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Public Transport Accessibility: A Literature Review

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RESEARCH ARTICLE

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Abstract

Accessibility is one of the most important outcomes of the transportation system. Public transport can be more attractive by providing "Door to door mobility" and development of transportation services is an important factor of social quality. Public transport accessibility has gained vital importance in designing and evaluating the transit system in terms of mobility and sustainability. Apart from the transport system itself, public transport accessibility has the considerable impact on life satisfaction in the form of perceived accessibility. Moreover, researchers have revealed several impact and correlation of provision of public transport accessibility to the environment and daily life which would have a noticeable impact on public health and other aspects of public daily life. Furthermore, the correlation between public transport accessibility and job opportunities has attracted the researchers' attention in the literature. Also, public participation in social activities has been investigated based on public transport accessibility and their close connection has been revealed under the topic of social exclusion. In this paper, the available literature on public transport accessibility has been reviewed. As a conclusion, it should be highlighted that not just the performance of public transportation but its impact on other social aspects should be considered while planning the public transport facilities.

Keywords

public transport accessibility, mobility, social exclusion, public health, sustainability, perceived accessibility

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1 Introduction

Public transport (PT) in urban areas has gained greater attention in recent years for improving sustainability and the quality of urban life. The economic and environmental performance of cities can be enhanced by connecting resources to destinations effectively and facilitating mass mobility (Bok and Kwon, 2016).

During the past two decades, a huge population growth is recorded in developing countries (Buhaug and Urdal, 2013). Increase in population has caused an increase in the demand for mobility. If the transport infrastructure is not capable of meeting the demands, this causes an increase in waiting times and congestion in public transport and streets (Samek Lodovici and Torchio, 2015). Public transport can be more attractive by providing "Door to door mobility" and development of transportation services is an important factor of social quality ((Jackiva) Yatskiv et al., 2017). Sustainability of transportation, environmental conditions of an area, public health and economic condition of residents can be raised by shifting from private transport to the public transportation, walking and cycling (Elias and Shiftan, 2012). This shifting will happen in the condition that the public transportation is widely available and accessible to the public.

In general, accessibility is labelled as the physical access to goods, services, and destinations. In the context of urban economics and geography, accessibility, which is one of the most important outcomes of the transportation system, is characterized as the facilitation in accessing a specific area or location (Mavoa et al., 2012). It is a measure of the advantage of the location of a zone or area compared to the other zones and areas (Biosca and Stepniak, 2013). Good accessibility of public transport improves the accessibility to other services as well (Abreha, 2007).

The main aim of the public transport accessibility assessment is to provide better connectivity of people and location in order to decrease the congestion on roads. In simple words, mobility through public transportation provides an opportunity to decrease inauspicious effects of car usages on environmental condition and healthfulness ((Jackiva) Yatskiv et al., 2017). Mobility level of a city can be improved by providing a well-organized transportation system. Hence, accessibility of public

transport stops, connectivity of modes of public transport and system mobility should be considered to provide a user-friendly system of public transport (Cheng and Chen. 2015).

Service access and urban public transport accessibility have always been a major service issue in urban public transport. In network design of transit services, researchers are often more focused on minimizing the user and operator cost rather than incorporating the issues of equity and access (Murray, 2003). Availability of infrastructure, ease of information, reduced time and cost are imperative factors in providing an attractive public transport with door to door access as well as the long-distance travel ((Jackiva) Yatskiv et al., 2017).

Since the lack of access to transportation leads to social exclusion, transport and land use policies focus on accessibility and aim at enabling people to reach destinations at reasonable costs and times (Hawas et al., 2016). Therefore, providing efficient public transport in terms of accessibility is one of the main objectives of policy makers and planners in metropolitan areas throughout the world (Saghapour et al., 2016).

In the current paper, the correlation of public transport accessibility to the other aspects of social life has been deeply reviewed and the studied factors are revealed for the further assessment in the forthcoming research work.

2 PT Perceived accessibility

Perceived accessibility is a measure of living a satisfactory life using public transportation. The aim of perceived quality is to apprehend the subjective measures which are based on the user perception, incorporating with subjective measures which refer to the quantitative measures of predetermined parameters (Lättman et al., 2016). In 2016, Lättman et al. proposed to consider the perceived accessibility in public transport as a complementary measure to conventional objective measures of accessibility by capturing the subjective element of accessibility, as opposed to conventional accessibility that is based on the same objective attributes for large areas or groups of people. They developed a measure of perceived accessibility by running a four items self-reported questionnaire from the users of public transport. The investigated items were as follows:

- It is easy to do (daily) activities with public transport.
- If public transport was my only mode of travel, I would be able to continue living the way I want.
- It is possible to do the activities I prefer with public transport.
- Access to my preferred activities is satisfying with public transport.

They suggested to use this measure of perceived accessibility in order to determine the traveller's (or possible travellers) opinion of accessibility in transport planning or accessibility-mapping, or for directing interventions aimed at improving accessibility to where they are best needed according to the individuals.

Evaluation of perceived accessibility provides a strong ground to complement theory on accessibility with subjective experiences of travellers to provide realistic basics in actual accessibility indicators (van Wee, 2016).

Different key aspects of perceived quality have been developed by researchers. Dalvi and Martin focused on ease of reaching the desired activities of the transport users (1976). Geurs and van Wee, (2004) discussed the perceived possibilities of travel. Furthermore, perceived opportunities to activities of interest are defined as the most important aspects of perceived accessibility by (Axhausen and Gärling, 1992).

3 PT accessibility and Public health

Public transport planning generally studies health impacts of public transport as a subordinate importance. Public health indicators for transport are considered as an issue with limited importance and often unheeded such the emission rate of the vehicle, crashes, basic mobility benefits and mental health in the process of economic analysis. Time to access and egress the PT has been treated as a disutility and 'penalty' in the past. Due to the ignorance, importance of the impact of transport to promote incidental active travel by reaching from the public transport to the destination (access and egress) for health was not considered effectively (Mulley et al., 2016). Considering the emission rate of a vehicle per mile rather than per capita causes a huge difference in the analysis of public transport health costs (Litman, 2010). There is a close connection between using public transportation and physical activities in human's lifestyle. Physically inactive lifestyles are a major public health challenge. For instance, in U. S. inactive lifestyles are responsible for about 200,000 deaths in the U. S. each year, second only to tobacco (U. S. HHS, 1996; McGinnis and Foege, 1993).

A recent study in 2018 studied the effects of unavailability of public transport in Barcelona over the air pollution and found that during the public transport strikes, level of NOX was increased between 4.4 % and 7.1 % and the same trend was recorded for the black carbon in air. In other words, the access to public transport has consequences on the air quality and health (Basagaña et al., 2018).

The access of public transit is likely to enhance the probability of meeting the public via physical activity. Research shows that the people who tend to walk to the public transport station achieve significantly more physical activity as compared to the other who use private transport to the activity points. Low income group of public with risk of obesity are likely to gain benefits of health from transport through walking (MacDonald et al., 2010).

Increasing the access to public transport to the majority of public will cause to provide opportunity to attain minimum level of daily physical activity. Active lifestyle can be directly affected by providing the opportunity of accessible means of public transport to public especially low income and minority groups (Besser and Dannenberg, 2005).

4 PT accessibility and Employment rates

The connection between the accessibility of transport and employment has always been an area of dispute in geography and planning of transport infrastructure (Johnson et al., 2017). Public transportation characterizes a productive strategy to challenge unemployment (Sanchez, 1998). It seems promising that transit can overcome the physical split-up between the residential locations workforces and job locations. The positive relationship between transportation accessibility and labour force attachment may not be coincidental role of public transport but due to spatial urban factors (Korsu and Wenglenski, 2010).

Transportation based on employment is becoming more difficult to the transport operator to provide dispersed and effective service in transit inaccessible land use patterns. In 1998, Sanchez revealed the connection of the accessibility of the transit system and employment using geographical information system to analyse the variation of employment characteristics of workforces with different levels of accessibility to the transport system. The result of the research characterised the access to transport services as a key factor to determine the labour participation and corresponding average rates (Sanchez, 1998).

To verify the previous study, Sanchez used two-stage least squares regression model to evaluate the relationship of accessibility of public transit with labour participation levels. The results justified the previous result of a strong relationship between access to public transit and the average rates of labour participation (Sanchez, 1999).

In a recent study in 2017, Johnson obtained the same results seconding the previous study by Sanchez. Research regarded the systematic variation of employment rate at the local level comparing the available public transport network. His model considered the employment as a function of accessibility as a major contribute in addition to other local labour variable to address the relationship. Result of the research found a significant statistical relationship as the association of higher employment levels with shorter public transport time. Finally, research proposed to consider the accessibility of public transport system as a vital parameter to address employment (Johnson et al., 2017).

Providing the transit facilities can widen the range of opportunities for employment. Transport should be seen as a service, which can also increase economic efficiency by adding access to opportunities such as seasonal prospects beyond their settlements (Gannon and Liu, 1997).

Research shows that public transport based job accessibility has a positive and indefinite effect on individual incomes. Urban public transport systems target, among other motives, to assist commuting and to improve individual performance on the labour market (Pons Rotger and Nielsen, 2015).

The regulation to the 2010 Child Poverty Act (Department of Education, 2010) says: "Transport infrastructure, and accessibility to local services for children and parents, and employment opportunities for parents, are important in all local areas and are likely to be particularly so for those living in more remote or rural areas where the effects of growing up in poverty may be compounded by poorer access to services".

Urban public transport systems aim, among other purposes, to facilitate commuting and hopefully to enhance individual performance on the labour market. Improved job accessibility may raise individual employment rates and earnings by different mechanisms. Workers may not consider relevant job vacancies due to excessive commuting time (Phillips, n.d.).

The study of the consequence of improved accessibility on incomes is an significant contribution to the literature on the effect of improved accessibility which tends to rely on the more indirect methodology (Pons Rotger and Nielsen, 2015).

Research on effects of job accessibility improved by public transport system in Copenhagen estimated minimum street distance from residences to a metro station. Employment percentages of residents were calculated for the analysis corresponding to distance from the metro station. Employment rate of 84.7 % was recorded where residence was ranging 0.5-2.7 km from station where the same parameter of employed was rated to 84.0 % for the residences ranging from 2.7-6.2 km from station. Same trend was recorded in case of earnings (Pons Rotger and Nielsen, 2015).

5 PT accessibility and Social exclusion

The concept of social exclusion has gradually become an important factor in social policy discussion. Briefly, social exclusion is a process which causes an individuals or groups of society to restrain in taking part in the normal activities in their residential area and has significant spatial demonstration (Fiona Raje 2006). However, in recent researches this term represents a complex concept including several dimensions which includes temporal, spatial, social network, societal, economic, political, personal and mobility disadvantages among different segments of society (Bocarejo S. and Oviedo H., 2012; Kenyon et al., 2002). In a recent study in 2015, Mackett studied the relation of access to public transport with the daily lifestyle of public and found that how transport contributes to the nature of social exclusion by providing barriers to access (Mackett and Thoreau, 2015).

Literature on social exclusion emphases more on the outcomes of transport deprivation than on the processes leading to it (Titheridge et al., 2014) and the categories of exclusion in transport are assorted, ranging from physical and spatial to socio-economic factors (Fransen et al., 2015).

Research on transport builds up on general notion to define transport-related social exclusion as the "process by which people are prevented from participating in the economic, political and social life of the community because of reduced accessibility to opportunities, services and social networks, due to whole or in part to insufficient mobility in a society and an environment built around the assumption of high mobility" (Kenyon et al., 2002). A survey conducted in Scotland found that the access to sports

facilities highly affects the participation, particularly of those aged group of 16-34 years (Murray and Ipsos MORI, 2006).

Policy concerns related to social inequalities in mobility and access to important goods and services have emerged and grown along with a policy interest in the causes and the effects of social exclusion.

Various studies focused under the domain of transport-related social exclusion have used geographical information systems (GIS) to unravel the connections between social disadvantage, public transport needs and public transport provision (Fransen et al., 2015).

A study in Belgium by (Fransen et al., 2015) was conducted to measure the public transport accessibility gaps. Researchers constructed the Index of Public Transport Needs (IPTN) and an Index of Public Transport Provision (IPTP).

Percentage of the population according to different age groups, vehicle ownership and the percentage of the active population that was unemployed was calculated in the area for each TAZ. Additionally the percentage of the population receiving subsistence per municipality, number of jobs and the student capacity was recorded and utilized as socio-economic situation indicator for an inhabitant's. The spatial distribution of socio-demographics characteristics was used to estimate a general index for public transport needs. Travel times were used based on O-D were used to determine the number of accessible opportunities for different time intervals for each TAZ. IPTN and IPTP were normalized to compare the indices. The Index of Public Transport Gaps (IPTG) was computed as the difference between public transport needs and provision.

6 PT accessibility and Mobility

Numerous transformative developments have changed the landscape of the urban mobility. With advent of time, new actors of advancements in the urban development, provision of the information and other technology-influenced factors have governed and act as major factors and plays role considering the urban mobility. With provision of the private modes of travel, the challenge is to bestow an efficient, affordable, and suitable alternative to conserve high quality standards of life (Policy Brief, 2016).

Accessibility was clearly defined as the potential for interaction in context of planning by Hansen (1959) while Mobility was defined as the potential for movement which is associated with the impedance component of accessibility. Mobility defines the difficulty to access a destination. Mobility is a requirement for participation in "modern life", (Hernandez, 2017).

In a latest study in 2018, (Mugion et al., 2018) reviewed the literature and investigated the effect of accessibility of urban public transport on sustainable mobility. Study developed a theoretical framework to cover the literature gaps by investigating the relationship among the intension of preferring private transport over the public transport, service quality provided for the urban public transportation system and service loyalty to urban public transport. They considered three step process 1-Territorial analysis to support the development of the 2-Qualitative survey with comprehensive interviews which further provided a foundation for building the structure of 3-Quantitative survey questionnaire survey with designed questionnaire. They found a direct connection of service quality as a measure of access to PT with the intention of using the public transport.

Effect of mobility is not confined to willingness of the users, according to (Ascher, 2007), "… mobility is a key condition of access to employment, housing, education, culture and leisure and family. The right to work, to have a home, to training involves the right to mobility. ... in a sense this right to mobility is a precondition of the other rights" (Ascher, 2007).

Mobility is difficult to measure at individual level as it requires trailing the behaviour of travel (Litman, 2011). Mobility is measured by actual movement or transit supply in the form of numbers of trips made or total kilometres travelled (Handy, 2002). An efficient public transportation system has the potential of increasing the level of mobility in cities. Hence, public transportation system should consider mobility of the system along with accessibility to stops/stations and connectivity to other transportation modes (Cheng and Chen, 2015).

Originally looked upon as a concept closely related to mobility, accessibility has been used in planning and evaluating the transportation system through activity-based approaches such as choice theory and travel behaviour (Axhausen and Gärling, 1992; Burns and Golob, 1976). The both factor are directly linked with each other so policies to increase mobility will generally increase accessibility as well and it will make the destinations easier to reach. But it is possible to have good accessibility with poor mobility and vice versa (Handy, 2002). Therefore, planning of enhancing accessibility may have very different consequences than planning efforts that emphasis on improving mobility (Handy, 2002). The mass mobility and quality of urban lives can be improved by establishing public transport networks that are accessible to pedestrians within a reasonable walking distance (Bok and Kwon, 2016).

7 PT accessibility and Sustainability

The current challenges for cities and the world-wide environment are not only aiming to reduce global warming and the pollution and emissions but they are improving the quality of life for citizens. Currently, cities are also major donors to environmental problems, emitting more than 70 percent of all greenhouse gas emissions and the energy consumption globally (Cohen and Muñoz, 2016). Transport sector is a major contributor to the CO_2 emissions in urban areas (Elias and Shiftan, 2012). Efficient public transport (PT) networks are prime feature for well-operative and sustainable cities (Kujala et al., 2018). Shifting from private motorized vehicles to public transportation, walking and cycling can increase

the sustainability of transportation and accordingly, improve the environment, economics and public health (Elias and Shiftan, 2012).

Interest in sustainability of transport and its implications is growing in policy making and academia. Sustainability deals with the concerns about usage of current resources and it goals to maintain a level of resources for the future generations. Economic point of view relates the sustainability to focuses on the idea of optimizing the efficiency of resources, subject to transport planning sustainability aims to achieve better accessibility and the ability to reach the desired location with less resource consumption. (Vega, 2011)

Conversely, sustainability and accessibility can easily conflict each other – in case of transportation infrastructure, sustainability appreciates the shared space but accessibility desires to remove these obstacles. (Tyler, 2017)

Therefore concept of sustainable accessibility arises which balances between the sustainability and accessibility. It uses the spatial information to evaluate intermodal sustainable accessibility. This concept utilizes the spatial information like urban trips and in particular area and information of trip to work that can be acquired from the actual multi-modal analysis. (Cheng et al., 2007)

The advantage of this framework by (Vega, 2011) is the less data requirement to run the analysis which may not be available for under developing and small cities. Analysis compares the accessibility index evaluation of transport mode with index of energy performance as an indicator for sustainability, to perform multi modal analysis use spatial conflict analysis to identify ways of achieving a balance between accessibility and sustainability.

8 PT accessibility and Economical, Spatial and temporal efficiency

Increase in urban populations with time have caused increase in traffic causing congestion on roads and environmental impacts; urban planner are more attracted towards public transport than private transport (Benenson et al., 2011; Kawabata and Shen, 2006). This surge in attraction is due to the large capacity of public transportation modes, punctuality, low cost, low volume, high speed and its convenience for passengers to travel even inside the congested city centres.

Accessibility can be evaluated with respect to two basic categories (Delafontaine et al., 2012) - Place based and Person based (Miller, 2007). The spatial–temporal accessibility of a public transport system measures the spatial–temporal limitations faced by passengers based on their predefined activities and the ability of the transport system to facilitate trading time for space in movement (Cheng et al., 2018). Place-based category associates a level of accessibility with a spatial location units or location criteria for analysis. They elaborate accessibility in terms of physical parting between the location desired for daily activities and a base location such as residence or workplace.

In 2017, (Dadashpoor and Rostami, 2017) found a link between the role of spatial proportionality to estimate the efficiency of public transport accessibility. Study aimed to measure spatial parity based on service availability, accessibility and mobility. Results shown that city (Gorgan) doesn't enjoy proper spatial proportionality. Central and northern districts of the city have more facilitation of public transport than the eastern, southern and western districts which causes difference between the supply and demand. Research suggested that designing the network with appropriate relationship between spatial proportionality in all areas can help the planners to reduce the effects of poor accessibility in certain areas causing inequality in the service.

Public services and agencies are under greater inspection than ever before because of the scarceness of the resources and capacities of the societies to afford the services and willing to invest in them. Mononen built a feasible process to evaluate the socio-economic benefits of public transport using multi criteria decision analysis. Return of public investment was captured through benefit to cost (B/C) ratio. Results indicated that all of the B/C observed ratios were at least equivalent to, or greater than unity which depicts the relative advantage of the service attributes over the investment (Mononen et al., 2017).

Overall, Table 1 shows the summary of the previous studies on public transport accessibility.

9 Conclusions

Public transport (PT) in urban areas has gained greater attention in recent years due to ever increasing of the world population. Public transport can be more attractive by providing more accessible services. Therefore, the accessibility factor in designing the public transport infrastructures is of great importance. In this paper, the available literature on public transport accessibility (PTA) has been reviewed and the connection between (PTA) and different aspects of either transportation system including mobility and sustainability or human life including employment rates, public health, social exclusion etc. have been investigated. Considering the aforementioned, as a conclusion, it should be highlighted that not just the performance of public transportation but its impact on other social aspects should be considered while planning the public transport facilities.

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Table 1 Summary of previous studies on public transport accessibility.

Reference	Category	Indicators	Description	PT mode
(Fransen et al., 2015; Kenyon et al., 2002; Bocarejo S. and Oviedo H., 2012)	Social Exclusion	Real Accessibility, index of public transport needs (IPTN), index of public transport provision (IPTP) and Index of Public Transport Gaps (IPTG)	Real Accessibility is termed as the number of jobs that inhabitants in different zones of the city are actually reaching. IPTN determines a general index for public transport needs. It incorporates spatial distribution of defined socio-demographics groups. Study used parameter such as age, proximity to diverse primary facilities, social status to evaluate the indicator. IPTP describes the provision of public transport network to different primary facilities such as hospital, supermarkets and administrative centres for every traffic analysis zone quantitatively. Index uses parameter such as OD matrices between traffic analysis zones and travel times to estimate the number of accessible opportunities (specific time intervals) for each traffic analysis zone. IPTG estimates the difference between IPTN and IPTP. The values of both indicators were normalized to make their units symmetric. Higher values of the index shows the attention required in public transport needs for the area and vice versa.	Trams, trains and buses
(Lättman et al., 2016; de Oña et al., 2013; van Wee, 2016)	Perceived accessibility	Reliability/ Functionality, Information, Comfort, Courtesy/ Simplicity (on board), Frequency, Punctuality, Speed, Fare, Cleanliness, Space, Temperature	First referenced study conducted a survey to evaluate reliability/functionality, information, courtesy/simplicity and comfort subjectively. Reliability of the public transport system was accessed through the perception of the users about travel time, number of departures, distance to bus stop, trip coordination, payment option and punctuality. Indicator for information was accessed through variables such as mobile application, information at bus stop and information on homepage. Courtesy or simplicity incorporates the announcements, staff behaviour, information on board and boarding and alighting while comfort was accessed through air quality, cleanliness, lighting, noise level and overall comfort scoring. In addition to previous study, speed, frequency, punctuality, fare, cleanliness, space and temperature were accessed through the same technique of subjective evaluation of user perception for public transport.	Bus
(Sanchez, 1998; Sanchez, 1999; Johnson et al., 2017; Pons Rotger and Nielsen, 2015)	Employment rate	Employment (per cent), income, long term unemployment	Employment rate and income level was recorded before and after the construction of metro station in Copenhagen and empirical evidences of the effects of improved access to jobs on individual earnings was evaluated. Long term unemployment rate denotes the unemployed status for more than two years. Data was collected.	Bus and tram and train
(Vega, 2011; Cheng and Chen, 2015; Coppola and Papa, 2013)	Sustainability	Environmental Performance, energy performance, Urban trips modal split,	Sustainable accessibility measures aims to make equilibrium between the accessibility and the losses in environmental conditions. The loss in environment condition was accounted by the indicator such as CO_2 emissions, energy use, traffic noise and resource consumption are primarily caused by automobile trips. Urban trips modal split data accessed through concerned departments reveals the accessibility of the network connections in the city area. Increase in percentage of public transport trips in the model split reveals the sustainable accessibility.	Bus, tram and train
(MacDonald et al., 2010; Basagaña et al., 2018; Besser and Dannenberg, 2005)	Public health	NO_x, BC BMI (obese), walking time,	Concentration of black carbon (BC) and NO_x is indicator for the air quality which directly affects the health conditions, data was recorded from 2009-2016 for normal days and the days and strike days and compared with the standards. Total transit related walking time for individual to and from transit station was recorded during their assigned travel day. Body mass index (BMI) was calculated using self-stated height and Weight in kg/m^2.	Light rail transit, bus, metro and Rail
(Dadashpoor and Rostami, 2017; Mononen et al., 2017; Miller, 2007)	Economical, Spatial and temporal efficiency	Mean distance in total facility, Number of choices in total facility, B/C ratio	Mean distance to nearest total facilities was exhibits the spatial efficiency of public transport which was accessed by estimating the number of city population in quartiles and share of city population in quartiles. Range, Standard deviation, mean and quartiles of the resulting values were used to evaluate efficiency. Benefit to cost ration represents the return of public investment in public transport sector to evaluate socio-economic efficiency at system level. Results indicated that all of the B/C observed ratios were equal or greater than unity which depicts the relative advantage of the service attributes over the investment in Finland.	Overall public transportation
(Hernandez, 2017; Mugion et al., 2018; Cheng and Chen, 2015)	Mobility	Transit network, Service quality	Transit network defines the availability of public transportation infrastructure is the area. Transit network covers the empirical value of provision of public transport. It also calculates the mobility with mean of numbers of trips and person-miles covered. Service quality of the public transport accessed through survey included the aspects of travel time, reliability, comfort and so on.	Bus and subways

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