Abstract

Generally, the cost of public transport has increased. Previous research has identified peak hour traffic as the main cost driver, mostly because the travel demand increases the number of vehicles and drivers needed. The purpose of this study is to identify measures aiming to reduce travel with public transport during peak hours, conducted through a semi-systematic literature review. The measures found were fare price differentiation, rewards, information regarding vehicle crowding, staggered school hours, flexible working hours, and working remotely. No studies of soft measures (e.g., campaigns and travel advice) for transport demand management were found. The results indicate that commuters with flexible working hours might have limiting factors that affect their ability to change departure time, for example, activities in connection to work and family responsibilities.

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Keywords: Peak hour traffic; public transport; departure time; measures; effect

1. Introduction

Traffic flow is unevenly distributed over the day. This is because the general travel pattern in society is mainly constrained by working hours for schools and workplaces. Generally, the demand is highest around 7-9.15 a.m. and 4-7.30 p.m. (Hale & Charles, 2009), leading to what is called peak hour traffic. For public transport, during the peak hours there is crowding and a higher number of passengers per hour compared to other hours of the day. Since the number of public transport vehicles and drivers is based on the transport demand during these peak hours, there are large vehicle fleets and drivers not being effectively used. Further, crowding results in public transport appearing less attractive (Hickman et al., 2018). If the public transport system is to be able to handle an increasing number of travellers, there is a further need to spread the travel flow more evenly throughout the day.
Generally, the cost of public transport has increased. A study by Avenali et al. (2017) concludes that the key cost drivers in Italian public transport are commercial speed (ratio between the total number of bus kilometres supplied and the total number of net driving hours), average age and degree of renewal of the bus fleet, and the average salary per driver. This increasing cost is also the case in Sweden. A report published by the Swedish government agency Transport Analysis (Trafikanalys, 2019) shows that between 2009 and 2018 the number of public transport kilometres increased by 20% and the number of passengers increased by 30%. During the same period, the costs increased by 50%. The ticket revenues increased by 55%, but since the ticket revenues only cover approximately half the costs (differs between regions) the cost coverage has decreased. Research conducted by Camén and Lidestam (2016) and Lidestam et al. (2018) has identified peak hour traffic as the main cost driver for public transport in Sweden. The main reasons stated in the studies are that the number of buses and drivers is dimensioned according to the short and sharp morning peak which has the highest demand of the day. In a study of the cost-efficiency of the Swedish public transport Vigren (2016) discusses that the number of buses and drivers needed in a contract area is determined by the peak demand. The large bus fleet is not fully utilised other hours of the day, the size of the buses is larger than needed for the average demand, and due to working time regulations, the shortest time a driver can be scheduled is three hours (which is longer than the peak) (Camén & Lidestam, 2016). A study by Lidestam and Jonsson (2018) concludes that the number of vehicles, and hence the costs, can be reduced significantly by marginally changing the scheduled timetable. This leads to the need to even out the travel demand during the morning and in the afternoon. There is thus a need to gain a deeper understanding of incentives, such as perceived costs and benefits of transport demand measures, to fully comprehend the challenges and success factors of measures that spread out the travel demand. Additionally, during the Covid-19 pandemic, several measures were and are used to reduce crowding on public transport. These challenges will continue after the pandemic to be able to reach a cost-effective public transport system.

The purpose of this study is to identify measures aiming to reduce travel by public transport during peak hours. Through a literature review, different measures are mapped outlining their design and characteristics. An earlier literature review by Hale and Charles (2009) focuses on managing peak demand for passenger rail and includes network capacity and planning, ticket price differentiation, policy, and passenger demand management. This review will focus more on soft measures aimed at individuals (e.g., information, and reward programs), economic incentives, and measures aimed at organisations (e.g., encouraging flexible working hours and working remotely), and not on infrastructure or traffic planning, thus complementing the results by Hale and Charles (2009).

The quantitative literature search process will be complemented with a qualitative analysis of the different measures found. From the review, there will be an attempt to answer the following research questions:

1. What measures are used to reduce travel with public transport during peak hours?
2. Which factors influence the effect of measures aiming to reduce travel during peak hours?

2. Method

This literature review is based on the methodology of Avni et al. (2015) and Snyder (2019). The result from the literature search process is presented with the help of the structure defined in PRISMA 2020 (Page et al., 2021). The review is semi-systematic (Snyder, 2019), with the aim to identify all potentially relevant researched measures that are significant within the scope of the study and synthesise these. Research question 1 is answered through the semi-systematic review. Question 2 is answered through a less extensive literature search.

The search process was conducted in six steps, following the methodology in Avni et al. (2015). The first two steps included the definition of the search topic and scope (presented in the introduction) and limiting which resources to include in the search. The databases used were Transportation Research International Documentation (TRID), Scopus, and Web of Science. The databases were chosen to be able to cover the full scope of the review, which included research done within both transportation and behavioural science. The third step was to choose search terms, followed by a compilation of the search strategy and the iterative process of running the search. The focus of the literature review is to find different implemented and studied measures with the aim to reduce travel during peak hours. Four keywords were identified: travel, measure, reduce, and peak hour. Identification of synonyms, related terms, narrower terms, and broader terms was done by using the Transportation Research Thesaurus (Transportation Research Board,
n.d.) and by studying keywords used in relevant articles. In this conference paper, the measures presented are limited to public transport as a transport mode. The fourth step in the methodology by Avni et al. (2015) was to compile the search strategy and run the search. The search terms, listed in Table 1, were combined with Boolean operators to form a search string. Each keyword and its synonyms form a search block with each term combined with the operator OR. All four blocks were combined by the operator AND, to form the final search string.

Table 1. The search terms divided into search blocks, with the four blocks combined by AND to form a search string. Truncations are used in the form of an asterisk (include any ending) and a question mark (include different spellings). Quotation marks are used to specify that adjacent words be searched as a phrase.

<table>
<thead>
<tr>
<th>Travel</th>
<th>Measure</th>
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<th>Peak hour</th>
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<tr>
<td>travel OR</td>
<td>measure OR</td>
<td>reduce* OR</td>
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<td>lessen OR</td>
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<td>trip OR</td>
<td>intervention OR</td>
<td>decrease OR</td>
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<td>“Public transport*” OR</td>
<td>motivation OR</td>
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The literature search includes articles published between 1990 and February 2022. The three scientific databases differed in how the search could be conducted and in which way the results could be filtered by using inclusion and exclusion criteria. The search fields used in Scopus were title, abstract, and keywords, in TRID all keywords, and for Web of Science all fields. Categories and subject areas relating to transportation, transport economics, and behavioural science were included.

The review of the search results was the fifth step. It was conducted through an iterative exclusion process, starting with assessing titles, then abstracts, and finally the full text. In each step of the process, the focus was on measures that reduce daily travel during peak hours with public transport. Articles concerning congestion connected to accidents, tourism or single, major events were excluded. In addition, articles regarding measures focusing on relieving congestion in general, e.g., traffic signals, infrastructure, road pricing, and land use, were excluded. The inclusion of articles focused on how to reduce congestion and crowding during peak hours and the effects of the measures. Articles in English were included, and the search was geographically limited to studies conducted in Europe, North America, China, South Korea, Japan, Singapore, and Australia. These areas have similar challenges with congestion and crowding and have introduced different measures of interest to this literature review. The literature search process is outlined in Fig.1, with the number of articles found in the respective database, and how many articles were excluded in each step.

Fig.1. Step five of the literature search process, the iterative exclusion process. Adopted from Page et al. (2021)
The final step was to organize, synthesise and analyse the collected resources. In this conference paper, the focus is on measures used within public transport, and only one study per measure is presented. The results from the final step are presented in the succeeding chapters.

3. Results

The first sub-section focuses on measures aimed at individuals and organisations to reduce travel during peak hours with public transport. This paper presents a selection of different measures found, with one study regarding each measure used as an example of design and effect. Factors that influence the effect of the proposed measures are presented in Section 3.2.

3.1. Measures to reduce travel during peak hours

The two main measures aimed directly at individuals to reduce their travel during peak hours by public transport are varieties of price differentiation and rewards, that usually incentivise an earlier departure time. There are also studies regarding measures that used information about crowding on public transport to stagger travel during peak hours. Included in this study are also measures used during the Covid-19 pandemic to reduce crowding in public transport since lessons learned from those could be applied in other settings. Different measures that are possible to use at workplaces and schools to spread out working hours are presented in the second half of this section.

Price differentiation is a measure that has been and is currently tested in several locations, to help shift some of the demand to the off-peak periods. The most common design of price differentiation in public transport is to have a higher fare during peak hours (morning and afternoon during weekdays) and a lower off-peak fare at all other times (Kamel et al., 2020). As opposed to the flat fare, a differential fare incentivises travellers to shift departure time and spread the travel demand. The downside is that trips can shift to other modes, such as cars, and thus increase congestion (Kamel et al., 2020). Cervero (1990) states that the potentially most effective way to capture the higher marginal cost of providing public transport during peak hours is by differentiating between peak and off-peak fares. The measure is cost-effective and implementation can be done fast (Kamel et al., 2020). Furthermore, if effectively used, price differentiation reduces crowding during peak hours and should result in more efficient economic conditions for public transport (Hale & Charles, 2009). Travellers who are more likely to shift departure times due to a price differentiation to a higher degree have more flexible travel times, receive other discounts, or travel short distances and end their trip close to pre-peak (Halvorsen et al., 2020).

An example of a price differentiation measure is the pre-peak fare discount that was introduced in Hong Kong in September 2014. Trips that end between 7.15 and 8.15 a.m. receive a 25% fare discount when alighting in the city centre, shifting passengers away from the peak period around 8.00-9.00 a.m. (Halvorsen et al., 2020). An evaluation made by Halvorsen et al. (2020), concludes that two months after the introduction 2.5% of the morning trips had shifted out of the peak. Compared to that 27% of the trips made between 7.00 and 9.30 a.m. end during the discount period concludes that most of those who receive the discount did not make a behavioural change. Of those who shifted to a pre-peak departure a bit over 70% sustained their new travel behaviour after three months, and about 65% after two years.

Instead of fare discounts, there are examples of measures that incentivise an earlier morning departure with different types of rewards. In an experiment conducted in the Netherlands the participants, chosen from passengers with an annual train pass, could earn a monetary reward (Peer et al., 2016). The reward period was 15-18 weeks long. If the morning and afternoon trip, from a specified origin-destination pair, started outside peak hours the participants received a monetary reward. The size of the reward is based on the length of the trip and divided into two reward levels, ranging between 1.5 and 4.5 euros per trip. During the reward period, there was a decrease in peak travel by 21.8%. In the post-measurement period, the decrease in peak travel was 11.1%. It is concluded by Peer et al. (2016) that the result might not be representative of the general population since the participants were not randomly selected and that the people who signed up on average were more flexible, more likely to travel off-peak or near off-peak, and more likely to prefer an arrival time outside peak, compared to a surveyed non-participant group.

Another studied measure to reduce travel during peak hours is information to public transport passengers regarding the vehicle’s crowding, either real-time information or based on a prognosis made from historical data. By providing
information the passengers can make informed decisions regarding departure time, travel mode, and route choice. Drabicki et al. (2021) have developed a framework for modelling the effects of real-time crowding information on the travel experience. The model was used to simulate the effects of the information system during the afternoon peak in a public transport network of Kraków, with regards to shifts in passenger flow. The study shows that real-time crowding information decreased 36% of the worst and the moderate crowding experience and affected a reduction in waiting time due to denied boarding by 30%. Even though the crowding information only was accurate for 56% of the passenger decision instances.

Throughout the Covid-19 pandemic, various measures have been used to reduce the number of people who travel by public transport, especially during peak hours. A study by Höcherl et al. (2021) explores how social distancing can be achieved through different demand management measures that are enabled by new technologies. Three measures were discussed regarding different ways to be assigned a time travel slot, either by reservation, auctioning or tradable travel permits. Slots during peak could come with a fee or be assigned based on job type. The study (Hörcher et al., 2021) also suggests a fare differentiating system based on departure time or travel route and that multiple measures should be implemented simultaneously.

School and work trips contribute to a large part of the high peak demand. By spreading out the demand for trips to workplaces and schools it is possible to also lower the peak demand. The scope of studies regarding flexible working hours is extensive, especially compared to the number of studies regarding staggered school starting hours. A Swedish study by Ljungberg (2009) found that 20% of the passengers during peak hours were travelling with a school card and suggests that by staggering school hours the demand in the busiest peak period can be reduced. The study (Ljungberg, 2009) surveys pupils and interviews teachers and headmasters regarding (1) half of the pupils starting one hour later or (2) one third starting half an hour earlier, one third starting the same time as today, and one third starting half an hour later. A cost-benefit analysis demonstrates that the generalised cost for the pupils to change school hours could be the same size as the reduction in costs for needing fewer buses during the peak (and, by extension, in the entire bus fleet). The overall largest challenge found by the study (Ljungberg, 2009) is to get the headmasters and the public transport authority to cooperate. Research by Liu et al. (2017) focuses on the commute of all household members which typically consists of two consecutive trips when first dropping off children at school and then travelling to the workplace. The study concludes that coordinating starting hours of school and at workplaces can reduce congestion and lower the total travel cost.

Besides trips to school, another main contributor to the high peak demand is commuting to work. Many workplaces offer flexible working hours which in theory can contribute to staggering the departure time for commuters. An American study (Hartgen et al., 2012) states that one-third of employers consider congestion being a moderate or major problem for business travel, commuting, and shipping. However, 82% of the employers did not think that they were the ones responsible to find a solution. Of the surveyed employers, 5% suggested measures that the employer could implement, e.g., flexible working hours, remote working, and incentives for carpooling, and 5% suggested an increase in infrastructure capacity. A Dutch study (Noordegraaf & Annema, 2012) concludes that most support from employers regarding measures to reduce peak hour demand is connected to the level of feeling responsible for employee commute behaviour, if human resource managers have a positive approach, having flexible working hours, and are already working with behavioural management measures. Rahman et al. (2022) studied how having flexible working hours in Austin, Texas, positively affected traffic congestion and work-life balance. For those with flexible hours, the probability that they would travel during peak hours was reduced and there was an increased possibility that they would have a departure time after the peak. Furthermore, flexible working hours contribute to increasing productivity and personal well-being. When using a two-stage optimisation model Yushimoto et al. (2012) found that when staggering starting hours for employees the alternative starting times should be placed at the shoulder of the peak period. The shift was achieved by providing incentives. Both those who shifted starting time and those who did not benefit from the reduced congestion.

The option of working remotely is another alternative for employers to help reduce the daily travel demand, a possibility that has been further enabled through the development of information and communication technologies. Working from home or from an alternative location makes the person more likely to avoid travel during peak hours, with more people avoiding the morning peak than the afternoon peak (Stiles & Smart, 2021). A Swedish study by Vilhelmsen and Thulin (2016), conducted on data from 2005 to 2012, indicates that working remotely outside the
workplace has become routine for 20% of the Swedish workforce. Nearly one-third of the commuting-based workers assessed that their job tasks allow for working remotely.

3.2. Factors influencing the effect of peak travel reducing measures

Several factors affect a person’s possibility to change their departure time to avoid peak hour traffic. The factors are either real constraints, e.g., non-flexible working hours, or perceived constraints, e.g., costs related to changing departure time. There are several constraints built into how a person chooses to travel to school or the workplace. It could be people’s preferred sleeping patterns, standard hours for schools and workplaces, social constraints in the form of leisure activities and family routines (Hale & Charles, 2009), family structure, and commuting distance (Rahman et al., 2022). Mannering (1989) states that a commuter’s decision regarding departure time and which route to take is based on two categories of information, either from experience or real-time. Individual characteristics, such as being risk-averse or a risk seeker, and family responsibilities may affect the possibility to choose. The study conducted by Mannering (1989) shows that an increase in age relates to a decrease in changes made, which is connected to older people being more risk-averse. Married people and women are less likely to change routes, compared to unmarried people and men (seen as risk seekers). Perceived benefits and sacrifices affect the passengers’ intention to travel outside peak hours. A study conducted on passengers in Beijing’s subway system (Wang et al., 2020) found that a positive impact on a commuter’s intention comes from previous experience of peak avoidance, compliance with social norms and the perception of a more comfortable and less crowded trip. Perceived sacrifices are costs connected to money, physical energy, uncertainties, time, and mental strain. A study by Kim et al. (2009) concludes that travel time, trip purpose, the need to arrive at a specific time, and sociodemographic factors affect the change of departure time based on real-time crowding information.

Two Danish studies have compared morning commuters’ willingness to change departure times. The first study (Haustein et al., 2018) divides commuters into three categories; unhurried timely commuters (25%), self-determined commuters (37%), and busy commuters (38%). The self-determined commuter is younger, with more flexible working hours, is flexible with arrival time, more willing to reschedule its departure time to avoid peak hours and is less dependent on others when choosing transport mode. The busy commuter wants to arrive on time and has a short travel time. The second study was done with commuters by car (Thorhauge et al., 2021) regarding flexibility constraints and conclude three segments of commuters; Unconstrained (30%), Constrained around work (19%), and Constrained after work (51%). The unconstrained commuter is flexible with regards to their morning commute, has few daily constraints and is most likely to change their departure time to lower their travel cost and time. Individuals belonging to this segment are likely to be single without children, have flexible work hours and belong to a mid-range income group. Commuters in the other two segments are less likely to be flexible regarding their departure time. Individuals in these segments generally are high-income earners, have child(ren), do not work full-time and have fixed work hours.

Working remotely, or telecommuting, can contribute to reducing the number of people travelling at peak hours. During the last two decades, the type of work tasks that are possible to perform outside the workplace has grown. A Swedish study (Vilhelmson & Thulin, 2016) concludes that, in addition to an enabler like digitalization, contributing factors to being able to work remotely are job characteristics, job assignment, the manager’s trust and control, type of job contract, and individual and household work-life balance. Factors that significantly increase the likelihood of regularly working remotely are being male, having a family and young children, living in a large urban area, education at the university level, permanent employment, and working in advanced services.

4. Discussion

The different measures included in this study are either aimed directly at the individual or indirectly through measures used within an organisation. The full potential of the measures is not evaluated, since only one example of each measure is included in this study. When targeting individuals directly either different monetary incentives are used or through providing information. When using monetary incentives the commuter needs to experience a reduction in their total travel cost, and a reduction of the ticket price or giving a reward has to compensate for the discomfort of changing behaviour. If the ticket price already is low, then introducing a price differentiation will not lead to a large change. The use of crowding information seems to have the potential to reduce the travel demand, even though the
information provided is not completely accurate. The results from the review indicate that the perception of a more comfortable trip makes a positive impact on the intention to change departure time. Halvorsen et al. (2020) discuss several ways to improve the suggested measures. It is suggested that a price differentiation fare scheme could be structured as a rebate with a weekly pay-out, to attract those who overlook small discounts, or a lottery instead of a guaranteed pay-out. School and commuter trips are named as the largest contributor to the high peak travel demand and by working with schools and workplaces it can be possible to spread out the demand. The review results suggest that both headmasters and corporate management seem to be key players when introducing staggered working hours and the possibility to work remotely. The studies included in this paper give the impression that the willingness to work with these questions is low. For schools there seem to be a lack of incentives. Employers seem to be aware of the problems that congestion creates for the company, but few thought that they were the ones that should contribute to a solution, or maybe felt a lack of tools or influence over the employee's daily life planning.

When targeting commuters with flexible working hours with measures to make them change their departure time there is also a need to consider other factors that might limit their ability to change behaviour. Limiting factors found in this study are, for example, activities in connection to work, family responsibilities, if the person is risk-averse, unwillingness to change, and uncertainties. There is a share of the workers (that have flexible working hours) that are more suitable to target, and they are flexible with their arrival time, are less dependent on others when choosing transport mode, and are willing to change (if it lowers their travel time and cost). There is an increase in the intention to change departure time if the person has experienced peak avoidance or if an earlier departure is perceived as more comfortable. When designing measures, they can include elements of incentivising to try out a change in departure time or information regarding that an earlier departure is less crowded and more comfortable.

5. Conclusion

Through a literature review, several measures were presented that are used to reduce travel during peak hours with public transport. Aimed directly at individuals are fare price differentiation, monetary rewards, and information regarding vehicle crowding. All measures included in this review results in a reduction in travel during peak hours. Within organisations, staggered or flexible working hours are used to reduce the need to commute during peak hours. In addition, the possibility to work remotely reduces the peak travel demand. When formulating the purpose of the study there was an expectation that the result would include studies regarding the use of soft measures (e.g., campaigns, travel advice, and try out activities) for transport demand management. No studies of these kinds of measures were found.

Many commuters experience real and perceived constraints regarding the possibility to change their departure time. The results indicate that activities or responsibilities after work have a high influence on the choice of departure time, and an increase in the likelihood to change departure time is if the person has previous experience of travelling off-peak. The findings in this study can be utilized by public transport authorities and local governments working with lowering the cost of public transport by reducing the travel demand during peak hours.

A more comprehensive literature review that includes different designs and implementations can contribute to a general recommendation regarding execution and effect. Further research should be conducted regarding how to communicate with schools and employers regarding their role in contributing to and enabling a reduced travel demand during peak hours.

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References


