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van Soest, Dennis; Tight, Miles R.; Rogers, Christopher D. F

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Dennis van Soest, Miles R Tight, Christopher DF Rogers

School of Engineering, University of Birmingham, Birmingham, United Kingdom

Dennis van Soest (corresponding author)
Department of Civil Engineering, School of Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
Phone: +44 (0) 7835167752
Email: dxv632@bham.ac.uk
ORCiD: https://orcid.org/0000-0002-4863-8818
LinkedIn: https://www.linkedin.com/in/vansoest/
Twitter: @dennesoes

Miles R Tight
Department of Civil Engineering, School of Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
Phone: +44 (0) 1214145071
Email: m.r.tight@bham.ac.uk
ORCiD: https://orcid.org/0000-0002-6635-8721

Christopher DF Rogers
Department of Civil Engineering, School of Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
Phone: +44 (0) 1214145066
Email: c.d.f.rogers@bham.ac.uk
ORCiD: https://orcid.org/0000-0002-1693-1999

Exploring the Distances People Walk to Access Public Transport

A shift from private motorised transport to more active transportation can, among other things, deliver significant health benefits. The main disadvantage of active transport (in particular walking) for most people compared to private motorised transport is the limited range. Public transport can complement the use of active modes and extend their range. Therefore, there might be potential to increase physical activity through an increase in public transport use. This article takes a closer look at how walking relates to the use of public transport by examining existing literature on the topic. It aims to study how far people walk to and from public transport and what key factors influence this.

Scopus, TRID and Web of Science have been searched systematically for relevant articles, conference papers and books. After screening of titles and abstracts, 41 relevant publications were identified. Studies were included if they quantified the amount of walking (measured as either distance or time) that is directly related to the use of public transport. Studies that quantified walking using general measures of daily physical activity or daily walking or that used stated preference designs were excluded. The public transport systems considered in this paper are mass transport systems in urban areas, either road- or rail-based, with fixed schedules and stops. Demand responsive transport services, which can offer door-to-door travel, are not considered, as these systems can to a large extent eliminate the need to walk.

In the identified publications, a large variety of walking distances and times have been reported, and these seem to be highly context-specific. The paper establishes the evidence for the wide range of factors that influence walking related to public transport, which have been categorised as personal, public transport-related, environmental, and journey-related. The different methods that have been used are discussed by critically analysing their advantages and limitations. Only a limited number of these methods used allow for an accurate assessment of the walking distances to and from public transport. The paper concludes with suggestions for future research, such as a need for more accurate measurement of walking and research in different geographical areas to shed light on underlying influences of culture and climate.

Keywords: walking, public transport, physical activity, access, egress

Introduction

A shift from private motorised transport to more active transportation can, among other things, deliver significant health benefits (e.g., Martin, Panter, Suhrcke, & Ogilvie, 2015). The main disadvantage of active transport (in particular walking) for most people compared to private motorised transport is the limited range. For instance, in England, 81% of the trips shorter than 1 mile are undertaken on foot or by bike[1], whilst this share drops significantly for trips more than 2 miles, with about 80% of those trips undertaken by car (Department for Transport, 2016).

Public transport (PT) can complement the use of active modes and extend the range considerably (Rietveld, 2000). For this reason, and the fact that cars bring many other well-known concerns, there might be potential for a modal shift towards active and public transport, which would decrease the use of cars and simultaneously contribute to increases in physical activity (Tight, Rajé, & Timms, 2016). Since urban planning can influence travel behaviour (Næss, Peters, Stefansdottir, & Strand, 2018), it is relevant to understand how walking relates to PT journeys in order to achieve an increase in physical activity. A frequently adopted guideline in PT planning around the world is that, based on observations, people would be willing to walk up to 400m for buses and 800m for rail transport (e.g. Canepa, 2007). It is however often found that there is a lot of variance in the real distances people walk to or from PT (e.g. El-Geneidy, Grimsrud, Wasfi, Tétreault, & Surprenant-Legault, 2014).

[1] The number of active trips might in fact be higher, due to the underreporting of short trips and exclusion of trips that are not on the public highway (e.g. walking in shops, airports, and nature).

A significant body of research, especially over the last decade, has been developed which provides more insights into public transport-related walking (PTW). This paper aims to study how far (distance or time) people walk to and from PT systems and what key factors influence this, by reviewing the existing literature on this topic. It assesses the methods used to measure PTW length, and subsequently considers which are the major influencing factors. Furthermore, it attempts to define future research needs to add further insights into PTW.

The PT systems considered in this paper are mass transport systems in urban areas, either road or rail-based, with fixed schedules and stops. Demand responsive transport services, which can offer door-to-door travel are not considered, as these systems can, to a large extent, eliminate the need to walk.

Rissel et al. (2012) have already reviewed literature on physical activity related to PT use, although the focus of that literature review was on the general physical activity that is gained by PT users. The present review takes a transport or urban planning perspective, and focuses more on PTW distances on a trip level rather than general physical activity time, as these can be more directly related to the built environment and transport characteristics, which are modifiable by planners.

Method

Three common databases used in transport studies (Scopus, Web of Science, and TRID) were searched in October 2017 for relevant studies. The scope was limited to peer-reviewed books, articles and conference papers in the English language. Potentially in scope items needed to include both walking and public transport elements. The walking aspect was represented by the key terms[2] ‘walk*’, ‘physical activ*’, ‘active commut*’, ‘active travel*’, and ‘pedestrian’. For the public transport aspect, the key terms ‘transit’, ‘public transport*’, ‘bus’, ‘rail*’, ‘tram’, ‘metro’, or ‘subway’ were used. Studies were included if they quantified the amount of walking (being in either distance or time) that is directly related to the use of public transport. Studies that quantified PTW using general measures of daily physical activity or walking, studies that only focused on walking proportions in access transport, or those that used stated preference designs were excluded, since these studies are less able to shed light on the true walking distances at the trip level.

The selection process is shown in Figure 1. The results of Scopus (*n*=5,322), Web of Science (*n*=4,495) and TRID (Transport Research International Documentation) (*n*=3,902) were merged in one EndNote library. Duplicates were removed automatically but, due to slightly different formatting in the three databases, many were not detected by the system. All titles were screened for precise alignment with regard to the inclusion criteria, and 384 records were left in the database for potential selection. For these records, the abstract was checked and, where there was doubt, also parts of the full text. In the end, 35 studies were selected for the review. Six studies were published after the initial search process and included later. The reference lists of all publications were checked as well.

[2] (*) can represent any character(s)

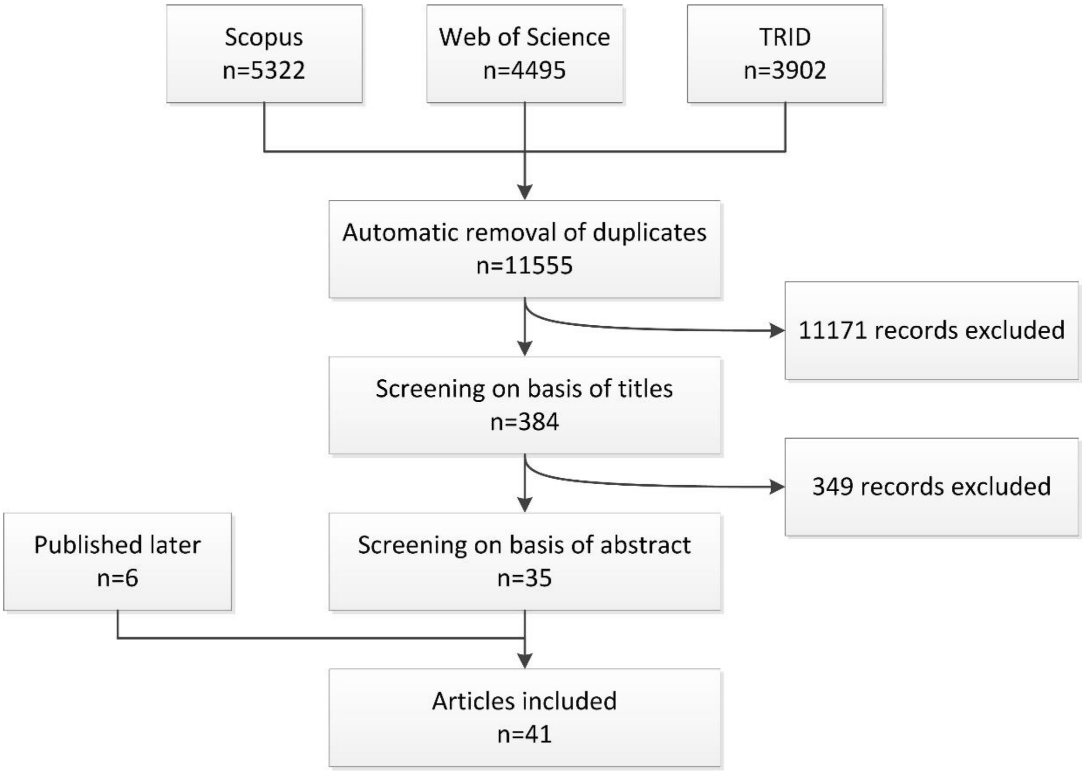

Figure 1: Article selection process

The studies identified are listed in Table 1. The table provides information on the country of study, the PT modes considered (bus, bus rapid transit (BRT), tram, metro, light rail (LRT) and train) and which aspects of walking were considered. In one round-trip by PT, four types of walking stages can be distinguished; it is either at the home or activity end of a journey, and either an access trip (towards PT) or an egress trip (from PT).

Table 1. Overview of studies concerning walking distance or time to public transport

Study	Public transport mode	Major data source	Physical activity
Agrawal et al. (2008) San Francisco, USA Portland, USA	LRT	Survey at 5 stations, with map n=328 travellers (18+)	Traced walking route distance to PT
Alshalalfa & Shalaby (2007) Toronto, Canada	Bus, metro	Transportation Tomorrow Survey Toronto; n=15830 morning peak trips	Straight-line distance to PT
Besser & Dannenberg (2005) USA	Bus, train	National Household Travel Survey; n=3312 trips (travellers 18+)	Self-reported time to/from PT
Chaix et al. (2014) Paris, France	Bus, tram, metro, LRT, train	Survey with accelerometer and GPS; n=234 adults	Physical activity time related to PT use
Chia et al. (2016) Brisbane, Australia	Bus	South-East Queensland Household Travel Survey; n=679 trips (adults, 18+)	Self-reported time to PT
Daniels & Mulley (2013) Sydney, Australia	Bus, train	Sydney Household Travel Survey; n=1906 trips	Shortest network distance to PT
Day et al. (2014) New York, USA	Bus, BRT	Survey at 3 bus stop pairs; n=403 travellers (18+)	Self-reported distance to PT in blocks
Durand et al. (2016) California state, USA	Bus, train	California Household Travel Survey; n=400 trips (children, 5-17 y/o)	Self-reported time to/from PT
El-Geneidy et al. (2014) Montreal, Canada	Bus, metro, train	Montreal OD survey; n=16014 trips	Shortest network distance to nearest PT stop on used route
Evans & Addison (2009) UK	Train	National Travel Survey; n=5749 trips	Self-reported distance to/from PT

Study	Public transport mode	Major data source	Physical activity
Freeland et al. (2013) USA	Bus, train	National Household Travel Survey; n=4195 trips	Self-reported time to/from PT
Garcia-Palomares et al. (2013) Madrid, Spain	Metro	Madrid Household Mobility Survey; n=17000 trips	Shortest network distance to/from PT
He et al. (2018) Nanjing, China	Metro	Survey at 6 stations, origins marked on map; n=611 passengers	Shortest network distance to PT
Hoback et al. (2008) Detroit, USA	Bus	On-board travel survey, with information on origins	Shortest network distance to/from/in PT for several route options
Jiang et al. (2012) Jinan, China	BRT	Survey at 19 stations, with map; n=1233 travellers	Traced walking route distance to/from PT
Johar et al. (2015) Delhi, India	Bus	Survey at various stations about walking distances; n=1748 commuters	Self-reported distance to/from PT
Ker & Ginn (2003) Perth, Australia	Train	Survey at 5 stations, with map	Distance to/from PT
Kim (2015) San Francisco, USA	LRT	Following people from 2 stations; n=139 travellers (18+)	Measured distance and time from PT
Kim et al. (2010) Busan, South-Korea	Bus, LRT	Survey at 6 stations, with map; n=600 travellers	Traced walking route distance to/from PT
Kim & Nam (2013) Seoul, South-Korea	LRT	Surveys at 7 stations, with information on destinations; n=635 travellers	Shortest network distance to/from PT
Krygsman et al. (2004) The Netherlands	Bus, tram, metro, train	Dutch national travel survey; n=1700 trips (travellers 12+ y/o)	Self-reported time to/from PT
Lam & Morrall (1982) Calgary, Canada	Bus	Survey at stops in 5 areas, with map	Traced walking route distance to/from PT

Study	**Public transport mode**	**Major data source**	**Physical activity**
Li & Deng (2015) Shanghai, China	LRT	Survey at 5 stations, with map; n=317 travellers	Traced walking route distance to/from PT
Morency et al. (2011) Montreal, Canada	Bus, metro, train	Montreal OD survey; n=31950 trips	Shortest network distance to/from PT and calculating amount of steps
O'Sullivan & Morrall (1996) Calgary, Canada	LRT	Survey at 23 stations, with information about origins/destinations; n=2294 travellers (18-65 y/o)	Distance of likely walking route to/from PT
Patterson et al. (2018) UK	Bus, LRT, train	National Travel Survey; n=3638 trips	Self-reported time to/from PT
Petersen (1968) Washington D.C., USA	Bus	Survey of bus riders with information about origins/destinations; n=2448	Distance of likely walking route from home to PT
Ratanawaraha et al. (2015) Bangkok, Thailand	LRT	Survey aboard trains from 34 stations; n=1020 travellers	Self-reported distance to/from PT
Rodriguez-Gonzalez & Aguero-Valverde (2017) San José, Costa Rica	Bus	Survey at 10 stops, with map	Traced walking route distance to/from PT
Seneviratne (1985) Calgary, Canada	Bus, LRT	Surveys in CBD; n=886 travellers	Traced walking route distance to PT
Sun et al. (2016) Beijing, China	Metro	Walking together with travellers; n=495 adults (18-65 y/o)	Measured time from PT
Townsend & Zacharias (2010) Bangkok, Thailand	LRT	Following people from 6 stations; n=1489 travellers	Measured distance from PT

Study	Public transport mode	Major data source	Physical activity
Vandebona & Tsukaguchi (2013) Japan	Bus, train	Postal survey in 15 cities; n=3560 individuals	Time to/from PT
Voss et al. (2015) Vancouver, Canada	General	Survey with accelerometer and GPS; n=42 high-school students (12-14 y/o)	Measured time to/from PT
Wang & Cao (2017) Minneapolis-St Paul, USA	Bus, LRT	On-board survey with information on destinations and used stations; n=7077 travellers	Shortest network distance from PT
Wasfi et al. (2013) Montreal, Canada	Bus, metro, train	Montreal OD Survey; n=6913 trips (18+, to school/work)	Shortest network distance to/from nearest PT stop on used route
Xi et al. (2016) Toronto, Canada	Metro	Transportation Tomorrow Survey Toronto; n=21470 trips	Straight-line distance to PT
Yu & Lin (2016) USA	General	National Household Travel Survey; n=18180 trips	Self-reported time to/from PT
Zacharias & Zhao (2017) Beijing/Tianjin/Shenzhen, China	Metro	Following random passengers in 43 walking environments with GPS; n=2409 passengers	Traced walking route distance from PT
Zhao & Deng (2013) Nanjing, China	Metro	Survey at 16 stations, with map; n=1544 peak-hour travellers	Traced walking route distance to/from PT
Zuo et al. (2018) Cincinnati, USA	General PT	GPS-based household travel survey; n=1330 trips	Tracked walking route to/from PT

Measuring Public Transport-Related Walking

The methods used are important in comparing the different studies, as they largely determine the quality of the results. Some methods allow more factors influencing PTW to be taken into account, while others might give a limited, but perhaps more accurate, picture of the walking characteristics. The different studies are discussed according to the main method that was used to assess the amount of walking in PT journeys. Firstly, studies that use subjective data as a major data source are discussed, meaning that the data regarding PTW distances were self-reported by participants. The second section deals with studies using more objective methods to measure PTW distances.

Studies Using Subjective Data

Examining data from national/regional surveys

A group of studies use data coming from national travel surveys or other regional/local surveys by governmental bodies or PT operators. In such surveys, the focus is typically on travel time rather than distance, because this is easier to estimate for respondents. People usually need to register all their trips in a travel diary for a certain period of time, often including the origins and destinations, the (main) mode used, the start and end time, and possibly other characteristics. Table 2 presents the results of such studies, in which there appears to be some variance across countries and according to the type of PT.

Table 2. Overview of studies considering walking distances to/from public transport, using national travel surveys

Study	Sample	Result	
		Mean	**Median**
Besser & Dannenberg (2005) USA, n=3312 Bus, train	Adults walking to/from PT	24.3 min/day	19.0 min/day, 4.0 min/trip
Chia et al. (2016) Australia, n=679 Bus	Bus users, 18+	6.62 min	
Durand et al. (2016) USA, n=400 Bus, train (State-wide survey)	Children 5-17 y/o using PT		21 min/day
Evans & Addison (2009) UK, n=5749 Train	Surface rail journeys	1077m (access+egress, within London), 872m (one end in London), 795m (outside London)	
Freeland et al. (2013) USA, n=4195 Bus, train	Adults walking to/from PT		21 min/day
Krygsman et al. (2004) Netherlands, n=1700 Bus, tram, metro, train	PT users 12+ y/o	5.9 min (bus), 9 min (train)	
Patterson et al. (2018) UK, n=3638 Bus, LRT, train	Passengers walking to/from PT	28.1 min/day (train), 16.0 min/day (bus)	
Yu & Lin (2016) USA, n=18180 General PT	Adults walking to/from PT	7.6 min (home) 7.87 min (activity)	

The reliability of these walking times reported is however doubtful. In the USA's National Household Travel Survey, participants record their trips for 24 hours in a relatively limited travel diary, but additional questions are asked in a follow-up telephone interview, including questions about the access and egress modes for PT trips and the respective travel times (U.S. Department of Transportation, 2004). In the English survey, participants are requested to record their trips for a period of seven days. They have to report all trip stages, which are the trip parts completed by different modes or leading to intermediate destinations (e.g. access and egress walks). However, walks under 1 mile (1.6 km) are only registered on the first day (seventh day in earlier editions), to reduce respondent burden (NatCen Social Research, 2017), which implies that many short walks to/from PT are not reported. There can also be confusion about, for instance, how walks with intermediate destinations should be reported.

The usage of self-reported data can also lead to underreporting, as people can forget to include certain trips, particularly short walk trips. Sometimes only half of actual transport and activity gets reported (Ong, 2014). Self-reported duration might also be subject to experiential influences and people have a tendency to round times at 5 minute intervals (e.g., Chia et al., 2016), even though every minute of difference has a relatively large impact with regard to short walking stages.

Besides large-scale national surveys, several studies used secondary data from other mobility surveys. As these studies are carried out in a smaller spatial area, they can include more detailed data about the trips, sometimes enabling a finer analysis. These studies typically contain origin and destination data and construct potential walking routes by calculating the shortest path to the used stop or station (Alshalalfah & Shalaby, 2007; Daniels & Mulley, 2013; García-Palomares et al., 2013; Morency et al., 2011; Wang & Cao, 2017). In two studies (El-Geneidy et al., 2014; Wasfi et al., 2013), only the public transport route used was known, so the walking route to the nearest station or stop on that service was assumed to be used. Table 3 presents an overview of some results from these studies, in which distances clearly differ per mode and often exceed the conventionally assumed limits of 400/800m.

Table 3. Overview of studies considering walking distances to/from public transport, using secondary data sources other than national travel surveys

Study	Result						
	Mode	**Average**	**Percentiles**				
			25%	**50%**	**75%**	**85%**	
Alshalalfa & Shalaby (2007) Canada, n=15830	Bus Metro			+100m			
Daniels & Mulley (2013) Australia, n=1906 trips	Bus Train	461m 805m	162m 539m	364m 749m	655m 1018m		
El-Geneidy et al. (2014) Canada, n=16014 trips	Bus (city centre) Metro Train	276m 565m 818m		214m 527m 785m	371m 731m 1103m	484m 873m 1259m	
Garcia-Palomares et al. (2013) Spain, n=17000 trips	Metro	420m		375m			
Wang & Cao (2017) USA, n=7077 trips	Bus LRT	464m 657m				815m 1092m	
Wasfi et al. (2013) Canada, n=6913	Bus Metro Train	12-40 min both ways 20-35 min 35-50 min					
Xi et al. (2016) Canada, n=21470 trips	Metro (Pedestrian catchment)	707m					

Custom Surveys at Stations

Another group of studies conducted custom surveys at stations, which frequently included maps on which the participants indicated their (approximate) origin and/or destination (He et al., 2018; Ker & Ginn, 2003; Heungsoon Kim & Nam, 2013; O’Sullivan & Morrall, 1996; Petersen, 1968). In addition to origins and destinations, several researchers asked travellers to trace their walking route (Agrawal et al., 2008; Jiang et al., 2012; K. W. Kim et al., 2010; Lam & Morrall, 1982; Li & Deng, 2015; Seneviratne, 1985; Zhao & Deng, 2013). These studies could therefore provide a better idea of the real walking routes, since they did not reconstruct walking routes based on certain assumptions. For example, although PTW distance tends to be minimised (Agrawal et al., 2008), the often-assumed shortest path in these reconstructions can underestimate the real walked distance (Hess, 2012), as various factors can lengthen walking routes, such as the (un)attractiveness of certain paths (Hyungkyoo Kim, 2015), accompaniment, or the need to visit other destinations en-route. To get insights into the chosen routes, Agrawal et al. (2008) asked respondents to indicate avoided places besides tracing the routes walked. Yet, these tracing studies assume that participants are all able (and willing) to trace their real routes correctly on a map. This is not an easy task for everyone, as implied by O'Sullivan and Morrall (1996) in which route tracing was left out due to difficulties experienced by the participants.

Johar et al. (2015), Ratanawaraha et al. (2015) and Vandebona & Tsukaguchi (2013) only used self-reported distances, which can be rather unreliable. Day et al. (2014) measured distance in street blocks, which is more reliable as a self-reported measure, but only useful in grid-structured areas and inaccurate where block sizes vary. Table 4 lists the findings of the most accurate studies using map tracing. Similar to the previously discussed methodology, a highly variable distribution of distances emerges.

Table 4. Overview of findings regarding walking distances using map tracing studies

Study	**Result**					
	Mode	**Average**	**Percentiles**			
			25%	**50%**	**75%**	**85%**
Agrawal et al. (2008) USA, n=328	LRT	837m	435m	756m	1094m	
Chaix et al. (2014) France, n=234	Bus, tram, metro, LRT, train	1.6-2.9 minutes of physical activity more per 10 minutes of trip time than car users.				
Jiang et al. (2012) China, n=1233	BRT	549m (typical) 586m (transfer) 1392m (terminal)		435m 458m 1311m		

Study	Result					
	Mode	Average	Percentiles			
			25%	**50%**	**75%**	**85%**
Kim et al. (2010) South-Korea, n=600	Subway Bus	564m (CBD) 499m (sub-CBD) 447m (regional) 430m (CBD) 372m (sub-CBD) 339m (regional)				
Lam & Morrall (1982) Canada	Bus	327m 170-373m, depending on service and area		292m	450m	
Li & Deng (2015) USA, n=317	LRT		+/- 500m	+/- 675m		980m
Rodriguez-Gonzalez & Aguero-Valverde (2017) Costa Rica, n=305	Bus	310m	150m	250m	400m	
Seneviratne (1985) Canada, n=886	Bus LRT	250m 287m		215m 265m		
Voss et al. (2015) Canada, n=42 children	General	9 minutes of physical activity per school trip				
Zhao & Deng (2013) China, n=1544	Metro	882m (typical) 682m (transfer) 1291m (terminal)		821m 624m 1094m		

Studies Using Objective Data

Surveys Including Objective Tracking

Some studies included objective measurement tools such as GPS-trackers combined with accelerometers (Chaix et al., 2014; Voss et al., 2015; Zuo et al., 2018). This type of method can accurately track travel behaviour in a detailed way, assuming that the participation does not affect behaviour. Except for Zuo et al. (2018), these studies were conducted in the field of public health and were therefore more focussed on the health benefits of PT usage, rather than PTW distances and influencing factors related to the transport system and built environment.

Observational Studies

In three studies, researchers followed travellers on their trip from PT towards their destination (Hyungkyoo Kim, 2015; Townsend & Zacharias, 2010; Zacharias & Zhao, 2017). The travellers were unaware of their participation in the study, which perhaps gives the best representation of real walking behaviour, assuming that the participants did not notice the researchers who were following them. However, for both practical and ethical reasons, these studies could not reveal much detailed information about other factors, such as the participants, and only egress trips could be taken into account.

Finally, in one study (Sun et al., 2016), researchers walked together with participants from a metro station towards their destination while they recorded the route. Compared to the methodology of following people, travellers in this case were aware of their participation in a study, which potentially influenced their walking activity. However, the opportunities to ask questions and, for instance, gather perceptions about the built environment are beneficial.

Factors of Influence

Various studies considered factors that possibly influence PTW, which can be categorised as personal factors (relating to the traveller and his/her household), factors referring to characteristics of the PT service, environmental factors, and factors related to the journey. Although studies often identified the effects of several factors, not all studies used statistical tools to assess their significance. This section reviews the available evidence in the literature concerning the factors that influence the PTW distance (or time), considered in at least two publications. Table 5 presents an overview of the relative effects reported in the publications reviewed.

Table 5 Overview of effects per study ([+] positive, [-] negative, [n] n-shaped effect, [u] u-shaped effect, [/] insignificant; double signs indicate a relatively strong effect)

Study	**Gender: Female**	**Age**	**Available vehicles**	**Driving licence**	**PT card**	**Household size**	**Income**	**Education**	**Employment**	**Ethnicity: white**	**PT frequency**	**PT type (rail > bus)**	**Density**	**Location: CBD**	**Purpose: work**	**Time: morning**	**Trip length**	**Transfers**	**Frequency of use**
Distance based																			
Alshalalfa & Shalaby (2007)	-	/	+	+	-						++	++	-	--	/	/		-	
Daniels & Mulley (2013)	/	nn	/	/	--		+		++			++			++	-	+		
El-Geneidy et al. (2014)	-	-	+			+	+				+	++	-	-	+	-	+	-	
Garcia-Palomares et al. (2013)	-	n	+							+									
He et al. (2018)	/	nn					--								+				u
Jiang et al. (2012)	/	/	/				--		/					-	/				/
Johar et al. (2015)	-	/					-								+				
Kim (2015)	/																		
Kim et al. (2010)	+	-	-				-		/					+					/
Kim & Nam (2013)	-	/	/				/		/					/	+				
Lam & Morrall (1982)											+			-					
Morency et al. (2011)	-	-										++		-	++				
O'Sullivan & Morrall (1996)	-													--					
Petersen (1968)							-												
Townsend & Zacharias (2010)	/	/											/		--				
Wang & Cao (2017)				-								++	++	--	-		-		
Wasfi et al. (2013)	-	-					++				+	++	/			/			
Zacharias & Zhao (2017)													/						
Zhao & Deng (2013)	/	nn					/		/					-	/	+			
Zuo et al. (2018)			-				-							--					
Time based																			
Besser & Dannenberg (2005)	+	/	++				--	--		--		/	+						
Chaix et al. (2014)												++							
Chia et al. (2016)		-																	
Durand et al. (2016)	/	/	/	--		/	--		/	--		+							+
Freeland et al. (2013)	/	/	-				--	-	/	-									
Krygsman et al. (2004)	+	-	/			-			+			++	+	-			+	-	
Patterson et al. (2018)	-	n	+				-			+		++							
Sun et al. (2016)	/	/											+						
Yu & Lin (2016)	/		/				-	u		-			--		+				

Personal

Gender

The studies that found a gender effect mostly reported that women tend to walk shorter distances than men. Feelings of a lack of safety, which are more prevalent among women, might play a role. There are, however, some studies in which women were found to walk for longer (Besser & Dannenberg, 2005; Krygsman et al., 2004), making the role of gender in walking to and from public transport less clear. Gender could be strongly related to cultural aspects. The share of women in the workforce (The World Economic Forum, 2016) and, related to this, responsibilities in the household, can vary significantly between countries, leading to different gender effects in travel behaviour. Other cultural norms regarding clothing and activities can affect travel patterns as well (Almahmood, Scharnhorst, Carstensen, Jørgensen, & Schulze, 2017). This suggests that the gender effect on PTW can be explained to a large extent by factors such as differences in travel purpose and car availability, which vary through cultural norms.

Age

Studies that found a significant age effect typically discovered that people in the youngest (i.e. children, youth) and oldest age-categories tend to walk less and shorter distances than younger adults. This is a very logical pattern, which is likely related to factors such as the physical abilities of the person and differences in activity-travel schedules. Moreover, especially younger children are dependent on permission from their parents or guardians to walk and use PT. Although some studies found a negative relationship between age and walking distances (El-Geneidy et al., 2014; Morency et al., 2011; Wasfi et al., 2013), this might be due to the analysis tools used, as most common statistical methods can detect linear effects only.

Available vehicles and the possession of a driving licence or public transport pass

People who have more private vehicles available generally walk less, but the PTW distances are often found to be longer. This can be explained by the fact that in most studied areas, the people with more vehicles tend to live further from the PT services than the people who are more dependent on this form of transport, perhaps partly due to self-selection of home locations. Often, areas with higher car ownership levels have lower densities, implying that PT services are less financially viable, which leads to longer walking distances.

A similar effect can be expected for the possession of a driving licence, although it is perhaps a weaker indicator for the dependence on PT than the availability of private vehicles. Alshalalfa and Shalaby (2007) found that PT riders walk further if they have a driving licence, whilst Daniels and Mulley (2013) showed it was insignificant. Arguably, the possession of PT passes has a stronger and inverse influence. As pass-holders usually need to pay a monthly or annual fee, they are likely regular PT users, who can be expected to live closer to PT-systems (Alshalalfah & Shalaby, 2007; Daniels & Mulley, 2013), although free passes can increase PT use as well (e.g. Coronini-Cronberg, Millett, Laverty, & Webb, 2012). The possession of a driving licence, in contrast, is for a long term and does not necessarily imply that one has regular access to a vehicle.

However, the particular study area and related housing situation influences this effect, as contrasting results were found by Jiang et al. (2012). They distinguished captives and choice riders, and found that captives walk longer distances to BRT systems. This is almost certainly due to the freedom of choice riders, who can choose another transport mode if they find the distance to PT too long, although Chia et al. (2016) did not find significant differences between captives and choice riders.

Household size and housing type

Two studies found a significant influence of household size. El-Geneidy et al. (2014) found PTW distances to be on average about 7 metres per trip longer per additional person in the household. On the other hand, Krygsman et al. (2004) saw a decrease in PTW time if there were young children in the household.

Similarly, five studies looked at the influence of the type of housing. Alshalalfa and Shalaby (2007) discovered that people living in apartments walk shorter PTW distances than people living in houses. Two South-Korean studies (Heungsoon Kim & Nam, 2013; K. W. Kim et al., 2010), however, found the opposite effect. Additionally, Patterson et al. (2018) discovered that people living in rented houses walk less than house owners and Durand et al. (2016) saw an increase for people living in mobile homes compared to single-family attached homes. Generally, smaller households and smaller dwellings like apartments tend to be located in areas with higher densities and higher availability of PT services, leading to shorter PTW distances, but the effect relies on the characteristics of the built environment of the study area.

Income

North-American and Australian studies found a positive relationship between income and PTW distance (Daniels & Mulley, 2013; El-Geneidy et al., 2014; Wasfi et al., 2013), whilst Asian and European studies found a negative one (He et al., 2018; Jiang et al., 2012; Johar et al., 2015; K. W. Kim et al., 2010; Patterson et al., 2018). The North-American studies that focus on PTW time instead of distance also found a negative effect (Besser & Dannenberg, 2005; Durand et al., 2016; Freeland et al., 2013; Yu & Lin, 2016).

The variability in results indicates that the effect of income depends on the study context. Income can be associated with the housing situation, as well as vehicle availability and the type of job or lifestyle and related travel-patterns. Moreover, cultural aspects are likely to play an important role. In some cultures, PT (particularly bus) has a very low status, implying that people with a higher income do not use it much. In other cultures, PT is also used by travellers from higher income-classes (e.g. Buehler & Pucher, 2012).

Employment and Education

People who work fulltime (Daniels & Mulley, 2013), or households with dual income (Krygsman et al., 2004) were found to walk more. Patterson et al. (2018) discovered that people with managerial occupations walked more than those with intermediate or routine occupations. Finally, Wasfi et al. (2013) found that students walk further than others. An associated indicator is the level of education, which was studied in three North-American publications, all finding a negative effect on PTW time (Besser & Dannenberg, 2005; Freeland et al., 2013; Yu & Lin, 2016). The effect of employment or education on PTW appears to be weak, and is expected to be related to income and household type.

Ethnicity

In North-American studies, white people were found to walk shorter PTW distances than other ethnicities (Besser & Dannenberg, 2005; Durand et al., 2016; Freeland et al., 2013; Yu & Lin, 2016), whilst European studies found white people to walk further (García-Palomares et al., 2013; Patterson et al., 2018). This effect is likely partially related to income, and, similarly, dependent on culture and status of PT services.

Public transport characteristics

Type

The type of PT appears to be an important factor for the access and egress walking distances. Also in the traditional guidelines walking distance to rail transport is assumed to be double the walking distance to buses (800m and 400m). People tend to walk longer distances to trains, then metro or LRT, and the shortest to buses. It could be stated that the longer the range of the mode, the longer the walking distances to and from that mode, although this can be biased by the total trip length (Krygsman et al., 2004). The effect can partly be attributed to the perceived status of the mode, as there tends to be a preference for rail-borne transport (Anderson, Nielsen, & Ingvardsson, 2016).

Frequency

Four Canadian studies revealed a positive influence of bus frequency on the PTW distances (Alshalalfah & Shalaby, 2007; El-Geneidy et al., 2014; Lam & Morrall, 1982; Wasfi et al., 2013). Because a higher service frequency is associated with a higher level of travel comfort (e.g. less waiting time or planning effort), these results confirm the expectations that PT riders are willing to walk more if the offered service is better. They are consistent with the findings of stated preference surveys by Rose et al. (2013) and Mulley et al. (2018). The evidence should be strengthened by research in other contexts.

Station function and route spacing

Three studies in China and Canada (Jiang et al., 2012; O'Sullivan & Morrall, 1996; Zhao & Deng, 2013) found that people walk longer distances to terminal stations of a public transport line than other stations, which is reasonable due to the lack of further boarding possibilities.

Only Alshalalfa and Shalaby (2007) directly studied route spacing as a factor influencing the PTW distance. They compared three sets of parallel routes, spaced differently from each other. Their results pointed in the logical direction that the PTW distance decreases if the density of PT routes increases. The association was not distinct, though, which could relate to differences in service quality of the studied routes. Wang and Cao (2017) found a negative effect of the number of PT stops on the PTW distances.

Environment

Density

Density can impact PTW distances through various mechanisms. If the density is higher around the PT stop, on average the origins or destinations are closer, and the density of PT services will often be higher as well. Therefore, the distances people need to walk decrease. However, density can also relate to better walkability characteristics, which can attract more walkers, either through increasing the share of walking to access/egress transport, or by expanding the catchment area around the stop. Moreover, the distances people choose to walk can be lengthened. A lower density of the built environment can also lead to lower expectations of PT services, and higher acceptability of longer walking distances (Vandebona & Tsukaguchi, 2013).

Station location

In most studies, people walk shorter distances to and from PT stops located closer to the central business district (CBD). This is likely related heavily to a higher density of stops and stations, which reasonably leads to shorter distances that people need to walk. Kim et al. (2010) however found the opposite effect, which might relate to the finding that land use variety can significantly lengthen the distance people choose to walk (Zacharias & Zhao, 2017).

Walkability

As described earlier, Jiang et al. (2012) found that people walk further to stations on a more walkable corridor. El-Geneidy et al. (2014) studied the effect of street connectivity, and found a positive relationship, whilst for Wasfi et al. (2013) this was insignificant. A positive relationship would be in line with other walkability research, in which street connectivity often plays a role. Higher street connectivity is associated with better walkability, because it reduces the average detour compared to straight-line distance. Fewer detours also arguably leads to shorter PTW distances, as shown by Kim et al. (2010), Wang and Cao (2017) and Zacharias and Zhao (2017). Also a visually higher connectivity can lead to shorter walks (Sun et al., 2016). Park et al. (2015) studied specifically the effect of walkability on the PTW distances. Improving walkability at the micro-level for pedestrian corridors leading to a station was found to increase the distances people are willing to walk. This suggests that an increased walkability can shorten the distances people need to walk, but in some cases can also lengthen the distances people choose to walk.

Safety

The effect of (the perceptions of) safety can be related to traffic or crime. The influence of crime characteristics on the PTW distances is not well researched. There is evidence that crime levels have a negative impact on the probability of walking to PT or using PT at all (S. Kim, Ulfarsson, & Hennessy, 2007; Tilahun & Li, 2015). Additionally, the researchers who considered the effect of different station types (Jiang et al., 2012; Zhao

& Deng, 2013) associate this partly to differences in crime perceptions. Agrawal et al. (2008) found that the route choice to PT is influenced by safety issues, but rather related to traffic than crime.

Weather

O'Sullivan and Morrall (1996) reported that weather influenced the choice of some respondents to use PT or walk directly to the destination. It is however rarely explicitly addressed in the research around PTW, although in Canada, Lam and Morrall (1982) found longer PTW distances in winter time than in summer. This was rather surprising, but, according to the authors, might be related to a lower availability of shortcuts due to snow and ice.

Journey

Purpose

Generally, people undertake longer PTW trips for journeys to work than for other purposes. Some studies however found that some other purposes led to longer distances (Krygsman et al., 2004; Morency et al., 2011; Sun et al., 2016; Townsend & Zacharias, 2010; Wang & Cao, 2017).

Time of day

Four studies considered the time of day as an explanatory variable. Daniels and Mulley (2013) and El-Geneidy et al. (2014) found that PTW distances are longer in the evening, whereas Zhao and Deng (2013) found longer distances in the morning. The evidence for an effect of the time of day on PTW distances is not yet strong. The effect is presumably strongly related to daylight and travel purpose with, for instance, a high share of work-related trips in the typical peak hours.

Trip length

Trip length effects were studied in six publications. Although Wang and Cao (2017) found a negative elasticity of -0.06, it was generally discovered that longer PT journeys lead to longer walking distances as well (Daniels & Mulley, 2013; El-Geneidy et al., 2014). The ratio between access/egress distance and total distance, however, reduces slightly (Krygsman et al., 2004).

Transfers

The number of transfers in a PT trip was negatively related with PTW distances or times (Alshalalfah & Shalaby, 2007; El-Geneidy et al., 2014; Krygsman et al., 2004), except for metro-journeys (Alshalalfah & Shalaby, 2007). This is arguably related to the undesirability and perceived inconvenience of transfers (Hine & Scott, 2000), which could imply that people are also less willing to make an effort to walk to and from the PT-system. Because metro systems typically offer high quality service with high frequencies, the transfers are much less onerous, which makes their influence on PTW distances insignificant.

Frequency of use

Of the three studies examining the influence of usage frequency, only He et al. (2018) found that people who rarely or very often travel walk further than people who travel regularly. Durand et al. (2016) also found that children or adolescents have longer daily PTW times when adults in the household use PT as well.

Type of walking stage

Many studies do not distinguish between the home and activity side, or access and egress trips. If they do so, almost all studies focus on the home side and/or the access trip. Exceptions are Kim (2015), Townsend and Zacharias (2010) and Wang and Cao (2017), who focus on egress journeys only. Differences between walking stages can occur, mainly because the availability of modes is usually different at the activity-side (Krygsman et al., 2004) and trips between two points can be asymmetrical (Bailenson, Shum, & Uttal, 2000).

There is little knowledge available about how home and activity side differ, and how particular activity characteristics might affect this. Both Krygsman et al. (2004) and Yu and Lin (2016) considered a journey from home to work, and found activity side walking trips to be slightly longer than at the home side.

Conclusions and Future Research

Using Public Transport regularly has been shown to positively influence health, as PT journeys often include access and egress trips on foot. A number of studies have examined these walk stages in more detail and attempted to quantify their lengths, with varying results. The conventionally assumed 400m or 800m thresholds for walking for bus and rail transport respectively tend to be inaccurate in many cases. How far people walk to and from public transport is dependent very much on the particular location and circumstances, ranging from an average distance of 170m to buses in Calgary, Canada (Lam & Morrall, 1982) to an average of 1392m to terminal BRT stations in Jinan, China (Jiang et al., 2012).

The relevant studies identified have adopted a range of methods to study PTW. These include (1) the examination of data from national or regional travel surveys, (2) conducting questionnaire surveys at stations, sometimes including map-tracing, (3) following or walking with passengers, and (4) tracking passengers using GPS-devices and accelerometers.

The first method in particular can be questioned regarding its accuracy. Short walk stages that function as access or egress trips related to another main mode are often underreported in national surveys. Also studies using the second method frequently assume that travellers take the shortest path. Studies that attempt to accurately report walking distances are those using methodologies in which routes are traced on a map, in which travellers are followed, GPS/accelerometer tools are used, or in which researchers walk together with the travellers. Hence, there is only a very limited amount of research on real PTW distances.

As results differ greatly across study locations (e.g. Agrawal et al., 2008; Daniels & Mulley, 2013; Wang & Cao, 2017), factors that potentially influence the PTW were considered. In the existing literature, a range of factors have been found to play a role, although the strength of the evidence for each factor differs. The results were sometimes contrasting, showing the need for more research in different urban settings to explore the influence of certain factors in a more detailed way. One of the restrictions is that many factors are related to each other, making it more difficult to study effects separately. Moreover, the current research has a very limited ability to distinguish demand and supply effects on walking distances. The research has been able to find how much people currently walk to and from PT (demand), but not which other options were available to them (supply). The effects of changes in PT services could not be established either, as well as the characteristics of those that did not use the current PT services.

A limitation of the review is that a large amount of relevant research on this topic is possibly available within public transport operators or consultants, but this body of research is hard to access. The review was also limited to publications in the English language, which can restrict the inclusion of research from some areas of the world where other languages are used.

An attempt has been made to design a preliminary conceptual framework of influences on PTW distances, based on the underlying key factors revealed in the discussion of the established evidence, as shown in Figure 2. The factors are separated into supply (defining the need to walk) and demand (defining the willingness to walk), and factors that are directly modifiable by urban or transport planning authorities are distinguished from non-modifiable factors.

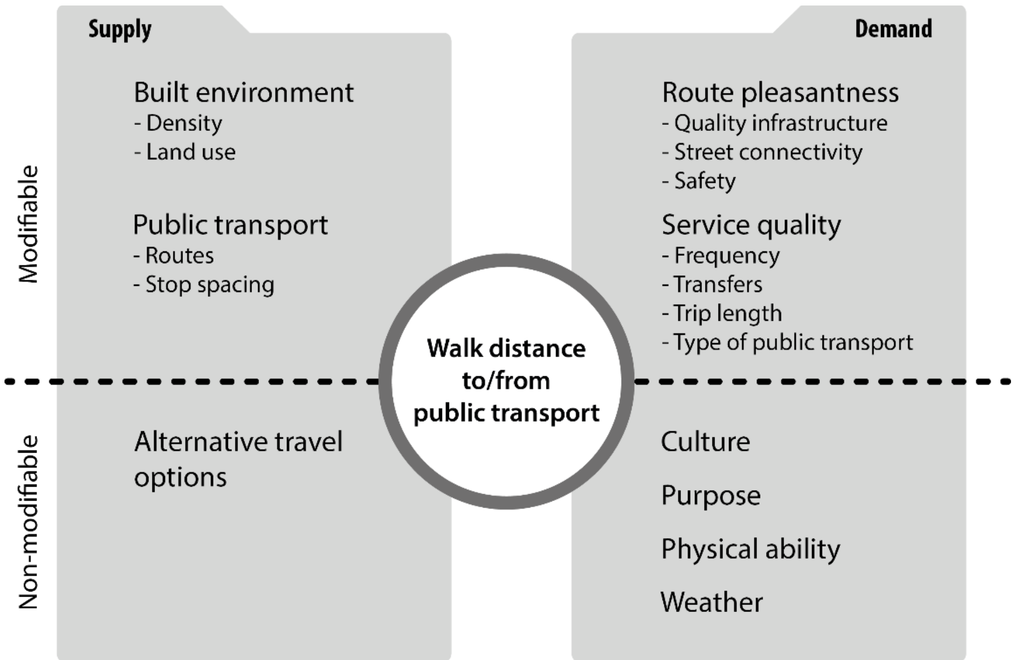

Figure 2. Preliminary conceptual framework to explain PT-related walk distances

Whereas the non-modifiable factors define the context in which PTW takes place, the modifiable influences can be used by urban or transport planning authorities to influence the distances people walk to and from PT. The alternative travel options available determine whether someone is PT-captive or not, which is considered as a personal situation in this framework and therefore non-modifiable. This can be influenced to some extent, for example through car restrictive policies.

The factors that are found to influence PTW do not fundamentally differ from factors that have been found to affect urban walking in general, particularly regarding built environment characteristics (e.g., Saelens & Handy, 2008; Van Holle et al., 2012). Specific to PTW are the attracting characteristics of PT that affect how far someone is willing to walk, along with the PT services offered and the transport options available to people that define the need for walking a certain distance to/from PT.

Future research

One of the limitations of the established evidence is that the studies that provide information about most of the factors did not address PTW using an accurate method. They made assumptions about using the shortest path (Daniels & Mulley, 2013), or using the nearest stop (El-Geneidy et al., 2014), or they used a simple straight-line distance (Alshalalfah & Shalaby, 2007).

There is a need for more accurate measurements of PTW. The use of GPS-devices and accelerometers can give detailed results, but studies that deployed these devices have focussed on measuring physical activity in general and have not yet fully explored the opportunities they offer, for instance by looking closely at the walking routes taken. As these kinds of sensors are generally built into smartphones, which are possessed by most of the population in developed countries (Poushter, 2016), such methods become increasingly more accessible.

Future research should also consider more influencing factors, and especially the competition between several PT services or stations/stops. This competition is hardly considered in the existing literature and might well affect walking distances, as some studies indicate (e.g., Alshalalfah & Shalaby, 2007; Jiang et al., 2012). Considering this issue in greater detail, as well as other factors related to the spatial context, could provide valuable insights for PT planning practice. This might also reveal more about the differences between the demand and supply of walking, as this heavily influences how much someone would need to walk to be able to use public transport.

Finally, there is a lack of research in the European context. Most studies covered in this review are from North-America, Australia or Southeast Asia, even though PTW distances can be very context- and culture-specific (Jiang et al., 2012; Mulley et al., 2018). For instance, cultural effects are expected to underlie the influence of factors such as gender and income. Although this bias might relate to limiting the review to sources in English, larger projects that study PTW using a single method in several (international) contexts would be valuable. They could shed light on the large variance between the results of different studies and can also enable the influence of cultural differences and climate on PTW to be established.

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