestrians cannot just cross the street with a green light; they must pay attention to approaching trams. Unpleasant/activating.



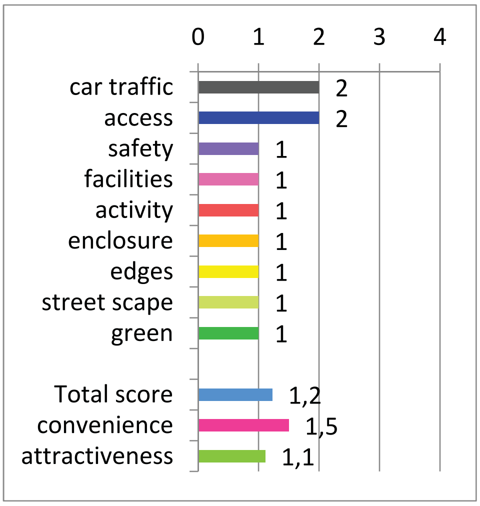
14 Street and tram rail crossing at public transport stop Zentral in Zürich, 20.08.2013. Pedestrians cross a little trafficked carriageway via a zebra crossing, and two tram rails without a signal. The tram rails are located within the area of the public transport stop, though trams arrive at the stop from three different directions, which makes crossing the rails very complex. Unpleasant/activating.



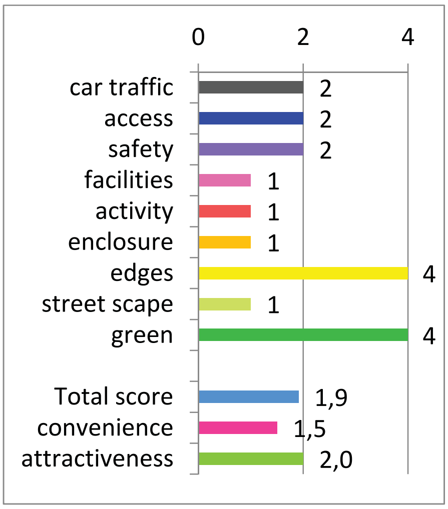
15 Carriageway crossing on the Zentralplatz, Biel, 29.08.2013. The Zentralplatz is a central square in Biel. The whole square is designed as shared space with a marked carriageway for cars. About 10,000 vehicles cross the square every day. Pedestrians have right of way all over the square. The square is built over a river, and loosely surrounded by five-storey high buildings of different periods. A café with outside seating, a roof with sitting facilities, and further benches invite people to stay. The streetscape design is partly very simple, but a number of interesting objects, a fountain and greening create an interesting urban square. Pedestrians were observed crossing the carriageway that is part of the shared space on the square. In contrary to the usual settings, pedestrians have right of way and vehicles are required to wait. Unpleasant/activating.



16 Underground passage in the Central Station Zürich, 22.08.2013. This pedestrian passage is part of an underground shopping centre under the Central Station in Zürich. The passage is about six metres wide and 3.5 metres high. Several shop windows and displays and shop entrances are located to the left and right along the passage. The passage is newly built in a modern design of higher quality, with bright illuminated glass elements on the walls and a dark stone floor.Pleasant/activating



17 Pedestrian underpass under a railway line in Zürich Oerlikon, 22.08.2013. The underpass consists of a simple round concrete construction that spans over a paved pedestrian path, about 25 metres long and 2.5 metres wide. Simple lighting from the ceiling is provided in the centre of the underpass. Unpleasant/deactivating



18 Limmatquai, Zürich, 12.08.2013. A footpath between a tram carriageway and the river *Limmat*. Car traffic along the *Limmatquai* is restricted to delivery. Facades on the other side of the footpath are detailed and vertically structured, but some 50 metres away. The footpath leads directly along the river *Limmat* and opens onto attractive views over the river. The pavement design and the fencing towards the river are technical and monotonous. Some trees along the pavement. The very attractive view over the river justifies the categorisation, pleasant/deactivating.

9.4 Data collection for public transport stop investigations

Most video observations took place between 15.30 and 18.00h. Planning of the locations for cameras took about one hour and needed to be undertaken right before the film session. Parked trucks and other obstacles can influence the setup for the cameras. Video cameras captured all possible footpaths leading to the stop. It was essential to hang up notices informing passers-by about the undertaken inquiry. Informing authorities such as police, city administrations, and public transport operators appeared important.

The captured video material from each camera was synchronised by time, and pedestrians that departed from the stop could then be followed up[94]. Rewinding the video footage after a person arrived at the stop also enabled the pedestrians who walked towards the stop to be observed. In order to be able to play the video footage forward and backward, all videos were converted to a *mpg 2* format. Contemporaneous playback of six videos in high definition format remains impossible with today's available data hardware. The used software enables synchronised video tracks to be switched off, but videos remain synced when playing and viewing only one track. Better and faster computer hardware could significantly ease the developed method in the future.

The following features for each of the 444 observations were registered in cross tables, ordered in five groups:

General data:

- Arriving or departing from stop
- Observation start and stop time as well as duration of observation
- If interesting, a short description of specific aspects of behaviour or other important conditions

Behaviour and individual context

- Step frequency in the environment close to the stop
- Step frequency in largest observable distance from the stop, often in side streets
- Running when occurring for more than five seconds
- Social aspect of walking, alone, as pair, or in groups and with children

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[94] Video software: *Light Works*, different versions

- Carried items (hand baggage, shopping bag, backpack, combinations of bags, other)
- The estimated age (under 18, 19 – 30, > 31, and elderly/disabled pedestrians)
- Number and duration of chosen stops; duration of stops was deducted from observation time
- Activities performed for more than five seconds while walking (talking, phoning, looking at phone/map, other activity)
- Required reactions to other pedestrians, cyclists and cars (excluded reactions required for street crossings)
- When observable, entered or exited buildings (supermarket, shop, restaurant/catering/convenience store, residential, office/work, other)

General environmental conditions for walking

- The corridor of the pedestrian network though which pedestrians accessed/departed the stop as indicated on maps
- Categorical evaluation of the pedestrian environment (using the previously defined dimensions, *activation* and *pleasantness*) close to the public transport stop and more distant in the pedestrian network around the stop
- Number of vehicles per hour (derived from counts from the video material) on the public transport corridor and other larger streets

Distances, detours

- Walked distance in metres (derived from the mapped walking path)
- As the crow flies distance between public transport stop and end/start point of observations (derived from map)
- The detour factor (as the crow flies distance divided by the walked distance)
- Four reasons that caused the walked detour (city structure, street layout, city structure together with street layout, other reasons)
- The walked access speed derived from the walked distance and the observation time (including waiting times for street crossing, excluding time for other chosen stops)

Street crossing behaviour

- Number of street crossings and the kind of crossing facility (traffic light, zebra crossing, other formal crossing, informal crossing)
- How often a pedestrian was required to wait for street crossings at different crossing facilities
- If pedestrians crossed streets on a red traffic light for pedestrians.

9.5 Short descriptions of the 14 investigated public transport stops

The stops, *01 Rathaus* and *02 Strøget*, were located most centrally and directly linked to the central pedestrian areas in Zürich and Copenhagen. The stop 02 *Strøget* was located on a large central urban square. The stop 01 *Rathaus* lies close to an urban square located on a slab that stretches over the river *Limmat* and links the stop with the old city centre. Stops 03 *Elmgade*, 04 *Kreuzstrasse*, and 05 *Bülowsvej* are located in dense urban areas with a street block structure formed by five-storey buildings along the street network. Numerous shops and facilities along the public transport corridor characterise the environments around these stops. The pavements are often relatively narrow, between 1.5 and four metres. The public transport corridor along stop 03 *Elmgade* and 04 *Kreuzstrasse* allows car access only for public transport vehicles, and delivery and does not permit car parking. Both corridors are narrow, and space for green features remains limited. The public transport corridor along the stop 05 *Bülowsvej* shows similar characteristics to those in the corridor along stops 03 and 04, but car traffic is not restricted and the corridor provides some space for car parking between carriageways and pavements. Trees find space between the car parking facilities and minor junctions.

The three stops, 06 – 08, are located in residential urban areas. Some facilities are located on the ground floors along the public transport corridor around the stops. All environments appear relatively green. The environment around stop *06 Englischviertel Strasse* is characterised by large villa buildings and multiple dwelling units in green gardens. The stop *07 Palmeria Square* is situated on a park-like urban square that dominates the impression of the broader surroundings. Narrower streets depart from the square. Streets are typified by three- to four-storey rows of houses, many of which function as multiple dwelling units. Larger villas functioning as multiple dwellings characterise the environment south-west from the public transport corridor at stop *08 Hölderlin St.* On the northeast side, more simple and lower multiple dwelling units and double houses of a less dense urban environment dominate the environmental impression. Along public transport corridors 06, 07, and 08, car traffic is not restricted but moderate with under 1000 cars per hour during my observations.

The stop *09 Bernin Platz* lies next to a larger traffic junction within a predominantly residential area. A commercial centre with several shops and services lies at a distance of 70 metres from the stop. Stop *10 The Level* is located next to a park that none of the observed pedestrians accessed. The stop is located close to an important sub centre 150 metres to the east. A large and busy street junction characterises the environment at the stop. Stop *11 Sølvtorvet* is also located between a park and a large and complex street junction. The urban surroundings consist predominantly of residential units.

Stop 12 *Randkløve A*. is located along a suburban arterial. A carpark lies between the stop and some shopping facilities. A four-lane street and large-scale buildings with workplaces and hotels characterise the environment around public transport stop 13 *Technopark*. The public transport corridor at stop 14 *Holmens K*. is a busy four-lane street near to a larger street junction. Hotels and work related larger-scale buildings characterise the surroundings.

9.6 Maps of registered walking routes during the public transport stop investigations

The maps from Copenhagen are downloaded from: http://kbhkort.kk.dk

The maps from Zurich are downloaded from: http://www.stadtplan.stadt-zuerich.ch/zueriplan/stadtplan.aspx?AspxAutoDetectCookieSupport=1

The maps from Brighton are downloaded from: http://www.brighton-hove.gov.uk/localview

Maps have been downloaded with permission between August and October 2013.

Red lines in all maps indicate walking routes of approaching pedestrians, yellow lines indicate walking routes of departing pedestrians. The numbers served to distinguish different footpaths. The stops are yellow indicated in the centre of the maps. The grey lines represent the distance to the stop as the crow flies from the start- or end-point of each observation.

Figure 102: Stop 01 Rathaus, Zürich

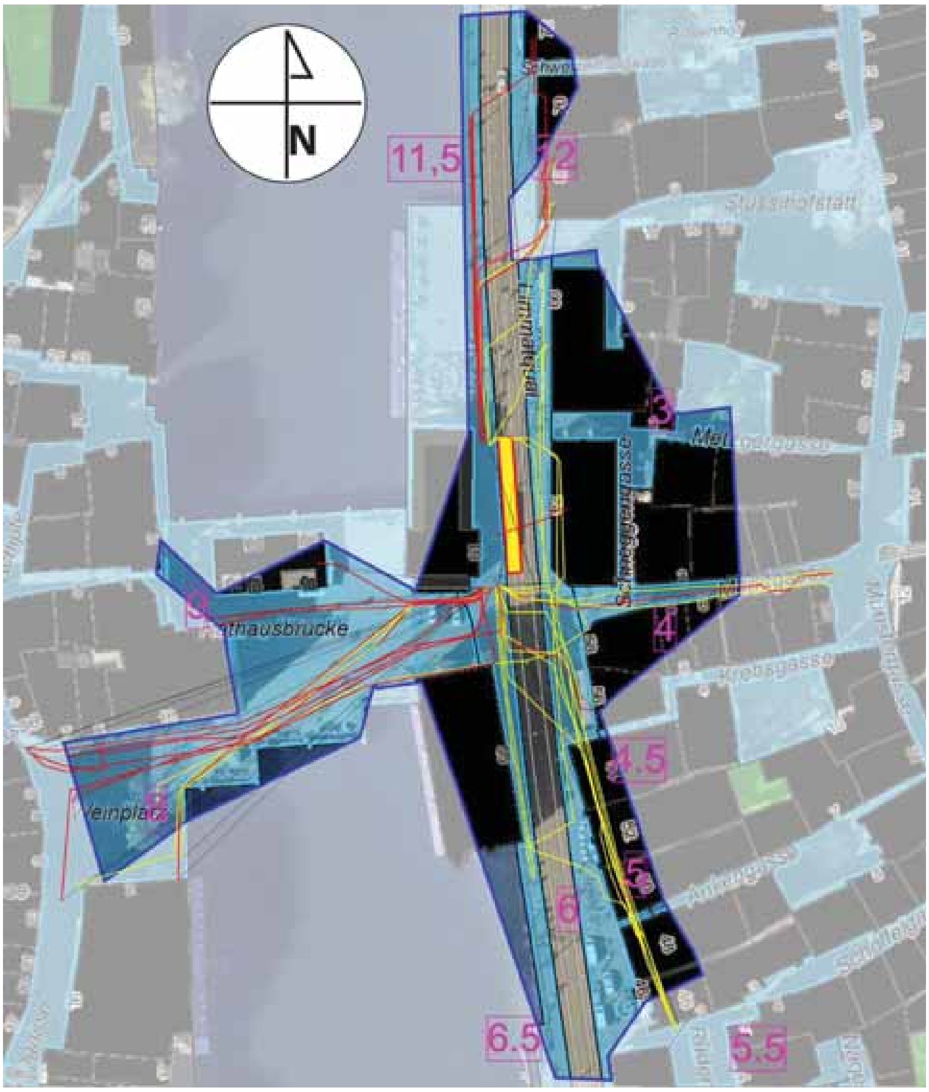


Figure 103: Stop 02 Strøget, Copenhagen

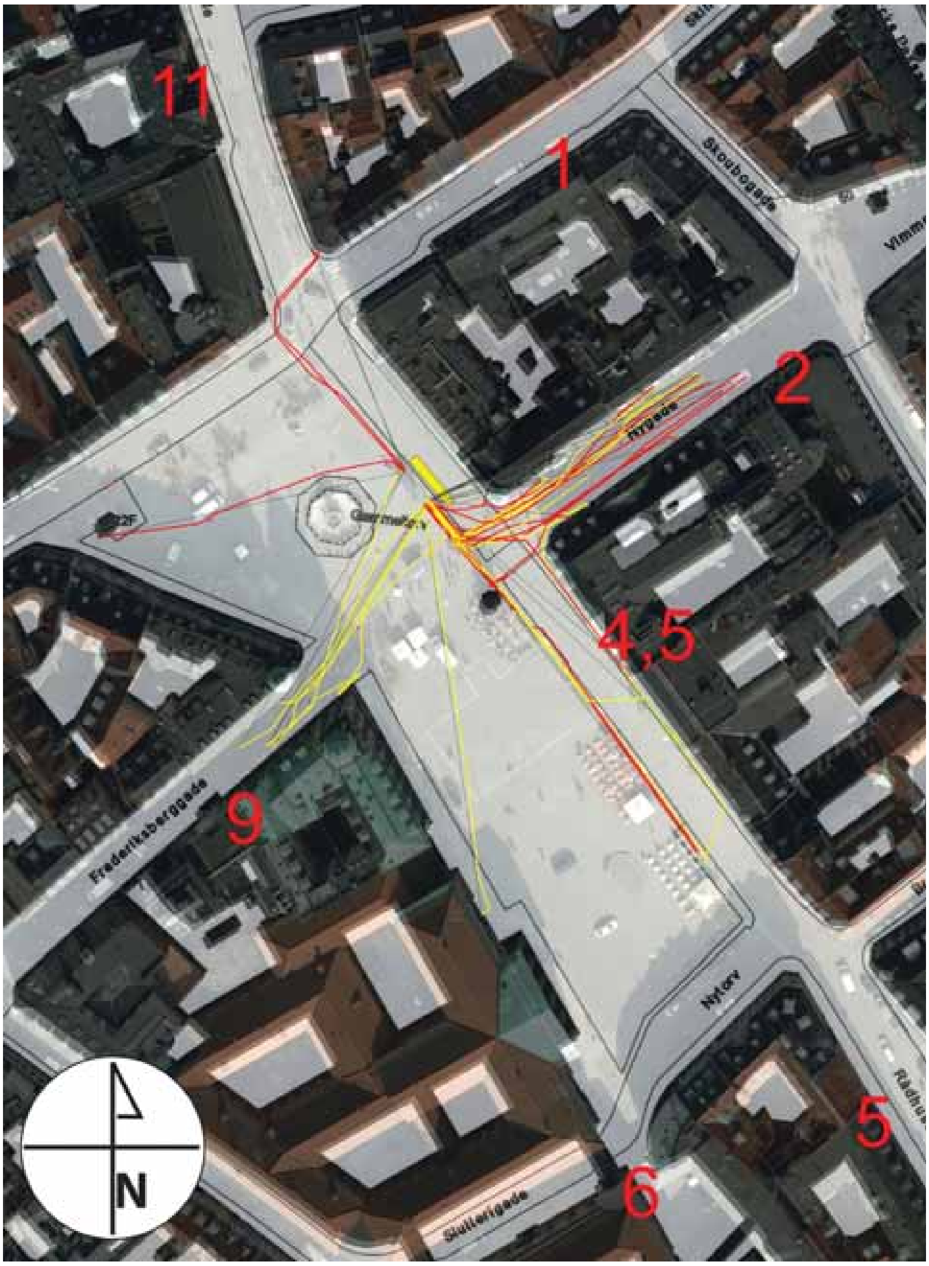


Figure 104: Stop 03 Elmgade, Copenhagen

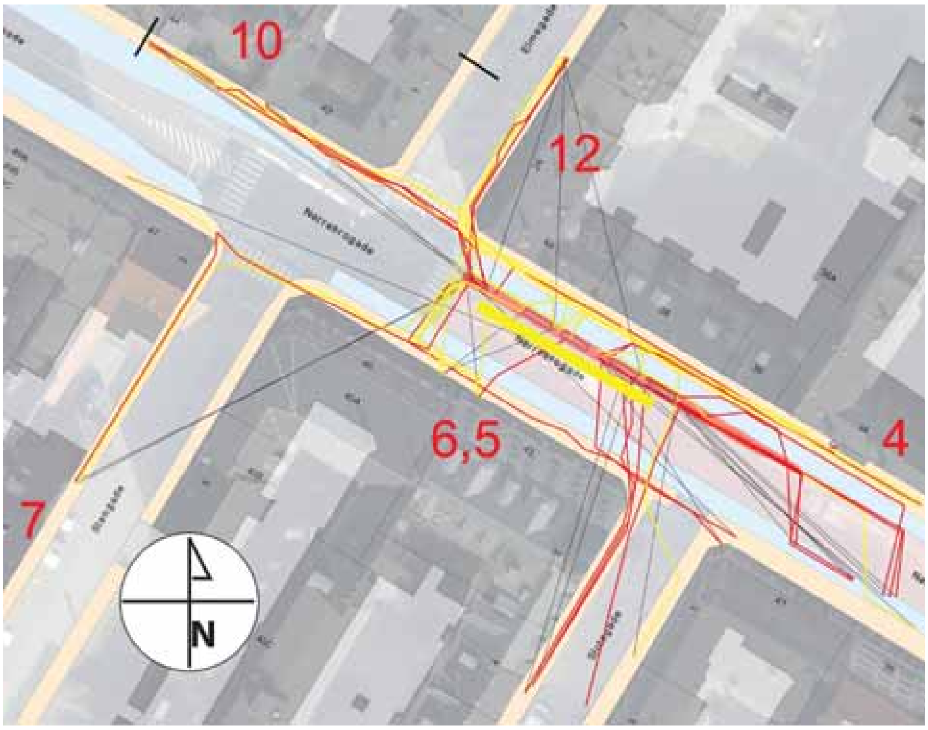


Figure 105: Stop 04 Kreuzstrasse, Zürich

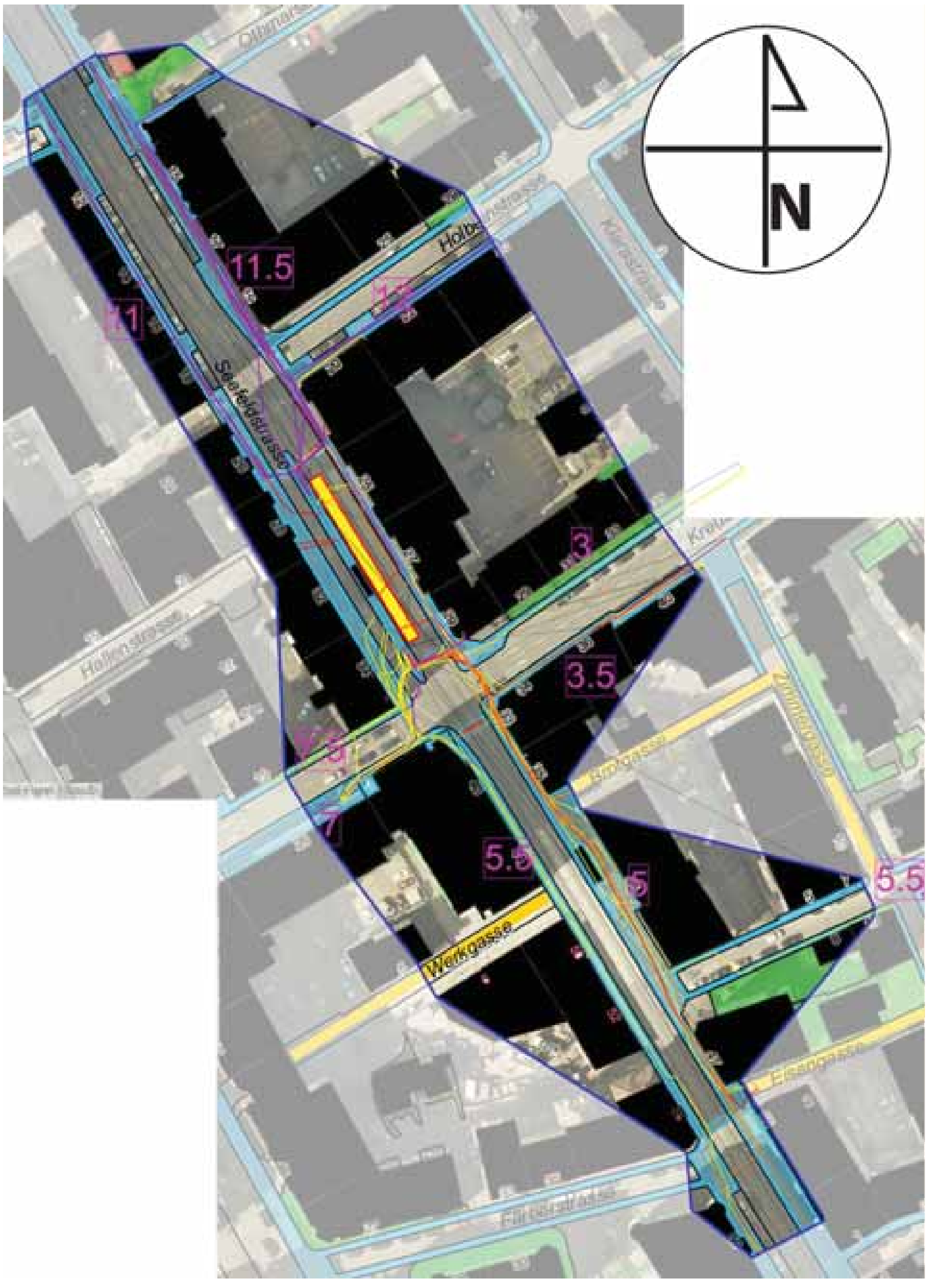


Figure 106: Stop 05 Bülowsvej, Copenhagen

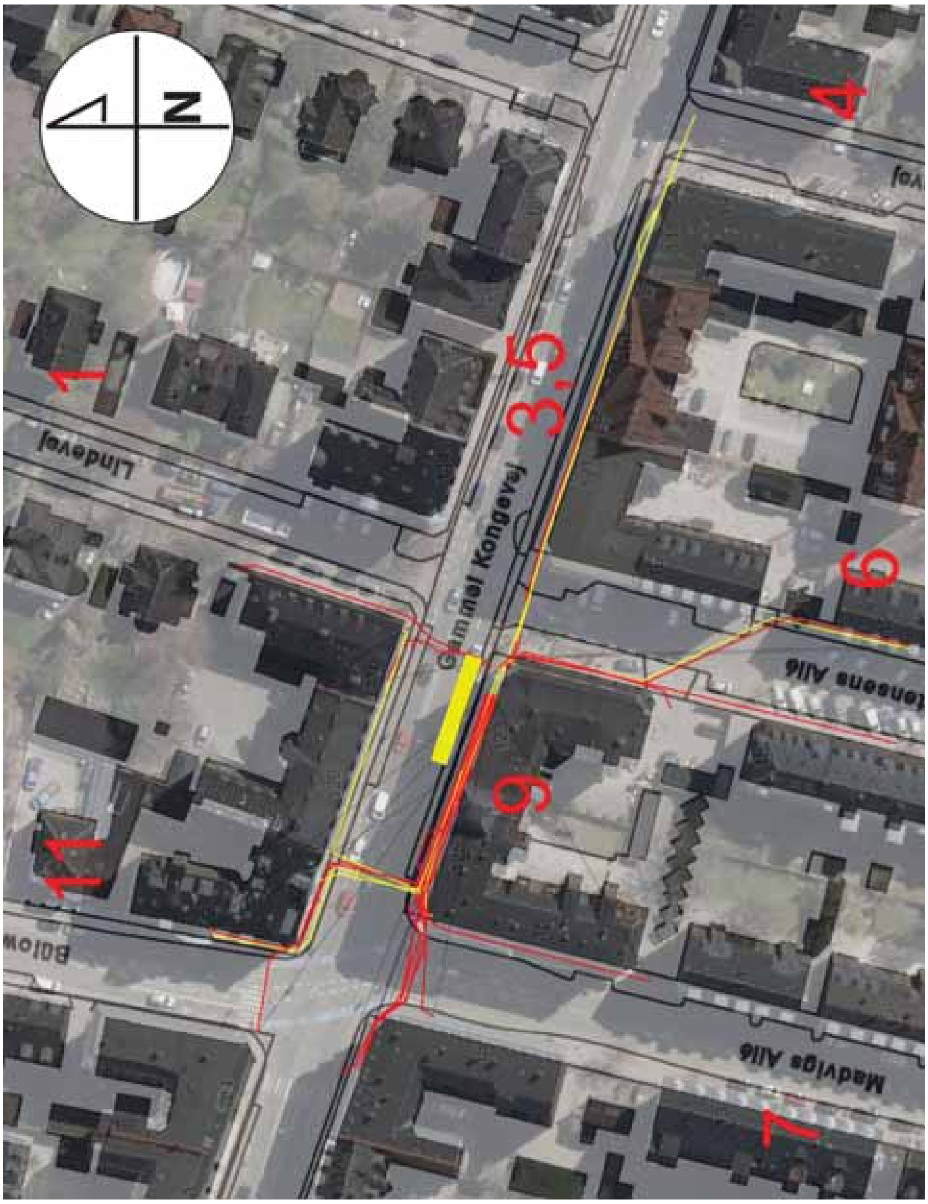


Figure 107: Stop 06 Englischviertelstrasse, Zürich

Figure 108: Stop 07 Palmiera Square, Brighton

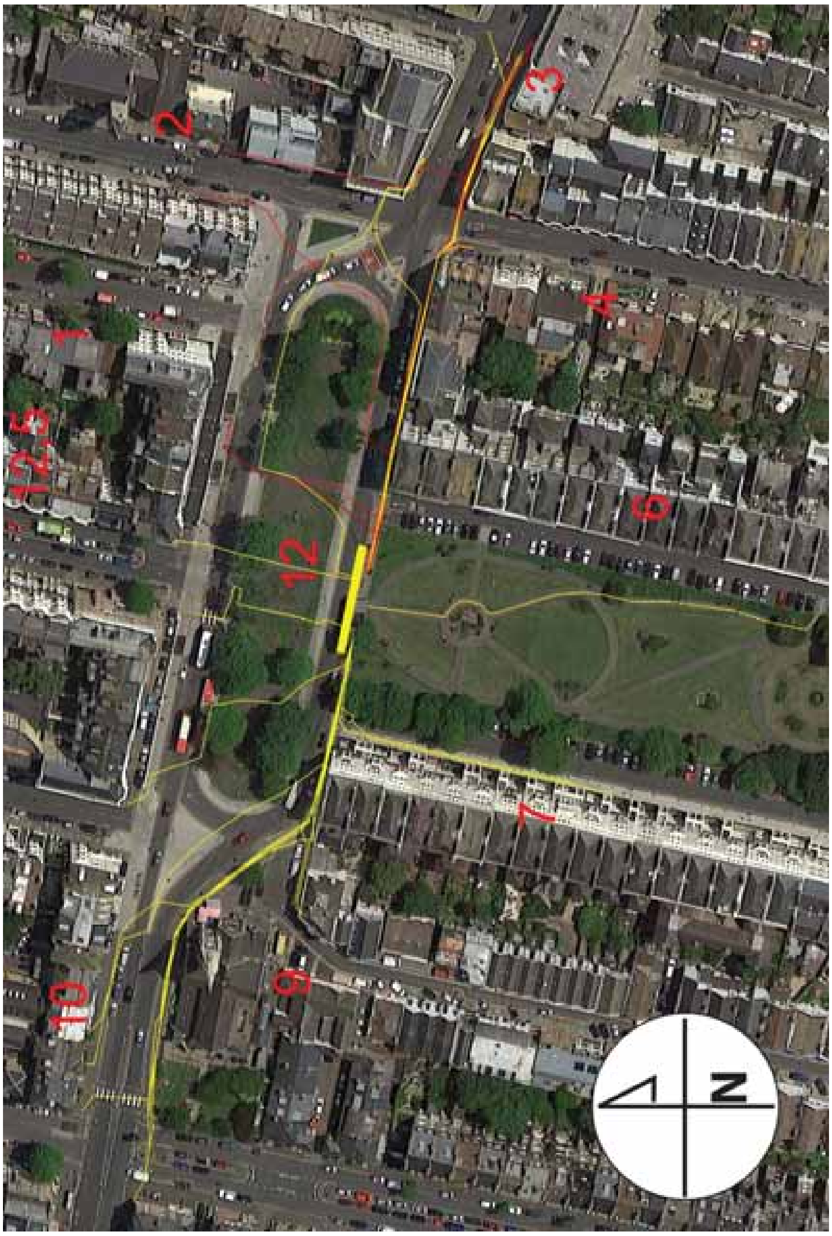


Figure 109: Stop 08 Hölderlinstrasse, Zürich

Figure 110: Stop 09 Berninaplatz, Zürich

Figure 111: Stop 10 The Level, Brighton

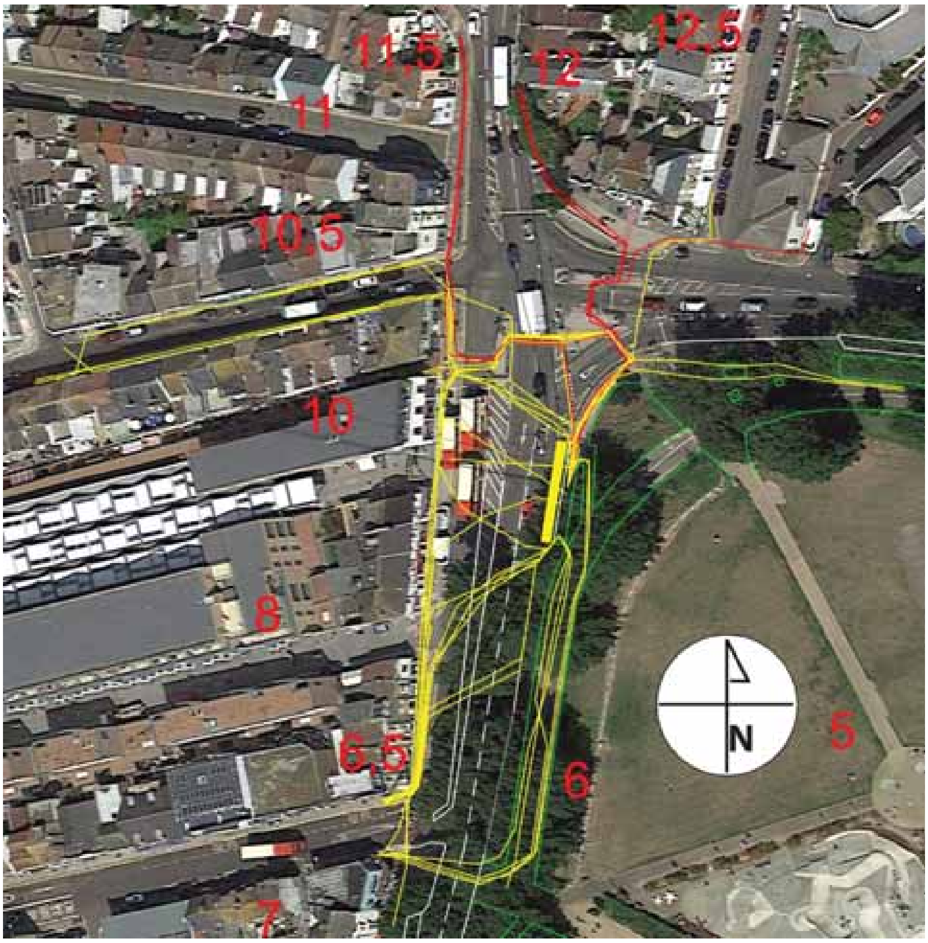


Figure 112: Stop 11 Sølvtorvet, Copenhagen

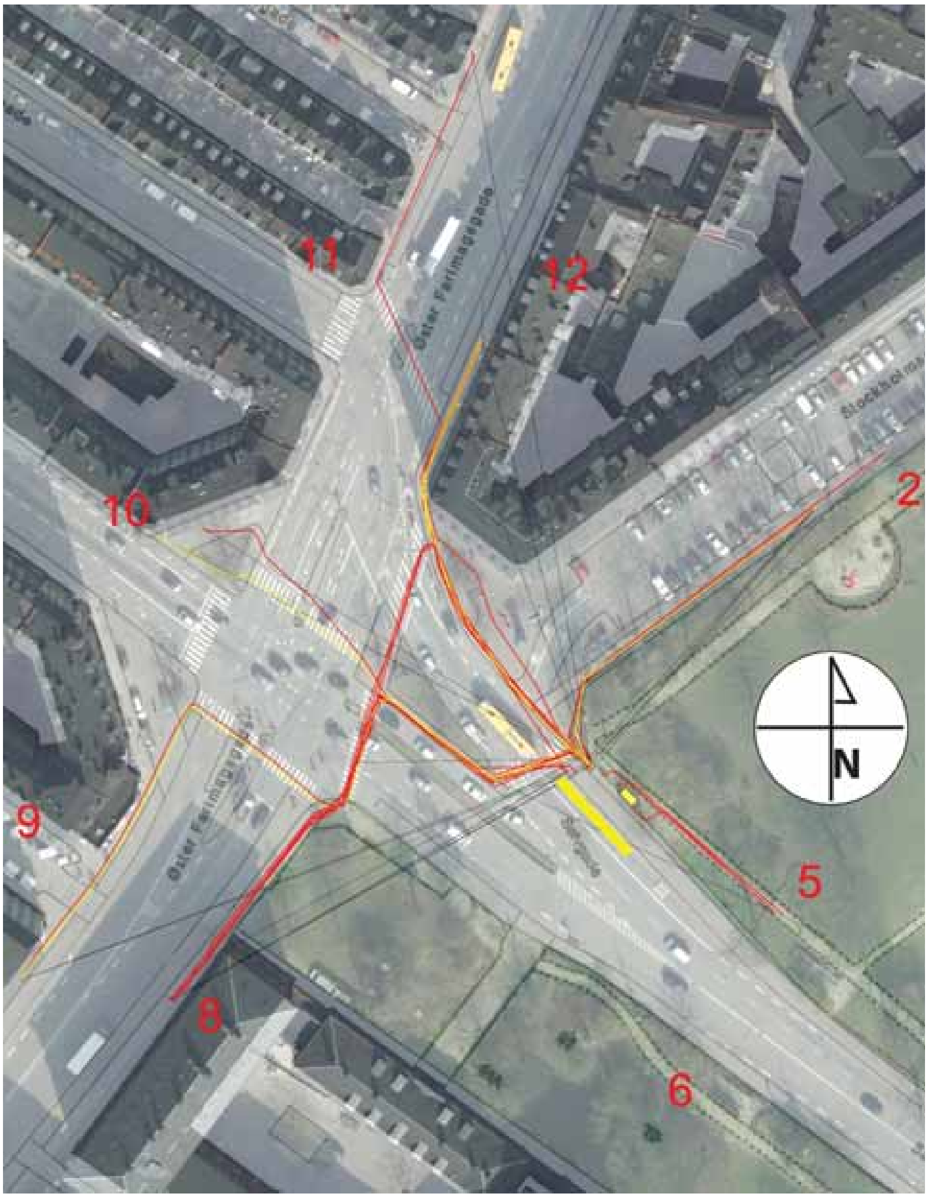


Figure 113: Stop 12 Randkløve Alle, Copenhagen

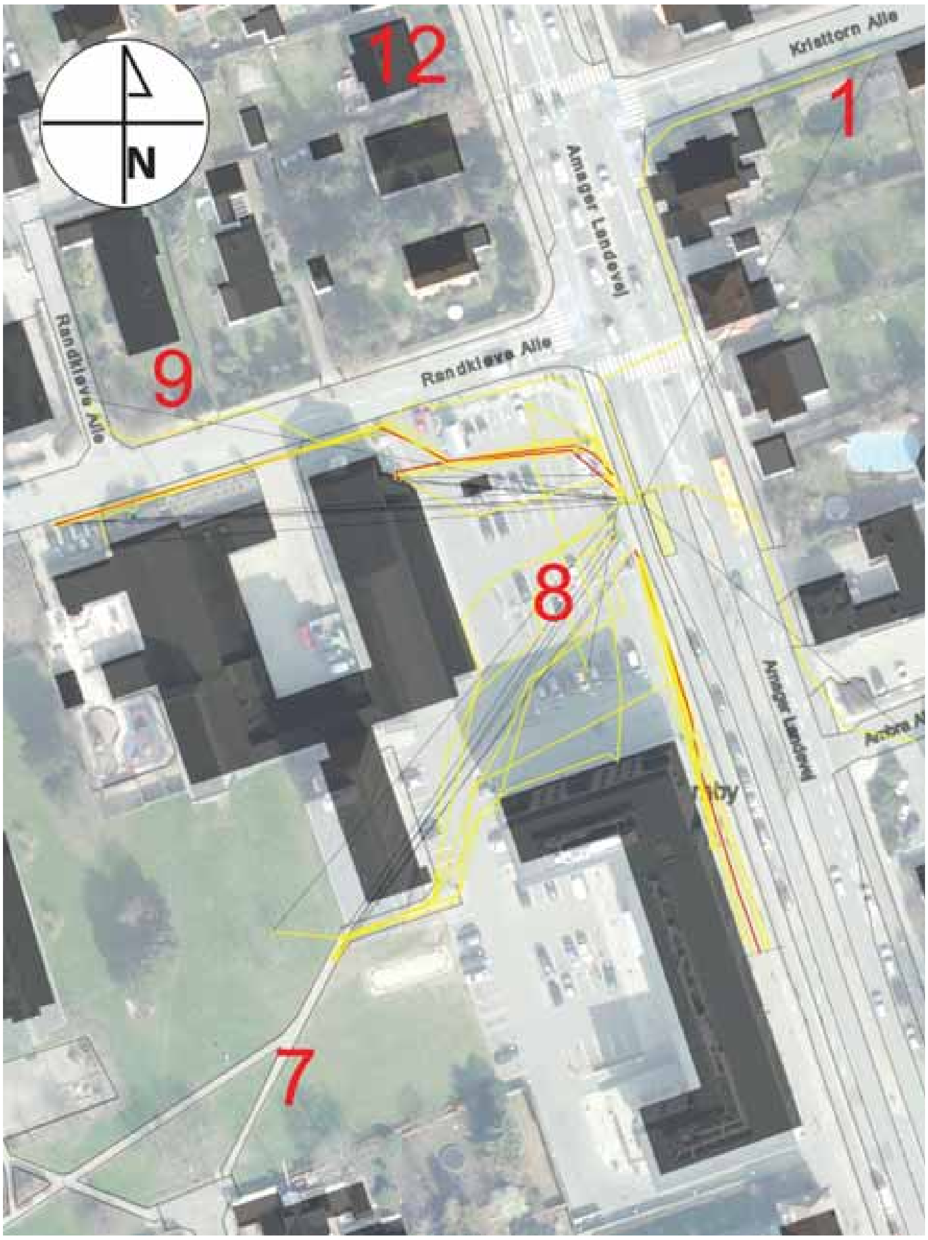


Figure 114: Stop 13 Technopark, Zürich

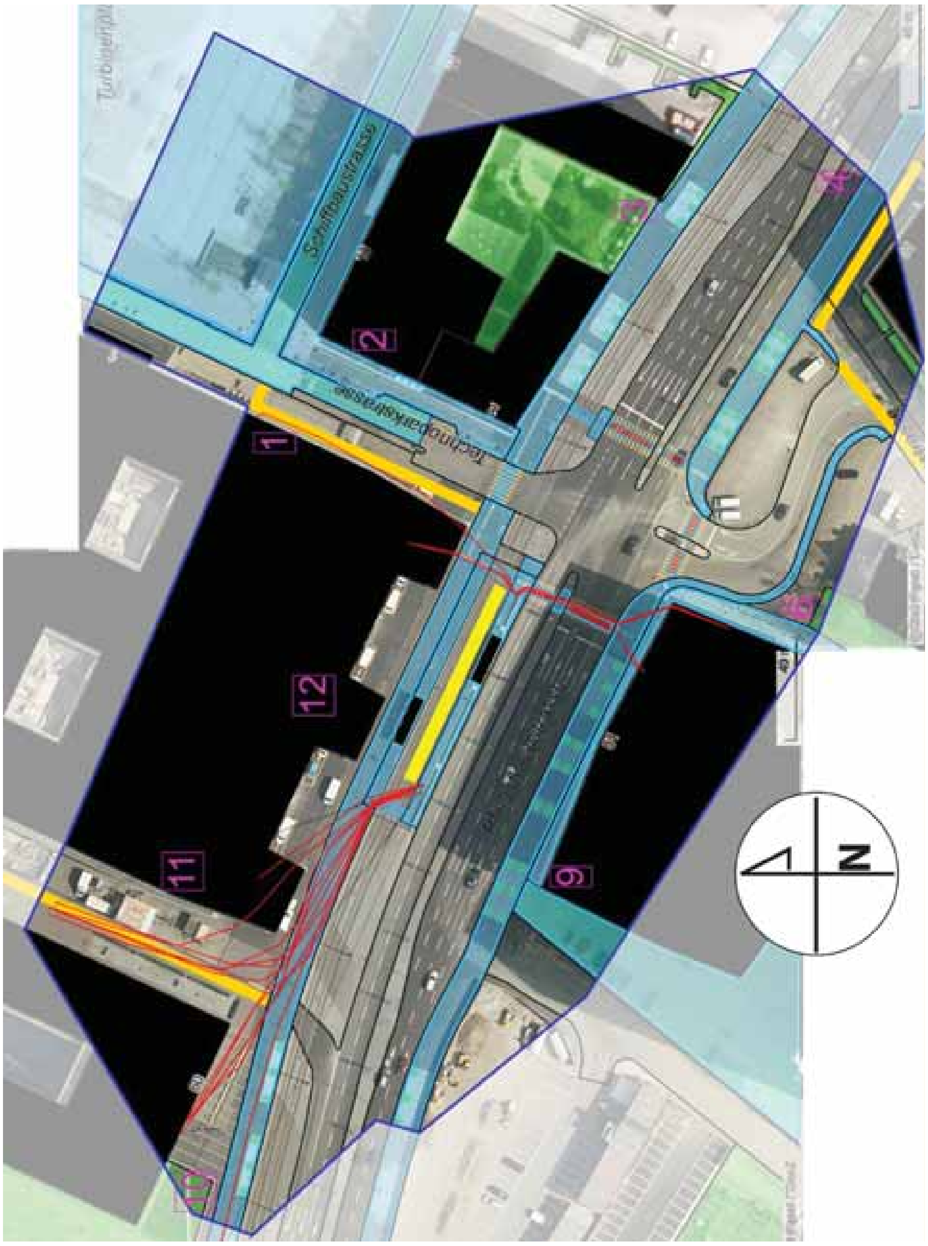
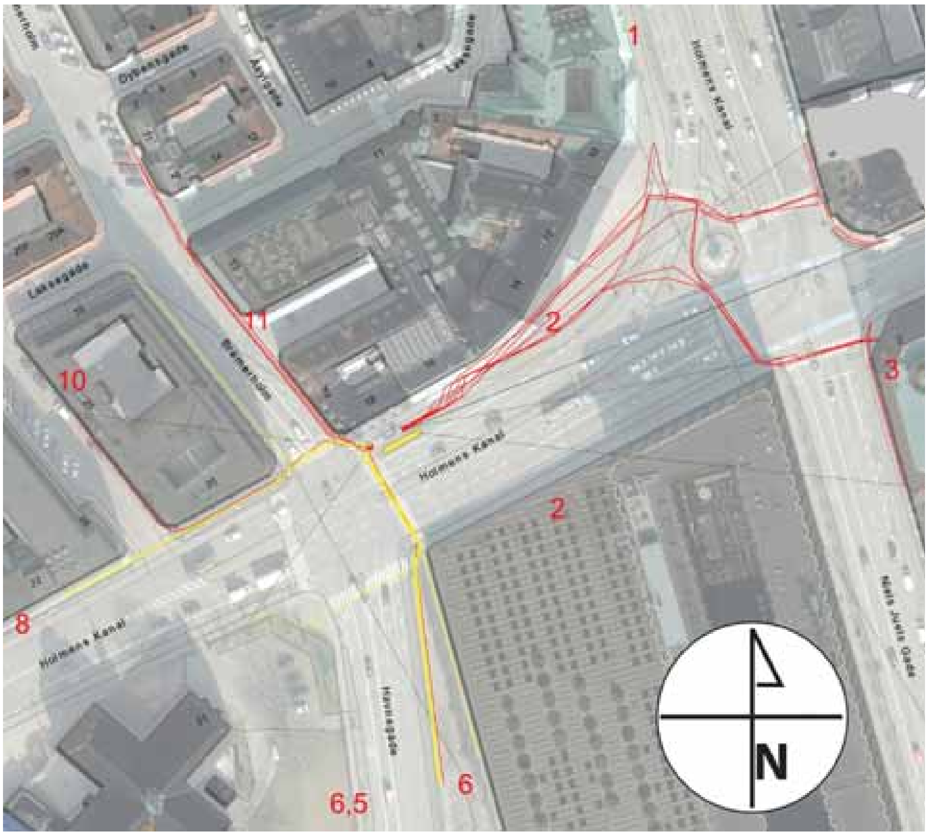


Figure 115: Stop 14 Holmens Kirke, Copenhagen



10 Appendix 3

10.1 Statistical step frequency analysis for walking in four different environments

The analysis uses 350 measures of the step frequency of observed pedestrians during the public transport stop investigations. The frequency was measured at some distance from the stop, as explained in Section 4.5.1. As not all 444 observations allowed the frequency to be measured at these locations, the analysis comprises only 350 observations. Results of the statistical analysis are presented and discussed in Section 6.1. This section turns only to the statistical questions of the analysis.

Table 12: Descriptive statistics for the step frequencies measured at some distance from the stops in the public transport stop investigation

Mean	114,1
Standard Error	0,73
Median	115
Mode	114
Standard Deviation	13,68
Sample Variance	187,27
Kurtosis	9,564
Skewness	1,118
Range	148
Minimum	65
Maximum	213
Count	351

Table 12 shows the descriptive statistics of the frequencies measured at some distance from stops. The average step frequency is 114.1 steps per minute. The frequency ranges relatively widely between people who stroll, those who walk slowly due to disabilities, and others who run. Accordingly, the standard deviation reaches a value of 13.7 steps per minute, and the values for kurtosis and skewness show that the data is not exactly normally distributed.

Table 13 shows the results of the multiple linear regression analysis with the step frequency as dependent variable. All independent variables are dummy variables. The *circumplex model for the walking environment* defines four environmental characteristics (Chapter 4.4), of which three are included as independent variables in the analysis. “Stressing environments” serve as reference. The independent variable “Running pedestrians” filters out significantly higher frequencies of the few running pedestrians to increase the fit of the model.

Table 13: Regression results for the step frequency (dependent variable) influenced by the environmental characteristics (independent variables), and running as control variable. Stressing environments serve as reference for the three environmental categories presented in the table.

Regression for SF distant			
R-square		0,20	
Significance F		0,00	
Confidence interval		0,95	
Degrees of freedom		4	
Observations		350	
	Coeff	t	
(Constant)	114,7	94,7	***
Exciting environment	-3,4	-2,2	**
Relaxing environment	-3,2	-1,6	*
Boring environment	-1,6	-0,7	
Running pedestrians	25,1	9,0	***
Level of significance: *** > 0,01; ** > 0,05; * > 0,10			

The constant shows the average walking speed in stressing environments for pedestrians that do not run or walk in one of the other three environmental contexts that the independent variables specify. Walking speeds in boring environments appear -1.6 steps per minute lower than in stressing environments (given that they do not run), but the difference to frequencies in stressing environments remains insignificant. Most interestingly, it appears that, at 2.2 and 1.6 steps per minute, step frequencies remain significantly lower in exciting and relaxing walking environments.

The included independent variables explain 20 percent of the step frequency variation. Hence, the step frequency varies to 80 percent for reasons that are not reflected by the independent variables included in the model. This is not surprising when we consider that factors, such as the purpose of walking, fitness, and numerous other individual conditions, influence how fast people walk. The result of central interest remains the significantly different average step frequency in relaxing and exciting environments as compared to stressing and boring environments.

10.2 Statistical step frequency analysis of approaching and departing pedestrians

The statistical analysis presented in this section aims to uncover differences in the walking behaviour of arriving and departing pedestrians, which is reflected in the averages of the step frequency. Of further interest is how walking environments influence average step frequencies, as explained in Section 5.2.

Table 16 presents the results of two separate multiple linear regression statistics for approaching and departing pedestrians. The step frequency serves as dependent variable, measured at an average distance of 80 metres from public transport stops (explained in Section 4.5.1). The independent variables are divided into six groups:

A. Individual conditions
B. Performed activities while walking
C. Detours
D. Accessing buildings close to the stop
E. Environmental characteristics
F. Street crossings

Most independent variables are dummy variables, apart from two continuous variables that are indicated in Table 16. The reference variables for the included dummy variables are shown in Table 17.

The step frequency analysis for approaching pedestrians comprises all observations that allowed frequencies to be measured (1) at some distance from the stop (average 90 metres), and (2) when pedestrians enter the *closer stop environment* (as explained in Section 4.5.1).

Table 15 and Table 14 show the descriptive statistics of the data set for approaching and departing pedestrians. The descriptive statistics already show a difference between both data sets. The step frequency of approaching pedestrians shows a higher standard deviation, also reflected by a much higher value for the range of the data set. Accordingly, the values for kurtosis and skewness are higher than for the data from departing pedestrians. This effect is mainly caused by pedestrians who run to the public transport stops, causing significantly higher frequencies. When departing from stops, no observed pedestrian ran.

Both statistical analyses filter out the effect of many factors that influence step frequencies. Therefore, the regression coefficient for the *constant* no longer shows an average for an existing condition. For example, the regression for arriving pedestrians filters out the effect of time pressure by including the step frequency change that appears when pedestrians reach the closer stop environment (as explained in Section 4.5.1 and 5.1. Haste substantially increases the step frequency of those who walk towards the stop. However, we can easily calculate a realistic step frequency by adding up the coefficients of independent variables that would reflect a realistic scenario for walking.

The explanatory value of the regression for *approaching pedestrians* shows, at 55 percent, a relatively high association between the dependent and the independent variables in the regression statistics. Filtering out the higher step frequency for running pedestrians substantially reduces the range of the data set, increasing the model fit. Of the 15 included independent variables, only four remain insignificant. I consider the insignificant variables as theoretically relevant but derived from conditions that either occur rarely in the data set (phoning while walking) or result in different frequency reactions such as for variables *walking for work/education purposes*; *reacting to other pedestrians*; and *detour factor 1.1 – 1.29*. A higher variation causes insignificant coefficients for these variables. There are certainly a number of individual conditions that the regression can naturally not include. We do not yet know the effect of either worn clothes and shoes or the quality of the surface people walk on. These factors have not been investigated in this research, nor, to my knowledge, have they been investigated by other researchers to date. However, individual conditions alone can easily cause the 45 percent of unexplained variation in the data set. I consider the effect of specification errors due to (1) non-included relevant independent variables, or (2) included irrelevant variables not to threaten the regression statistics (for the frequency analysis of approaching pedestrians) to as high a degree as we might expect when investigating human behaviour.

How extensive does the effect of measurement errors appear to be in the statistics for approaching pedestrians? Even though the dependent and independent variables derive from human behaviour, which naturally varies between individuals, variables are mostly not indicators but direct measures of observable behaviour. I consider measurement errors to remain relatively low. Further, Table 18 shows the correlation coefficients (bivariate Pearson correlation, two tailed) between all included independent variables. Some few correlation coefficients with higher values range between 0.3 and 0.4. Low correlation between independent variables indicates that multicollinearity is unlikely to influence the statistics for approaching pedestrians.

Table 15: Descriptive statistics for the step frequency measured distant from stops for approaching pedestrians

Mean	114,7
Standard Error	1,35
Median	115
Mode	114
Standard Deviation	16,87
Sample Variance	284,5
Kurtosis	8,47
Skewness	1,45
Range	148
Minimum	65
Maximum	213
Count	155

Table 14: Descriptive statistics for the step frequency measured distant from stops for departing pedestrians

Mean	113,5
Standard Error	0,79
Median	114,5
Mode	114
Standard Deviation	10,54
Sample Variance	111,2
Kurtosis	1,87
Skewness	-0,51
Range	81
Minimum	69
Maximum	150
Count	187

The regression analysis for *departing pedestrians* in Table 16 shows a lower explanatory value of 32 percent as compared to approaching pedestrians. Of the 18 included independent variables, six remain insignificant. Theoretically, these six variables do not appear irrelevant. Insignificant coefficients result again either from too few observations for the respective variable or from people reacting unequally in the conditions an independent variable describes. For example, the variables for performed activities while walking result in different (partly insignificant) frequency alterations. Some pedestrians are capable of maintaining a fast step while looking at their smart phone screen; others have to reduce the frequency of their steps while doing so. Eating an apple may reduce frequencies only slightly. Handling a whole burger requires the use of both hands and certainly forces steps to slow down. Too few observations and higher variation can easily result in insignificant coefficients, even though the respective independent variables are relevant for the step frequency.

Specification errors rise rather with non-included but relevant variables. It is likely that the reason for higher unexplained variance in the regression on step frequencies of departing pedestrians is numerous individual conditions. As explained in Section 6.2, the behaviour of departing pedestrians appears more diverse than those of approaching ones. The lower R-square value for departing pedestrians is well explained by a higher diverse pedestrian behaviour when walking away from stops. Due to the more diverse individual behaviour, the statistical relationship between dependent and independent variables declines.

I consider the effect of measurement errors as rather low for the same reasons as explained for the frequency analysis of approaching pedestrians. Table 18 shows low correlation between the independent variables included in the regression analysis for departing pedestrians. Most coefficients remain significant and pre signs appear as I expected. Multicollinearity seems not to threaten the statistics.

Two independent variables from group E show that two of the previously specified pedestrian access corridor types influence the step frequency, the variable *Arriving at public transport corridor through footpath network on other side of public transport corridor,* and the variable *Arriving through corridor with departing public transport vehicle*. How and why these variables influence pedestrians on the way to the stop is discussed in Section 6.2 in more detail. Both variables represent important control variables for the regression statistics in Table 16.

We have little existing data for comparisons. The statistical analyses described in the previous Section 10.1 show variations that mean that statistical results in Table 16 do not appear unrealistic. As the suggested methodology is relatively new, it is possible that so-far unknown factors influence step frequencies, such as the walking surface or worn shoes and clothes. Until more research is conducted on step frequencies and conditions that lead to alterations, the results of the analysis in this section should be considered with some care.

Table 16: Regression analysis with the distant measured step frequency (Section 4.5.1) as dependent variable; coefficients for each independent variable show the increase and decrease of the dependent variable in steps per minute. All independent variables are dummy variables if not specified differently in brackets

	Regression analysis		Arriving pedestrians			Departing pedestrians	
	R-square		0,55			0,32	
	Significance F		0,00			0,00	
	Standard error		11,87			9,16	
	Confidence interval		0,95			0,95	
	Degrees of freedom		15			18	
	Observations		154			187	
Group	independent variable	Coeff	t		Coeff	t	
	Constant	107,2	49,6		122,5	31,3	
A	Frequency close minus frequency distant (continuous)	-0,3	-4,7	***			
A	Running	26,6	8,3	***			
A	Disabled	-14,9	-4,3	***	-11,1	-5,0	***
A	Walking in pairs and groups	-4,6	-1,6	*			
A	Walking for work/education purposes, and access to shop	4,6	1,4				
A	Walking in Zürich during summer holiday season				-3,2	-2,1	**
B	Chosen stops	-4,1	-2,5	**	-2,1	-1,6	*
B	Phoning while walking	-6,2	-1,5		-11,3	-2,0	**
B	Talking while walking				-3,6	-1,4	
B	Listening to music while walking				2,3	0,5	
B	Other activity while walking				-4,7	-1,5	
C	Detour factor 1,1 – 1,29	3,1	1,4				
C	Detour factor (continuous)				-5,8	-1,7	*
C	Detours caused by urban structure	4,9	1,7	*			
C	Detours caused by public space layout	3,8	1,7	*	4,6	2,6	*
C	Detours caused by the urban structure and public space layout				2,7	1,4	
C	Detours caused by other reasons				9,5	3,0	***

Table continued

Table 16 continued

		Arriving pedestrians			Departing pedestrians		
Group independent variable (continued)		Coeff	t		Coeff	t	
D	Access to shops and services close to stop				-6,2	-2,18	**
D	Access to residential and work related buildings close to stop				-8,2	-2,81	***
E	Arriving at public transport corridor through footpath network on other side of public transport corridor	6,1	2,3	**			
E	Arriving through corridor with departing public transport vehicle	6,9	2,0	**			
E	Reacting to other pedestrians	2,0	1,4				
E	Environment unpleasant deactivating				-3,3	-1,3	
F	90 – 700 vehicles on crossed streets				-1,9	-2,3	**
F	Over 700 vehicles on crossed streets	4,9	1,8	*			
F	Waiting more than once at street crossing	-7,5	-1,6	*			
F	Wait at traffic light for street crossing				5,2	2,6	***
F	Wait for informal street crossing				7,8	2,0	**
F	Walked with red traffic light				-2,4	-1,0	

Level of significance: *** > 0,01; ** > 0,05; * > 0,10

Table 17: Variable type and reference variable for dummy variables for regression in Table 16

Variable group	Independent variable	Var. type	Reference variable
A	Frequency close minus frequency distant (continuous)	Cont.	*Not available*
A	Running	Dummy	Not running
A	Disabled	Dummy	Non-disabled
A	Walking in pairs and groups	Dummy	Walking single
A	Walking for work/education purposes, and access to shop	Dummy	Carrying no, or other bag
A	Walking in Zürich during summer holiday season	Dummy	Walking in Copenhagen or Brighton out of holiday season
B	Chosen stops	Dummy	Walking without chosen stops
B	Phoning while walking	Dummy	Walking without phoning
B	Talking while walking	Dummy	Walking without talking
B	Listening to music while walking	Dummy	Walking without listening to music
B	Other activity while walking	Dummy	Walking without performing activity
C	Detour factor 1,1 – 1,29	Dummy	Detour factor 0 - 1.0 and > 1.3
C	Detour factor (continuous)	Cont.	*Not available*
C	Detours caused by urban structure	Dummy	No detour
C	Detours caused by public space layout	Dummy	No detour
C	Detours caused by the urban structure and public space layout	Dummy	No detour
C	Detours caused by other reasons	Dummy	No detour
D	Access to shops and services close to stop	Dummy	Longer walking distance
D	Access to residential and work related buildings close to stop	Dummy	Longer walking distance
E	Arriving at public transport corridor through footpath network on other side of public transport corridor	Dummy	Arriving at stop through other footpaths
E	Arriving through corridor with departing public transport vehicle	Dummy	Arriving at stop through other footpaths
E	Reacting to other pedestrians	Dummy	No reaction to other pedestrians
E	Environment unpleasant deactivating	Dummy	Non unpleasant/deactivating walking environment

Table continued

Table 17 continued

F	90 – 700 vehicles on crossed streets	Dummy	< 90 & >700 vehicles on street
F	Over 700 vehicles on crossed streets	Dummy	< 701 vehicles on street
F	Waiting more than once at street crossing	Dummy	Waiting once and not waiting at street crossing
F	Wait at traffic light for street crossing	Dummy	Waiting at other type of street crossing and not waiting
F	Wait for informal street crossing	Dummy	Waiting at other type of street crossing and not waiting
F	Walked with red traffic light	Dummy	Waited at red traffic light or no waiting time

Table 18: Correlation table for independent variables for the regression analysis on the distant measured step frequency (Section 4.5.1) of arriving pedestrians, R-values from bivariate Pearson correlation

	Frequency close minus frequency distant (continuous)	Running	Disabled	Walking in pairs and groups	Walking for work/education purposes, and access to shop	Chosen stops	Phoning while walking
Frequency close minus frequency distant (continuous)	1,00	0,12	-0,07	0,17	0,11	0,00	0,10
Running	0,12	1,00	-0,04	-0,17	0,08	-0,09	-0,09
Disabled	-0,07	-0,04	1,00	0,02	0,03	0,07	-0,08
Walking in pairs and groups	0,17	-0,17	0,02	1,00	-0,07	0,28	-0,05
Walking for work/education purposes, and access to shop	0,11	0,08	0,03	-0,07	1,00	0,11	0,00
Chosen stops	0,00	-0,09	0,07	0,28	0,11	1,00	-0,04
Phoning while walking	0,10	-0,09	-0,08	-0,05	0,00	-0,04	1,00
Detour 1,1 – 1,29	-0,08	0,04	0,00	-0,13	-0,09	0,09	0,10
Detours caused by the urban structure	-0,13	-0,10	0,04	0,04	-0,10	0,04	-0,04
Detours caused by public space layout	0,03	0,13	-0,03	-0,11	-0,04	-0,07	0,02
Arriving at public transport corridor through footpath network on other side of public transport corridor	-0,05	-0,06	0,08	0,10	0,15	0,02	0,09
Arriving through corridor of departing public transport vehicle	-0,07	0,01	0,18	-0,07	-0,12	0,01	-0,09
Reacting to other pedestrians	-0,08	0,05	0,15	0,13	0,07	0,11	0,00
Over 700 vehicles on crossed streets	-0,11	0,08	0,03	-0,21	-0,16	0,04	-0,02
Waiting more than once at street crossing	-0,01	0,11	0,03	-0,04	-0,08	0,01	0,07

Table continued

Continuation of Table 18

	Detour 1,1 – 1,29	Detours caused by the urban structure	Detours caused by public space layout	Arriving at public transport corridor through footpath network on other side of public transport corridor	Arriving through corridor of departing public transport vehicle	Reacting to other pedestrians	Over 700 vehicles on crossed streets	Waiting more than once at street crossing
Frequency close minus frequency distant (continuous)	-0,08	-0,13	0,03	-0,05	-0,07	-0,08	-0,11	-0,01
Running	0,04	-0,10	0,13	-0,06	0,01	0,05	0,08	0,11
Disabled	0,00	0,04	-0,03	0,08	0,18	0,15	0,03	0,03
Walking in pairs and groups	-0,13	0,04	-0,11	0,10	-0,07	0,13	-0,21	-0,04
Walking for work/education purposes, and access to shop	-0,09	-0,10	-0,04	0,15	-0,12	0,07	-0,16	-0,08
Chosen stops	0,09	0,04	-0,07	0,02	0,01	0,11	0,04	0,01
Phoning while walking	0,10	-0,04	0,02	0,09	-0,09	0,00	-0,02	0,07
Detour 1,1 – 1,29	1,00	0,13	0,12	0,16	-0,01	-0,09	0,18	0,01
Detours caused by the urban structure	0,13	1,00	-0,37	-0,04	0,17	-0,01	-0,22	-0,11
Detours caused by public space layout	0,12	-0,37	1,00	-0,06	-0,16	-0,09	0,22	0,22
Arriving at public transport corridor through footpath network on other side of public transport corridor	0,16	-0,04	-0,06	1,00	-0,17	-0,04	0,03	-0,11
Arriving through corridor of departing public transport vehicle	-0,01	0,17	-0,16	-0,17	1,00	0,19	-0,20	-0,08
Reacting to other pedestrians	-0,09	-0,01	-0,09	-0,04	0,19	1,00	-0,19	-0,06
Over 700 vehicles on crossed streets	0,18	-0,22	0,22	0,03	-0,20	-0,19	1,00	0,34
Waiting more than once at street crossing	0,01	-0,11	0,22	-0,11	-0,08	-0,06	0,34	1,00

10.3 Statistical analysis to determine time delays at street crossings

While pedestrians were observed during the data collection process, I did not measure the time pedestrians were forced to wait at street crossings due to resource limitations. This analysis isolates time delay that occurs with street crossings from other conditions that cause delays in order to identify how long pedestrians wait on average when they cross streets at traffic lights, at zebra crossings, informally, or otherwise. The procedure of the analysis is described in Section 5.5.

Multiple linear regression statistics serve to calculate the average waiting times at street crossings. The *access speed* serves as dependent variable. The access speed results from the time pedestrians need to walk the distance between A and B. We should not confuse the access speed with the walking speed. Forced stops before street crossings influence the time pedestrians need to reach stops and, accordingly, the access speed. Equally, the individually chosen walking speed influences how fast pedestrians arrive at B from A.

The regression statistics use all registered factors that influence the access speed as independent variables. By doing so, the statistics separate the effect of the conditions that cause a change in the access speed. From these speed alterations, we can calculate time delays, as explained in Section 5.5. The independent variable *step frequency* indicates the walking speed and filters the effect of the individual walking speed.

When filtering out the effect of all factors that are relevant for the access speed, the constant of the regression statistics must theoretically turn to zero. This is nearly what the results of the regression statistics in Table 20 show. The mean access speed of 77.1 metres per minute (as shown in Table 19 with the descriptive statistics) reduces to 6.4 metres per minute after filtering out the effect of 19 independent variables that derive from the observations.

The data shows no significant difference between pedestrians that approach the stop and those who depart. Therefore, the regression statistics do not differentiate between approaching and departing pedestrians. The data set contains only observations that allowed the step frequency to be measured at two locations, (1) at some distance from the stop and (2) close to the stop. Therefore, the analysis uses only 330 observations of the total 444. Apart from the two independent variables with the step frequency measures in Table 20, all variables are dummy variables.

Table 19: Descriptive statistics of the access speed for all observations with two step frequency measures from the public transport stop investigation

Mean	77,10
Standard Error	1,13
Median	76
Mode	94,29
Standard Deviation	20,64
Sample Variance	426,21
Kurtosis	5,61
Skewness	1,18
Range	179
Minimum	21
Maximum	200
Count	331

The R-square value in Table 20 shows a statistical association between the squared access speed and the independent variables included in the regression. According to the statistics, the 19 independent variables can 'explain' 62 percent of the access speed variation (independent variable). When we consider that the data derives from human behaviour, which can be very diverse, the high explanatory value is surprising. However, we must remember that the data reflects numerous unconsciously performed reactions to environmental conditions. Further, the independent variables for step frequencies filter out a good part of individually different behaviour, which is highly relevant for the access speed. The high explanatory value of the statistics appears, therefore, not unrealistic.

The inclusion of 19 independent variables raises the question of whether some of these variables are mistakenly included but also whether relevant factors that influence the access speed remain missing. The observations from which the data derives have been conducted very carefully. Initial observations served to identify conditions that influence walking. For about 200 walking routes to and from stops, any step frequency variation that occurred during the observation has been measured. This time-consuming work enabled most conditions that influence the access speed to be identified. Observations cannot always identify the individual reasons for different access speeds but enable the effect to be measured. I evaluate the influence of specification errors as not substantial for the regression statistics in Table 20.

Rather more influential are measurement errors. Firstly, the step frequency varies on average between five to seven times along observed walking paths. The statistics include only two frequency measures at the start and end of the observations (as explained in Section 4.5.1)[95]. Secondly, the step frequency does not reflect exactly the walking speed, as it does not contain information on the step length. As demonstrated in Section 3.2, however, averages for frequencies reflect well averages of the walking speed. Thirdly, the measured distances walked are not exact and can vary between +/- 1.5 metres on average.

Fourthly, some independent variables indicate only a condition without measuring it exactly. For example, the variable *running* indicates only whether a person ran during the observation but not how long the observed pedestrian had been running. None of the observed pedestrians ran from the start to the end of the observation. Hence, the independent variable *running* does not reflect a generalisable speed difference between running and walking. The coefficient for running remains specific to the data set but filters out the effect of those who ran for a shorter or longer section of the observed walking route. The data specifies neither how long pedestrians performed activities while walking, nor the level of a pedestrian's disability. These rough measuring methods disable generalisation on the resulting coefficients for these independent dummy variables in the statistics. We should remember that the analysis in Table 20 intends only to isolate the effect of street crossings.

I consider the four described measurement errors and inaccuracies as the most important factors that reduce the explanatory value of the regression statistics. Table 22 shows the unsquared correlation coefficients between all pairs of independent variables. The coefficients do not indicate that the independent variables correlate to a degree that would result in multicollinearity problems in the regression statistics.

The statistics in Table 20 allocate the 19 independent variables into four groups, A - E. The results for group C, street crossings, are discussed in detail in Chapter 6.5. The following text discusses all variables that influence the access speed in groups A – B and D. These variables serve as control variables to isolate the effect of street crossings on the access speed.

[95] We may also consider the non-included frequency measures as resulting in a specification error.

Table 20: Regression series with the access speed (metres per minute) as dependent variable. Coefficients show the average access speed increases or decreases (in metres per minute) with the conditions described by the independent variables. Apart from both step frequency variables (continuous variables), all variables are dummy variables. The correlations between independent variables (Table 22) remain low.

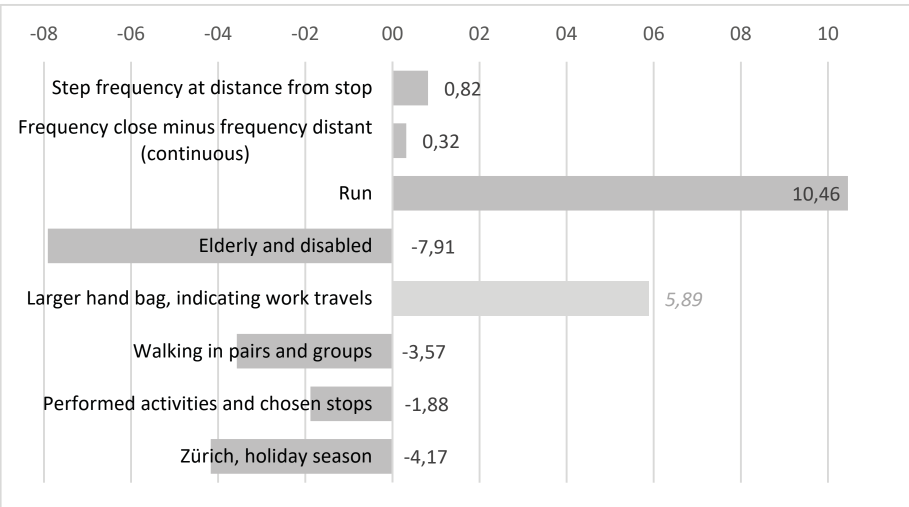
	R-square	**0,62**		
	Significance F	**0,00**		
	Standard error	**13,13**		
	Confidence interval	**0,95**		
	Degrees of freedom	**19**		
	Observations	**330**		
Variable group	**Independent variables**	**Coefficient**	**t**	
	Constant	**-6,44**	**-0,80**	
A	Step frequency at distance from stop (continuous)	**0,82**	**12,14**	***
A	Frequency close minus frequency distant (continuous)	**0,32**	**4,40**	***
A	Run	**10,46**	**2,74**	***
B	Elderly and disabled	**-7,91**	**-3,07**	***
B	Hand baggage, indicating work travels	**5,89**	**3,05**	***
B	Walking in pairs and groups	**-3,57**	**-1,67**	*
B	Performed activities and chosen stops	**-1,88**	**-1,76**	*
B	Zürich, holiday season	**-4,17**	**-2,49**	***
C	90-700 vehicles on crossed street	**-3,71**	**-3,56**	***
C	> 701 vehicles on crossed street	**-5,88**	**-2,34**	**
C	Wait for red traffic light	**-20,38**	**-8,44**	***
C	Wait at zebra crossing	**-15,32**	**-1,60**	
C	Wait at other formal crossing	**-12,65**	**-1,61**	

Table continued on next page

	Continuation of table on previous page			
C	Wait for informal crossing	**-18,21**	**-4,99**	***
C	Street crossing at traffic light	**3,69**	**2,51**	**
C	Street crossing at zebra crossing	**9,83**	**3,14**	***
D	Access through footpath network	**-4,02**	**-1,95**	**
D	Access though corridor with arriving PT vehicle	**-3,57**	**-1,45**	
D	Detour caused by public space layout and urban structure	**6,46**	**3,04**	***
Level of significance: *** > 0,01; ** > 0,05; * > 0,10				

Figure 102 summarises all individual conditions that influence the access speed from groups A and B of independent variables in Table 20. Of course, the individual chosen step frequency (indicating the walking speed) substantially influences the access speed. The independent variable *step frequency distant from stop* indicates the individual step frequency of the observed pedestrians. Each increase in the frequency by the value 1.0 results in an 0.82-metres-per-minute increased

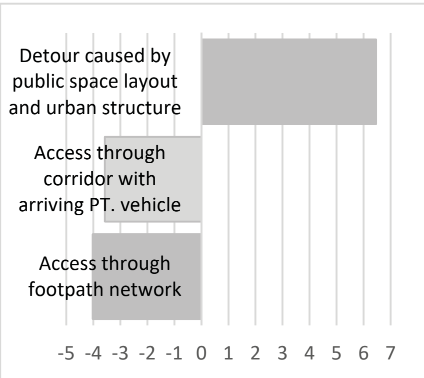
Figure 116: Eight conditions that increased or decreased the access speed of approaching and departing pedestrians in metres per minute; values present the coefficients for independent variables in the regression presented in Table 22, insignificant coefficients are shown in light grey



access speed. The following Section 10.4 shows how we can calculate the average walking speed from the coefficient of this independent variable.

The variable *frequency close minus frequency distant* accounts for the frequency alteration that often occurs when people get close to the stop or when they depart the closer stop surroundings (as discussed in Section 5.1). This variable can become positive or negative and accounts for frequency alterations that occur close to the stop.

Figure 117: Environmental characteristics along the access routes that increase/decrease the access speed. Values present the coefficients for independent variables in the regression presented in Table 22



The remaining five variables in Figure 102 appear to be logical. Elderly and disabled pedestrians walk slower. People walk faster on routinely performed journeys to or from work (as bags indicate, but the variable remains insignificant)[96], and walking in pairs or groups requires people to walk slower. When pedestrians perform activities while walking, paying limited attention to the route ahead requires slower walking speeds. The holiday seasons in Zürich also reduced the average access speed as people walk slower[97].

Figure 103 shows three variables that describe some environmental characteristics of walked routes. The analysis of step frequencies in Section 5.2 shows a frequency increase with detours. Accordingly, the access speed rises. Pedestrians on the way to the stop walk with reduced frequency along pavements

[96] The registered carried bags only indicate that the observed pedestrians are travelling to or from work places. The indicator, bags, remains relatively rough and contains possibly numerous pedestrians that are not on the way to or from work. Accordingly, the result for the coefficient of this variable remains insignificant.

[97] We have to remember that all these independent variables only indicate whether a pedestrian appeared to be disabled, whether a person performed an activity, and so on. The variable does not specify further the grade of disabilities, or the kind and duration of performed activities. Therefore, these variables represent relatively rough indicators and should not be used for generalisations.

in the public transport corridor from where they can spot the approaching bus or tram. These walking routes allow them to see whether the bus or tram is close to the stop. The second variable in Table 22 indicates, accordingly, lower walking speeds, but the t-statistics for this variable remain insignificant. The footpath network consists usually of a calmer environment, where many pedestrians walk slower, as indicated by the last variable in Table 22.

Figure 118: The influence of conditions that increase/decrease the access speed in metres per minute at street crossings. Values present the coefficients for independent variables in the regression presented in Table 22, insignificant coefficients are indicated in light grey

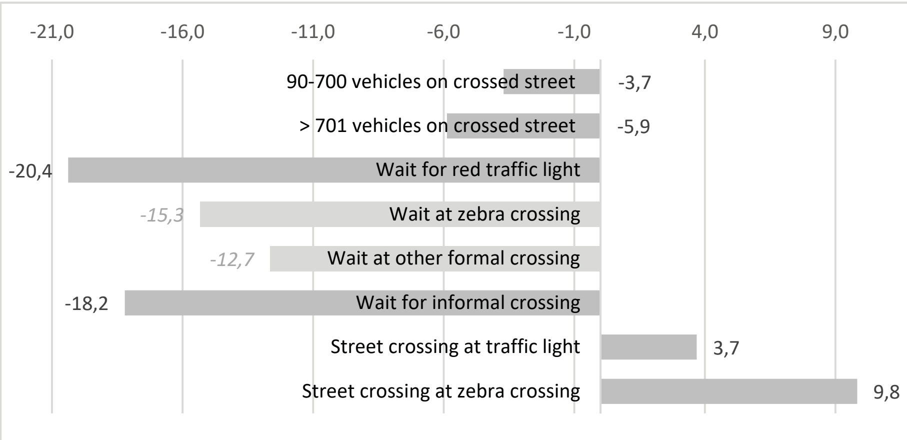


Figure 104 presents the relevant conditions that increase or decrease the access speed when pedestrians have to cross streets. The table shows the extensive effect on the access speed when having to wait at street crossings. The variables *wait at zebra crossing* and *wait at other informal crossing* remain insignificant, however. Both variables are theoretically not irrelevant, but I consider waiting times at these two street crossing facilities to vary more extensively. We have to remember that the variables for waiting times at the four crossing facilities do not indicate the average waiting time alone. To derive the average waiting time, the coefficients need to be added to the coefficients for the number of vehicles on the streets.

The two variables at the bottom of Figure 104, *street crossing at traffic light* and *street crossing at zebra crossing*, show an access speed increase for all pedestrians who cross streets at these two crossing facilities, regardless of whether they waited or not. The variables, *crossings streets informally* and *crossing streets otherwise formally*, serve as reference variables. These two reference conditions do not result in an alteration of the access speed.

At traffic lights, pedestrians either speed up to catch a green phase (to avoid waiting), or they slow down as the traffic light shows red anyway. When pedestrians were approaching the traffic light slowly, the signal often turned green as they reached it and they could cross the street without waiting. The statistics suggest that these speed variations at traffic lights result on average in a slightly increased access speed as compared to the reference variables. At zebra crossings, pedestrians can proceed fast as they have the right of way, increasing the access speed.

Does no alteration of the access speed for the two reference variables, *crossings streets informally* and *crossing streets otherwise formally*, appear explicable? Other informal crossings occur mostly where there are few cars, and pedestrians are not bothered. When crossing streets informally, pedestrians watch out for cars, while they walk, before they can cross. While concentrating on cars, many pedestrians slow down, but walk significantly faster when crossing the carriageway. These speed alterations likely add up to an unchanged average access speed, as compared to zebra crossings and crossing streets at traffic lights.

Table 21: Access speed reductions (metres per second) when pedestrians had to wait at the specified crossing facility at streets with varying traffic flows; grey values indicate conditions that occurred never or rarely

	0-89 vehicles	90-700 vehicles	> 700 vehicles
Traffic light	-17,4	**-21,1**	**-23,3**
Zebra	-4,6	**-8,3**	**-10,5**
O. formal	**-12,7**	-16,4	-18,5
Informal	**-18,2**	**-21,9**	-24,9

Table 21 displays the access speed reductions that occur at the four defined types of street crossings with varying numbers of vehicles on streets, for all pedestrians that waited[98]. As explained in Section 5.2, the access speed between A and B reduces when pedestrians have to wait before crossing streets. The time delays that occur when having to stop before crossing streets are

[98] Greyed out in Table 21 are conditions that occur only rarely in my case studies. The total number of zebra crossings remained low, even though these facilities appear practical for pedestrians. Fewer than 90 vehicles per minute do not require traffic lights or zebra

calculated from these access speed reductions[99].

Do the coefficients for the independent variable appear realistic? We can test this by calculating a fictional access speed. For a single walking, non-disabled, non-running pedestrian, who does not cross a street and walks with an unvaried frequency of 115 steps per minute, the access speed would be 94.3 metres per minute. This access speed derives only from the chosen step frequency of 115 steps per minute and remains unaffected by any environmental conditions. When calculating an access speed only as a result of the step frequency (by holding the effect of all other independent variables constant), this access speed reflects the walking speed. The following Section10.4 explains that the coefficient for the step frequency in Table 20 equals the average step length in metres – 0.82 metres.

Does the so calculated walking speed appear realistic? Molen et al. (1972) find average walking speeds of 89.5 metres per minute with a frequency of 118 steps per minute and a step length of 0.76 metres along a pavement of a thoroughfare and a covered passage[100], as presented in Section 3.2. The parameters that we can calculate from the regression statistics in Table 20 do not fit exactly the findings of Molen et al. but are very close. A slightly higher walking speed does not appear unrealistic when accessing public transport stops. Whyte (1988) finds fast pedestrians walk at a speed of 106 metres per minute. Pedestrians even speed up to 133 metres per minute in passing situations (p. 64). Against the background of Whyte's findings, an average of 94.3 metres per second, when accessing a public transport stop, does not appear unrealistic.

The conditions that the independent variables in Table 20 describe alter the average calculated walking speed of 94.3 metres per minute. People who travel to or from workplaces are 5.9 metres per minute faster. Annoying detours increase the speed further by 6.5 metres per minute. These conditions would result in a walking speed of 106.7 metres per minute. According to Whyte's observed fast

crossings to organize interactions between cars and pedestrians. Other formal crossing facilities appeared only when the traffic on the crossed side streets was low. Pedestrians perform informal street crossings whenever possible. The number of informal crossings only reduces on large four-lane streets with more than 1500 cars per hour.

[99] The time delay is calculated by multiplying the access speed values with the average walked distances in the data set. Average walked distances were 97.2 metres for those that waited at traffic lights, 101.8 metres at zebra crossings, 109.1 metres at other formal crossing facilities, and 84.3 metre at informal street crossings.

[100] For male and female pedestrians combined

walking speed of 106 metres per minute, the results from the regression statistics remain realistic. We can calculate walking speeds for a range of conditions that the independent variables describe. These speeds remain within the range of realistic walking speeds.

The independent variable *running* does not, however, enable calculate the speed for running to be calculated, as explained earlier. Likewise, independent variables *disabilities* and *walking in pairs and groups* disable generalisations. Both serve to filter out an effect that appears in the data set, but the calculated results remain specific for the observations in the data that are influenced by *disabilities* and *walking in pairs and groups*.

The results of the regression statistics in Table 20 do not appear unrealistic. However, we need to remember that the effect of waiting times before street crossings derives from a calculation and not from observations. This still bears some insecurity, and the results should be considered with care.

Table 22: Correlation table for all independent variables in the regression with the access speed as the dependent variable; shown are R values from a bivariate Pearson correlation

	Step frequency at distance from stop	Frequency close minus frequency distant (continuous)	Run	Elderly and disabled	Hand baggage, indicating work travels	Walking in pairs and groups	Performed activities and chosen stops	Zürich holiday season	90-700 vehicles on crossed street	> 701 vehicles on crossed street
Step frequency at distance from stop	1,00	-0,23	**0,43**	-0,26	0,06	-0,19	-0,20	-0,09	0,03	0,14
Frequency close minus frequency distant (continuous)	-0,23	1,00	0,14	-0,06	-0,05	0,12	0,03	0,11	0,04	-0,06
Run	**0,43**	0,14	1,00	-0,05	-0,06	-0,03	-0,07	0,00	0,08	0,05
Elderly and disabled	-0,26	-0,06	-0,05	1,00	-0,14	0,00	0,07	-0,06	-0,03	-0,01
Hand baggage, indicating work travels	0,06	-0,05	-0,06	-0,14	1,00	-0,02	0,01	-0,07	-0,02	0,06
Walking in pairs and groups	-0,19	0,12	-0,03	0,00	-0,02	1,00	0,12	-0,03	-0,01	-0,06
Performed activities and chosen stops	-0,20	0,03	-0,07	0,07	0,01	0,12	1,00	-0,07	-0,01	0,02
Zürich holiday season	-0,09	0,11	0,00	-0,06	-0,07	-0,03	-0,07	1,00	-0,08	0,08
90-700 vehicles on crossed street	0,03	0,04	0,08	-0,03	-0,02	-0,01	-0,01	-0,08	1,00	-0,39
> 701 vehicles on crossed street	0,14	-0,06	0,05	-0,01	0,06	-0,06	0,02	0,08	-0,39	1,00
Wait for red traffic light	0,07	0,06	0,00	-0,05	0,04	0,02	0,05	-0,07	0,08	0,34
Wait at zebra crossing	-0,04	0,03	-0,03	0,02	-0,04	0,13	-0,04	0,15	-0,01	0,06
Wait at other formal crossing	-0,01	0,02	-0,03	-0,04	0,07	0,06	-0,02	0,09	0,06	0,01
Wait for informal crossing	0,07	-0,07	-0,01	0,00	-0,01	-0,03	0,02	-0,16	0,08	0,11
Street crossing at traffic light	0,12	-0,05	0,06	-0,01	0,13	-0,01	0,04	-0,10	0,08	0,49
Street crossing at zebra crossing	0,02	0,05	0,03	-0,04	0,00	-0,08	0,06	0,08	-0,11	0,01
Access though footpath network	0,01	-0,07	-0,12	0,00	0,07	0,09	0,01	0,06	-0,02	-0,02
Access though corridor with departing PT vehicle	-0,02	0,06	0,13	-0,04	-0,04	0,00	-0,02	0,00	0,10	-0,05
Detour caused by public space layout and urban structure	-0,01	0,07	-0,06	-0,01	0,04	-0,04	0,00	0,12	-0,09	0,25

Table continued

Table 23: Continuation of Table 22

		Wait for red traffic light	Wait at zebra crossing	Wait at other formal crossing	Wait for informal crossing	Street crossing at traffic light	Street crossing at zebra crossing	Access though footpath network	Access though corridor with departing PT vehicle	Detour caused by public space layout and urban structure
Step frequency at distance from stop	Table continued	0,07	-0,04	-0,01	0,07	0,12	0,02	0,01	-0,02	-0,01
Frequency close minus frequency distant (continuous)		0,06	0,03	0,02	-0,07	-0,05	0,05	-0,07	0,06	0,07
Run		0,00	-0,03	-0,03	-0,01	0,06	0,03	-0,12	0,13	-0,06
Elderly and disabled		-0,05	0,02	-0,04	0,00	-0,01	-0,04	0,00	-0,04	-0,01
Hand baggage, indicating work travels		0,04	-0,04	0,07	-0,01	0,13	0,00	0,07	-0,04	0,04
Walking in pairs and groups		0,02	0,13	0,06	-0,03	-0,01	-0,08	0,09	0,00	-0,04
Performed activities and chosen stops		0,05	-0,04	-0,02	0,02	0,04	0,06	0,01	-0,02	0,00
Zürich holiday season		-0,07	0,15	0,09	-0,16	-0,10	0,08	0,06	0,00	0,12
90-700 vehicles on crossed street		0,08	-0,01	0,06	0,08	0,08	-0,11	-0,02	0,10	-0,09
> 701 vehicles on crossed street		0,34	0,06	0,01	0,11	0,49	0,01	-0,02	-0,05	0,25
Wait for red traffic light		1,00	-0,06	-0,06	-0,11	**0,66**	0,01	-0,04	0,03	0,05
Wait at zebra crossing		-0,06	1,00	-0,02	-0,03	-0,09	0,08	-0,01	0,06	0,08
Wait at other formal crossing		-0,06	-0,02	1,00	-0,03	-0,03	-0,04	0,07	-0,07	0,11
Wait for informal crossing		-0,11	-0,03	-0,03	1,00	-0,13	0,05	0,04	-0,03	0,02
Street crossing at traffic light		**0,66**	-0,09	-0,03	-0,13	1,00	-0,10	0,00	-0,01	0,13
Street crossing at zebra crossing		0,01	0,08	-0,04	0,05	-0,10	1,00	-0,05	0,05	-0,04
Access though footpath network		-0,04	-0,01	0,07	0,04	0,00	-0,05	1,00	**-0,67**	0,31
Access though corridor with departing PT vehicle		0,03	0,06	-0,07	-0,03	-0,01	0,05	**-0,67**	1,00	-0,25
Detour caused by public space layout and urban structure		0,05	0,08	0,11	0,02	0,13	-0,04	0,31	-0,25	1,00

10.4 Calculation of an average walking speed from the regression results with the access speed as independent variable

The independent variable ***step frequency distant from stop*** in Table 20 derives from the frequency measured at some distance from the public transport stop. The coefficient for the independent variable *step frequency distant from stop* indicates an average access speed increase of 0.82 metres per minute; for each 1.0 more step per minute, the frequency increased (while the effect of all other independent variables is held constant). The coefficient for *step frequency distant from stop* in Table 20 allows the average walking speed to be calculated, as described in the grey text box.

> Calculating the average step length and the average walking speed
>
> If each additional step undertaken per minute increases the speed by 0.82 metres per minute, then the coefficient for the step frequency from the regression statistics in Table 20 shows, at the same time, the average step length, 0.82 metres per step. Together with the average step frequency of 114.1 steps per minute, as derived from the data sample (all included 330 observations), we can calculate the average walking speed:
>
> 114.1 s/min x 0.82 m/s = 93.6 m/min
>
> - m/min = metres per minute
> - s/min = steps per minute
> - m/s = metres per step
>
> The previously presented data from Molen et al. (1972) similarly shows averages for the frequency (114.1 steps per minute), walking speed (85.9 metres per minute), and step length (0.74 metres per step), when results for male and female pedestrians are combined. As about 40 percent of pedestrians in the data from the public transport stop investigation experience time pressure, higher values for step length, frequency, and speed appear plausible.

The variable *frequency close minus frequency distant* in Table 20 describes the change in the speed of steps that occurs when pedestrians enter or exit the *closer stop surroundings* (defined in Section 2.4). The frequency can increase, decrease, or does not vary, as Section 5.1 analyses. The variable filters out the influence of the frequency variation, which indicates time pressure. The variable *running* filters out the effect of a longer step length that increases the access speed.

For all observed pedestrians that ran for an unspecified period (but longer than five seconds), the access speed increases by 10.5 metres per minute. The increase results from longer steps when running. While walking, at least one foot has ground contact. Running includes a short flight phase after one foot has left the ground and before the other foot touches the ground again, explains Weidmann (1993). This short flight phase results in substantially longer steps that result in a substantial speed increase (pp. 16–19).

10.5 Statistics for the analyses of head movements and time looked down

10.5.1 T-tests investigating differences between specific environments

A series of t-tests (Table 24) compares head movements and looking down between the three studied street crossing locations and, further, in boring and exciting walking environments. T-tests show in which environments head movements and looking down differ statistically significantly.

Table 24: Results of t-tests (assuming unequal variance) for head movements (HM) and looking down (LD) for combinations of case studies

Observation locations	Compared locations	Test type	p-value HM		p-value LD	
13 Z. Station	14 PT stop Zentral	two tailed	0,04	**	0,06	
13 Z. Station	15 Zentralplatz	one tailed	0,00	***	0,39	
13 Z. Station	Exciting env.	one tailed	0,00	***	0,00	***
13 Z. Station	Boring environment	one tailed	0,00	***	0,42	
14 PT stop Zentral	15 Zentralplatz	one tailed	0,00	***	0,07	**
14 PT stop Zentral	Exciting env.	one tailed	0,00	***	0,00	***
14 PT stop Zentral	Boring environment	one tailed	0,00	***	0,00	***
15 Zentralplatz	Exciting env.	two tailed	0,54		0,30	
15 Zentralplatz	Boring environment	one tailed	0,00	***	0,00	***

Level of significance: *** <0.01, **<0.05, *<0.1

10.5.2 Regression statistics for the influence of the environment score on head movements and looking down

This analysis uses the data from the pedestrian observations, as described in Sections 4.3 and 6.3.2. Two multiple linear regression analyses are used to calculate whether the dependent variables (1) *head movements per minute* and *seconds looked down per minute* are influenced by seven (analysis for head movements) and six (analysis for looking down) independent variables. Results of the statistics are presented in Table 27.

Of central interest is the influence of the independent variable *total environment score*. The score is a continuous variable that ranges between 1.0 and 3.0. Independent variables *seconds looked down per minute* and *step frequency* are continuous variables. All other independent variables are dummy variables. The reference for both city variables *Copenhagen* and *Brighton* is the third city *Zürich*. These variables indicate differences between the three cities where pedestrians have been observed. The reference to the independent variable *walking with others* is single walking, and for *performed activities* the reference is pedestrians that do not perform an activity while they walk.

The explanatory values for the regression analyses are 35 percent (head movements) and 29 percent (looking down). Both dependent variables describe an aspect of pedestrians' behaviour that those who walk perform certainly unconsciously. However, individual interests or the emotional status of those who walk influence how pedestrians attend to their visual surroundings. Pedestrians may walk in an *autopilot modus*, while being engaged with their own thoughts, as discussed in Section 3.4. These individually different and unmeasurable conditions explain well the variation in both models that the statistics cannot associate with the included independent variables. The individual context for walking accounts very likely for a great part of the 'unexplained' variance of both dependent variables.

Measurement errors can occur for the variables *head movements* and *looking down*, as well as for the *step frequency*. I do not, however, consider measurement errors among these variables to be substantial. All three features of pedestrian behaviour are directly observed and relatively easy to measure. The variable *performed activities* is only a rough indicator. The variable does not determine how long pedestrians were engaged in doing something while walking. Neither does the variable specify what kind of activity was performed. Due to the rough measuring methods, the variable contains some random variation that reduces the explanatory value of the regression statistics somewhat.

The most important independent variable is the *total environment score*. This variable can contain both specification and measurement errors. The process to determine the environment score may miss environmental features that are relevant for visual

Table 25: Descriptive statistics for head movements per minute in case studies 01 to 12 from the observation studies. Walking environments were either boring or exciting.

Mean	29,7
Standard Error	0,56
Median	28,00
Standard Deviation	13,90
Sample Variance	193,15
Kurtosis	0,37
Skewness	0,53
Range	96
Minimum	0
Maximum	96
Count	625

Table 26: Descriptive statistics for seconds looked down per minute in case studies 01 to 12 from the observation studies

Mean	19,3
Standard Error	0,61
Median	17,14
Standard Deviation	15,13
Sample Variance	228,79
Kurtosis	-0,56
Skewness	0,54
Range	60
Minimum	0
Maximum	60
Count	625

stimulation or may include factors that are irrelevant. The analysis in the following Section 10.5.3 shows that most environmental categories behind the total environment score appear relevant for the studied dependent variables, apart from *car traffic restrictions*. However, the process to arrive at a score for a walking environment can be a source of measurement errors and specification errors. The score is not, and cannot be, an exact measure of the visual walking environment.

The R-square values are more extensively influenced by specification errors due to non-included (and unmeasurable) individual factors of the observed pedestrians. The independent variable *total environment score* likely comprises both, specification and measurement errors. I consider that a large part of the variation in the two dependent variables, which the statistics cannot associate with the independent variables, derives from the variable for the total environment score.

Does the R-square value appear realistic? As Section 3.4 discusses, psychologists consider 50 percent of human behaviour to derive from individual backgrounds and experiences and 50 percent from the surrounding environment. Visual stimulation accounts for 80 percent of all information the brain receives from sense organs. Head movements are a form of human behaviour that results from stimuli that the visual sense organs receive from the environment. According to these findings from psychologists, the visual urban surroundings determine theoretically around 40 percent (50 percent of 80 percent) of head movements pedestrians perform. Of the remainder, 10 percent are influenced by other than visual stimuli and 50 percent by individual backgrounds and preferences. Against this theoretical background, the explanatory values of both regression statistics in Table 27 are not unrealistic.

Table 25 and Table 26 present the descriptive statistics for head movements per minute and the seconds looked down per minute. Both data sets do not show an exact bell shaped curve, but the values for kurtosis and skewness remain low. The data set does not threaten significance tests. Table 28 shows the unsquared correlation coefficients for each set of independent variables. Correlations remain low and indicate that multicollinearity does not affect the statistics of both regression analyses in Table 27.

The variable *seconds looked down per minute* is assigned a specific role in the regression for head movements in Table 27. The time looked down influences the number of head movements a pedestrian is able to perform. When looking down all the time, pedestrians cannot perform any head movements. However, the time pedestrians look down is also influenced by (the independent variable) *total environment score*, as the second regression in Table 27 demonstrates. Hence the independent variables *seconds looked down per minute* and *total environment score* (in the regression for head movements) interact. The effect of the environment score on head movements is mediated by the time pedestrians look down. In an equal manner, the step frequency mediates head movements. Section 6.1 shows that the frequency varies with changing environmental conditions. The interaction effect between frequency and the environment score remains, although much lower than the interaction between looking down and the environment score.

From the regression results presented in Table 27, we can calculate the average head movements and the time looked down for an environment score with value 1.0 (unattractive), 2.0, and 3.0 (attractive), as Section 4.3.2 presents. As a basis for the calculation, a walking speed of 115 steps per minute is determined for a pedestrian who does not perform activities.

The time looked down is calculated with the following coefficients from the statistics in Table 27 with the independent variable *looking down*:

- Constant = C (20.98 seconds per minute on average, as the coefficient for this independent variable shows)

- Step frequency = SF (115 steps per minute times the coefficient for the step frequency of 0.13)
- Average variation in the three cities = CA (average between all three cities is the sum of coefficients for city variables, where Zürich equals zero, divided by three)
- Total environment score = ES (for the lowest environment score with value 1.0 the average time looked down equals -9.62 seconds per minute, as the coefficient for this independent variable shows)

The average time looked down in an environment with an environment score value of 1.0 and a step frequency of 115 steps per minute is calculated with the following formula:

C + SF + CA + ES = 2.98 – (115 x 0.13) + ((3.41 + 4.59 + 0)/3) – 9.62 = 28.9 (unit = seconds looked down per minute)

The average for the number of head movements is calculated accordingly from the coefficients of the independent variables from the regression statistics for head movements (Table 27). This calculation includes the results for the time looked down with the following variables:

- Constant = C (1.11 head movements per minute)
- Seconds looked down per minute = LD (28.9 seconds, as calculated above)
- Step frequency = SF (115 steps per minute times the coefficient for the step frequency of 0.10)
- Average variation in the three cities = CA (average between all three cities is the sum of coefficients for city variables, where Zürich equals zero, divided by three)
- Total environment score = ES (for the lowest environment score with value 1.0, the average head movements per minute equal 7.50 per minute, as the coefficient for this independent variable shows)

The average number of head movements per minute for a walking speed of 115 steps per minute in environments with the score 1.0 is calculated as follows:

C + LD + SF + CA + ES = 1.11 + (115 x 0.10) + ((4.42 + 5.56 + 0)/3) + 7.50 = 17.3 (unit = head movements per minute)

Table 27: Results for regression analysis of head movements and looking down

(↑) indicates a positive correlation between dependent and independent; **(↓)** indicates a negative correlation; **(○)** indicates a non-significant influence of the independent variable on the dependent variable

Regression statistics **head movements per minute (HD)**	
R-square	0.35
Significance F	0.00
Confidence interval	0.95
Degrees of freedom	7
Observations	625

Regression statistics **Seconds looked down per minute (LD)**	
R-square	0,29
Significance F	0,00
Confidence interval	0,95
Degrees of freedom	6
Observations	625

Independent variable	**HM** Coefficient	t-Stat		**LD** Coefficient	t-Stat		Direction correlation HM	LD
Constant	1.11	0.16		20.98	2.66			
Seconds looked down per minute	-0.21	-5.96	***	-	-		-	-
Step frequency	0.10	1.85	*	0.13	2.00	**	↑	↑
Performed activities	-2.02	-1.99	**	3.59	3.14	***	↓	↑
Walking with others	4.20	3.28	***	-1.24	-0.85		↑	○
Copenhagen	4.42	3.22	***	3.41	2.20	**	↑	↑
Brighton	5.56	3.99	***	4.59	2.92	***	↑	↑
Total env. Score	7.50	10.99	***	-9.62	-14.33	***	↑	↑

Level of significance: *** > 0,01; ** > 0,05; *>0,10

Table 28: Correlation table for independent variables included in the regression analyses on head movements and looking down with the total environment score

	Looking down	Step frequency	Performed activities	Walking with others	Copenhagen	Brighton	Total env. score
Looking down	1,00						
Step frequency	0,11	1,00					
Performed activities	0,15	-0,05	1,00				
Walking with others	0,04	-0,13	0,40	1,00			
Copenhagen	-0,03	-0,03	0,11	0,13	1,00		
Brighton	0,09	0,01	-0,07	-0,14	-0,74	1,00	
Total env. Score	-0,51	-0,09	-0,10	-0,09	0,08	-0,05	1,00

10.5.3 Regression statistics for the analyses of head movements and looking down with environmental categories as independent variables

Table 30 presents the results of the regression statistics for the two analyses with head movements (per minute) and seconds looked down (per minute) as dependent variables. Statistics include the same independent variables as in the statistics presented in the previous subchapter in Table 27. Only the total environment score is replaced by six independent variables that specify the environmental character of the locations for pedestrian observations in more detail. The six environmental variables derive from the environmental categories that the *environment matrix* defines (Chapter 4.3.2). These six variables are ordinal variables that range between 1 and 4. The interval between these variables is assumed to be close to equal.

Not all categories from the environment matrix are included as independent variables. The environment categories *access* and *sense of security* are excluded as they appear theoretically irrelevant for the amount of visual stimulation pedestrians receive from their surroundings. The variable *car restrictions* showed insignificant results and was excluded. Theoretically, the irrelevance of car traffic for pedestrians' visual stimulation makes sense. Cars are a source of negative stimuli such as noise and dust. Pedestrians cannot shut down their visual sense from vehicles as traffic is a source of danger that needs to be monitored. However, these sources of negative stimulation do not attract pedestrians' visual attention otherwise.

The replacement of the variable *total environment score* with six environmental variables provides better options to exclude environmental factors that appear irrelevant for pedestrians' visual stimulation. Better differentiating variables reduce the amount of specification error in the model. Accordingly, the R-square value increases in statistics for both head movements and looking down to 38 and 29 percent, respectively, as compared to the statistics with the total environment score in the previous Section 10.5.2.

Section 6.4 discusses the statistical result for the independent environmental variables. Results for all other independent variables change only slightly as compared to the regression statistics in the previous section 10.5.2. Only the differences between the cities disappear when replacing the total environment score with the six environmental variables. The differences between cities derive likely from a specification error in the variable *total environment score*. The score is calculated from nine environmental categories (defined by the environment matrix), which comprise conditions that are irrelevant for head movements.

Table 29 shows the unsquared correlation coefficients between each set of all independent variables. Some of the independent variables show higher correlation values. Berry and Feldman (1985) suggest that correlation values below 0.8 are not problematic for a data set of reasonable size (p. 43). The independent environmental variables *activity*, *facilities*, *enclosure*, and *edges* show correlation values above 0.8 in Table 29. These high values show that these independent variables vary close to parallel, likely exposing the statistics to multicollinearity problems. However, unless independent variables do not correlate by the value 1.0, the underlying assumptions for the statistical procedure are not violated (p. 40). It appears interesting that, despite high correlation between these variables, all coefficients show a statistically significant variation from the constant. Significant coefficients indicate that multicollinearity may not threaten the statistical results. Further, the pre signs of the coefficients appear as expected and are explicable.

The results for the four environmental variables do not appear completely displaced but should be handled with care. To receive more valid results on the question which features whether the visual walking environment increases pedestrians' stimulation, we need case studies with more diverse environmental characteristics. When the values for the independent environmental variables vary to a minor degree parallel, statistical methods provide better possibilities to compute the influence of these different variables on head movements. The employed data set unfortunately limits to some degree the statistics presented in Table 30.

Table 29: Correlation table for independent variables included in the regression analyses on head movements and looking down with the categories from the environment matrix

	Looking down	Step frequency	Performed activities	Walking with others	Facilities	Activity	Enclosure	Edges	Street scape	Green
Looking down	1,00									
Step frequency	0,11	1,00								
Performed activities	0,15	-0,05	1,00							
Walking with others	0,04	-0,13	0,40	1,00						
Facilities	-0,45	-0,09	-0,11	-0,09	1,00					
Activity	-0,42	-0,07	-0,13	-0,14	**0,89**	1,00				
Enclosure	-0,46	-0,10	-0,09	-0,13	**0,85**	**0,83**	1,00			
Edges	-0,48	-0,09	-0,10	-0,09	***0,85***	**0,89**	**0,92**	1,00		
Street scape	-0,42	-0,04	-0,09	-0,10	0,41	0,57	0,67	0,75	1,00	
Green	0,07	0,04	0,02	0,07	-0,55	-0,42	-0,34	-0,30	0,33	1,00

Table 30: Results for regression analysis of head movements and looking down with the eight categories from the environment matrix (Section 4.3.2). ***(↑)*** *indicates a positive correlation between dependent and independent;* ***(↓)*** *indicates a negative correlation;* ***(○)*** *indicates a non-significant influence of the independent on the dependent variable; Cor. Coef. = Correlation Coefficient*

Regression statistics **head movements (HM)**	
R-square	0,38
Significance F	0,00
Confidence interval	0,95
Degrees of freedom	10
Observations	624

Regression statistics **looking down (LD)**	
R-square	0,29
Significance F	0,00
Confidence interval	0,95
Degrees of freedom	9
Observations	624

Independent variable	**HM**			**LD**			Direction correlation	
	Coefficient	t-Stat		Coefficient	t-Stat		HM	LD
Constant	- 6.65	- 0.90		15.42	1.80			
Seconds looked down per minute	-0.21	- 6.02	***	-	-		↑	-
Step frequency	0.10	1.83	*	0.13	2.08	**	↑	↑
Performed activities	-1.63	-1.64		3.48	3.05	***	○	↑
Walking with others	4.15	3.26	***	- 1.38	- 0.94		↑	○
Copenhagen	-	-		-	-		○	○
Brighton	-	-		-	-		○	○
Car restrictions	-	-		-	-		○	○
Facilities	- 0.72	- 0.56		- 6.49	-5.00	***	○	↓
Social activity	5.80	4.48	***	3.73	2.48	***	↑	↑
Enclosure	3.25	2.27	**	2.00	1.20		↑	○
Edges	3.90	2.17	**	- 0.24	- 0.12		↑	○
Street scape	- 5.51	-3.25	***	- 6.59	- 3.39	***	↓	↓
Green	6.03	3.90	***	1.10	0.61		↑	○

Level of significance: *** > 0,01; ** > 0,05; *>0,10

10.6 Regression analysis for the pleasantness of walking to tram stops in Zürich

The following text describes the regression analysis for the evaluated pleasantness, as dependent variable, of walking to tram stops in Zürich. Interviewees evaluated the walk to the stop with a six-point Likert scale; the value *1* equals an unpleasant experience, and value *6* equals a pleasant experience. The regression analysis uses the resulting values from 1 to 6 as a dependent variable that is influenced (to a varying degree) by 49 independent variables. Table 31 presents the results of the calculated statistics.

The data set for the regression analysis includes 552 interviews of the conducted 596. Excluded are people that did not walk to the stop, interviews where communication appeared difficult, and interviews with missing data.

Forty-nine dummy variables that derive from the answer options in the questionnaire serve as independent variables. Independent variables that remain insignificant, and do not have an effect on the results of other independent variables, are excluded. Table 31 shows all independent variables, the reference variables (if relevant), and the questionnaire questions from which the independent variables derive.

Not surprisingly, the R-square value of the statistics appears lower than for most of the regression statistics that have been so far discussed in Appendix 3. A lower explanatory value derives, on the one hand, from specification errors and, on the other, from measurement errors, as the following text discusses.

The specification error derives from non-included individual factors that certainly contribute to the evaluated pleasantness of the walk to the stop. This issue is discussed in Section 6.5.2. Moreover, including so many independent variables that show insignificant results raises the question of whether all variables are of theoretical relevance. Section 6.5.1 has already discussed why the results for photos that indicate assumedly pleasant walking environments remain insignificant. A high average evaluated pleasantness in the data set reduces the possibilities to find significant results that further increase the evaluated pleasantness of the walk to the stop from the average mean. This problem certainly also influences other variables that possibly increase the pleasantness of walking.

Section 6.5.1 discusses all independent variables with significant coefficients. The following text focuses on variables that do *not* result in a significant variation from the constant. How often travellers undertake the journey they report on certainly influences how they experience the walked trip, as Section 6.5.1 discusses briefly. Along regular performed journeys, travellers are familiar with the surroundings for walking, they know which additional destinations are available along the walking route, and they know how long it will take to reach the stop. Regular travellers are also used to walking to tram stops. It is likely that the environmental experience of regular travellers differs from the impression of non-regular travellers or from those who undertake this journey for the first time. Even though the calculated coefficients all remain insignificant, they show meaningful pre signs. While the variation between travelling *<2x per week* and 2-3x per week remains nearly equal, the evaluated pleasantness drops slightly for regular travellers that perform the walk to the stop routinely more than three times per week. The other extreme, first time travellers, appear to experience the walk to the stop as being more pleasant. The results show a slight increase in the pleasantness with decreasing routinely undertaken travels. Routines may bore pedestrians.

Equally, the purpose of the journey does not significantly alter the reported pleasantness of the walk to the stop. Despite these results, it does not appear far-fetched that the purpose of the journey represents an important context for travelling, and hence for the experience of the journey. Travel to work represents a different context from, for example, a journey for leisure purposes. Being forced, during interviews, to reflect on the experience of walking may not bring into awareness the fact that the purpose of the journey influences the subjective experience of the trip. These variables are of theoretical relevance for the model, even though the model fails to show its influence on the dependent variable.

Similarly to the travel purpose, the type of performed street crossing has a theoretical relevance for walking, despite insignificant results for the coefficients of the respective independent variables. The analysis of time delays at street crossings (Section 5.5) and step frequencies (Section 5.2) underpin my consideration that these variables are relevant for the pleasantness of walking. However, street crossings are events that occur only occasionally along the walk to the stop. The influence of these occasional occurrences may shape the remembered impression of walking less than conditions that are permanently relevant along the whole walk to the stop, such as environmental characteristics. Despite insignificant coefficients, results for the type of street crossing indicate a feasible tendency. Zebra crossings and other crossing facilities are more pleasant to use than crossing at traffic lights. Least pleasant are underpasses. These tendencies, which the coefficients indicate, reflect results from other analyses in this research.

The variable *performed activity while walking* remains insignificant. The variable does not specify what kind of activities the interviewees performed while walking to the stop nor for how long these activities were performed along the walking route. The variable remains therefore relatively rough. Other investigations of this research show, however, that the performance of activities significantly influences the observable walking behaviour. The variable appears theoretically relevant for the pleasantness of walking, but the statistics fail to show a significant effect. Numerous unconsciously performed activities may not have been reported and hence, additionally, blur the results for this variable.

The questions on car availability as an alternative travel option for the journey undertaken on foot and by tram also show no significant effect on the pleasantness of walking. Theoretically, it does not appear far-fetched to assume that those who choose to travel on foot and by tram might consider this form of transport as pleasant. Differently, among the group of travellers without travel choice, more interviewees might experience walking and public transport as less pleasant. The statistical results reflect this tendency but remain insignificant. It is possible that the effect of this variable group interacts with the effect of the question on the attitude towards walking. The latter variable shows significant results.

More critical is the question of whether the employment status of travellers appears relevant for the pleasantness of the walking trip to the stop. Nevertheless, the (insignificant) tendencies that the coefficients show appear explicable. Pupils, students, and apprentices experience walking as being less pleasant than those who work. It is likely that the first group consists of more people that have no other travel option. Self-employed travellers may experience a higher work load and more time pressure; accordingly, the pleasantness of walking drops. The unemployed and pensioners may have more time available, increasing the pleasantness of walking. However, such explanations remain somewhat speculative. Excluding the variables on the employment status from the regression resulted in a change of other variables, indicating an interaction with other variables. Interaction effects can cause insignificant coefficients. I decided therefore to include the variables for the employment status as control variables.

According to the regression statistics, there are no differences between male and female pedestrians. Considering that the survey was conducted in more lively urban areas at daylight, the results appear plausible. However, this independent variable also interacts with other variables and remained in the regression as control variable.

Results of other groups of independent variables have been discussed in Section 6.5.1. It is my evaluation that the effect of specification errors derives predominantly from non-included individual factors that influence the pleasantness of walking. All included independent variables have at least a theoretical relevance for the pleasantness of the walking trip to the tram stop. Low and insignificant results can stem from a high average of evaluated pleasantness, measurement errors, and interactions between the groups of independent variables.

Correlations between the 49 independent variables remain low. Of the 1200 correlation values (49*49/2), 13 range between 0.19 and 0.30, four between 0.29 and 0.40. Variables *unemployed/trip purpose leisure* and *unemployed/trip purpose service* correlated between 0.39 and 0.50. Variables *crossed at zebra crossing/crossed trafficked street* showed a correlation of 0.53, indicating that 53 percent of those who cross trafficked streets do so at zebra crossings. Variables *walked for longer than 10 minutes more than three times during the last seven days* and *walked for longer than 10 minutes two to three times during the last seven days* show a correlation coefficient of -0.71, indicating that less than 71 percent walked for longer than 10 minutes either 2-3 times or more than three times during the last seven days. Correlation coefficients for all remaining 1181 correlation coefficients of independent variables remain below the value 0.20. These results do not directly indicate the presence of collinearity effects. However, groups of variables that belong to a specific question in the questionnaire can correlate with variable groups that belong to another question, as the discussion of insignificant independent variables highlights.

How do measurement errors influence the calculated statistics in Table 31? Firstly, we need to remember that results derive from interviews. As compared with the observational investigations reported in previous sections of Appendix 3, the method of interviews naturally includes a higher number of measurement errors. These challenges have been discussed in Section 4.2.3. Interviewees may misunderstand a question, they may not see a meaning in the asked questions, and they may provide wrong or inexact answers for a number of reasons. Interviewees may interpret questions differently; they may have unequal capabilities to recall the walking trip to the stop and so on. All described aspects can cause measurement errors.

Secondly, it is not possible to measure directly the questioned conditions for the individual walking trip to the stop. Many predefined answer options provide only a very rough picture on the character of the walk to the stop. Answers to most questions have only the character of indicators, rather than being measures. Thirdly, interviewees may interpret and use the Likert scale to indicate the remembered pleasantness of the walk to the stop differently. Hence, the dependent variable of the regression statistics, the evaluated pleasantness of the walk to the stop, remains itself relatively rough and has only an indicating character.

Summarised, the regression statistics in Table 31 are exposed to four challenges: firstly, specification errors that derive from individual conditions. These unmeasurable factors probably influence the reported pleasantness of walking; secondly, measurement errors that are omnipresent in surveys with predefined questions, conducted under time pressure, targeting questions that interviewees are possibly not aware of; thirdly, interactions between variable groups. A somewhat parallel variation between variable groups is likely to reduce the coefficients of some independent variables that otherwise show an explainable tendency. Fourthly, high average results for the evaluated pleasantness in the data set limit possibilities to separate significant effects of independent variables that increase the pleasantness of the walk to the tram stop. Keeping these four shortcomings of the regression statistics in Table 31 in mind, the resulting explanatory value of 25 percent remains a satisfying result.

Table 31: Regression analysis with the evaluation of the walk to the stop as dependent variable

R-square	0,25				
Significance F	0,00				
Standard error	3,36				
Confidence interval	0,95				
Degrees of freedom	49				
Observations	552				
Questionnaire question	Reference	Independent variable	Coeff	t	Sig.
		Constant	5,51	18,80	***
Photos		Street, traffic	-0,39	-4,12	***
		People, activity	-0,08	-0,72	
		Interesting buildings	0,13	0,81	
		Crowding	-0,48	-2,79	***
		Unattractive, boring	-0,45	-4,00	***
		Trees, green	0,10	0,81	
		Shop windows	0,03	0,24	
		Waiting, street crossing	-0,05	-0,39	
Frequency undertaken journey	< 2x per week	2-3x per week	0,01	0,07	
		>3x per week	-0,08	-0,77	
		first time	0,09	0,65	
Purpose of journey	Trip to or from work	Job related	-0,04	-0,19	
		Education	0,18	1,01	
		Shopping, errands	-0,11	-0,61	
		Service	-0,16	-0,98	
		Leisure	-0,04	-0,28	
		Accompany	-0,74	-1,48	
		Other	-0,04	-0,11	
Direction of travel	From home	Direction home	-0,10	-1,07	
Change	Not changed	Changed once	-0,21	-2,01	**
		Changed from train	-0,13	-0,97	

Table continued

Continued table for the regression with the evaluation of the walk to the stop as dependent variable

Interview question	Reference	Independent variable	Coeff	t	Sig.
Time walked	<3 min	3-5 min	-0,22	-2,37	**
		6-10 min	-0,42	-2,57	***
		11-15 min	0,33	0,79	
		>15 min	-0,61	-1,89	*
Errands	No errand	Shopping	0,15	1,01	
		Service	-0,76	-3,03	**
		Leisure	0,39	0,75	
		Eating	-0,21	-1,10	
		Accompany	0,87	1,77	*
		Other	-0,06	-0,30	
Street crossing	No crossing	Yes	-0,20	-1,73	*
Location street crossing	Traffic light	Zebra crossing	0,16	1,15	
		Underpass/bridge	-0,36	-1,20	
		Other crossing	0,04	0,16	
Performed activity while walking	No activity	Yes	-0,07	-0,75	
Sensed time pressure	No time pressure	Yes	-0,19	-1,63	*
Experience safety	Safe for a 7–year-old	Perhaps safe	-0,36	-3,29	***
		Perhaps not safe	-0,60	-4,16	***
		Not safe for a 7-year-old	-0,46	-3,57	***
Attitude walking	Walked 0x more than 10 min	Walked 1x more than 10 min	0,37	1,57	
		Walked 2-3x more than 10 min	0,19	1,04	
		Walked >3x more than 10 min	0,34	2,09	**

Table continued

Continued table with the evaluation of the walk to the stop as the dependent variable

Interview question	Reference	Independent variable	Coeff	t	Sig.
Car availability	No car available	Car available	0,01	0,08	
		Car available but unpractical	-0,02	-0,21	
Occupation	Employed	Pupil, student apprentice	-0,08	-0,53	
		Self employed	-0,23	-1,56	
		Unemployed/pensioner	0,12	0,82	
Sex	Male	Female	0,00	-0,03	
		Level of significance: *** > 0,01; ** > 0,05; * > 0,10			

10.7 Calculations for the estimation of the environmental effect on acceptable walking distances

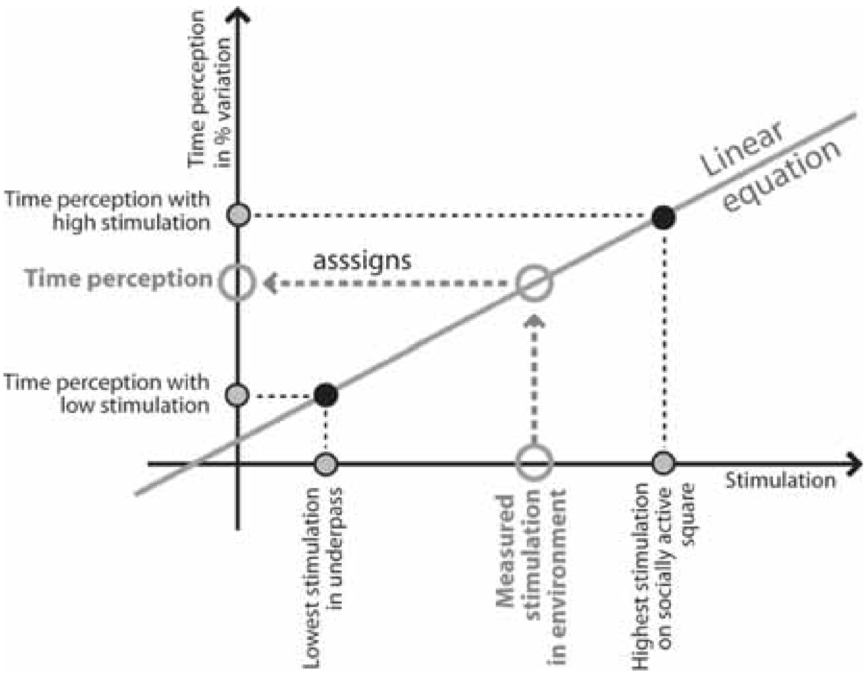
How can we associate the two different units (1) *variation of perceived time with different levels of stimulation* and (2) measures for *stimulation* in different walking environments? Psychologists describe the subjectively perceived time as a percentage of the objectively measured time. To measure pedestrians' stimulation, I used the unit *head movements per minute*. To associate both units, I suggest the following procedure.

I suggest that the highest stimulating environment (a socially active square) corresponds with time perception under high stimulation. Inversely, the lowest stimulating environment I investigated (an underpass) corresponds with time perception under low stimulation. The two paired measurements (*high stimulation/ time perception* and *low stimulation/time perception*) define two data points in a coordinate system with the y axis *time perception* and the x axis *stimulation* (see Figure 105). The two data points define a linear equation that runs through both data points. The linear equation is:

$\mathbf{f_{(x)} = 0.6x + 0}$.

The value x represents a measure of stimulation, represented by the number of average head movements that pedestrians perform per minute in a specific walking environment. We can calculate the percentage time variation for each measure of stimulation with the help of the equation for stimulation.

Figure 119: Linear equation to assign values of stimulation with subjectively perceived time (unit = percentage variation of objective time)



In an equal manner, we can associate the units (1) *variation of perceived time with pleasant/unpleasant experiences* with the *measurements for the pleasantness of walking* that derive from the interview analysis in Section 7.5. The pleasantness of the walking environment has the unit of the Likert scale that was used to evaluate pleasantness during the interviews (six-point Likert scale). I defined the most pleasant and the least pleasant walking environment in the text of Section 7.6 by combining measures of investigated environmental characteristics. Most pleasant appear *socially active* surroundings with *shop windows* and *interesting buildings*. These environments correspond with a time perception for a pleasant experience. Inversely, the least pleasant appear to be *boring pavements* along *trafficked streets*, which correspond with the time perception of an unpleasant experience. The two pairs for *perceived time* and *pleasantness* again define a linear equation. The equation is:

$$\mathbf{f_{(x)} = 14.035x + 0,6145}$$

This equation allows us to calculate how the perceived time varies (in percentage of the objective time) for each condition that caused a variation of pleasantness on the Likert scale during the interviews (see Section 7.5).

Table 33 and Table 34 show the percentage variation of pedestrians' time perception (in reference to objective time) as a consequence of varying stimulation. Table 32 shows the percentage variation of time (in reference to objective time) as a consequence of a varying pleasant walking experience. The pleasantness of walking alters with environmental characteristics and compromised safety due to traffic dangers. Table 35 shows how I suggest estimating pedestrians' time perception as a result from eleven different walking environments. As suggested in the text of Section 7.6, I add up the results in Table 34, Table 33, and Table 32. Table 35 shows how pedestrians perceive the time spent walking as the result of altering *stimulation* and the *pleasantness* in different walking environments. Table 35 shows how the results are calculated from the estimations in Table 32, Table 33, and Table 34.

Table 32: Percentage variation of subjectively perceived time (in reference to objective time) with altering levels of pleasantness in different walking environments

Evaluation of pleasantness

Code	Conditions that influence pleasantness	% variation
A1	Interesting buildings	-4,5
A2	Shop windows	-3,1
A3	People/activity	-1,6
A4	Trees, green	-4,1
A5	Street traffic	+2,8
A7	Crossing trafficked street	+0,1
A6	Compromised safety street crossing	+3,9
A8	Unattractive/boring	+3,6
A9	Crowding	+4,0

Table 33: Percentage variation of subjectively perceived time (in reference to objective time) with altering levels of stimulation that are caused by the quality of environmental attributes (see Section 20.1)

Code	Environmental attribute that influences stimulation	% variation
C1.0	Shops and shop windows, < 2 doors per 100m	0%
C1.2	3 - 7 doors per 100m	-1,7%
C1.3	> 7 doors per 100m	-3,4%
C2.0	Walking, no stationary activities	0%
C2.1	Walking, necessary activities	-1,3%
C2.2	Walking, stationary, optional, and necessary activities	-2,5%
C3.0	Street width/building height 1:3 and wider	0%
C3.1	Street width/building height 2:1	-0,9%
C3.2	Street width/building height 1:1 and narrower	-1,7%
C4.0	Facades closed, passive, boring, and horizontally structured	0%
C4.1	Facades somewhat closed, some variation	-1%
C4.2	Transparent ground floor, varied, vertically structured	-2,1%
C5.0	No pedestrian facilities such as benches, technical, no identity	0%
C5.1	Designed, clean, somewhat boring, few facilities	-1,6%
C5.2	Benches, bins, other facilities, well designed, strong identity	-3,2%
C6.0	No green	0%
C6.1	Three dimensional green, trees	-1,6%
C6.2	Trees and greening, well designed	-3,2%

Table 34: Percentage variation of subjectively perceived time (in reference to objective time) with altering levels of stimulation in different walking environments

Stimulation indicated by head movements

Code	Environment that influences pedestrians' stimulation	Studied location	% variation
B1	Socially active square with attractive facades, no green	Study 12 Amagertorv	-7,5
B2	Busy pedestrian street with shops, narrow, no green	Average studies 07 - 11	-5,1
B3	Relaxing environment with scenic view, or park, few people	Study 18 Limmatquai	+2,7
B4	Boring environment, large scale and closed facades, few pedestrians	Average studies 04 - 06	+5,1
B5	Boring footpath along trafficked street	Average studies 01 - 03	+2,1
B6	Underpass, few pedestrians, no stimulation	Study 16, underpass	+7,5
B7	Complex or informal street crossing	Average studies 13 + 14	+7,5

Table 35: Calculation of the percentage variation of time spent walking as result of varying levels of stimulation (affected by walking environments as shown in Table 33 and Table 34) and different pleasant walking experiences in different walking environments (as shown in Table 32). The second column of the table shows how the percentage variation is calculated from results in Table 32, Table 33, and Table 34.

Environment typology	Code of added % values according to Table 7, 8, 9	% variation
Socially active square with attractive facades, no green	B1 + A1 + A2, +A3	-17
Busy pedestrian street with shops, narrow, no green	B2 + A2 + A3	-10
Relaxing environment with scenic view, or park, few people	B3 + A4	-1
Boring environment, large scale and closed facades, few pedestrians	B4 + A8	+9
Boring footpath along trafficked street	B5 + A8 + A5	+8
Underpass, few pedestrians, no stimulation	B6 + A8	+11
Complex or informal street crossing	B7 + A5 + A7 + A6	+14
Square with attractive facades, no shop windows, greening, few people	B1 – C2.1 – C1.3 + C6.2 + A1 + A4	-14,6
Relaxing park environment with social activity	B3 + A3 + A4 + C2.2 + C6.2	-8,7
Crowded pavement with boring facades and no green along trafficked street	B5 + C2.2 + A3 + A5 + A8 + A9	+9,7
Crowded underpass	B6 + C2.2 + A8 + A9	+13,9

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