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Walking distances to public transport in smaller and larger Norwegian cities

Aud Tennøy*, Marianne Knapskog, Fitwi Wolday

Institute of Transport Economics, Department of Mobility, Gaustadalléen 21, 0349 Oslo, Norway

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ABSTRACT

This paper contributes to the scarce empirical knowledge concerning distances and durations of walking trips to public transport in smaller cities and in European cities. Results show that walking trips to local public transport stops last 4.1–6.0 min (328–520 m), on average, in different cities, and walking trips to railway stations last 6.6–8.6 min (528–688 m). Walks are longer on the workplace side than on the home side of the journey. Walking distances to local public transport stops increase with city size. Short trips to stops increase the likelihood of using public transport for commutes. Survey results suggest that higher frequencies and direct connections are more important than shorter walks to stops to make more people commute by public transport in the smaller cities. The results may be relevant for smaller and larger cities aiming to improve public transport competitiveness versus the private car on commutes.

1. Introduction

There are several motivations for smaller and larger cities to shift mobility from private cars to more sustainable modes of transport, such as reducing greenhouse gas emissions, congestion, local pollution and noise and improving public health, well-being, inclusion, commute satisfaction and liveability (Banister, 2011, 2018; Carmona et al., 2018; Chatterjee et al., 2020; European Environment Agency, 2018; Gehl, 2010; Krogstad et al., 2015; Martin et al., 2015; Pucher and Buehler, 2010; Sallis et al., 2016; UN Habitat and World Health Organization, 2020). In the Norwegian context, this is also spurred by the long-standing objective of zero growth in passenger road traffic volumes (total vehicle kilometres travelled by private car) in urban regions (Ministry of Local Government and Modernisation, 2012, 2014, 2017; Ministry of Transport and Communications, 2013, 2017, 2021), the national walking strategy (Norwegian Public Roads Administration, 2012) and the United Nations (2017) Sustainable Development Goals.

Smaller cities aiming to achieve sustainable mobility goals face a lack of research knowledge when defining their strategies for developing land use and transport systems to attain such goals. This is because limited attention has been paid to smaller cities in previous research. Results of studies done in the context of larger cities may be useful for smaller cities, but there are important differences between them. One is that significantly lower proportions of trips are made by public transport in smaller cities compared with larger cities, as found in surveys in Norwegian (Hjorthol et al., 2014), German (Reichert et al., 2016), Portuguese (Silva et al., 2021) and North American (Sidloski and Diab, 2020) cities. However, examples from small and medium-sized Norwegian cities have shown that improvements in public transport levels of service have resulted in increased patronage (see e.g. Engebretsen et al., 2017; Nielsen, 2016, Norconsult AS, 2017), and other cities aim at achieving similar results. Important issues when designing public

* Corresponding author.

E-mail addresses: ate@toi.no (A. Tennøy), mkn@toi.no (M. Knapskog), fwo@toi.no (F. Wolday).

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transport services to attract more passengers is how far people accept to walk to public transport, and the trade-offs between walking distances to stops and other qualities of the services, like frequency and speed (McLeod et al., 2017; Nielsen et al., 2005; Walker, 2008). We return to this in Section 2. The scarcity of empirical knowledge concerning these issues in smaller cities hampers their progress. A literature study by Soest et al. (2020) found, for instance, no studies of distances and duration of walking trips to public transport conducted in smaller cities.

The paper contributes to the existing literature with novel empirical knowledge regarding the durations and distances of walking trips to public transport in Norwegian cities of different sizes, the influence of walking distance on public transport competitiveness, and what changes to public transport services are most important to attract more passengers. It presents results from a comparative case study, conducted in four Norwegian cities that vary in size from 28,000 to 1,020,000 inhabitants. All cities are largely self-contained regional cities, not smaller cities interwoven in metropolitan regions dominated by a larger city.

Two types of surveys have been conducted in the cities: one targeting employees and focussing on their commutes and another asking passengers at public transport stops about their journey. A strength of the study is its focus on concrete journeys – either the actual journey in the public transport stop survey or the commute in the commuter survey. By investigating walking distances to public transport in smaller and larger cities in the same study and by the same methods, the study both provides novel knowledge of walking distances in smaller cities and a basis for understanding how walking distances vary with city size, which might also make previous studies more useful for smaller cities. The surveys allowed for comparing trips at the home and the activity-side on public transport journeys; in contrast, most previous studies have collected data on the home side only (Soest et al., 2020).

The paper sets out to answer the following research questions:

- (i) What are the distances and durations of walking trips to public transport and how do these parameters vary between smaller and larger cities?
- (ii) How do the distances and durations of walking trips to public transport affect the competitiveness of public transport on commutes in smaller and larger cities?
- (iii) What changes are more important to improve public transport competitiveness on commutes in smaller cities and how important is reducing walking distances to stops compared with other improvements to public transport services?

Findings have been discussed with respect to what implications they might have for the planning and development of land use and public transport systems in smaller cities.

The aim of the paper is to contribute empirical knowledge and theoretical understandings that are relevant for cities of different sizes aiming at developing their land use and public transport systems in directions supporting a shift to more sustainable mobility.

The paper is organised as follows. Section 2 describes the theoretical understandings and relevant existing empirical knowledge. Section 3 covers the research design and methodology. Section 4 presents the findings, and they are discussed to answer the research questions in Section 5. Finally, Section 6 offers concluding remarks.

2. Walking distances to stops and public transport competitiveness

Differences in travel time between modes of transport have proven to be an important factor affecting the competitiveness of modes of transport (Altieri et al., 2020; Downs, 2004; Goodwin, 1996; Hägerstrand, 1970; Heinen et al., 2010; Lunke et al., 2021; Noland and Lem, 2002; Pucher et al., 2010). This is also reflected in what qualities are understood to characterise competitive public transport systems – high frequencies, short walking distances to stops (coverage), high speed, good punctuality, few and/or easy transfers, simple and logical systems, as well as reasonable fares (Curtis and Scheurer, 2016; Buehler and Pucher, 2011; dell’Olio et al., 2011; Dodson et al., 2011; Kahn et al., 2021; McLeod et al., 2017; Nielsen et al., 2005; Redman et al., 2013; Walker, 2008; 2012). Planners aiming at improving public transport competitiveness versus private cars need to prioritise between these factors. Available resources can, for instance, be used to provide either more lines with lower frequencies and shorter walking distances or higher frequencies on fewer lines and longer walking distances (McLeod et al. 2017; Nielsen et al., 2005; Walker, 2008). If acceptable walking distances to stops are either over- or underestimated, faulty analyses might result in less competitive public transport services. How far people walk to public transport is, therefore, important knowledge in the design and development of public transport systems. It is also important knowledge in land use planning to enable planners to steer development of new housing, workplaces and other activities to locations where distances to well-served public transport stops are acceptable and to organise the urban structure in ways that enable competitive public transport systems (Dodson et al., 2011; Næss et al., 2019; Newman and Kenworthy, 2015; Tennøy et al., 2014; Wägener and Fürst, 2004).

Despite the importance of knowing acceptable walking distances to public transport, the literature acknowledges that current knowledge is weak. There are frequent references to 400 m to local public transport stops and 800 m to railway stations as the rule of thumb, although authors have underlined and documented that there are large variations depending, for instance, on the public transport mode, urban context and people’s abilities and preferences (Agrawal et al., 2008; Daniels and Mulley, 2013; El-Geneidy, et al., 2014; McCormack et al., 2008; Soest et al., 2020). In their literature review, Soest et al. (2020) identified 41 relevant studies that had adopted different methods and measures to document walking distances. They distinguished between studies based on national travel surveys; questionnaire studies at stations, often combined with map tracing of actual routes; and walking along with or GIS-tracking passengers. All had challenges related to accuracy and reliability, and the results for distance and duration varied widely. Average walking distances found in studies relevant for this paper range from 170 to 549 m to local public transport stops and 805–882 m to railway stations.

All these results come with warnings that they are uncertain. For instance, many studies have referred to self-reported distances and durations of trips that are not necessarily in accordance with real distances and durations. Agrawal et al. (2008) found that mean self-reported distances to six railway stations were 11% longer than measured (real) distances. Throughout the literature, there is a common understanding that self-reported duration is more reliable than self-reported distance, because people would need to know how long it takes to walk to the public transport stop they use but would not need to know how far it is (Soest et al., 2020). This has also been demonstrated in a study by Ralph et al. (2020). When translating walking distance to walking duration or vice versa, the average walking speed for an adult is often defined as 4.8 km per hour or 80 m per minute (Bohannon, 1997; Minetti, 2000; Schimpl et al., 2011). Several studies have found that the walkability of a route affects people's perceptions of distance (El-Geneidy et al. 2014; Hillnhütter, 2016; Jiang et al., 2012; Park et al., 2015), but overall, people tend to choose the shortest path (Agrawal et al., 2008). Soest et al. (2020) uncovered that many studies do not distinguish between trips at the home and the activity side of a journey, and that those who do mostly focus on the home side.

However, average walking distances to stops should not be confused with the distance people accept to walk to public transport. Distances might, for instance, be short because the distances between activities and stops in general are short, as discussed by Daniels and Mulley (2013). When using research findings concerning walking distance to public transport in the planning and development of land use and public transport services, arguably, results for 75th percentiles might convey more about the willingness to walk compared with mean or median results.

Existing literature tends to argue that higher frequencies, straighter lines and faster services are more important than shorter walking distances to stops, if the aim is to increase patronage (McLeod et al. 2017; Nielsen et al., 2005; Walker, 2008). In their review of 74 public transport improvement studies, Redman et al. (2013) observed that all types of improvements had effects and that frequency had the strongest influence on public transport demand. However, in their meta-analysis of three different studies, Ewing and Cervero (2010) found a public transport demand elasticity of -0.29 with respect to walking distances to stops, meaning that public transport demand would decrease by 2.9% if walking distances increase by 10%. Experiences from smaller Swedish and Norwegian cities seem to support that increasing frequency is more important than reducing walking distances (Kahn et al., 2021; Nielsen, 2016).

As stated, Soest et al.'s (2020) literature review displayed that only few studies have been made in the context of European cities, and all have been made in large cities or entire countries. This is problematic for European cities and smaller cities aiming at improving public transport competitiveness, for instance, when Norwegian cities follow the National Planning Guidelines (Ministry of Local Government and Modernisation, 2014) and define walking distance to public transport as a criterion to decide what can be built in specific locations (Trondheim Municipality, 2020). It is also a problem when they seek to optimise their public transport services to become more competitive.

We use the term 'walking distance to public transport' or 'walking distance to stops' when not distinguishing between types of stops. We use the terms 'walking distance to local public transport stops' and 'walking distance to railway stations' when referring to that specifically. Local public transport in Oslo includes trams, buses and metro, while it includes only buses in the other cities.

3. Research design, data and methodology

3.1. A comparative case study

The research was designed as a comparative case study, conducted in four Norwegian cities of different sizes. This design allows for analyses within each city, taking relevant contextual factors into account, and for conducting comparative analyses across cities to understand how city size affects results (Flyvbjerg, 2006; Stake, 1995; Yin, 2003). The cities vary in size from about 28,000 to 1,020,000 inhabitants in the continuous urban settlements as defined by Statistics Norway (2021a) – that is, clusters of buildings inhabited by at least 200 persons, and where the distance between buildings does not exceed 50 m. All cities are the main city in their local region and are largely self-contained in terms of workplaces, workforce (Statistics Norway, 2021b) and amenities. Three cities are monocentric and one is polycentric; see information about the cities in Table 1. The public transport level of service varies with city size. The public transport system in Oslo is very good and includes buses, trams, metro and railway. In the three smaller cities, buses are the main mode of local public transport. All cities have railway stations, but the railway is important in local intra-city transport only in Oslo. It seems that the railway plays a role in longer commutes to and from Hamar, located 90 min from Oslo by railway, as we shall return to.

3.2. Data collection

Data for the study were collected through two types of surveys to try to overcome some of the problems identified with respect to data collection in previous studies. The commuter survey targeted employees working in private and public businesses located in the different cities, and it was designed to collect data concerning commutes from those commuting by public transport as well as by other modes. Respondents were asked by what mode they had commuted to work on the day they answered the survey, and data from those

Table 1
Characteristics of the case cities.

	Hamar	Kristiansand	Stavanger	Oslo
Type of city	Monocentric	Monocentric	Polycentric	Monocentric
Population municipality ¹	25,838	64,057	131,743	676,813
Population continuous urban settlement ²	28,000	84,000	225,000	1,020,000
Types of public transport	Bus (and railway)	Bus (and railway)	Bus (and railway)	Bus, tram, metro and railway
Proportion of all daily trips made by public transport in the urban settlements ³	7.6%	10.9%	9.9%	28.8%
Proportion of all daily trips made as car driver in the urban settlements ³	60.7%	49.3%	54.8%	35.8%

¹ Within the municipalities, [Statistics Norway \(2020\)](#).

² Within the continuous urban settlements, [Statistics Norway \(2021a\)](#).

³ Data from the National Travel Survey 2013/14 and 2017/18 – slightly different continuous urban settlement definitions than Statistics Norway.

commuting by public transport were used to calculate walking distances on trips to public transport. A filter question asking if respondents knew the route they would use if they commuted by public transport was used to select which respondents were asked questions requiring such knowledge. In Oslo, 98% of all respondents expressed familiarity with the public transport route they would use between home and work, while 86% gave the same response in Kristiansand and 71% in Hamar (this survey was not conducted in Stavanger¹). These respondents and those who commuted by public transport were asked questions about what mode of transport they used or would use on trips to stops at the home side and the workplace side of the public transport journey as well as the durations and distances of these trips, route choice motivation, walkability and how they perceived the public transport level of service between home and work. All respondents were asked about commute satisfaction and what it would take for them to choose public transport for their commutes more often, as well as background questions. The survey focussed on commutes mainly because these are concrete journeys and because we believed many would know their public transport commute route even if they did not use it often. Surveying actual and potential public transport users allows for analysing how distances to stops, as well as other factors asked about in the survey, affect public transport usage.

With small populations and low proportions of trips made by public transport in smaller cities, the number of respondents using public transport is low in most surveys, for instance, in national travel surveys and other surveys sent to the general population. To increase the number of respondents using public transport, a survey targeting public transport users at public transport stops was conducted in the three smaller cities. Interviews at bus stops need to be quite short, and this survey focussed on mode of transport on trips to public transport, the distances and durations of these trips, route choice motivation and background information about respondents.

The public transport stop survey received 720 responses in total, and the commuter survey received 7,146 responses, with the latter having a large proportion of answers from respondents in Oslo (see [Table 2](#)). [Table 2](#) displays the very low number of respondents commuting by public transport in the commuter survey in Hamar. The surveys were conducted between May 2019 and February 2020.

3.2.1. The commuter survey

Invitations to participate in the commuter survey were sent to private and public businesses located in the case cities using geocoded information from the Central Register of Enterprises ([Statistics Norway, 2016](#)). In Hamar and Kristiansand, large businesses were also contacted directly with a request to participate. Companies agreeing to participate could either provide us with their employees' e-mail addresses, so we could send surveys directly to them, or as most did, forward an e-mail with a survey link to their employees. Kristiansand municipality forwarded the survey to all employees in municipal businesses. Distributing the survey this way means that we cannot know whether our sample of respondents is representative of employees working in businesses located in the three cities, because we do not know the characteristics of the total sample of employees. Moreover, we cannot know whether the respondents are representative of those invited to participate in the surveys because we do not know the characteristics of those who were invited by their employers. These limitations were known when we designed the study, which did not aim at statistical generalisation. We know that the locations of respondents' workplaces are representative with respect to workplace locations in Oslo. Key characteristics of the respondents are listed in [Appendix A](#). While there was gender balance among respondents in Hamar, participation was somewhat dominated by women in Oslo, and it was clearly dominated by women in Kristiansand. The latter is probably a result of a high number of respondents employed by the municipality. Since the commuter surveys targeted employed persons, there were few young and old respondents. A large majority of respondents in all cities had a driving licence, access to a car and access to parking at work.

3.2.2. The public transport stop survey

Respondents to the public transport stop survey were recruited randomly at public transport stops and routes covering different

¹ A large study covering many of the same topics as our commuter survey had been conducted yearly in Stavanger for some years. We believed we could use data from this study in our analyses, but we could not. Our understanding was that approaching respondents in Stavanger with our survey would both result in a low number of respondents in our study and reduce the number of respondents in the long, ongoing survey in Stavanger, and we refrained from doing so.

Table 2

Number of respondents to the surveys.

Surveys	Hamar	Stavanger	Kristiansand	Oslo	Total
Public transport users at stops	157	391	172	Not conducted	720
Commuters, by e-mail, all modes	347	Not conducted	1,378	5,421	7,146
- whereof public transport commuters	38	-	281	3,035	3,354

parts of the case cities. In many cases, all those waiting at a stop or riding a bus were asked if they were willing to contribute, and those who agreed were interviewed. Interviews in Stavanger were conducted at public transport stops in the city centre, in the office and retail park Forus (about 13 km from the city centre), and in the housing areas around Hinna (about 6 km from the city centre). Interviews in Kristiansand took place in the city centre and in the office and retail park Sørlandsparken, about 11 km from the city centre. In Hamar, the city centre was the prime area for interviews, as Hamar does not have an out-of-city office/retail park similar to Forus or Sørlandsparken. The questions and alternative answers were read aloud by a researcher or student assistant, who registered the answer on an iPad. If the interviewees were in a hurry or if they preferred, the survey was sent by e-mail to be answered online. Key characteristics of respondents are listed in [Appendix B](#). One interviewer in Stavanger refrained from asking many respondents questions concerning age and occupation, resulting in a high proportion of unknowns with respect to this in the Stavanger sample. We found a female dominance among respondents in all three cities and a higher representation of those aged 20–29 years compared with other age groups. These tendencies are in accordance with findings in the Norwegian national travel survey from 2013/14 with respect to who uses public transport more frequently than others. Since respondents were recruited at public transport stops, the characteristics of those interviewed should reflect the characteristics of public transport users rather than the total population in the area.

3.3. Data cleaning

Data from both surveys were cleaned to eliminate reporting errors before calculating the durations and distances of walking trips to public transport. Visual inspection on maps revealed that some respondents in the public transport surveys had reported the distance and duration of the entire trip rather than for the trip to the public transport stop, and these data were excluded. Outliers were excluded from both surveys by adopting cut-off boundaries of a maximum of 30 min and a maximum distance of 3 km. These boundaries were defined after an inspection of the data revealed that most trips were within these boundaries and that the lengths of the longer trips indicated erroneous reporting, such as respondents reporting that they walked to the public transport stop when, in reality, they drove, or that they erroneously had typed an extra cipher in the questionnaire. Zero values were excluded in the analyses because they represented cases where respondents had not reported data on either duration or distance of the specific walking trip to the public transport stop.

3.4. Data analysis

SPSS and STATA programs were used in the analyses. When analysing the durations and distances of trips, the relevant reports were selected (commuting by public transport, the specific public transport mode, that they walked to the public transport stop, that this trip was 3,000 m or shorter and 30 min or shorter, exclusion of zero values), and means, medians, percentiles and standard deviations were analysed by the statistical programs. Similarly, relevant reports were selected, and the frequencies analysed for other descriptive results are reported in the paper. Simple cross tabulations were conducted to analyse how answers concerning commute satisfaction varied with mode of transport in the commuter survey.

A logistic regression analysis was performed based on data from the commuter survey to investigate the effect of walking duration to public transport on the likelihood of commuting by public transport. The dependent variable is a dummy variable assuming a reference value (0) if a respondent had selected other options than 'public transport' to the question 'By what mode do you normally commute?'. The model comprised durations of walking trips to public transport, commuting distances and socio-demographics as independent variables. Reported walking times between home and the public transport stop and between the workplace and public transport stop were the variables of interest among the independent variables. Socio-demographics and commuting distances entered the model as control variables. Commuting distance was meant to control for effects of locations of respondents' dwellings in the urban structure. A challenge when analysing how the distances and durations of walking trips to public transport affect the use of public transport is that this also is influenced by other urban structure factors, and some of them are correlated. For instance, those living in central parts of Norwegian cities often have the shortest distances to public transport but also the shortest commutes ([Statistics Norway, 2016](#)), resulting in high proportions of commutes made on foot or by bicycle instead of by public transport. Following this, analyses can show a low proportion of commutes by public transport in areas with the shortest distances to public transport, where the causal explanation is connected to overall urban structure mechanisms rather than distances to public transport. As we did not have information about the respondents' addresses, we used commuting distance as a substitute for centrality of the locations of their residences. The model was run only on respondents who stated their familiarity with the route they would use if they commuted by public transport and reported that they would make trips to public transport on foot. Commuting distance was log-transformed to mitigate potential heteroscedasticity problems.

4. Findings

4.1. Durations and distances of walking trips to public transport

Analyses of both types of surveys show that walking was the dominant transport mode for trips to public transport in all case cities (see [Appendix C](#)). Answers from public transport users in both types of surveys were analysed with regard to self-reported distances and durations of walking trips to public transport at the home side and at the workplace side of the public transport journey, regardless of the public transport mode; see results in [Table 3](#) (see [Appendix D](#) for details). As discussed in [Section 2](#), previous research has found that self-reported durations of trips to public transport are more reliable than self-reported distances ([Ralph et al., 2020](#)). To get a clearer picture of the deviations between self-reported distance and duration, distances were also calculated on the basis of self-reported duration using average walking speed of 80 m per minute ([Bohannon, 1997; Minetti, 2000; Schimpl et al., 2011](#)).

Key findings in [Table 3](#) are that the average self-reported duration of a walking trip to public transport across the two surveys and four cities varies from 4.6 to 6.6 min on the home side of the journey and 4.1–6.2 min on the workplace side. Median values (in brackets in the table) vary from 3 to 5 min on both sides. Average self-reported distances vary from 352 to 521 m on the home side and from 292 to 545 m on the workplace side, while medians vary from 200 to 500 m.

When comparing self-reported durations of walking trips from the two different types of surveys for the same trips within Hamar and Kristiansand, respectively, the results show very small deviations on the home side and larger deviations on the workplace side, with 1.3 min in Hamar and 1.1 min in Kristiansand. There are also deviations, following the same patterns, with respect to self-reported distances. Comparisons of self-reported distances with distances calculated according to self-reported durations for all results in [Table 3](#), show only small deviations for trips from home to stops (up to 30 m) and somewhat more significant deviations for trips from stops to the workplace (up to 80 m). In total, this means that there are uncertainties in the data that we need to be aware of, especially on the workplace side. The results do not give clear indications of which self-reported distances and durations are more reliable. For Hamar, one might assume that results from the public transport survey are more reliable, as the number of respondents is much higher than in the commuter survey.

The results in [Table 3](#) do not indicate any systematic variation in durations and distances of walking trips to public transport with city sizes. The longest trips are found in the smallest city, Hamar, and in the largest city, Oslo. These cities also have large proportions of public transport trips made by railway in the commuter study, with 60% in Hamar and 29% in Oslo, compared with only 2% in Kristiansand. The high proportion of railway commuters in Hamar was unexpected, because the railway mainly serves regional travel in this city, and it indicates a relatively high number of inter-city commuters in the commuter survey in Hamar. We know from the literature ([Section 2](#)) that walking distances to railway stations generally are longer compared with those to local public transport stops. Therefore, new analyses distinguishing between walking trips to local public transport stops and railway stations were conducted using data from the commuter survey (the public transport survey did not distinguish between public transport modes).

These results are more comparable across cities in our study and with findings in previous studies, and they would be more useful for planning practice. The results are shown in [Table 4](#); see detailed results in [Appendix E](#). Results from the public transport stop survey in Stavanger are included in [Table 4](#) for comparative reasons. There were very few walking trips to railway stations in the Kristiansand survey, which is why walking trips to railway stations have not been analysed and why the results for walking trips to local public transport stops are the same as in [Table 3](#).

[Table 4](#) shows that walking trips to local public transport stops in each city last, on average, 4.1–6.0 min on the home side of the journey (calculated distance, 328–520 m) and 4.1–5.1 min on the workplace side (calculated distance, 328–408 m). Median duration values are 5 min or shorter in all cases. The 75th-percentile duration results vary from 5 to 8 min on the home side and from 5 to 7 min on the workplace side. Self-reported distances vary from 374 to 470 m on the home side and from 292 to 406 m on the workplace side of the journey, with median values of 425 m or shorter in all cases.

Focussing on self-reported durations of walking trips, a qualitative comparison of the results from the four cases show increasing durations of trips to local public transport stops with increasing city size, with the exception that walking trip duration is longer in Hamar than in Kristiansand on the workplace side. We must bear in mind the very low number of respondents in the commuter survey in Hamar. The finding remains if only walks to bus stops in Oslo are included, they lasted 5.3 min at the home side and 5.2 min on the workplace side of public transport commutes.²

Walking trips to railway stations are significantly longer compared with those to local public transport stops. These walking trips last, on average, 8.2 min in Hamar and 8.6 min in Oslo on the home side and 7.3 min in Hamar and 6.6 min in Oslo on the workplace side. This means that the average trip duration on the home side is the longest in Oslo, while it is the longest in Hamar on the workplace side. The 75th-percentile duration is 10 min for both types of trips in both cities.

Differences in route choice motivation could explain why walking durations of trips to local public transport stops increase with increasing city size but results from the commuter survey display that this is not the case in this study. On the question ‘Why do you choose the route you do?’ which allowed multiple answers, 73–80% of respondents chose the answer ‘It is the shortest route’ (see details in [Appendix F](#)). This was followed by ‘It is the only route I can choose’, selected by 17–39% of respondents. This indicates that a high proportion of respondents did not find that they have a shorter route they could have chosen. There was a clear tendency for a

² Detailed analyses of data from Oslo show that walking trips to public transport on the home side of the public transport varied with mode of public transport: 5.1 min for tram, 5.3 min for bus, 6.8 min for subway, 8.6 min for railway. At the workplace side, the figures were: 5.1 min for tram, 5.2 min for bus, 4.9 min for subway, 6.6 min for railway.

Table 3

Summary of average self-reported duration (minutes) and distance (metres) of walking trips to public transport in the public transport stop surveys (PTS) and by public transport users in the commuter surveys (CS), not distinguishing between public transport modes.

	Hamar		Kristiansand		Stavanger		Oslo	
	PTS ¹	CS	PTS	CS	PTS ²	CS	PTS	CS
Duration, self-reported								
To/from home	6.3 (5 ³)	6.3 (5)	4.8 (4)	4.6 (4)	4.8 (3)	–	–	6.6 (5)
To/from workplace	4.9 (4)	6.2 (5)	5.2 (3)	4.1 (3)	4.8 (3)	–	–	5.5 (5)
Distance, self-reported								
To/from home	497 (300)	475 (425)	352 (300)	374 (300)	399 (300)	–	–	521 (450)
To/from workplace	400 (300)	545 (500)	327 (200)	292 (200)	399 (300)	–	–	448 (350)
Distance, calculated from duration								
To/from home	504 (400)	504 (400)	384 (320)	368 (320)	384 (240)	–	–	528 (400)
To/from workplace	392 (320)	496 (400)	416 (240)	328 (240)	384 (240)	–	–	440 (400)

¹ Number of respondents is low in Hamar.

² Trips to homes/workplaces are not distinguished in Stavanger.

³ Median values in brackets.

Table 4

Summary of average self-reported duration (minutes), self-reported distance (metres) and calculated distance (metres) of walking trips to local public transport stops and to railway stations, based on the commuter survey (the Stavanger results are from the public transport stop survey).

	Trips to local public transport stops				Trips to railway stations	
	Hamar ¹	Kristiansand ²	Stavanger ³	Oslo ⁴	Hamar ¹	Oslo
Duration, self-reported						
To/from home	4.1 (3.5 ⁵)	4.6 (4)	4.8 (3)	6.0 (5)	8.2 (7.5)	8.6 (8)
To/from workplace	4.3 (4.5)	4.1 (3)	4.8 (3)	5.1 (4)	7.3 (7)	6.6 (5)
Distance, self-reported						
To/from home	425 (425)	374 (300)	399 (300)	470 (400)	517 (450)	721 (625)
To/from workplace	323 (230)	292 (200)	399 (300)	406 (300)	675 (600)	554 (500)
Distances, calculated from duration						
To/from home	328 (280)	368 (320)	384 (240)	520 (400)	656 (600)	688 (640)
To/from workplace	344 (360)	328 (240)	384 (240)	408 (320)	584 (560)	528 (400)

¹ Number of respondents is very low in Hamar.

² The results for local public transport in Kristiansand are the same as in Table 3 because the material only contained data on walking trips to local public transport stops.

³ The Stavanger results are from the public transport stop survey; the commuter survey was not conducted in Stavanger. The Stavanger study does not distinguish between the home and work sides of public transport trips.

⁴ Local public transport in Oslo includes metro, trams and buses.

⁵ Median values in brackets.

higher proportion of respondents in Oslo to answer that they choose the shortest or the only route, followed by Kristiansand and Hamar.

Across the results reported in Table 4, there is a clear tendency for the average self-reported duration of a trip between home and a public transport stop to last longer compared with a trip between the workplace and a public transport stop within each city. The one exception is on trips to local public transport in Hamar, where the number of respondents was very low.

4.2. Effect of distances to transport stops on the competitiveness of public transport

Results from the logistic regression analysis modelled to analyse how durations of walking trips to public transport influence the likelihood of commuting by public transport are presented in Table 5. They show significant relationships in Kristiansand and Oslo, also when controlling for socio-demographics and commuting distance. Oslo shows the most robust relationship. The elasticity estimates indicate that the magnitude of association between the outcome variable and the variables of interest (walking duration to public transport) is much greater in Kristiansand (−0.2 and −0.3) than in Oslo (−0.07 and −0.05). The regression analysis was not conducted on data from Hamar due to a low number of public transport commuters, which would make the results highly uncertain.

4.3. Factors affecting public transport competitiveness on commutes

Results from the commuter survey were used to analyse what affects the competitiveness of public transport on commutes in the three differently sized cities. Analyses of the modal splits on the latest commute by all respondents in the commuter survey showed, as

Table 5

The effect of walking duration on trips to public transport on the likelihood of commuting by public transport.

	Kristiansand				Oslo			
	Coefficients	Robust S. E.	Elasticity	P > z	Coefficients	Robust S. E.	Elasticity	P > z
Reported walk time between home and a public transport stop	-0.046 (0.775)	0.023	-0.219	0.046	-0.023 (0.895)	0.009	-0.069	0.007
Reported walk time between workplace and a public transport stop	-0.075 (0.701)	0.028	-0.296	0.008	-0.021 (0.920)	0.010	-0.051	0.032
Log of commuting distance	0.696 (1.781)	0.120	1.007	0.000	0.917 (2.378)	0.051	0.751	0.000
Age	-0.010 (0.897)	0.010	-0.353	0.317	-0.011 (0.877)	0.004	-0.236	0.003
Gender (man = 0)	-0.242 (0.895)	0.224	-0.130	0.280	0.394 (1.217)	0.081	0.093	0.000
Number of children	-0.447 (0.631)	0.116	-0.314	0.000	-0.381 (0.695)	0.043	-0.143	0.000
Income	-0.214 (0.723)	0.083	-0.564	0.010	-0.098 (0.830)	0.024	-0.206	0.000
Education	0.070 (1.051)	0.142	0.132	0.622	0.093 (1.061)	0.068	0.115	0.172
Constant	-0.526	0.661		0.426	-0.732	0.257		0.004
Nagelkerke R^2	0.145				0.190			
No. of obs.	639				3162			

Note: Standardised values in brackets.

expected, that public transport competes better on commutes in the larger cities compared with the smaller cities, while the use of private cars competes better in the smaller cities compared with the large city (see Fig. 1, data in Appendix G).

All respondents in the commuter survey were asked, 'How satisfied are you with your commute?' The answers were analysed with respect to how this varied with mode of transport. See results for Hamar, Kristiansand and Oslo in Figs. 2–4, and data in Appendix H. In all cities, the highest commute satisfaction was found among those who reported commuting on foot, followed by those commuting by bicycle. When comparing responses from those commuting by public transport and by car, the proportions of respondents stating they are very satisfied or satisfied were quite similar across all three cities. When comparing commute satisfaction among public transport users across cities, only a weak tendency of increasing commute satisfaction with increasing city size was found. For car commuters, there was no systematic tendency.

Those stating familiarity with the public transport route between home and the workplace, regardless of what modes they used on their commutes, were asked to consider whether they agreed with several statements about the public transport services on this route (see Table 6).

Respondents in all three cities largely agreed that walking distances to public transport are short, with 79–85% strongly or somewhat agreeing that this is the case on the workplace side of the public transport commute and 73–81% on the home side. Respondents were more critical of other aspects of the public transport services. Across the cities, 48–70% of respondents strongly or somewhat agreed with the statement 'There are good public transport connections between where I live and where I work', and the proportion that (strongly) agreed was highest in Oslo, followed by Kristiansand and Hamar. This tendency of a higher proportion of respondents agreeing to the positive statements with increasing city size was also found in most other statements, except for two, where respondents in Hamar were more positive compared with those in Kristiansand (distance between the public transport stop and work; that it is easy to transfer between public transport modes). Only commuters in Kristiansand and Hamar rated the statement 'The price of public transport is too high'; 64% in Hamar and 63% in Kristiansand strongly or somewhat agreed with this statement.

All respondents in the commuter surveys in Kristiansand and Hamar were asked what it would take for them to choose public transport more often on their commutes; see results in Table 7. Higher frequencies, lower fares and no transfers were the most frequently selected suggestions for improvement. Few responded that stops closer to home (6–7%) or to the workplace (3%) would make them commute by public transport more frequently.

Respondents in Hamar and Kristiansand who commuted by public transport or stated familiarity with the route they would use if they did were asked about the quality of walking trips between public transport and the workplace (see results in Table 8). Respondents

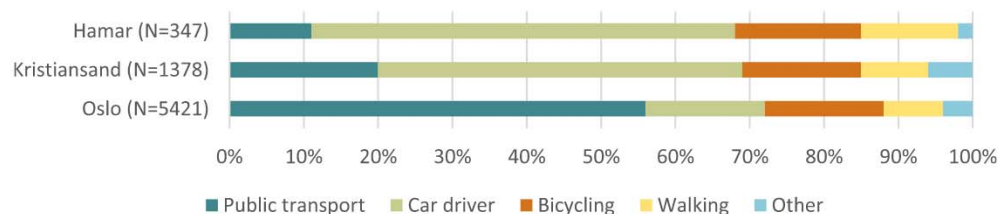


Fig. 1. Modal split on commutes to workplaces located in Hamar, Kristiansand and Oslo in the commuter survey, number of respondents in brackets.

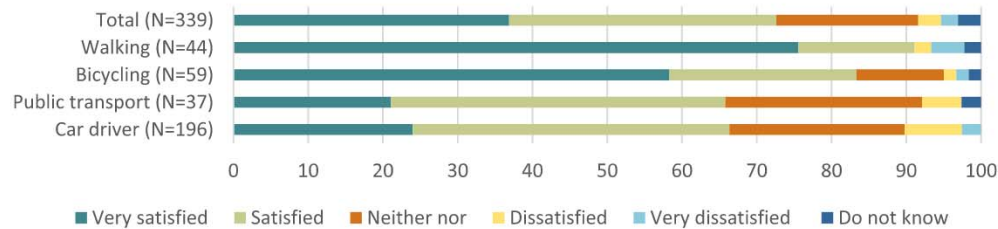


Fig. 2. Commute satisfaction of users of different modes of transport in Hamar based on data from the commuter survey, number of respondents in brackets.

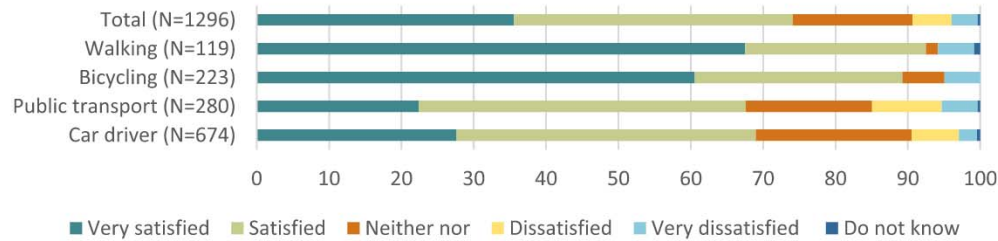


Fig. 3. Commute satisfaction of users of different modes of transport in Kristiansand based on data from the commuter survey, number of respondents in brackets.

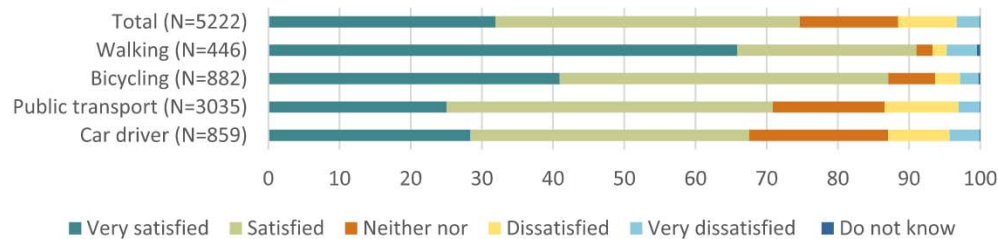


Fig. 4. Commute satisfaction of users of different modes in Oslo based on data from the commuter survey, number of respondents in brackets.

seemed to find these trips highly walkable, with 72–76% strongly or somewhat agreeing with the statement ‘The pedestrian areas are well designed and accessible’ and 62–70% strongly or somewhat agreeing that ‘The route provides a nice walk’. Fewer agreed that winter maintenance is good (41–61%), and the fewest agreed that ‘It sometimes feels unsafe to walk here in the evening and at night’ (21–29%). Therefore, it does not seem that unpleasant or unsafe trips between public transport and workplaces negatively influence the competitiveness of public transport on commutes in these cities.

5. Discussion

5.1. Durations and distances of walking trips to public transport

In Section 4, data concerning self-reported durations and distances of walking trips to public transport, collected through commuter surveys and public transport stop surveys in four Norwegian cities of different sizes, were analysed. We focus in the discussion on the results from the commuter study, which distinguished between walking trips to local public transport stops and to railway stations, and data on self-reported durations of trips, which are understood to be more reliable than data on self-reported distances.

The analyses revealed that walking trips to local public transport stops, on average, varied from 4.1 to 6.0 min on the home side of the public transport journey in the different cities and from 4.1 to 5.1 min on the workplace side. Translating this to distances, by calculating durations with an average walking speed of 80 m per minute (from Schimpl et al., 2011), the average distances vary from 328 to 520 m on the home side and from 328 to 408 m on the workplace side. These results are within the range of what has been found in previous studies, as discussed in Section 2, where average walking distances ranged from 170 to 549 m (Soest et al., 2020). Walking trips to railway stations were found to be significantly longer, as expected, and they lasted within each city, on average, 8.2–8.6 min (656–688 m) on the home side and 6.6–7.3 min (528–584 m) on the workplace side. These distances are shorter than what has been found in previous studies, where walking trips to railway stations ranged from 805 to 882 m (Soest et al., 2020). The differences may be explained by differences in definitions, methods and, not least, city context, considering that the reviewed studies mainly were conducted in large cities and outside of Europe. There were also few comparable studies.

Table 6
Statements concerning properties of public transport services in the commuter survey for Hamar (N = 245), Kristiansand (K.sand; N = 1,178) and Oslo (N = 5,312). Sorted by the highest percentage of 'strongly agree' in Hamar.

Statement concerning	Strongly agree (%)			Somewhat agree (%)			Somewhat disagree (%)			Strongly disagree (%)			Do not know (%)		
	Hamar	K.sand	Oslo	Hamar	K.sand	Oslo	Hamar	K.sand	Oslo	Hamar	K.sand	Oslo	Hamar	K.sand	Oslo
Short distance to workplace stop	66	66	67	17	13	18	8	9	8	5	9	6	4	3	1
Short distance to home stop	61	63	61	12	15	20	8	9	11	17	11	7	2	2	1
Accessible information	43	55	63	31	26	26	12	8	6	6	4	3	8	7	2
Fares are too high	36	38	-	28	25	-	15	18	-	7	10	-	14	9	-
Public transport speed	26	28	42	29	33	31	17	17	16	12	10	9	16	12	2
Good public transport connections home/work	25	29	45	23	21	25	16	18	16	30	26	13	6	6	1
High frequency	23	33	45	21	17	22	18	19	17	29	21	14	9	10	2
Good punctuality	17	21	30	25	29	31	21	20	21	10	11	15	27	19	3
Easy transfer	15	15	38	19	18	27	15	15	15	14	14	9	37	38	11

Table 7

What commuters answered could make them use public transport more often on their commutes in Hamar (N = 347) and Kristiansand (N = 1,378) in the commuter survey. Respondents could choose multiple alternatives. Sorted by the highest percentage in Hamar.

	Hamar (%)	Kristiansand (%)
Higher frequencies	19	16
Lower fares	15	18
No transfer necessary	7	13
Stops closer to home	7	6
Fewer delays/better punctuality	7	6
More expensive and/or less convenient to use a private car	4	4
Stops closer to work	3	3
Real-time information at stops	3	2
More comfortable to travel by public transport	2	2
Easier access to public transport service information	1	1
Not relevant – I live so close to work I do not need motorised transport	13	8
Not relevant – I already commute by public transport	5	8
Not relevant for other reasons	8	10
Other	5	5

Table 8

Statements concerning the walkability of routes between public transport and workplaces in the commuter survey, asked in Hamar (N = 245) and Kristiansand (K.sand; N = 1,178). Sorted by the highest percentage answering 'strongly agree' in Hamar.

Statement concerning:	Strongly agree (%)		Somewhat agree (%)		Somewhat disagree (%)		Strongly disagree (%)		Do not know (%)	
	Hamar	K.sand	Hamar	K.sand	Hamar	K.sand	Hamar	K.sand	Hamar	K.sand
Good design	38	50	34	26	11	9	4	4	14	10
Nice walk	31	42	31	28	13	11	8	5	18	15
Good winter maintenance	14	32	27	29	29	16	15	6	15	17
Unsafe at night	7	9	14	20	9	15	44	33	27	22

When applying results from studies like this in the planning and development of land use and public transport services, 75th percentiles might be more useful measures than average (mean) values, by indicating the distances 75% of respondents walk shorter than. For the smaller cities of Hamar and Kristiansand, 75% of walking trips to local public transport stops lasted 5 min or less, with 5.8 min on the home side trips in Hamar as an exception (see [Appendix E](#) for details). Interestingly, if the 5 min are calculated by 80 m per minute, they correspond to 400 m, which is the distance frequently referred to as the rule of thumb for an acceptable walking distance to local public transport stops, as discussed in [Section 2 \(Soest et al., 2020\)](#). In the large city of Oslo, the 75th percentiles were 7 min (560 m) on the workplace side and 8 min on the home side (640 m), indicating that the 400-metre rule of thumb is too short here. The 75th percentiles for walking trips to railway stations were found to be 10 min on both sides of the public transport journey in Hamar as well as in Oslo, corresponding to 800 m, the distance frequently referred to as a rule of thumb for an acceptable walking distance to railway stations. Thus, the results from the commuter survey are in accordance with, and seem to support, the rules of thumb of 800 m as an acceptable walking distance to railway stations and of 400 m to local public transport stops (in smaller cities).

This interpretation of the findings might be challenged by other answers in the survey. When current and potential public transport commuters were asked how they perceive relevant aspects of the public transport services they used or could use on their commutes, respondents in all three cities largely agreed that distances to stops on both ends of the commute were short. Likewise, when respondents in Kristiansand and Hamar were asked what actions would make them choose public transport more often on their commutes, few answered that stops closer to home or the workplace would influence their choices with respect to this. These findings indicate that respondents would accept longer walks to public transport than in the current situation. This understanding is supported by [Agrawal et al.'s \(2008\)](#) study showing that self-reported distances to railway stations were 11% longer than real (measured) distances. In the Oslo case, the results clearly showed that the assumption of a 400-metre acceptable walking distance to a local public transport stop is too short. On this basis, our understanding of the findings is that many would accept to walk longer than indicated by the 400-metre rules of thumb for 'acceptable walking distance' to local public transport stops, and this is in accordance with what has been found in other studies ([Agrawal et al., 2008](#); [Alshalalfah and Shalaby, 2007](#); [Canepa, 2007](#)).

5.2. How durations and distances of walking trips to public transport vary with city size

A qualitative comparison of findings across the four cities showed increasing average duration of walking trips to local public transport stops with increasing city size, also if including only walks to bus stops in Oslo (where a substantial proportion of commutes by local public transport were made by subway, associated with longer walks). This could not be explained by differences in route choice motivation between respondents in the different cities. A large majority of respondents in all cities answered that they chose the shortest or the only route to a public transport stop, as has also been found in previous studies ([Agrawal et al., 2008](#); [Soest et al., 2020](#)), and the proportions of respondents answering this increased with city size. A comparison of walking distances to railway stations in the small city of Hamar and the large city of Oslo displayed no clear tendency. Walking trips between home and a railway station lasted

longer in Oslo than in Hamar, while trips between the workplace and a railway station lasted longer in Hamar than in Oslo. An explanation for the latter might be that many businesses attracting railway commuters to Hamar and that participated in the survey are located relatively far from a station but still within walking distance.

5.3. Differences in walking distances to stops between the home and workplace sides of public transport commutes

Few previous studies have distinguished between and/or investigated walking distances to public transport on both the home and the activity side of public transport trips, and the few studies considering this have found that trips are slightly longer on the activity side (Soest et al., 2020). In contrast, results from this study showed a clear tendency of longer walking trips on the home side compared with the workplace side. An explanation could be that a high proportion of public transport commutes goes to workplaces located in dense city centres, where distances between stops and workplaces are shorter than they are between stops and homes in less dense housing areas, as also suggested by Alshalalfah and Shalaby (2007).

5.4. How walking distances to public transport affect public transport competitiveness

A main reason for investigating how far and how long people walk to public transport is the assumption that the distances affect public transport competitiveness. This assumption was tested by conducting a logistic regression analysis using data from the commuter survey, and significant relationships were found in Kristiansand and Oslo between durations of walking trips to public transport and the likelihoods of answering 'public transport' to the question 'By what mode do you normally commute?'. The elasticity estimates indicate greater magnitudes of association between walking distance to a stop and public transport demand in the smaller city of Kristiansand (-0.2 and -0.3) compared with the larger city of Oslo (-0.07 and -0.05). A likely explanation for the disparities could be that a high proportion of public transport commutes in Oslo are to businesses located in the city centre, where parking accessibility is very low. Another explanation could be that the control for commuting distance, to reduce the effect of other urban structure-related mechanisms (as discussed in Section 3.4), did not capture these effects in full. In comparison, Ewing and Cervero (2010) reported an average elasticity of -0.29 in their meta-analysis, that was aggregated from three studies with elasticities ranging between -0.02 and -1.0 .

5.5. What affects public transport competitiveness on commutes more

Results from the commuter study showed, as expected, that public transport competes better on commutes in the larger city compared with the smaller cities, while private cars compete better in the smaller cities. A relevant question from a sustainable mobility perspective regards what changes are more important to improve public transport competitiveness versus the use of private cars on commutes in the smaller cities, and in this paper, how important reducing walking distances to public transport is compared with other potential improvements to public transport services.

When comparing commute satisfaction across respondents commuting by different modes of transport, surprisingly similar patterns were found across cities of different sizes, despite obvious differences between the cities in commute quality by car (congestion, parking accessibility) and by public transport (frequency, speed). Only a weak tendency of increasing commute satisfaction with increasing city size was found among public transport commuters, and no systematic tendency was found among car commuters. There were only small differences in commute satisfaction between commuters by car and by public transport within each city. Those commuting on foot or by bicycle reported by far the highest commute satisfaction in all cities, in line with what has been found in previous studies, mainly in large cities (Chatterjee et al., 2020). In contrast, when asking current and potential public transport commuters about relevant aspects of the public transport routes they used or could use on their commutes, the answers clearly indicated that the perceived quality of public transport services increased with increasing city size, which is in accordance with the real situation. The differences between these results are interesting. One explanation could be that those commuting by public transport 'know how good the services are', while non-users do not. A more plausible explanation could be that those who have the best public transport service for their commute are more likely to commute by public transport.

The survey design allowed for more detailed analyses of what improvements are more important to make public transport more competitive for commutes in the smaller cities. Answers from current and potential public transport commuters revealed, as mentioned, that commuters in all three cities largely agreed that distances to stops were short. Respondents in the smaller cities were significantly more critical of other aspects of the public transport services, like direct connections between home and work, ease of transfers, frequencies and fares. Likewise, when respondents in Kristiansand and Hamar were asked what actions would make them choose public transport more often on their commutes, higher frequencies, lower fares and no transfers were the most frequently selected suggestions, while significantly fewer respondents answered that stops closer to home or to the workplace would influence their choice. Respondents in Hamar and Kristiansand reported that they find their walking trips to public transport highly walkable and safe, meaning that improving the quality of their walking route is probably not an important measure to improve public transport competitiveness in these cities.

These results suggest that interventions other than reducing walking distances to stops would contribute more to improving public transport competitiveness on commutes in the smaller cities, and that they could be increased if that would result in other improvements. This is in accordance with suggestions by Nielsen et al. (2005), Walker (2012) and McLeod et al. (2017), who claimed that higher frequencies, more direct routes and easier transfers should be prioritised ahead of short walking distances when designing public transport services to attract more passengers. It is also in accordance with what has been experienced in Nordic cities of various

sizes, where the reorganisation of local urban bus services to fewer and straighter lines with higher frequencies and speeds, but also longer walking distances to stops, was followed by substantial increases in patronage (Kahn et al., 2021; Nielsen, 2016).

5.6. Implications for the planning and development of land use and public transport services

The results of this study suggest that the trade-offs between walking distance to a stop and other aspects of public transport services need to be reconsidered in the smaller cities to make public transport more competitive on commutes. The commuters in the surveys requested higher frequencies and higher speeds on public transport services, which could be achieved by concentrating resources in fewer and straighter lines. This would increase walking distances to stops, but the results indicate that commuters would accept longer walking distances than in the current situation. The results showed, however, that walking distances to public transport do affect public transport competitiveness, and smaller cities might understand distances to local public transport stops that are somewhat longer than 400 m as acceptable. Therefore, strategies aimed at fewer and straighter lines would be more successful if land use planning steered the development of new housing to areas located within 400–500 m from existing high-frequency stops.

The commuters also requested good connections between their homes and workplaces, preferably without transfers. In smaller cities, this can be achieved by locating workplaces and other activities attracting many people in and close to the city centre, because the city centre normally is the location to which most other areas of the city have direct public transport connections. Since railway stations normally are located in city centres, locating new housing and workplaces in the city centre would also increase the competitiveness of railway services on commutes, as it would provide walking distances and no need to transfer for those commuting by railway to and from the city. These suggestions are in line with long-agreed understandings, for instance, in the Norwegian national planning guidelines for coordinated land use and transport planning (Ministry of Local Government and Modernisation, 2014). The contribution of this study concerns the results from investigations in smaller cities, which show that these recommendations also are relevant in those contexts.

5.7. Reflections on data and methodology

While the commuter study worked out as intended, we see in retrospect that the public transport stop survey could have been more useful with more careful implementation. We tried to measure actual walking distances in the public transport stop surveys by asking respondents about addresses of the start point and the final destination of their journey to allow GIS-measuring of real walking distances. This failed mainly due to misunderstandings during data collection, inaccurate addresses and the fact that GIS did not measure the shortest route, and these results have not been presented or used in the paper. This problem could have been avoided to some extent if the interviewers had been better informed about how they should explain the questions and the importance of getting accurate answers. The results from this study would also have been more useful if the survey had distinguished between modes of public transport. Our pre-understanding was that railway played a minor role in commutes in the smaller cities, but the commuter survey showed that it played a larger role than expected in Hamar. Consequently, the intended comparison of reported walking distances and durations between the two types of surveys within the same cities had less value than intended. In future studies, we advise including a question about public transport mode. It was particularly unlucky that it was the public transport survey in Hamar that (probably) received many answers to the public transport survey from railway commuters, because very few respondents in the commuter study in Hamar commuted by public transport. The results concerning walking distances and durations to public transport in Hamar are uncertain because of this.

6. Concluding remarks

This paper contributes novel empirical knowledge to the literature on the durations and distances of walking trips to public transport by studying this in four Norwegian cities of different sizes. It was found that average walking distances to local public transport stops in three cities varied from 4.1 to 6.0 min, or 328–520 m, which is within the range of what has been found in previous studies, while they ranged from 528 to 688 m on trips to railway stations, which is shorter than what has been found in previous studies. Walking distances to public transport affected the probability of commuting by public transport both in a smaller and a larger city. These are significant contributions to the body of studies on European cities and to the body of studies on smaller cities, as few similar studies have been made in these contexts. It was found that average walking distances to local public transport stops increased with increasing city sizes, and there was a clear tendency of longer walking trips on the home side compared with the workplace side of public transport journeys, and few previous studies have systematically investigated these issues. Survey answers suggested that acceptable walking distances to public transport are longer than the current distances and longer than the frequently used rules of thumb of 400 m to local public transport stops. They also indicated that higher frequencies and speeds, and more direct connections, are more important to improve public transport competitiveness on commutes in the smaller cities than shorter walking distances to stops.

Limited attention has been paid to public transport competitiveness in smaller cities in previous research, and this study and its findings strengthen the empirical and theoretical knowledge base. We believe the results will be useful for cities of different sizes aiming at improving public transport competitiveness versus the use of private cars to achieve more sustainable and people-friendly cities. Shifts from private cars to other modes of transport contribute to a diversity of societal objectives. Therefore, the findings may be helpful for cities working towards any of the following United Nations (2017) Sustainable Development Goals: Good health and well-being (no. 3), Reduced inequalities (no. 10), Sustainable cities and communities (no. 11) and Climate action (no. 13). The results are

considered relevant to both smaller and larger European-style cities and more relevant for relatively self-contained and standalone regional cities than for smaller cities in interwoven polycentric urban regions dominated by a larger city.

CRedit authorship contribution statement

Aud Tennøy: Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Marianne Knapskog:** Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Funding acquisition. **Fitwi Wolday:** Methodology, Data curation, Formal analysis, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Key characteristics of respondents in the commuter survey

	Oslo		Kristiansand		Hamar	
	N	%	N	%	N	%
Number of respondents	5421	100	1378	100	347	100
Number of firms	214	100	27	100	21	100
Gender						
Female	2305	42.5	903	65.5	162	46.7
Male	1935	35.7	408	29.6	161	46.4
Other	30	0.7	19	1.4	6	1.7
Unknown	1151	21.2	48	3.5	162	46.7
Age						
19 or younger	29	0.5	2	0.1	1	0.3
20–29	346	6.4	88	6.4	16	4.6
30–39	998	18.4	241	17.5	52	15.1
40–49	1242	22.9	319	23.1	90	26.1
50–59	1069	19.7	370	26.9	104	30.1
60–69	573	10.6	164	11.9	46	13.3
70 or older	13	0.2	0	0	0	0
Unknown	1151	21.2	194	14.1	36	10.4
Income						
<299,000 NOK	66	1.2	31	2.2	3	0.9
300,000–399,000 NOK	90	1.7	79	5.7	6	1.7
400,000–499,000 NOK	593	10.9	279	20.2	44	12.7
500,000–599,000 NOK	1220	22.5	410	29.8	78	22.5
600,000–699,000 NOK	1070	19.7	238	17.3	62	17.9
700,000–799,000 NOK	655	12.1	95	6.9	54	15.6
800,000–899,000 NOK	450	8.3	55	4	20	5.8
900,000–999,000 NOK	296	5.5	26	1.9	16	4.6
>1,000,000 NOK	515	9.5	40	2.9	27	7.8
Unknown	390	7.2	102	7.4	29	8.4
Missing	76	1.4	23	1.7	8	2.3
Total	5421	100	1378	100	347	100
Driver licence						
Yes	4989	92	1307	94.8	336	96.8
No	432	8	71	5.2	11	3.2
Total	5421	100	1378	100	347	100
Access to car						
Car owner	4126	76.1	1234	89.6	326	93.9
Member of car sharing	214	3.9	8	0.6	0	0
Can borrow a car when needed	238	4.4	26	1.9	5	1.4
No	843	15.6	110	8	16	4.6
Total	5421	100	1378	100	347	100

(continued on next page)

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(continued)

	Oslo		Kristiansand		Hamar	
	N	%	N	%	N	%
Access to parking at workplace						
No	675	13	0	0	4	1
Yes, free on-street parking	406	8	0	0	43	12
Yes, charged on-street parking	465	9	93	6.7	40	12
Yes, free parking offered by my employer	1850	34	574	41.7	179	52
Yes, charged parking offered by my employer	667	12	81	5.9	70	20
Yes, other free parking	168	3	136	9.9	12	4
Yes, charged other parking (parking garage, etc.)	1075	20	326	23.7	41	12
Do not know	714	13	51	3.7	10	3
No	675	13	0	0	4	1
Other	395	7	50	3.6	12	4
Total	6415	118	1311	95.2	411	119
Type of public transport used on latest work-trip						
Bus	863	28.5	275	97.9	15	39.5
Metro	1054	34.8	0	0	0	0
Railway	877	29.0	6	2.1	23	60.5
Tram	189	6.2	0	0	0	0
Boat	51	1.7	0	0	0	0
Total	3026	100	281	100.0	38	100

Appendix B. Key characteristics of respondents in the public transport stop survey

	Stavanger		Kristiansand		Hamar	
	n	%	n	%	n	%
Number of respondents	391	100	172	100	157	100
Gender						
Female	150	38.4	117	68	102	65
Male	145	37.1	51	29.7	53	33.8
Other	3	0.7	4	2.3	2	1.2
Unknown	93	23.8	0	0	0	0
Total		100		100		100
Age						
19 or younger	50	12.8	16	9.3	15	9.6
20–29	58	14.8	53	30.8	37	23.6
30–39	29	7.4	28	16.3	18	11.5
40–49	15	3.8	22	12.8	17	10.8
50–59	13	3.3	22	12.8	27	17.2
60–69	5	1.3	13	7.6	20	12.7
70 or older	9	2.3	6	3.5	19	12.1
Unknown	212	54.2	12	7.0	4	2.5
Total		100		100		100
Occupation						
Employed, full-time	141	36.1	79	46	47	30
Employed, part-time	31	7.9	15	9	26	17
Student (university)	33	8.4	42	24	21	13
Student (secondary school, year 11–13)	58	14.8	5	3	11	7
Retired, on sick-leave, or social security	24	6.1	18	10	39	25
Other, will not say	11	2.8	13	8	13	8
Unknown	93	23.8	0	0	0	0
Total		100		100		100

Appendix C. Mode of transport on trips to public transport, reported by those commuting by public transport

	Hamar		Kristiansand		Stavanger		Oslo	
	N	%	N	%	N	%	N	%
Public transport stop survey, all trips to stops								
Walking	280	89	325	94	527	82	–	–
Cycling	3	1	2	1	8	1	–	–

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	Hamar		Kristiansand		Stavanger		Oslo	
	N	%	N	%	N	%	N	%
Car driver	12	4	6	2	4	1	–	–
Car pass.	16	5	3	1	2	1	–	–
Other/varies	3	1	8	2	1	15	–	–
total	314	100	344	100	542	100	–	–
Commuter survey, between home and public transport stop, those commuting by public transport								
Walking	23	64	203	85	–	–	2281	84
Cycling	3	8	9	4	–	–	83	3
Car driver	10	28	22	9	–	–	242	9
Car pass.	0	0	2	1	–	–	20	1
Other/varies	0	0	4	1	–	–	90	3
Total	36	100	172	100	–	–	2716	100
Commuter survey, between workplace and public transport stop, those commuting by public transport								
Walking	35	97	240	97	–	–	2668	97
Cycling	0	0	1	0	–	–	7	0.3
Car driver	1	3	2	1	–	–	5	0.2
Car pass.	0	0	1	0	–	–	9	0.3
Other/varies	0	0	3	2	–	–	49	2
Total	36	100	247	100	–	–	5289	100

Appendix D. Distances and time usage on walking trips to public transport, regardless of public transport mode, both surveys

Public transport stop survey: Self-reported distances (metres) and time-usage (minutes) on walking trips between public

		Hamar						Kristiansand						Stavanger					
		Mean	SD	25th % tile	Median	75th % tile	N	Mean	SD	25th % tile	Median	75th % tile	N	Mean	SD	25th % tile	Median	75th % tile	N
		Reported distances	<i>Home</i>	497	562	100	300	638	108	352	307	100	300	500	115	–	–	–	–
	<i>Workplace</i>	400	386	100	300	500	73	327	286	100	200	500	87	–	–	–	–	–	–
	<i>Total</i>	–	–	–	–	–	–	–	–	–	–	–	–	399	437	150	300	500	179
Reported time	<i>Home</i>	6.3	6.1	2	5	8	119	4.8	3.7	2	4	6	145	–	–	–	–	–	–
	<i>Workplace</i>	4.9	4.8	2	4	5	82	5.2	5.2	2	3	7	105	–	–	–	–	–	–
	<i>Total</i>	–	–	–	–	–	–	–	–	–	–	–	–	4.8	4.4	2	3	5	180

transport and origins/destinations, regardless of public transport mode. Cut-off boundaries: Duration >0 and <31 min., distance >0 and <3001 m.

Commuter survey: Self-reported distances (metres) and time-usage (minutes) on walking trips between public transport and home

		Hamar						Kristiansand						Oslo					
		Mean	Std. Dv.	25th % tile	Median	75th % tile	N	Mean	Std. Dv.	25th % tile	Median	75th % tile	N	Mean	Std. Dv.	25th % tile	Median	75th % tile	N
		Reported distance	<i>Home to stops</i>	475	372	200	425	700	22	374	356	150	300	500	200	521	415	200	450
	<i>Work to stops</i>	545	389	230	500	800	35	292	311	50	200	400	239	448	380	200	350	600	2665
Reported Time	<i>Home to stops</i>	6.3	4.8	2	5	9.3	22	4.6	3.8	2	4	5	201	6.6	4.4	3	5	10	2307
	<i>Work to stops</i>	6.2	2.9	4.8	5	8.5	34	4.1	4.3	1	3	5	230	5.5	4.0	3	5	7	2659

and workplaces respectively, regardless of public transport mode. Cut-off boundaries: Duration >0 and <31 min., distance >0 and

<3001 m.

Appendix E. Analyses distinguishing between trips to local public transport stops and railway stations in Hamar and Oslo

Commuter survey: Self-reported distances (metres) and time-usage (minutes) on walking trips between public transport and home

		Hamar, commute by railway				Hamar, commute by local public transport				Oslo, commute by railway				Oslo, commute by local public transport									
		Mean	Std.	25th	Median	75th	N	Mean	Std.	25th	Median	75th	N	Mean	Std.	25th	Median	75th	N				
		Dv.	%	tile	%	tile		Dv.	%	tile	%	tile		Dv.	%	tile	%	tile					
Reported distance	Home	517	445	113	450	738	12 425	274	200	425	550	10 721	517	300	625	1000	470	470	368	200	400	650	1838
	Work	675	381	400	600	825	22 323	301	100	230	600	13 554	434	300	500	800	762	406	347	190	300	500	1903
Reported time	Home	8.2	5.3	5	7.5	10	12 4.1	2.9	2	3.5	5.8	10 8.6	5.3	5	8	10	470 6.0	4.0	3	5	8	1837	
	Work	7.3	2.7	5	7	10	22 4.3	2.4	2.2	4.5	5	12 6.6	4.3	4	5	10	761 5.1	3.7	2	4	7	1898	

and between public transport and workplaces by those commuting by public transport. Distinguishing between trips to local public transport stops and railway stations. Cut-off boundaries: Duration >0 and <31 min., distance >0 and <3001 m.

Appendix F. Route choice motivation

At the home-side of the public transport journey: Answers to the question 'Why do you chose the route you do?' Multiple answers allowed. Number of respondents in the commuter survey: Hamar (n = 23), Kristiansand (n = 203), Oslo (n = 2265). Number of respondents in the public transport survey: Hamar (n = 121), Kristiansand (n = 151).

Home-side Statement	Commuter survey			Public transport stop survey	
	Hamar (%)	Kristiansand (%)	Oslo (%)	Hamar (%)	Kristiansand (%)
It is the shortest route	73.9	70.0	80.0	56.2	68.3
It is the only route I can choose	17.4	38.4	24.9	26.4	18.0
It is the safest route	13.0	8.4	7.2	8.3	3.7
It provides a nice walk	26.1	8.9	15.3	2.5	3.7
The route has a sidewalk	17.4	12.3	9.4	9.9	3.1
The speed limit is low	4.3	2.0	1.0	0	0
I bring or collect kids to the kindergarten	4.3	0.5	5.7	0	0
I have errands	0	2.0	2.2	4.1	4.3
Winter maintenance is good	4.3	5.4	-	-	-
Other	-	-	3.3	1.0	6.2

At the workplace-side of the public transport journey: Answers to the question 'Why do you chose the route you do?' Multiple answers allowed. Number of respondents in the commuter survey: Hamar (n = 22), Kristiansand (n = 210), Oslo (n = 2256). Number of respondents in the public transport survey: Hamar (n = 135), Kristiansand (n = 161).

Workplace-side Statement	Commuter survey			Public transport stop survey	
	Hamar (%)	Kristiansand (%)	Oslo (%)	Hamar (%)	Kristiansand (%)
It is the shortest route	72.7	75.2	79.3	65.2	60.9
It is the only route I can choose	22.7	23.8	24.6	25.9	41.0
It is the safest route	4.5	11.9	6.2	7.4	3.7
It provides a nice walk	22.7	10.0	11.9	2.2	3.7
The route has a sidewalk	9.1	11.4	9.4	3.7	5.0
The speed limit is low	0	0.5	0	0	0
I bring or collect kids to the kindergarten	4.5	1	0	0	0

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Workplace-side Statement	Commuter survey			Public transport stop survey	
	Hamar (%)	Kristiansand (%)	Oslo (%)	Hamar (%)	Kristiansand (%)
I have errands	4.5	1.0	1.4	0	0
Winter maintenance is good	0	2.4			
Other	–	–	1.7	1.0	3.1

Appendix G. Modal split, from commuter survey, all respondents (%)

	Public transport	Car driver	Bicycling	Walking	Other	Total
Hamar (N = 347)	11	57	17	13	2	100
Kristiansand (N = 1378)	20	49	16	9	6	100
Oslo (N = 5421)	56	16	16	8	4	100

Appendix H. Commute satisfaction, from commuter survey (%)

	Very satisfied	Satisfied	Neither nor	Dissatisfied	Very dissatisfied	Do not know	Total
Hamar							
Car driver (N = 196)	24	42	23	8	3	0	100
Public transport (N = 37)	21	45	26	5	0	3	100
Bicycling (N = 59)	58	25	12	2	2	2	100
Walking (N = 44)	76	16	0	2	4	2	100
Total (N = 339)	37	36	19	3	2	3	100
Kristiansand							
Car driver (N = 674)	28	41	22	6	3	0	100
Public transport (N = 280)	22	45	17	10	5	0	100
Bicycling (N = 223)	61	29	6	0	5	0	100
Walking (N = 119)	68	25	2	0	5	1	100
Total (N = 1296)	36	39	17	5	4	0	100
Oslo							
Car driver (N = 859)	28	39	20	9	4	0	100
Public transport (N = 3035)	25	46	16	10	3	0	100
Bicycling (N = 882)	41	46	7	4	3	0	100
Walking (N = 446)	66	25	2	2	4	0	100
Total (N = 5222)	32	43	14	8	3	0	100

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