Influence of Built Environment Characteristics and Proximity at Both Trip Ends on the use of transit.

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Influence of Built Environment Characteristics and Proximity at Both Trip Ends on the use of transit

By

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Summary

It is well known among the academicians and urban transport studies have repeatedly reiterated that transport transit-oriented development (TOD) can and is increasing the propensity to use transit. TOD essentially brings housing, jobs, entertainment options, restaurants, groceries closer to the transit stop. By doing so the aim is to increase the diversity of land use, residential and job densities around the transit stop. Now day to day activities of people is all in close distance to transit stop along with their housing and work locations. Assumption is that the need to use personal vehicle for completing daily chores will be drastically reduced as every activity is in close vicinity to their home and can be accessed by walking and for activities that are further away such as their jobs can be accessed via transit which is also closely situated. Despite limitations and obstacles, TOD areas have been fairly successful in increasing the transit ridership and reducing the automobile use.

But the success of a TOD area is only possible when people are living in TOD areas and more often than not, also their workplaces are in TOD areas. In that case both workplaces and residence are close to transit stops, thereby making transit a dominant mode choice. But what happens when only side of a work-based trip is well connected will people still use transit for work? Does living closer to transit stop (access time), still play a key role in influencing people to use transit even if workplace is further away from transit stop?

In order to answer the research gap, the research question in this study is formulated as follows: *What is the role of proximity to transit stop in increasing the propensity to use transit for work?*

Aforementioned research question overarches the effect of both access and egress time on the use of transit especially for work commute. To supplement the main research question, few detailed sub questions are also formulated, these sub questions help answer the research gap mentioned and when put together answers the main research question. In order to achieve the research objectives, this study uses the data that were collected in 2015 by inter-disciplinary research group, Transport research at McGill, Montreal, Canada in collaboration with Delft university of Technology, Netherlands. This data was primarily collected from the people living in TOD areas in the Netherlands, USA and Canada.

Based on the previous studies on determinants of transit use and the data that has been made available for this research, the influence of access time, egress time, age, household size, education, income, country of residence, home and work Walkscores on the use of transit for work commute has been investigated. Descriptive analysis of the data set has revealed that majority of the dataset represents a young adult, an average of 2.5members household size, highly educated-high income class, owning at least one car households. Above description of the data set is in line with findings in the literature regarding the type of population that would be attracted to a TOD. Guthrie and Fan (2016) found that developers perceive TOD to attract a small but distinct percentage of population, specifically younger household with high income and education levels.

The main aim of this research is to find the influence of access and egress time on the use of transit. In order to answer, first individual effects of proximity to transit stop from home and proximity to transit stop from destination are discussed, then the combined effect of access and egress time are discussed. Lastly the effects of other factors such as personal characteristics, built environment characteristics and country of residence are discussed.

Individual effect of access and egress time on the use of transit

Propensity to use transit is strongly influenced by proximity to station. However, proximity to station at both ends of a trip are important. Logistics regression results show that built environment characteristics, access time, egress time are all influencing the use of transit. People with access time lower than 4mins or under quarter mile are 3.5 times more likely to use transit than people living further away from transit. While on the other hand people who have workplaces under 8 mins of walking distances to transit stop are found to be 5 times more likely to use transit than people who are working further away. Findings of these two variables show that indeed it is important to have both job and residences closer to transit stop, but one step further, egress time or the time taken to walk from station to workplace, has stronger influence on transit use than access time, especially for work commute. There can be various explanations for this observation, plausible reason could be the familiarity of the area, i.e., people could be more familiar with the surroundings around their home locations than their workplace surroundings.

However, more interestingly, if a person resides little further away from transit stop (6-12minutes) they are still 2 times more likely to use transit but if a person's workplaces is situated a little further away i.e., in the range of 8 to 30mins from transit, they are only 1.5 times more likely to use transit. It is evident that there is undeniably a decrease in the use of transit by increasing access and egress distance. But there is a sharper decline in the attractiveness of transit when workplaces are situated further away from transit stops than people's residences. Although this rather strong decrease could be attributed to the fact that author used a larger range for egress time than access time. But to back these findings, Guerra and Cervero (2013) have also reported that if there are additional jobs and residences in same proximity to transit stop, jobs are likely to be correlated with a greater number of additional transit trips than residences.

Combined effect of access and egress time on transit use

As mentioned earlier in the research gap, along with individual effect of access and egress time, a person might alter their decision to choose transit based on both access and egress time. In order to capture this, possible combinations of access and egress time were chosen. First being when both sides of a trip are well connected; second, when only one side of a trip is well connected and other not well connected and third being when one side is well connected, and other side is moderately well connected. Contribution of each combination to the utility i.e., transit use is used to compare. Parameters of each combination of access and egress time are shown. It is evident that the use of transit is highest among all the combinations when both sides are well connected i.e., when access and egress times are low. This is understandable, as travelers are provided with comfort and ease that of a personal vehicle, where they step in and step out of transit to reach their workplaces.

When egress time is kept constant at and increasing the access time value, findings show that indeed there is a decrease in the use of transit, but this decrease is rather marginal. But, if access time is kept constant at low and increasing the egress time, there is a rapid decrease in the probability of using transit with increase in the egress time. This finding is rather interesting to note, as it reiterates the importance of having shorter egress time than access time to increase the propensity of using transit, especially for work commute. Same reason why egress is more important than access can be extended here to explain why low egress time is preferred over low access time. Additionally, perhaps by living in and around TOD area, the built environment of these areas could be promoting people to walk further at home locations. Furthermore, respondents in the study mostly dwelled in inner suburbs with one major transit stop apart from bus service, so people may be inclined to walk longer durations to access this transit service if their workplace is closely situated to this transit line. Lastly, implications of these findings in practice can be of great use especially for current and future TOD developers, this will be revisited again in the policy recommendations section.

Effect of built environment characteristics, personal characteristics and country of residence

Personal characteristics of a traveler that were included in the research were found to have no significant effect on the use of transit except for age variable. Transit use is found to reduce with increasing age of the traveler. Built environment characteristics are found to further increase the propensity of using transit. Pointing out the additional advantage of living in TOD areas, these areas create a walking friendly environment by having higher densities, pedestrian friendly designs and land use mix. This in turn increases the affinity to walk to transit stops and reduce the necessity to use private vehicles. Finally, people living in TOD areas in North America are more likely to use transit than people living in the Netherlands. This is expected, as in the Netherlands transit use is lower compared to other countries. This is due to the fact that bicycles are strongly ingrained in the Dutch culture, and thus are strong competitors for transit modes, especially for transit trips with relatively shorter trip lengths such as light rail.

To conclude, this study has contributed to filling the research gap. On further studying the influence of access and egress time, it is found that proximity to transit stop is an important determinant of transit use and it is essential for transport planners and urban designers to create a urban setting where a person's job and residence are close to a transit stop. For work commute trips, proximity to transit stop from workplace is found to strongly influence transit use than at residences. In fact, there's no substantial decrease in transit use if a person's access time is increased from 4 mins to 12 mins as long as their egress times are lower than 8 minutes. But there's a sharp decline in likelihood of using transit when egress time is increased even if access time is low. To put it simply a person is most likely to use transit if both residence and workplaces are closer to transit stop. But if that's not possible, keeping workplaces at close proximities to transit stop can still encourage people to use transit.

Recommendations to practice

From the perspective of space allocation for housing and workplaces in a TOD area, The finding of this research points out that having low access time as well as low egress time is an encouraging condition for transit to be the dominant mode choice for the work commute. Secondly, it is suggested not to develop a station area solely based on the thumb rule of a quarter mile or 400m catchment area. Rather, allocating a majority of the space that can be reached within 6 minutes (approx. 100 to 400m) by walk from transit stop for commercial/office space, retailers, restaurants or other services. Then housing in 4-11minutes (approx. 400-1000m) of walking time would be advised. By doing so developers can provide affordable housing beyond the 400m radius. It is important to note, built environment characteristics of a TOD area are pivotal as they promote people to walk further to access transit stops thereby retaining/increasing transit ridership, even when houses are placed a bit further. The benefits of these characteristics are recurrently reported in the literature and also echoed in this study. On the whole, as a consequence, TODs can expect two benefits, they can retain/increase transit ridership by providing more space for retail/office space. And secondly, it can also attract a wider mix of socio-economic groups, especially mid and lower-income groups, which might in turn further increase transit ridership.

The third recommendation is regarding TODs in suburbs of major cities with light rail stops, planners and urban designers need to focus on aligning workplaces/jobs along the transit corridor than developing dense residential areas around the suburban station. Findings of this study suggest shorter distances to workplaces from transit stops are important than from residences, to increase transit use. But it is necessary to make the station area a walker's paradise with ample green spaces and diverse land use, as this study shows that a high walkability index of an area can provide additional benefits and promote the use of transit further. In conjunction with supportive policies that discourage car use, such as limiting parking facilities and making them more expensive (Chava, 2018) are also important for suburban areas to make transit attractive.

Furthermore, soon new mobility services like Mobility-as-a-Service (MaaS) may help TOD areas by providing packages that can potentially link a plethora of non-motorized modes with transit services, thereby fixing the longer access times in inner suburbs. And also, at the egress side of the trip, if allocation/reallocation of workplaces along the transit corridor is expensive or is not possible, these modes and mobility services might potentially reduce the egress time as they are most certainly faster than walking, thereby still achieving short egress times. However, additional benefits of bike-sharing or MaaS in reducing the access and egress time cannot be suggested solely based on this study as there can be many other factors linked to it such as willingness to use such services.

The last recommendation would be for public transit design, findings of this study indicate people are willing to walk longer durations to access transit stops in TOD areas (this can be attributed to the fact that the findings of the study are based on the data collected from TOD areas). So, potentially stop spacing can also be increased for urban transit modes with stops in TOD areas. Increasing stop spacing would enable operators to provide a faster service which in turn can also increase the frequency of the line. Doing so, increases the reliability of the transit services and be beneficial for the traveler as waiting time and in-vehicle time can both potentially decrease with faster and more frequent transit service. In situations where there are multiple TOD areas on a single line, then the number of stops in such lines can be significantly reduced as the catchment area of TODs is much larger than a regular stop, achieving a coarser transit network.

As an ending note, the author firmly believes in the concept of TOD and in its potential to redefine the way people move and carry out their daily activities in an urban and suburban area. However, as it goes for any good policies or concepts, they are only as good as their implementation. TOD has the capacity to improve transit ridership and can also provide ample opportunities for emerging modes and other mobility services that are collectively pushing towards a sustainable future.

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1 Introduction

1.1 Background

The relationship between proximity to transit stops and travel behavior along with the effect of the built environment has received noticeable academic attention. Researchers suggest that bringing the basic facilities and residential areas in an urban area closer to transit stop would reduce the necessity for people to use private vehicles and promote sustainable trips (Ewing & Cervero, 2001; Nasri, 2016; Zhang et al., 2012). Among the efforts to combat auto dependency, transit-oriented development (TOD) is one of the forerunners. In recent times TOD has been implemented in many regions across the world in response to the growing congestion concerns.

"TOD is a form of land use that is related to high-density, mixed-use development and walkable design around transit stops. TOD brings various activities closer to residential locations and facilitates opportunities for walking, cycling and transit mode choices" (Kamruzzaman, 2015). Consequently, it is assumed that the travel behavior of people living in a TOD area is affected primarily by increasing mode choice alternatives and non-motorized modes. Nevertheless, creating such a surrounding in well-established cities is challenging due to the lack of space necessary to meet the requirements of a TOD. For these reasons, most of the locations with the characteristics of TOD are situated in the suburbs of major cities or intentionally planned transit stops in mid-sized cities.
Many researchers assume that living closer to transit stop implies frequent use of public transport modes (Knowles, 2020). Yet, closer transit stops at a home location cannot solely influence mode choice, as proximity of destination location to the transit stop is also important (Ibraeva et al., 2020). Overall, there is a large agreement that proximity of transit stops and built environment characteristics at both ends of the trip influence the use of transit and this agreement is reflected in the TOD concept. This arrangement is important for transit, as it makes transit relevant, competitive and achieve mode shifts (Crowley, 2001). TOD is already serving the efforts to make transit attractive by bringing residential areas close to a transit stop. Nonetheless, up to date, little research has been carried out in understanding changes in mode choice decisions with respect to various combinations of the proximity of transit stop at the start and end of the trip's location (Correia, 2020).

TOD environment implies that the distance to transit stations is more likely to be shorter. It is assumed that the likelihood of using transit increases with a decrease in distance between origin and transit stop. The same applies to the destination end, especially in the case of work trips. However, little is known whether living closer to transit stop would have a greater effect on the use of transit even if the workplace is also closer to transit. Analogously, is the effect of access time still stronger, if only one side is well connected or if neither of the sides is well connected. To explore how the current TOD areas influence the use of transit, it is important to investigate the individual effects of proximity to transit stop at both ends of the trip and as well as the combined effects. This is what the present study aims at exploring.

1.2 Research scope and goal

In his work, Faghri (2013) points out that bringing transit closer to people's home locations would contribute to an increase in the propensity to use transit. This is in agreement with other research works, where it was reported that, when the work location is well connected to transit, people are likely to use transit for work commute (Shen, 2016). On the other hand, only a few researchers have considered both trip origin and destination in their studies to conclude that both play an important role (Hubers, 2015).

These findings cannot always be generalized. In fact, considerable variability exists in the real world. It can happen that people live in a TOD area and also work in the TOD area, which would be an ideal setting for using transit. Then again, it is also possible to have a scenario in which people do not live in the TOD area but work in the TOD area. Also, people might live in a TOD area, but their work location may not be close to a transit stop. All of these possible scenarios are schematized in Figure 1.1

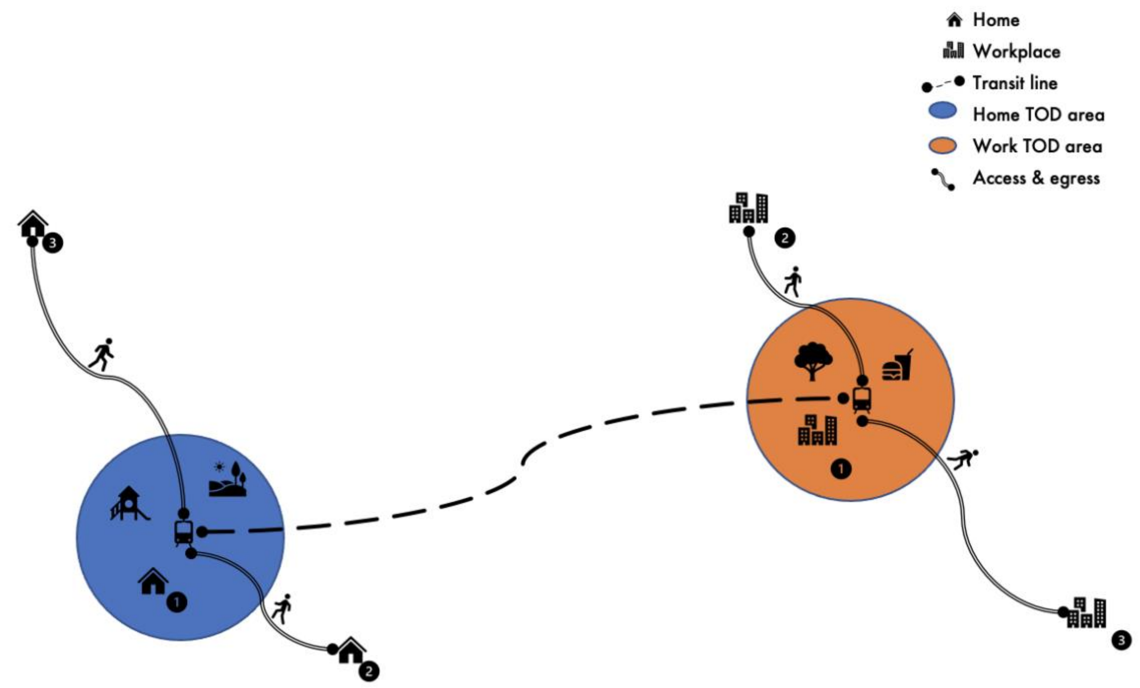

Figure 1.1 Schematic presentation of possible combinations of access and egress distance of a work trip

In the above scheme, Home 1 is situated in a TOD area i.e., in very close proximity to a transit stop. Home 2 is situated outside the TOD area, with a relatively longer walking distance to the transit stop, and home 3 is situated further away from the transit stop. Workplaces are also located and numbered according to the same order. The objective of this research is to examine the changes in the mode choice when people live at varying distances to a transit stop and have to reach workplaces at varying distances to transit stops. It is evident that living closer or working closer to a transit stop solely cannot influence the use of transit. As shown in Figure 1.1, if a person lives at Home 1 and job is at Workplace 1, the likelihood of using transit is very high as both sides of the trip are well connected. However, would it be the same if the person had to reach Workplace 2 or 3, which require longer walking distances? Similarly, if a person works at Workplace 1 but lives at Home 2 or 3, would this person still be using transit?

To study all these possible situations, it is important to first introduce the concepts of access time and egress time, which will be used in this research to represent the proximity to transit stops. With access time we will refer to the time taken to complete the first link of the trip (work-based trip in this study), that is the trip from home to the transit stop. On the other side, egress time will refer to the last link of a trip, from a transit stop to the workplace. To fully understand the extent to which these variables influence the propensity to use transit for the work commute, it is very important not only to consider them individually but also to take into account all the possible combinations of access and egress time.

Given the above goal of this research, the main research question will be:

What is the role of proximity to transit stop at both trip ends in increasing the propensity to use transit for work?

This main research question is further detailed in the following sub questions.

- *To what extent does the proximity to the origin and destination influence mode choice?*
- *To what extent does the combination of proximity to the origin and destination influence mode choice?*
- *To what extent the built environment characteristics play a role?*
- *To what extent the individual characteristics play a role?*

The objective of this research is to understand the extent to which proximity to a transit stop from origin and destination to destination stop individually influence the use of transit while controlling for external factors (personal and built environment characteristics) and also how the transit use changes with various combination of these variables. This study uses the data collected in 2015 by an inter-disciplinary research group, consisting of Transport Research at McGill, Montreal, Canada, and the Delft University of Technology, the Netherlands.

Data collected from respondents living in TOD areas with light rail stops and suburban rail stops (only two study areas) in the Netherlands, USA and Canada. Although the data is from respondents living around light rail, tram, Skywalk, metro, subway and suburban rail stops, the word transit represents these modes in the rest of the research. And also, when discussing the results of this study, the author makes it clear that these results can only be related to the aforementioned transit modes.

1.3 Scientific and societal relevance

The scientific significance of this research is that it will aid in understanding and improving the knowledge of how mode choice decision for work commute is affected by proximity and built environment characteristics along with other external factors. In particular, it is interesting to conduct such an investigation in the case in which only one end of the trip is located in the boundaries of the TOD area. Thereby, this study will contribute to understand the travel behavior of people living in TOD areas and give support to all the literature surrounding reduction in automobile use and making transit attractive in urban and sub-urban areas.

The societal relevance of this research is that the outputs will assist transport planners in understanding the changes in travel behavior depending on the location of home and workplaces. Making an urban region transit and active modes friendly is a time-consuming process and it requires vast knowledge on various factors surrounding it. This study aims at championing the efforts of making our cities more sustainable and transit friendly. Finally, findings of the comparison between two continents can help policymakers and urban transport planners from both the continents and around the world in tailoring TOD to fit the local context.

1.4 Outline

The structure of this research is outlined in Figure 1.2. It consists of conceptualization, data analysis and model estimation. Finally, the conclusion, discussions and future recommendations are introduced.

Literature review
The first step in the research is to review the literature to understand a TOD setting, various elements of TOD and how it is different from a regular station area. Thereafter, literature is also reviewed to relate with the past studies that have tried to examine the link between proximities and transit use, especially in a light rail setting. These findings will be helpful to relate the conclusion of the present study with that of literature. It is also important to understand the most common factors used when analyzing mode choice decisions, especially for the work commute. The literature review is an important start for shaping the research questions with the available data and understanding the definitions of the factors that could help to answer the stated research questions. After getting a clear picture of what the researcher will be studying, it is now important to understand how to materialize these research questions in a model and get the outputs. To do so, it is central to understand different modelling techniques and model types that were used in the past to conduct analysis similar to that in this research.

Theoretical framework
The next step of the research design is to build a conceptual framework using the literature review. This would be the foundation of the research. The idea is to map all the factors that could influence the mode choice of traveler. These factors are mapped to have a clear picture of the relation between the factors and the mode choice.

Data
Collected data from 2015 will be explained in detail. Chapter 4 would describe the survey sheet used to collect the data that will be used for this research. Survey locations and characteristics such as types of public transport available at the locations of data collection and its properties will be explained in detail. Understanding the study area is important to relate the data to the research objective and also to draw conclusions from the outputs of mode choice models based on personal characteristics of the respondents and characteristics of the study area.

Data analysis
Obtained data is analyzed using descriptive and discrete choice modelling. The descriptive analysis provides the representation of the obtained data at the first glance including characteristics and how these characteristics represent the scenario this study aims to understand. Discrete choice modelling is used to gain insights into the extent to which the factors that are proposed in the theoretical framework are influencing the use of transit for the work commute.

Conclusions and discussions
Using the results obtained from data analysis, in this chapter the main research questions and sub questions will be answered. Also, the limitations and scope of the study will be reflected and discussed in length. Later the findings of this study will be compared to the findings of relevant studies conducted by other researchers. Lastly policy implications and recommendations for future research will be deliberated.

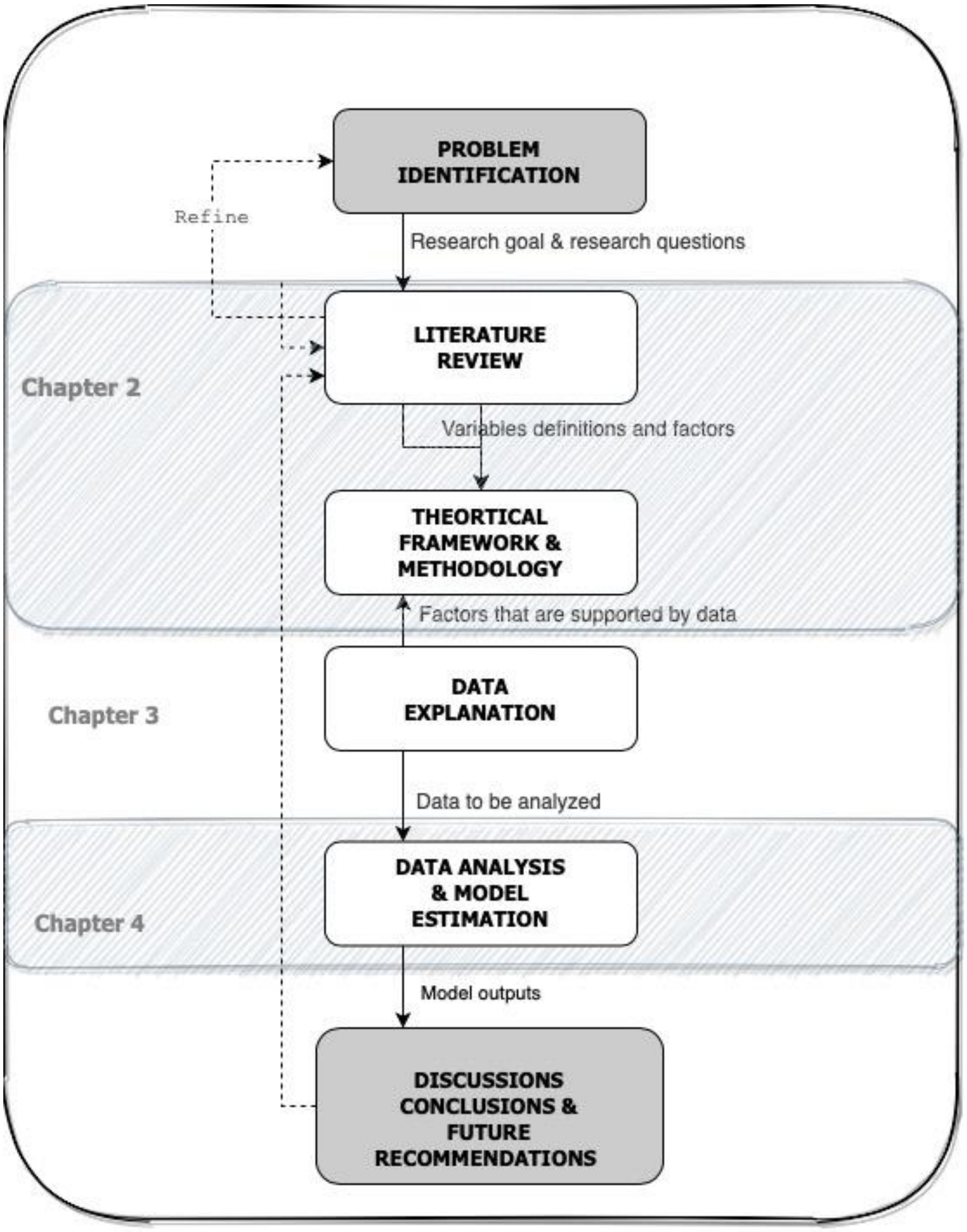

Figure 1.2 Overview of the research design

2 Literature review

Chapter 2, the literature review feeds the theoretical foundation of this research. The aim of this chapter is, first to understand TOD and its influence on travel behavior. Secondly, to comprehend the influence of various factors, especially those that are believed to promote the use of transit. Employing this knowledge and data, a theoretical framework is constructed. Section 2.1 shortly addresses the concept of TOD and its influence. Section 2.2 discusses the transit use determinants and various factors involved in the decision-making process. Finally, section 2.3 concludes the chapter by providing key takeaways and the theoretical framework of this research is put up.

2.1 Transit Oriented Development

Literature is studied to understand the concept of TOD and also the influence of TOD on travel behavior. It is important to understand TOD and its effects as data used for this study are collected from TOD areas. Therefore, reviewing past studies will help in understanding the limitations of the findings of the study and also expand the knowledge on TOD's characteristics that are influencing people to use transit. Next, a brief explanation of light rail and how light rails have come into light with the rise of TOD areas is also explored. Reviewing this is assumed to help the author when discussing the findings of this study.

2.1.1 TOD Definition

According to the current state of knowledge of the research community, various definitions for TOD are available. Depending on the viewpoint and viewpoints, some describe TOD as purely a high-density area built in the proximity of transit station and few others define it based on the walkability factors such as high density and mixed land use aspects (Cervero, 2008). Meaning, a high-density area designed for pedestrians with shopping, residential, employment opportunities available in close proximities without restricting the use of the personal vehicle. The US-based Center for Transit-Oriented Development (CTOD), a national clearinghouse on the topic, is the result of a collaboration with the Center for Neighborhood Technology and Strategic Economics and is funded by the US government. The CTOD definition of the concept is: TOD is a community development where a walkable neighborhood is located within 800m (half a mile) of a reliable transit stop and this neighborhood includes a mixture of residences, office spaces, entertainment, retail and other amenities (Thomas, 2020; CTOD, 2019).

Most of the theoretical definitions reviewed in the literature included some mutual fundamentals such as compact, pedestrian-friendly urban area, mixed-use community, high-density development, major transit station and mixed development around transit station (Limtanakool, 2006). There are different quantitative measurement criteria for TOD proposed by different approaches in practice. Bernick (1997) has specified a half-mile buffer zone around a transit stop as a TOD area. Their definition of TOD is as follows “a compact, mixed-use community, centered around a transit station that -by design- invites residents, workers, and shoppers to drive their cars less and ride mass transit more. The transit village extends roughly a quarter mile from a transit station, a distance that can be covered in about 5 minutes by foot. The centerpiece of the transit village is the transit station itself and the civic and public spaces that surround it. The transit station is what connects village residents to the rest of the region” (Nasri & Zhang, 2019; Bernick, 1997).

2.1.2 TOD and Travel behavior

Furthermore, to the studies related to the academic concepts of TOD and expected benefits attached to it, there are several studies focused on the empirical aspect of TOD. These studies aim to understand the effectiveness of TODs in terms of increasing transit ridership, reducing personal vehicle usage, reducing traffic congestion levels and increment in non-motorized trips.

According to a national study conducted by CTOD (2007), the fastest-growing household type are a couple with children, single parents, people living alone and immigrants. Consequently, this boosted demand for transit. CTOD (2007) indicated that by 2030, forty per cent of household would be considering high-density housing near transit. This illustration is all the more reasons why cities might invest more and more in TOD. TOD has grown to include small-scale developments such as cycling parking, walking path and public spaces encouraging not only high-capacity railways but also rapid transit rails such as metro, light rail, trams streetcars; and non-motorized travel modes such as walking and cycling. People dwelling close to TOD's have lesser car ownership and smaller household sizes (Ewing, 2010; Thomas, 2020).

Some of the key benefits of TOD are, decreases driving, parking needs for car, air pollution and greenhouse gas emission. Then it increases transit ridership, transit fare revenue, mobility options, property values near TOD and connection to jobs. TOD creates walkable communities, compact built-up developments that promote transit use, walking and cycling (CTOD, 2019). A successful TOD that achieved these benefits usually depends on the 5D's, density, design, diversity, distance to transit and destination accessibility. Density is one of the critical variables for increasing transit ridership. At the station level, the positive relationship between population density and transit ridership is well established. The consequence of high urban density is that more number of individuals inhabit or have jobs near transit stop thereby increasing the likelihood of using transit (Gutiérrez, 2011).

Cervero's earliest studies (Cervero, 1993) show that people living in TOD areas are around five times more likely to use transit to work. People working in a TOD area are three times more likely to use transit to work than the rest. More recent studies by Cervero, where he and his team analyses 17 TOD projects of varying sizes have found that people living in TOD areas are 2-4 times more likely to use public transit compared to people living elsewhere, confirming their previous findings. According to them, 3 main reasons for reducing automobile use are 1.) reduce in automobile ownerships as a result of residing in areas which are well connected and in the vicinity of public transport. 2.) residential self-selection 3.) availability of various retail stores and other activities within walking distance of residential areas (Cervero, 2008).

Within TOD areas transit use for work commute is higher compared to other purposes (Lund, 2004). Renne (2005) in an extensive study from 1970 to 2000, found that for work trips, transit mode share has increased from 15.1% to 16.7% while it has reduced from 19% to 7.1% across the rest of the regions in the study. Cervero (1993) found that proximity to transit stops is strongly associated with the use of public transport and other design considerations are unlikely to deter them from using public transport. Also, all else being equal higher employment densities and land use mix around transit stops would equate to greater transit ridership (Tumlin, 2003). More justifying findings according to Lund (2004) is that, for non-work trips, high densities of a residential area, retail, land use-mix are all important while these variables are not as important for work trips.

Distance to transit is also one of the critical factors in increasing the ridership of transit. Half-mile or 800m is widely deliberated to be the maximum distance that an individual will walk to approach urban transit modes such as light rail, metro/subway (Thomas, 2020). However, preferences for walking distances vary depending upon the trip purpose, transit mode, trip length, age, land use, safety, weather, the density of jobs, gender, education level, income level. It can also vary based on the cultural context, for example, Ker and Ginn (2003) have found 0.6 miles (1 km) as the distance dwellers in Perth, Australia was agreeable to walk. On the other hand, for American cities quarter mile or 400m is found to be a more reliable measure. In the following subsection, more about the effect of access and egress distance on transit use is deliberated.

2.1.3 Light rail and TOD

One of the essential characteristics of a light rail is its ability to share its infrastructure with buses or regional tram at urban sections or with all kinds of traffics if its infrastructure is rooted in routine traffic spaces. Bijl et. Al (2018) defines light rail as "Light rail is rail-bound form of public transport that is used on the urban region and the city. In contrast to tram and metro, light rail is suitable for integration to a certain extent in public space and, if desired, for mixing with regular road traffic". Figure 2.1 depicts light rail as a mode with commonalties between train, tram and metro.

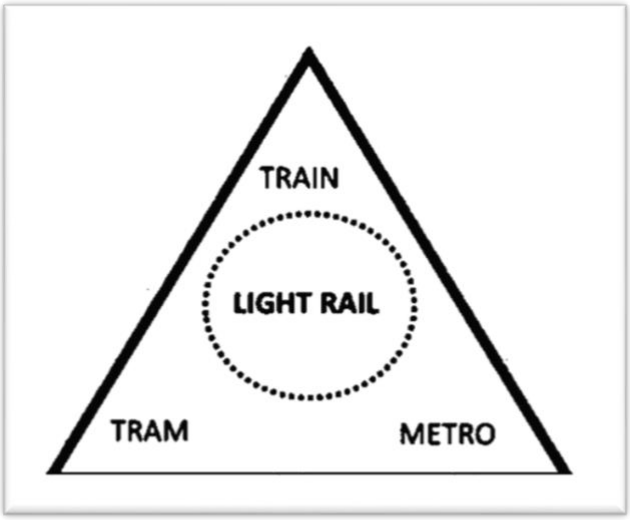

Figure 2.1 Light rail in a glance (Bijl et al., 2018)

Operation of such high-quality transit can bolster financial centers and prevent social segregations. Also, light rail is a arrangement of urban design and planning that Is increasingly used in TOD areas, as linking spatial development to stations, stops and their vicinities (Bijl et al., 2018). Light rail stops are built as a cheaper alternative to heavy rail investment in mid-range cities and in downtown areas where space is of utmost importance. Two main criteria taken into account for constructing light rail line are either there is a high residential density in the vicinity or a downtown or other cluster of high nonresidential activities (office, retails, hotels etc.). Heavy rail is estimated to attract urban development potential, or the sphere of influence is estimated to encompass a radius of 600 meters or 2000 ft, while light rail largely has inferior performance characteristics compared to heavy rail, so its potential for urban growth is expected to be lesser, around 300meters or 1000ft at the most (Cervero, 1984). According to Cervero (1984) most successful light rails are the one that are part of strong downtown transit network and well connected to heavy rail systems and secondly the ones where light rail line is connected to high density activity areas (e.g., shopping districts, malls etc.). Literature suggests that for a light rail to be successful, stops should be surrounded by high density residential areas, diverse land use mix, high density workspaces, connected to heavy rail network and public transport networks. Therefore, a home TOD location connected to light rail stops can be successful if they fulfil above requirements and also, its important this line should also be connected to other transport networks and high-density workspaces. This reinforces the need to study the effect of proximity and also built environment characteristics at both origin and destination side.

2.2 Determinants of transit use and walking distances

In the following section factors affecting walking distance to a transit stop is discussed in further detail. Along with walking distance there can also be factors affecting the use of transit. This research is concerned about the use of transit specifically examining how access and egress distance are influencing the use of transit. It is important to know factors affecting access and egress as well as the use of transit as a mode. In the previous sections, it was clear that access and egress distance influence the use of transit. But the built environment characteristics of TOD are not further explored. It is discussed in the following section.

2.2.1 Socioeconomic characteristics.

Gender

Studies on the influence of gender on walking distance are rather rare, El-Geneidy et al. (2014) found that males are more likely to walk longer distances at both the access and egress side of the trip. However, on the use of transit, there is no real consensus. Few researchers point out that women are more likely to use personal vehicles as they include personal errands or household errands along with their daily work commute, thus making public transport less attractive. While in cases where there is one automobile in the household, men or more likely to use personal vehicle and women depend on public transport or active modes for personal errands (Limtanakool, 2006).

Age

Elder people are found to walk a shorter distance to a transit stop and young adults are found to walk a longer distance to access a transit stop and getting to their destination. Also, young adults and college graduates are found to be the dominant age group that are willing to live closer to transit stops and use transit more frequently (Ren, 2020). As for the use of transit, there is no strong consensus on the impact of age as few of the studies found that older people are more likely to travel by public transport (Bhat, 1998). While other studies point out that usage of a car is more likely to increase with age (Habib, 2009).

Income and Education

Household income is found to affect the type of environment or surrounding characteristics and does not influence the walking distances directly. Higher household income classes often belong to neighborhoods with low population density. And this might influence the walking distance than income itself. El-Geneidy et al. (2014) state that households with high-income walk less often, but longer distances to transit stops. However, education is not of high importance and studies more often than not found an effect of education on the use of transit but not walking distances itself. Education and income are more often interconnected as higher education would mean higher income leading to a higher social status. Few studies argue the aforementioned point, indicating higher social status or income would mean owning a greater number of cars thus increasing the use of automobile. While few authors argue educated people are more likely to use public transport as they are aware of the environmental and sustainable issues (Ortuzar, 2011). Thus, making education more ambiguous and harder to point out its impact.

2.2.2 Trip Characteristics

Access and Egress

In literature, access and egress described as the first journey-leg (access) and the last journey-leg (egress) (Krygsman, 2004). Access and Egress determine the availability and convenience of using transit. It is the weakest link in a public transport chain. Improving access and egress can significantly reduce the transit trip time and found to be inexpensive options compared to enhancement of vehicle and infrastructure, which can be (Guerra, 2013) very expensive and frequently considered options at improving reliability and attractiveness of transit (Krygsman, 2004).

According to Murray and Wu (2003), the probability of using transit is higher when individual live or work around transit stops thus making access to a transit stop an important factor when planning transit service. However, access and egress can have different characteristics. Shelat (2018) found that transit travelers have larger access than egress distances. Gutiérrez (2011) finds that mean train access time by walking for home-based work trips as 8.6 mins but egress time as 12.5mins. Similarly, Krygsman et al. (2004) also studied the effect of access and egress time, found that train travelers spend more time for egress than for access and the author argues that the value of time for access side is higher because egress speeds are lower than access speeds.

Guerra (2013) reported that the ability to predict transit ridership using job-density, population and other factors were scarcely influenced by the varying size of the catchment area radius. Figure 2.2 shows that within the first quarter-mile radius, an addition 100 residents correlated to 34 additional trips per weekday, whereas an additional 100 jobs linked to 69 additional trips. Although the author agrees that closer jobs and people are to a transit stop, the more ridership it generates. However, placing jobs closer to transit stops are considered to have greater value (in terms of ridership) as in Figure 2.2 even if within a half-mile, an additional 100 residents still correlate with 25 additional trips. But in a half-mile, 100 jobs correlate with 42 additional trips. Indicating there is a stronger decrease in ridership level when jobs are moved from a quarter-mile to a half-mile than moving residents.

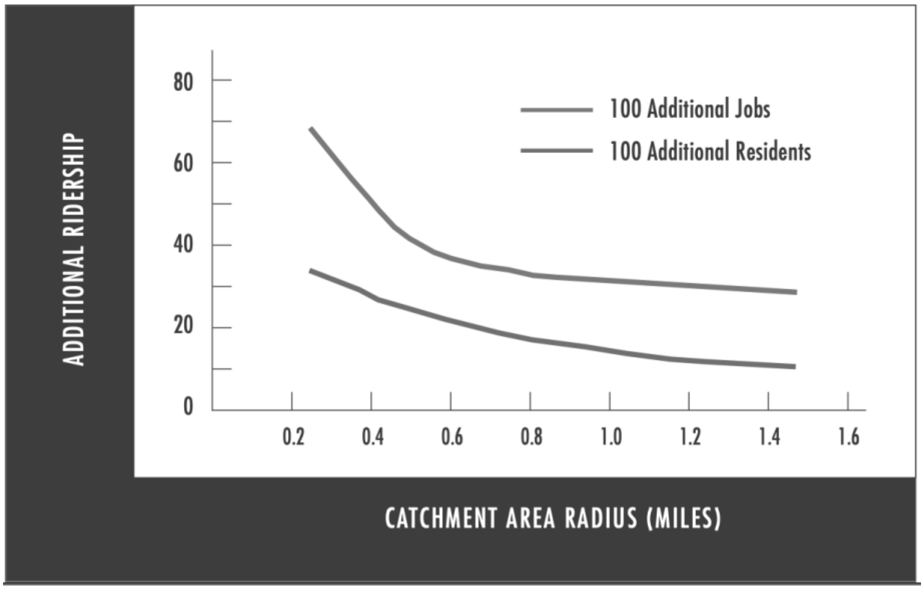

Figure 2.2 Relation between ridership and jobs – housing (Guerra, 2013)

Guidelines for walking distance to access transit stops are quarter mile or 400 m, or frequently use multiples such as 800m as key distance in network and service planning (Mulley, 2013). But these guidelines can be misleading, and studies have often pointed out that travelers would be willing to walk long distances. Krygsman et al. (2004) find that 30% of people walk than 10min on the access and the egress side 40% walk longer than 10 min to their destination, for a train. But for a tram, metro, bus services, the author reported no difference between access and egress time. (Shelat, 2018) However, walking (active modes in general) compared to other motorized access and egress modes involves a certain amount of physical effort. Since the catchment of transit is determined by access and egress modes, many researchers have considered how land-use and transport policies can enhance the catchment. Loutzenheiser (1997) mentions that. Density, diversity, design, layout, etc., are frequently considered to be spatial policy instruments to increase and/ or intensify catchments. However, the effect of built environment characteristics and individual characteristics in increasing the catchment of transit is not clear (Ren, 2020), Some research has shown that the walking distances increase with increasing density, diversity (Ewing, 2010) and while other research has found that it is a function of individual characteristics, with land-use characteristics being of secondary nature (Frank, 1994).

Trip purpose

Daniels and Mulley (2013) find that trip purpose is one of the main influences on walking distance. Chia et al. (2016) reported access distances were shorter for work trips than school trips. When compared to trips other than school, work trips have longer access distances (El-Geneidy, 2014). Travel motive has high relevance to mode choice decisions, of all the travel motives such as business, leisure, commuting trips have a higher share of public transport. For those reasons, this study tries to understand the factors influencing mode choice decision for daily work commute and also to come up with finding that could help improve the usage of public transport.

Other Trip characteristics

Travel distance has a significant influence on mode choice decisions, travelers tend to vary their decisions based on the trip distance, for shorter distances (under 1.2km) preferring walking or active modes and for distances under 30km private vehicle is found to be the preferred mode choice and for further distances, train is the most preferred choice (Kaufmann, 2000). Travel time is also an important determinant of mode choice decisions and is valued differently for different trip motives. Travel time studies more often than travel distance and are usually more significant than the latter. (Bhat, 1998). Finally, interchange and use of multiple modes to complete a trip (usually with public transport) is also seen as an important factor influencing mode choice decisions but surprisingly not frequently studied and also not labeled as significant (Witte, 2013).

2.2.3 Spatial and built environment characteristics

The importance of spatial and built environment characteristic's influence on mode choice was mentioned earlier in the first chapter. They are further investigated in this subsection. According to De Witte (2013) most frequently researched characteristics are density, diversity, public transport availability and parking. Density is the ratio of the number of inhabitants/built-up area and it is acknowledged as a prominent factor in elucidating the use of the certain mode of transit compared to others. Urban areas usually have high densities and also have better public transport compared to rural areas which are more often than not less dense. Limtankool (2006) finds that public transport is used additionally compared to private vehicles in denser areas paralleled to less dense areas. Thus, making it important to include it in the current study. Secondly, diversity is seen as an important factor for people to shift to public transport. Bastin (2006) supports the above statement that people who work closer to public transit stops are more like to use public transport if the station area is more diverse in terms of land use i.e., diverse patterns of residence, commerce, institutions, green space accommodated in the neighborhood of station area. Cervero (2002) finds that destination or work location alone is not important but also home location should also be equipped with high land use-mix to reduce the usage of a private vehicle.
Proximity to infrastructures such as road networks and public transport infrastructure at both trip ends is seen as one of the main factors for choosing mode but is understudied and is found to be less significant in influencing mode choice (Limtanakool, 2006). Hensher (2008) suggests distance to public transport stops at both origin and destination have a direct influence on public transport and Limtankool (2006) finds that proximity of public transport stops at destination side has a greater influence than the origin side. The interesting take away from these findings is proximity to public transport is found to be less significant when studied alone but it is found to have a very close relation to other spatial characteristics like density, diversity and parking availability at both origin and destination side.

2.3 Conclusions and theoretical framework

This chapter along with Chapter one provided knowledge to construct a theoretical framework for the rest of the research. In Figure 2.4 and Figure 2.3, factors and interrelations that were discussed in the previous sections are summarized. Also, the factors that are included in Chapter four are presented. In Figure 2.3, black lines indicate the relationships that are investigated in this research. The interaction effects between access and egress time are included as well.
Here a summary of the findings from the literature review is presented.

Conclusions
In the first section of this chapter, the definition of TOD and its expected benefits are discussed. The research community has various definitions of TOD and this definition has changed or the understanding of it has greatly improved over time. Commonly spoken elements of TOD are

as follows, a quarter-mile area around public transit stops which comprises a pedestrian-friendly community, high-density of jobs and residential spaces surrounded by a diverse use of land for retail, green spaces, entertainment activities. In the center of this community is transit which enables easy movement via well-connected transit. The expected benefits of this setting are residents are encouraged to walk more, use public transport and make personal vehicles as redundant as possible. Studies aimed at finding empirical evidence of the benefits of TOD have proven indeed TOD is seen to have a positive effect in improving the social welfare of people along with expected benefits such as rise in transit ridership levels and non-motorized travel trips.

Factors that were frequently used to study the use of transit were also studied in this chapter. Socioeconomic characteristics such as age, income, education, gender, were all found to influence the use of transit but there was little evidence found in the literature to argue if these factors also influence the access and egress time. Along with that, vehicle ownership is found to deteriorate transit use. Trip characteristics like trip purpose, travel time, travel cost, time of day, were all researched to determine their influence on transit use. Built environment characteristics were found to positively influence transit use and increase the catchment area of a transit stop. Finally, access and egress time were frequently reported to affect transit use. However, it is clear that distance travelers are willing to walk to a transit stop or their destination is highly contextual. They vary based on the mode, trip time, individual characteristics, built environment characteristics of the area and most importantly it is influenced by the country of residence. Although these variables depend upon various factors, it is found that people are willing to travel more on the destination side than at the home side. Lastly as a note, in this report, the word transit is used to represent light rail and suburban rail, this was previously mentioned in the first chapter. Interestingly, in the literature it is evident that every mode of transit has common factors influencing its use, however, the only difference is in the extent/magnitude of the effect. Therefore, in the following sections, when investigating the effects of the factors mentioned in Figure 2.3, it is important to remember that the results can be extended to the transit modes that are in the dataset but not all modes of transit.

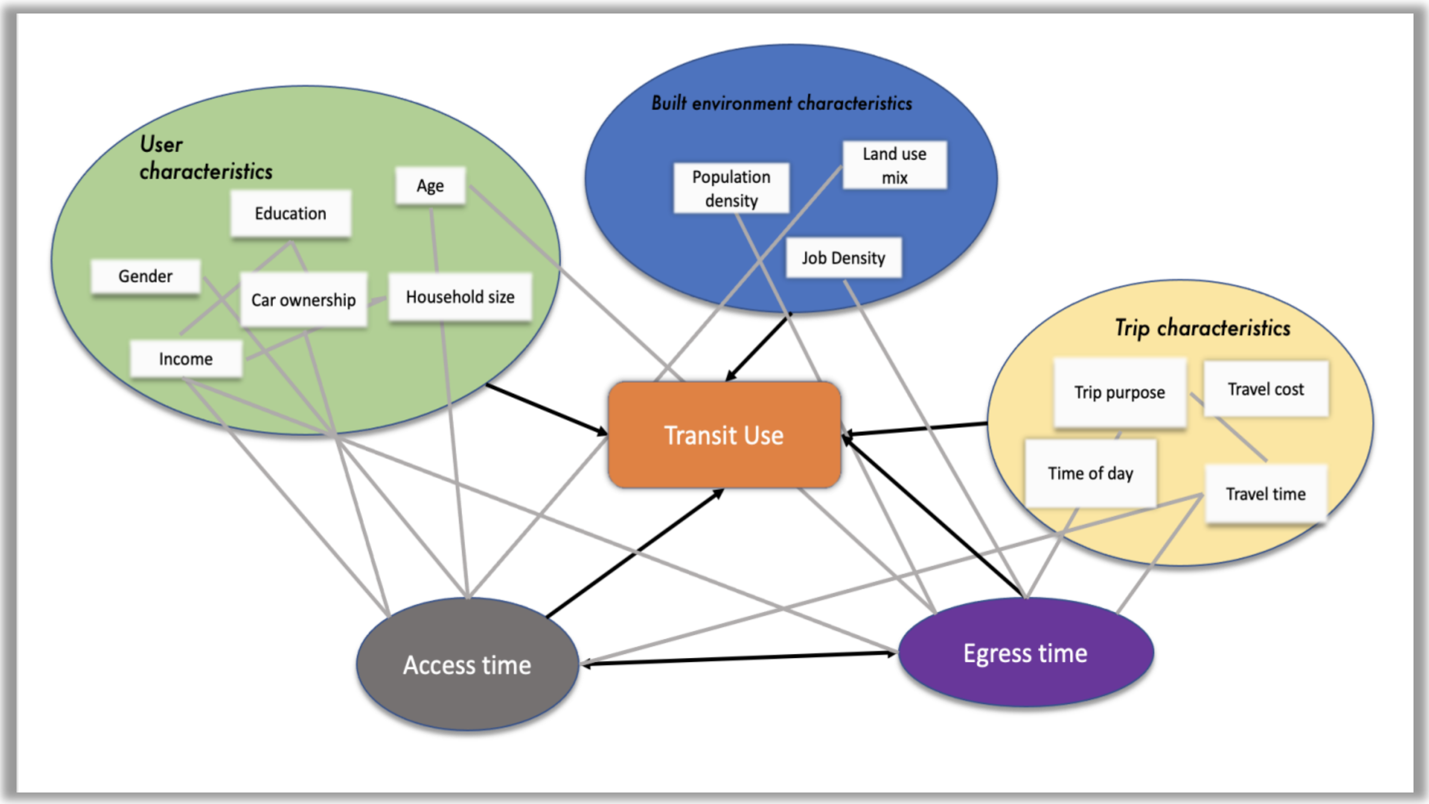

Figure 2.4 Theoretical Framework: Factors influencing transit use that are included in research

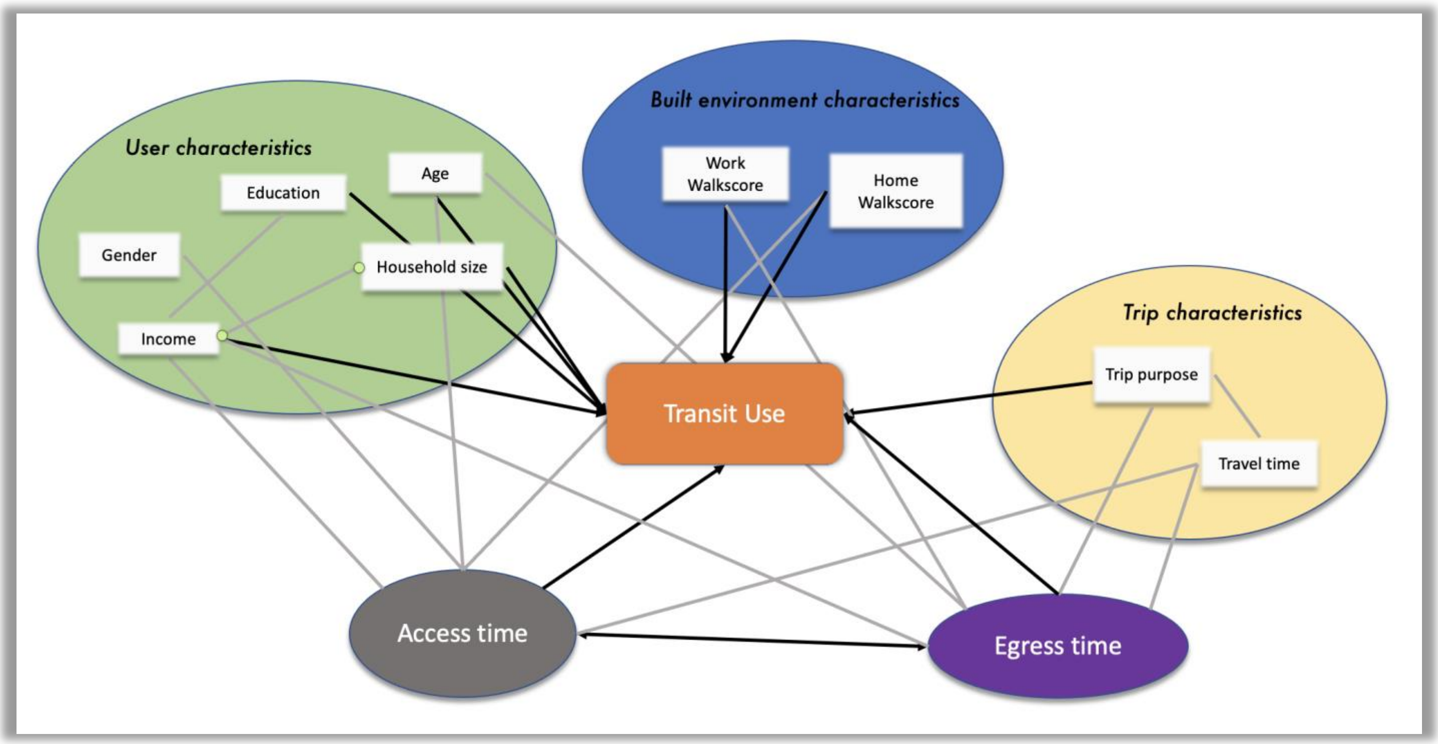

Figure 2.3 Theoretical Framework: Factors that are influencing transit use included in this research

3 Data

In this chapter, Section 3.1 deliberates about the study area. A brief description of all the areas from which data were collected is presented. Subsequently, Section 3.2 discusses the survey sheet used to collect data. This section provides an overview of the questions and the nature of information intended to collect. The focus of this section is to point out the similarities and differences in the transit stops located in the study areas and how the data obtained can be beneficial to achieve the research objectives. Section 3.3 provides a brief rationalization of walk scores (a variable used to capture built environment characteristics of an area) and how this was estimated using the data collected from the survey. In Section 3.4, the process followed to filter the entire data to exclude the observations that are not valid is elucidated. In Section 3.5 representation of the filtered data is discussed via descriptive statistics

3.1 Study area

Data were collected from people living in TOD areas in the United States, Canada and the Netherlands. In the Netherlands, regions of Pijancker, Delft and Rijswijk are part of the study area. In the United States, data were collected in Berkeley, California; Dallas, Texas: Downtown Plano, Mockingbird Station; Hayward, California; Rosslyn (Arlington), Virginia; South Orange, New Jersey. In Canada, data were gathered from people living around rapid transit stops in the cities of Vancouver and Toronto. These locations were chosen primarily because they were all TOD areas with a similar type of transit stops. Also, the data were collected from two continents to examine the parallels or dissimilarities in the travel behavior of the people living in TOD areas.

Figure 3.1 Study areas in North America

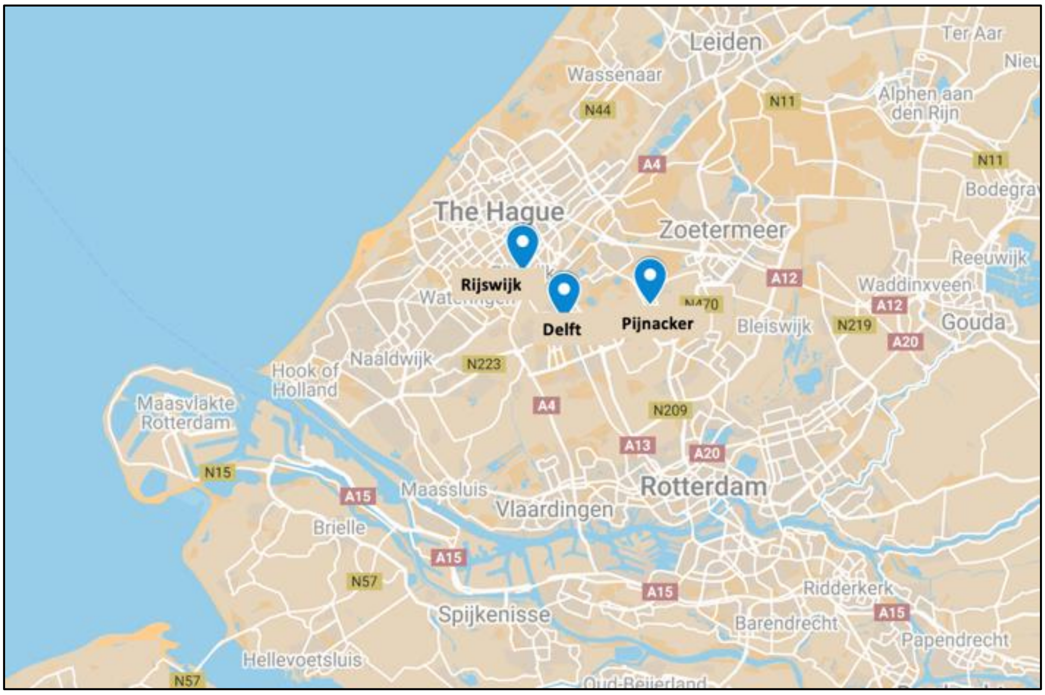

Figure 3.2 Study areas in the Netherlands

3.1.1 United States of America & Canada

Berkeley and Hayward are two cities well connected by the Berryessa/North San José–Richmond line or Orange line of Bay Area Rapid Transit (BART) line in the San Francisco bay area. The frequency of the orange line is 15 minutes. There are 3 station and 2 stations in Berkeley and Hayward respectively. Berkeley is a city on the eastern shore of San Francisco Bay, Alameda County, California with a population of 100,000 inhabitants approximately. It is also home to one of the oldest universities of the United States of America, meaning that a considerable number of potential young transit users are served with the orange line of BART. Moreover, Berkeley has one of the highest rates of bikers and pedestrians commute in the country. Regarding Hayward, itis also a city located in Alameda County, California with 150,000 inhabitants. As mentioned earlier, BART has two stations in Haywards, in Downtown Hayward and South Hayward. Along with the BART services, Hayward is also well served with bus transit.

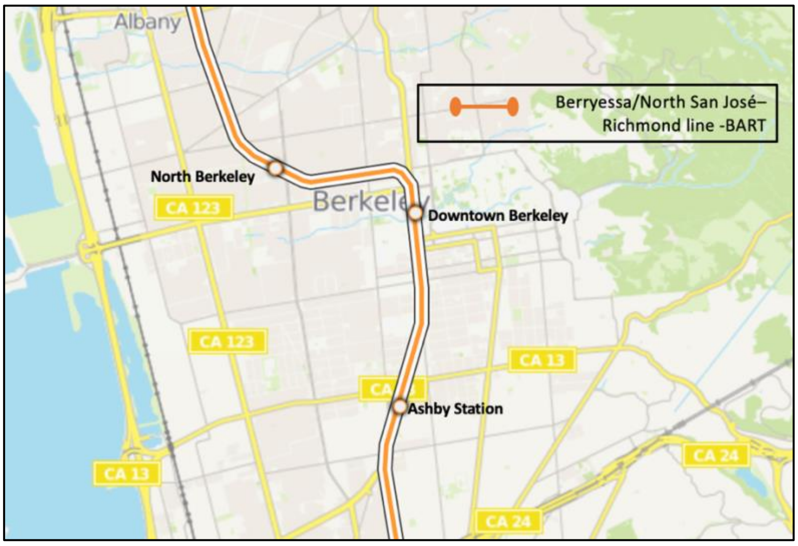

Figure 3.3 Stations areas from which the data were collected in Berkeley, California. (Source:Moovit, 2020)

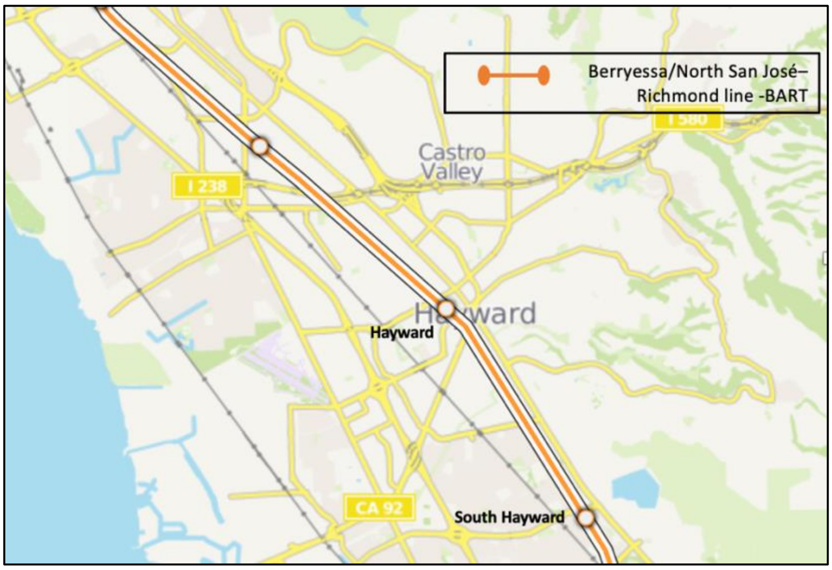

Figure 3.4 Station areas from which data were collected in Hayward, California. (Source:Moovit, 2020)

Downtown Plano is a major rapid transit station located in the city of Plano, serving the Red and Orange lines of Dallas Area Rapid Transit (DART). Plano is one of the 12 suburbs of the city of Dallas located approximately 20 miles away from downtown Dallas. It has around 250k inhabitants. The Redline and orange line of DART enable people living in Plano to travel back and forth to other suburbs and downtown Dallas, reducing auto dependency. Although there are two stations of DART light rail in Plano, data were collected only from the respondents living around Downtown Plano.

Mockingbird station serves Blue, Red & Orange lines of DART and a train every 10-15 minutes per line. It has the highest density of population living with 3 miles of any mass transit system in the state of Texas. It is situated in North Dallas, Texas. The below-ground Mockingbird station is surrounded by an outdoor mall on the ground level and other restaurants, services, entertainment options, office buildings and loft apartments. It is one of the first modern TOD areas in the state of Texas.

Rosslyn, Virginia is a heavily urbanized area in Northern Virginia with a population of 12k inhabitants. It presents a dense business section with 81% of the residents as college students. It is considered a major transportation hub with well-connected highways systems and Rosslyn station serving Blue, Orange and Silver lines of Washington metro system connecting several jurisdictions of Maryland and District of Columbia. Station serves 26 trains per hour per direction and a train every 2-3 minutes in the peak hours.

Finally, South orange is a suburban township in New Jersey with two stations namely South orange station and Mountain station on the Morristown Line, one of the commuter rails lines (suburban rail) operated by New Jersey Transit. Approximately 16k inhabitants are living there. On average there are 3-4 trains per hour traversing these stations. South orange station is one of the newly upgraded TOD areas with residentials, restaurants and other entertainment options surrounding the station.

In Canada, data has been collected from people living around SkyTrain stations in the city of Vancouver and Toronto Subway stations in Toronto. SkyTrain is one of the advanced metro systems which uses fully automated trains. SkyTrain provides high-frequency service, with trains arriving every 2.5 to7 minutes during peak hours. It has 53 stations served by three lines. Toronto subway has 4 rapid transit lines and 2 other lines under construction. Trains are arriving every 3-7 minutes at all stations.

In conclusion, study areas in Hayward, Berkeley, Downtown Plano station area, Mockingbird station area, Rosslyn, Vancouver and Toronto all have rapid transit lines. All of these study areas have a fast, reliable and frequent transit system ensuring trains every 2-15 minutes at transit stops. Also, most of these station areas have characteristics of TOD or are carefully planned to create a transit-friendly environment in recent years. The only standout being South Orange, Virginia, where the data has been collected from respondent living around suburban rail stop with relatively lower frequencies. However, South Orange station was also recently redeveloped to increase the diversity of land use by accommodating services, entertainment options, various cafes and restaurants in and around the station, hence also exhibiting characteristics of a TOD area. Lastly, all of the study areas are either situated in major cities or suburbs of major cities, connected by rapid transit rail. Based on the above discussion, it is safe to say that data was carefully collected from a population living in TOD areas with rapid transit or suburban rail stops in their vicinities.

3.1.2 Netherlands

Pijnacker is a town in the Dutch province of South Holland with a population of 27k inhabitants. Pijnacker has two stops on the Line E metro line, namely Pijnacker-Centrum and Pijnacker-Zuid. Line E of the Rotterdam metro was formerly a railway line, now renovated to a fast and high-frequency metro service connecting Den Haag and Rotterdam, two of the biggest cities in the Netherlands. Pijnacker-Zuid station is well connected by this metro line to major cities of the Netherlands and also to Rotterdam-Den Haag Airport. It is to be noted that this metro station is also well connected by the bus network of Pijnacker.

Delft is a city located between the Hague and Rotterdam in the province of South Holland with a population of nearly 100k inhabitants. Interestingly, Delft has two tram lines namely Line 19 and Line 1. Line 19 is part of the Randstad rail, connects Leidschedam via Leidschenveen and Ypenburg to TU Delft Campus, however the connection to TU delft campus is expected to be finished by fourth quarter of 2022. Nevertheless, travelers are well connected in the city by an extensive bus network connecting travelers on Line 19 to TU delft campus. Apart from Line 19, other line which is part of the Hague tram network is the only tram network which runs in the city of Delft and Tanthof. Line 1 serves 12 stops as showing in Figure 3.5, with a frequency of 6-7 trams per hour. Apart from the bus and tram services, Delft also has two heavy rail stops connecting the city to the rest of the Netherlands with intercity as well as stoptreinen. In the Netherlands, there are primarily two types of train namely stoptreinen (local train, which Dutch railways call Sprinters) and Intercity with fast long-distance service. The former is called stop trains in the Netherlands due to multiple stops on a running line just like a light rail.

Figure 3.5 Stops that are served by HTM Tram Line-1 in Delft. (Source:Moovit, 2021)

Rijswijk is town with nearly 50k inhabitants. Line 1 of the Hague tram network which connects Delft also traverse through Rijswijk. There are 6 stops that are served by Line 1 in Rijswijk with same frequency as in Delft. However, this tram line does not pass through the town. Line 17 of the Hague tram network connects Rijswijk station to the Hague central station and Hollands Spoor station. There are 12 tram stops as shown in Figure 3.6 that served by Line 17 with a frequency of 5 trams per hour. Apart from the tram line, Rijswijk also has heavy rail station primarily served by commuter rail or stoptreinen, connecting the town to the Hague and Rotterdam. There are 4 commuter trains stopping at this station per hour.

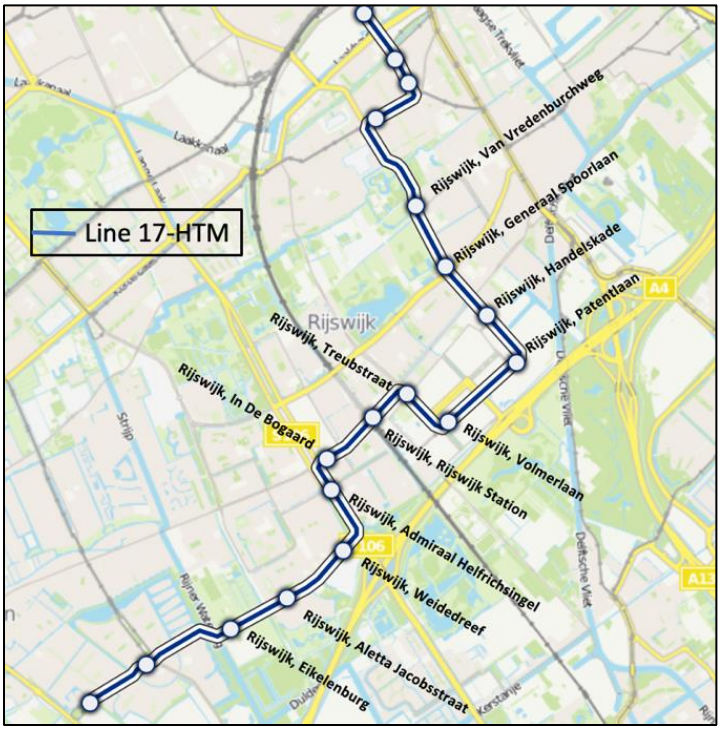

Figure 3.6 Tram line-17 in Rijswijk (Source:Moovit, 2021)

To conclude, among the three study areas, Pijnacker- and Rijswijk are suburbs of major cities in the Netherlands. Pijnacker-Zuid and Rijswijk both have light rail stops (along with a stop train station and an extensive bus network in all three areas), while Delft has tram, stop trains and intercity stations. However, these stop trains stop on average three to five minutes on most routes and are used for a maximum of thirty-minute travels, which is very similar to a light rail or a metro. Therefore, it is safe to say that the people living around the transit stops in the aforementioned study areas are all exposed to fairly similar transit options.

3.2 Data Sources

Data were collected by an inter-disciplinary research group, Transport research at McGill, Montreal, Canada in collaboration with Technische Universiteit Delft, Netherlands. The survey was conducted in The Netherlands and North America to better understand the travel behavior of residents living in TOD areas and compare the effects of the built environment of different TOD settings in Europe and North America and its effect on residents' travel behavior in their daily commutes as well as in other activities. This survey was conducted in July 2015 by TU Delft and McGill University.

In the following subsection, details about the survey questions used to collect data relevant to this research are explained elaborately. Although this survey tries to collect vast and diverse information ranging from information about the home and work locations to information of traveler's behavior during different weather condition, not all of the data collected were used for this thesis. This choice was made a few of the data were considered irrelevant to the stated research questions and partly because a considerable number of respondents have not answered questions related to few subjects, which is usually the case in most of the surveys.

3.2.1 Survey

The survey is used to collect data in The Netherlands, the United States of America and Canada. As mentioned in the previous section, data were collected from people living in and around TOD areas. Survey question can be broadly classified into 3 sections. These sections are:

1.Daily trip
2.Work and house location
3.Household and personal information

The following texts explain the questions asked in each section stated above together with their relevance to the current study.

1. Daily trip

Respondents were asked to pick one among the 11 locations where the survey was conducted. Thereafter, they were asked to answer about their employment status and if they are employed, how frequently are they supposed to travel in a regular week. On the same note, respondents were provided with a broad set of mode choice options and were asked to pick the mode used most frequently for the work commute. Mode choice options consisted of walk, bike, private automobile, carshare, carpool and transit. Transit consisted of the train, light rail, metro, tram, SkyTrain, subway. In this research, for simplicity reasons, the word transit is used when studying the influence of proximity to a transit stop on mode choice. Respondents were also asked if they have access to a vehicle provided by an employer, free car parking at the work location or any other incentive such as reduced transit fare or transit pass.

2.Work, school and house location.

Respondents were asked to pin their place of work and residence located on the map, providing latitudes and longitudes for every work and home location. This is of utmost importance for this study. Using these data and google API's, Euclidean distance between work and the home location was calculated. Also, the time taken to travel by car (with and without traffic) and by rail was calculated. Then, using the home location, the time taken to walk to the nearest transit stop was estimated. Similarly, using the work location egress time was also extracted. These variables are the main predictors for this study.

3.Household and personal information

Data related to household size, number of driving license holders in the household and number of cars and bikes available at house were obtained in this section of the survey. Also, availability of car parking at the house location or other locations was taken into account. Lastly, respondents were asked to provide their date of birth, gender, level of education and annual gross household income.

3.3 Walkscores

In this section, the variable used to capture built environment characteristics of a work location/home location is explained. Traditionally, built environment characteristics comprise densities, land-use mixture, urban designs in and around trips origin destination. Anyway, obtaining values of densities and land-use mixture values of each and every origin and destination of 1500 survey respondents is not an easy task, especially considering that the data were collected from three countries.

Because of the aforementioned reason, researcher is using Walkscores as mediating factor for built environment characteristics to study its effect on mode choice. This factor is readily available to get for all most any pin code in North America and Western Europe with a subscription from the walkscore website. (Brewster, 2009; Walkscore, 2021). Walkscore is a walkability index based on the distance to amenities such as grocery stores, schools, parks, libraries, restaurants, and coffee shops. It is provided by an API by a private company called Walkscore. For every address point the API analyses hundreds of walking routes to nearby amenities and based on the distance to the amenities in each category points are awarded. For example, if the closest amenity in a category such as library from the house location is within 0.4 km, maximum points are assigned to it. Number of points decrease with increasing distance and beyond 1.6 km no points are awarded for the amenity. Every category is weighed equally, and the points are summed and then normalized to yield a score between 0-100[1]. For explanation purposes, walkscores can be categorized into 4 categories, as shown in Table 3.1.

Table 3.1 Categories of walkscores. Source: Walkscore official website

Score	Description
90-100	Walker's paradise (Do not require to complete daily things)
70-89	Very walkable (Most errands can be completed on foot)
50-69	Somewhat walkable
0-49	Car-Dependent (Most errands need car)

As mentioned in subsection 3.2.1, respondents were asked to pinpoint their work and home locations on a map. This information is in the form of latitudes and longitudes. These latitudes and longitudes are then used to get the walkscores of home location and work location of every respondents by inserting the values in Walkscores API. Syntax for inserting the latitudes and longitude values in the API and then exporting the walkscores can be found in the Appendix-C.

3.4 Data cleaning

Considering the aim of the present study, which is to understand the influence of proximity to transit stops at home and workplaces on the use of transit for the work commute, it is imperative to include only the respondents who have provided their preference of mode for the work commute. Among 874 observations in the initial dataset, 207 observations did not contain a choice of mode. They are ignored for the analysis. These observations were mainly school commuter or non-workers, who did not report mode choice probably because they did not have to commute daily.

Among the observations with mode choice, only the ones with transit and car are included in the analysis, rejecting 157 more observations, who were travelling with other modes, primarily active modes. The reason for this exclusion is to have a level comparison for the factors that

[1] For more information regarding the mathematical description please visit https://www.walkscore.com/professional/walkability-research.php.

are studied. Therefore, this study only tried to find the effect of the variables mentioned in the theoretical framework on the use of transit compared to an automobile. Next, observations with work status as employed are only considered for the analysis. As mentioned earlier, transit use for work commute is a focal point of the study. Therefore, the 44 observations with work status other than employed (i.e., unemployed, retired or studying) are ignored in this analysis. Work commutes are chosen for this study because of a fixed home and work location, making it easier to understand the importance of access/egress time and also built environment characteristics of these locations. It can be argued school-based trips also represent the same characteristics, but the literature review pointed out that the effect of the considered variable can vary based on the trip purpose as well. To have a clear understanding of the considered variables on the use of transit, only one type of trip purpose was included. One observation without coordinates for home and work location was removed. This is obvious based on the previous discussions, coordinates of home and work locations are pivotal in this research as information regarding access/egress time and walkscores are impossible to calculate without the coordinates of these locations.

Lastly, data points with extremely high values of egress time were filtered. In the dataset, few observations reported very large egress time values. For example, an observation had 90 minutes of egress time, leading to more than 300 minutes of total travel time via transit. Also, few observations reported longer egress time than the in-transit time. Further examination of such outliers revealed that workplaces were situated in remote areas with no transit connectivity. Logically, in such a situation's workers are forced to use their vehicles. Therefore, these observations were ignored as cars represent the only realistic option to reach such places.

To limit the number of such outliers in the dataset, Z-score values are used to detect outliers. A standard cut off value of +/-3 further from zero is used (Shiffler, 1988). After using the same method for access and egress time variables, 31 observations with such extreme values were detected. These observations were all removed from the dataset.

The updated dataset contains 434 observations. The above-mentioned filter steps are illustrated in Figure 3.1

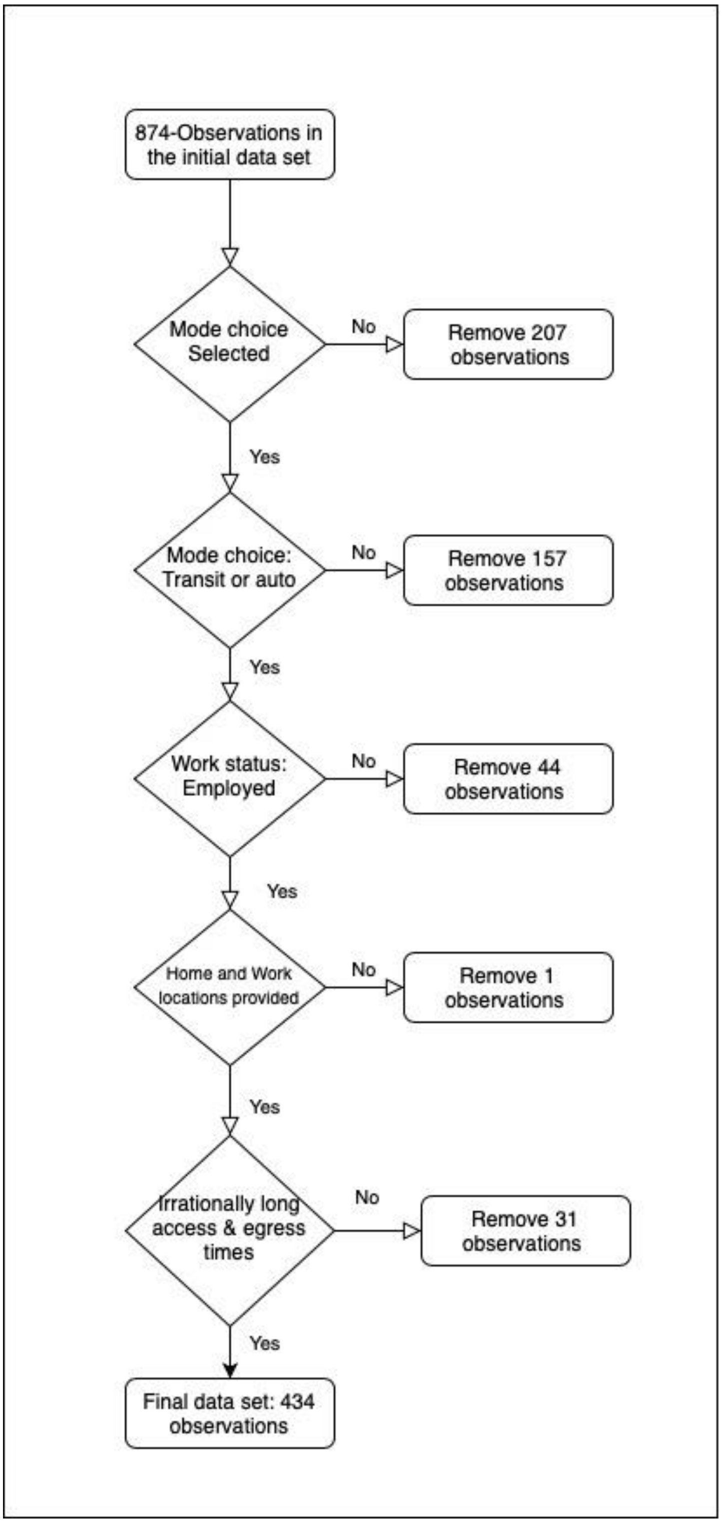

Figure 3.7 Data filtering process

3.5 Descriptive statistics

This section describes the population that the sample is representing. To do so, demographic characteristics of the data are compared to the demographic characteristics of the population.

3.5.1 Representation of the data

In total, data collected from 434 respondents were used for this research. Among these respondents, 181 were from the Netherlands and 253 were from the USA and Canada. To compare the data with the population, data have been split according to the country of residence. An overview of the age and education level of the respondents is presented in Table 3.2. In North America, data were largely collected from the USA. Hence, population averages of the USA are used to compare with the sample. In the Netherlands, more than half of the sample (~70%) falls in the category of 20 to 50 years, while only ~38% of the whole Dutch population (Central Bureau for Statistics, 2020) belongs to the same category. As the data were collected from people living near light rail and suburban rail stops, data could be overrepresenting the younger population. Similarly, in North America, ~74% of the sample lies in between 20 to 50 years but only ~39% of the population belongs to the same category. A similar explanation can be extended for the sample collected from the USA and Canada.

Table 3.2 Variance of Age and education in the sample and in the population of the Netherlands and the North America

Variables	Categories	N (no. of cases) Country-USA & CA	Share in sample	Population share	N (no. of cases) Country-Netherlands	Share in sample	Population share
Age	20-30	51	(20.16%)	(13%)	18	(9.9%)	(13.75%)
	30-40	81	(32.05%)	(12.51%)	56	(30.9%)	(13.46%)
	40-50	59	(23.34%)	(12.85%)	50	(27.76%)	(12.29%)
	50-60	44	(17.32%)	(14.74%)	41	(22.65%)	(12.91%)
	60-70	23	(9.13%)	(12.31%)	17	(9.39%)	(11.59%)
	>70	3	(1.11%)	(13.93%)	1	(0.5%)	(11.16%)
	Total number	253			181		
Education	Undergraduate & Graduates	192	(75.82%)	(19.52%)	69	(38.23%)	(12%)
	College & Diploma	48	(18.94%)	(61.48)	91	(50.4%))	(61%)
	Highschool & Below	13	(5.34%)	(20%)	20	(11.08%)	(9%)
	Total number	253			181		

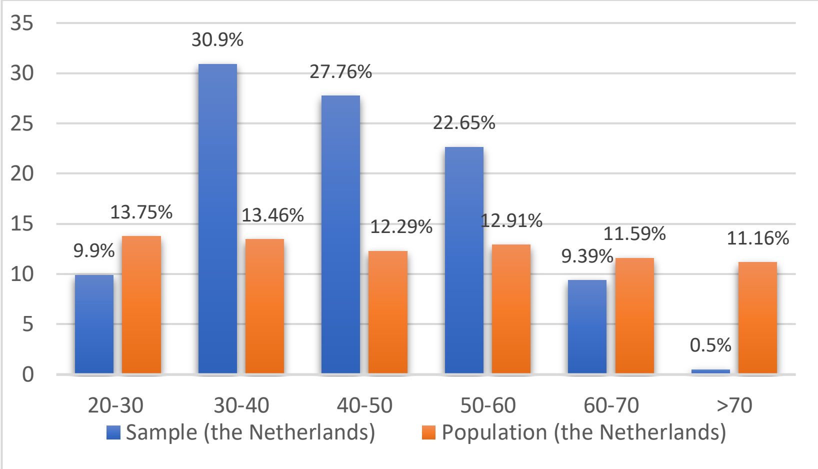

Figure 3.8 Comparison of age in the sample collected from the Netherlands with the population of the Netherlands

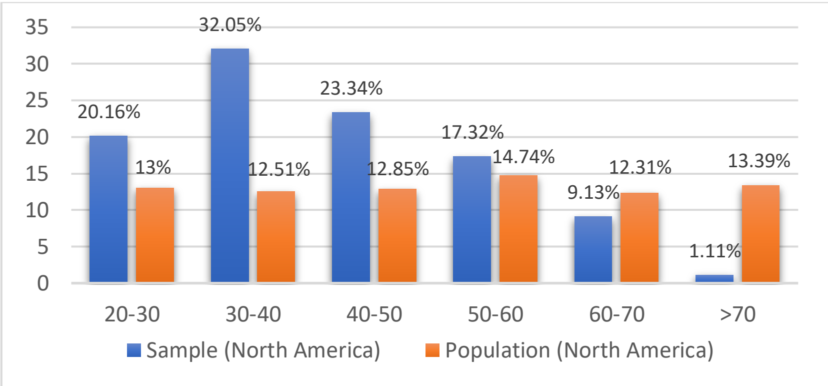

Figure 3.9 Comparison of age in the sample collected from North America with the population of North America

Regarding the education level, an overwhelming majority (~75%) of people represented in the sample holds a university degree or higher in the USA, which is far from the average of the nation at 36%. It is not surprising, as the link between the presence of light or heavy rail transit and a large population of younger college-educated people living around these transit stops is well documented in the literature (Guthrie, 2016). However, in the Netherlands, ~39% of the sample held an undergraduate degree which is not far from the population average of the Netherlands at 32%.

Regarding the income level, the sample divided into three categories, shown in Table 3.3. In North America and the Netherlands, the majority of the sample consists of medium to high-income households while the low-income household is largely underrepresented. This overrepresentation of high-income households can be attributed to the fact that the data have been collected from suburbs of major cities on both continents. There could be limitations in studying a section of the population because lower-income groups represent the majority of transit users. Also, job locations of fairly high-income households are more likely to be located in areas with good transit connectivity could have a bias towards using transit than low-income jobs where transit connectivity may not be as good. These limitations will be revisited in the last chapter. As for gender, the sample fairly represents the population distribution in the USA. On the other hand, men are overrepresented in the Netherlands.

Table 3.3 Variance of Income and gender in the sample and population

Variables	Categories	N (no. of cases) Country-USA & CA	Share in sample	Population share	N (no. of cases) Country-NL	Share in sample	Population share
Income level	<$40,000	31	(12.24%)	(30.10%)	27	(14.91%)	(70.97%)
	$40,000-$120,000	118	(46.71%)	(41.41%)	112	(61.11%)	(26.14%)
	>$120,000	71	(28.87%)	(28.53%)	15	(8.27%)	(2.97%)
	No information	33	(13.57%)		16	(14.31%)	
	Total number	253			181		
Gender	Male	125	(49.44%)	(49.64%)	118	(65.19%)	(49.48%)
	Female	126	(49.83%)	(50.46%)	61	(33.71%)	(50.52%)

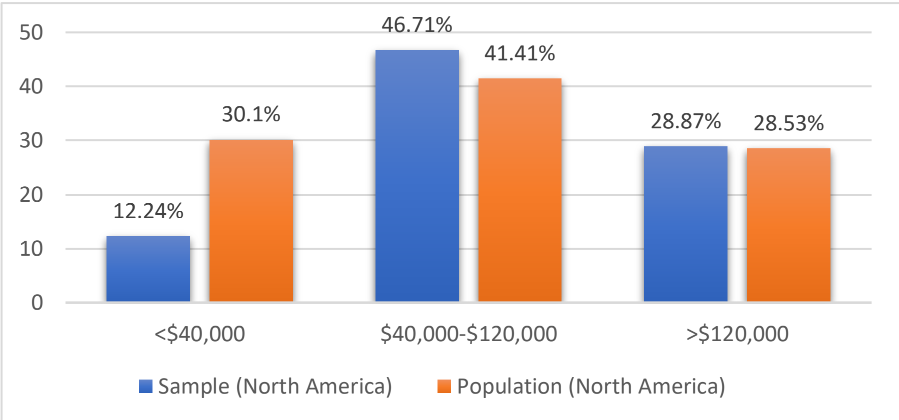

Figure 3.10 Comparison of Income level in the sample collected from North America with the population of North America

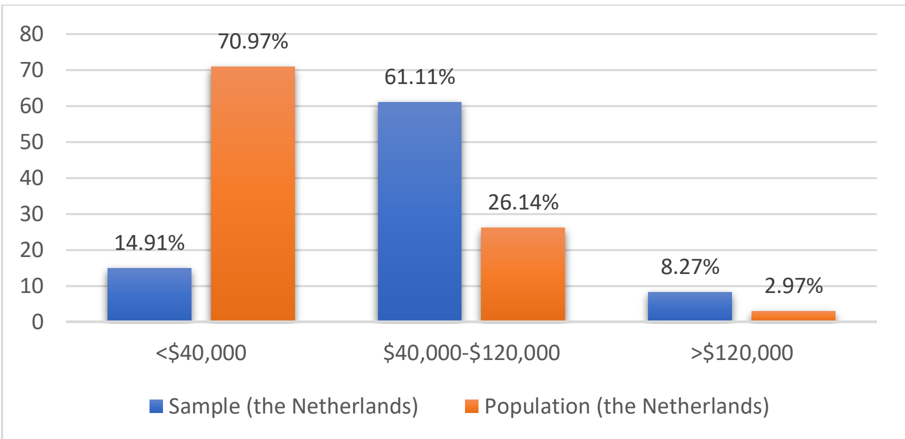

Figure 3.5 Comparison of Income level in the sample collected from the Netherlands with the population of the Netherlands

In the sample as shown in Table 3.4, ~90% of people owned at least one car in the Netherlands, which is far from population average, according to which only 70% of the Dutch households own at least one car (Statistics Netherlands, 2013a). On the other hand, ~83% of households owned at least one car in the USA, closely resembling the population of USA (~84%).

Regarding home walkscores, in the sample, the majority of people live in areas with walkscores more than 60 (see Section 3.4 for further explanation of walkscores), indicating a walking-friendly area. On the other side, car dependent areas are well underrepresented. This is mainly true for the sample collected from the Netherlands. Also, surprisingly only 16% of the sample collected from North America are car-dependent neighborhood, but in the US even TOD areas are car friendly perhaps not as much as suburbs (for e.g., places for car parking were observed in several study areas in the US when checked using Streetview). Nevertheless, a greater number of car friendly neighborhood observations are located in North America than in the Netherlands. There is somewhat an even representation of walkscore in each category. Nonetheless, the majority of the respondents works in areas with higher walkscores. This could be because, although the data has been collected from suburban regions, they could still be working in the central business districts of the nearby cities (and hence the high work walkscores).

Table 3.4 Variance of Car ownership, Home & work walkscores in the sample and population

Variables	**Categories**	**N (no. of cases) Country-USA & CA**	**Share in sample**	**Population share**	**N (no. of cases) Country-NL**	**Share in sample**	**Population share**
Car ownership	Zero cars	36	(14.21%)	(17%)	17	(9.32%)	(8.78%)
	One car	121	(47.87%)	(53%)	92	(50.78%)	(30.10%)
	More than one car	96	(37.92%)	(30%)	72	(39.69%)	(58.12%)
	Total number	253			181		
Home walkscore	Walker's paradise (90-100)	50	(19.73%)		47	(25.94%)	
	Very walkable (70-90)	115	(45.44%)		102	(56.85%)	
	Somewhat walkable (60-70)	53	(20.94%)		28	(15.74%)	
	Car dependent (<60)	41	(16.20%)		4	(2.11%)	
	Total number	253			181		
Work walkscore	Walker's paradise (90-100)	68	(26.83%)		63	(34.80%)	
	Very walkable (70-90)	94	(37.02%)		27	(10.82%)	
	Somewhat walkable (60-70)	47	(18.36%)		69	(38.14%)	
	Car dependent (<60)	44	(16.18%)		22	(16.42%)	
	Total number	253			181		

In Table 3.5 an overview of the sample in terms of means and standard deviations is given. The average of access time reflects the characteristics of a TOD area. Apart from the extreme outliers mentioned in Section 4.1, even after data cleaning, a few outliers were still included in the data to reflect the reality instead of trying to improve the model. For these reasons, a small portion of access and egress time outliers were still kept in the data. As for standard deviation, egress time values contain a relatively large variability in the dataset, representing the wide array of workplaces in the sample. This can be an advantage for the study, as it would help to understand how the use of transit could vary based on the changes in connectivity at the destination.

Table 3.5 - Overview of factors and their representation in the sample

Variable	Country- Netherlands		Country- USA & Canada	
	Mean	**Std. dev**	**Mean**	**Std. dev**
Age	44.9	11.36	41.64	12.36
Household size	2.54	1.24	2.54	1.81
Home walkscore	71.34	12.41	71.54	20.18
Work walkscore	73.79	25.52	73.99	24.5
Access time	5.39 (min)	3.66	6.26	5.42
Egress time	10.23 (min)	9.15	11.85	10.6
Commute time ratio (train/auto)	2.2	1.13	2.3	1.11

As a final point, findings of descriptive statistics indicate that the sample does not represent the entire population, both for the Netherlands and North America. Instead, it represents the population living around the transit stops mainly light rail lines. This could be explained by the fact that data were not collected randomly. Sample represent a relatively young populations that is mostly well educated, a relatively higher income category and mostly living in relatively walking friendly surroundings.

4 Model estimation and Results

In this chapter prepared data is explored to answer the research questions. The analysis of the influence of proximity to transit stops on transit use and transit use model estimation outputs are presented.

4.1 Transit use models

Section 4.1.1 discusses about the modelling approach. Then section 4.1.2 discusses analysis approach and the modelling method applied to reach the outcomes. Later, the predictor variables included in the analysis and the coding scheme of individual variables are presented. Lastly, outputs of the regression models are given, and the individual models are interpretated in an elaborate manner.

4.1.1 Analysis Approach

As already stated, this research tries to predict the use of transit for work commute by analyzing the influence of proximity to transit stops at origin and destination. To do so, access and egress time values were used, and two distinct models were developed. The first one investigates the role that access, and egress time individually play on the use of transit. The second model instead takes into account the possible combinations of these variables. The goal is to study whether both access time and egress time do influence the use of transit while controlling for other external factors such as personal characteristics, built environment characteristics and country of residence.

Studying the combined effect of access and egress time will provide a holistic view of transit use with proximity to transit stops. The possible combinations of these variables might have a strong impact on this research. For example, even if one side of the trip is well connected, a person might not use transit because the other end of the trip is not well connected. Vice versa could also be possible. The combinations are divided into three categories:

- Both origin and destination side of a work-based trip are well connected.
- Only one side of the trip is well connected, either origin or destination.
- Only one side of the trip is well connected, and other side is moderately well connected

The enter procedure is employed for the inclusion of the variables for all the models. This is a procedure for variable selection in which all the variables in a block are entered into the analysis at the same time. The main motive is to determine the influence of access and egress time (also the interaction terms for combined effect), as these are the main predictors. So, these variables are included in the first block. The control variables related to personal characteristics, built environment characteristics and country of residence are included one after the other separately. SPSS presents the outputs of each block and the correlation between the predictor variables and the control variables.

4.1.2 Modelling approach

To achieve the research objective, logistic regression is used. Logistic regression is the appropriate regression analysis to conduct when the dependent variable is binary. Logistic regression is primarily used to describe data and also to explain the relationship between the

binary dependent variable and one or more nominal, ordinal interval independent variable. The main assumptions of binary logistic regression are
1 The dependent variable should be binary
2 There should be no outliers in the data
3 There should be no high multicollinearity among the independent variables
The dependent variable in this research is the use of transit (use of transit for work commute versus the use of a car for work commute). Logistic regression models are estimated in SPSS. This model is used to understand the individual and the combined effects of access and egress time while controlling for other external factors.

Before proceeding to the results, the considered set of predictors and the coding scheme are discussed in the next section.

4.1.3 Predictor variables and coding

The descriptive statistics sections have previously provided insight into the variance of some of the factors, such as individual characteristics (education, income, age, gender, car ownership), country of residence (NL, NA). In this section, variances of the rest of the factors that are directly related to the research questions are discussed. At the same time, the reasons behind the categorization of a certain predictor variable will also be elucidated.

Analogous to the variance tables shown in descriptive statistics, in this section variation is explored. In Table 4.1, the variance of the predictor variables is not separately based on the country of residence as the analysis is conducted using the entire dataset. Access and egress time are categorized into three levels depending on the walking time to transit stops at home and workplace. The idea is to understand the influence of each level and compare the variations. Categorical variables are preferred over continuous variables because the objective of this study is to see how the combination of access and egress time effect transit use and also to compare these categories. Using continuous variables would only enable to study single interaction effect i.e., access* egress. But to explain the variation in the combined effect of access and egress for every combination that was mentioned in the previous section, categorical variables are preferred over continuous variables.
Categorization of these variables was made partly based on the guidelines, frequently reported findings in the literature regarding the average walking time (both access and egress) for light rail and partly derived from multiple trials to find the best cut-off points that are deemed to fit the data best. Access time – Low variables aims at studying the effect of living in TOD areas. Access time- Middle, when a person is living less than a kilometer from the transit stop. The rest of the values are labelled as Access time – High. Similarly, egress time is also categorized in three levels as presented in Table 4.3. High will be used as a reference category.

Table 4.1 Variance of ordinal variables

Variables	Categories	Relative frequencies across all levels (%)
Access time	Low (<4mins)	40.55
	Middle (4-11mins)	49.76
	High (>12mins)	9.21
Egress time	Low (<8mins)	41.01
	Middle (8-30mins)	38.4
	High (>30mins)	20.04
Work Walkscore	High (>70)	66.33
	Low (<70)	33.67
Home Walkscore	High (>70)	58.75
	Low (<70)	41,25

Table 4.2 Considered variables in regression, and coding scheme

Variables	Coding Scheme
Choice of mode	(1: Transit, 0: Car)
Access Time – Low	(1: less than 4mins)
Time – Middle	(1: 4-11mins)
Time – High	reference category
Egress Time – Low	(1: less than 8mins)
Time – Middle	(1: 8-30mins)
Time – High	reference category
Work walkscore	(1: more than 70, 0: less than 70)
Home walkscore	(1: more than 70, 0: less than 70)
Age	(Continuous, [years])
Education	(1: Undergraduate degree or higher, 0: College diploma or lower)
Income	(1: 80$k or higher, 0: lower than 80$k)
Country	(1: Netherlands, 0: North America)

In Table 4.2 the variables that are included in the analysis along with the coding scheme is presented. Variance Inflation factor (VIF) test is used to assess any collinearity of the predictor variables and no multicollinearity has been reported. In the next section regression results are presented.

4.1.4 Regression Results

In the first model, categories of access and egress time variables are included along with variables related to personal characteristics and walkability index of work and home location. In the second model, interaction terms are included to the previous model.

Interpretation of first model

Table 4.3 reports the outputs of the first model. A positive value of the coefficient (B) of access time – low indicates the difference between low and high as the reference category. So, a one-unit increase (from high to low) in the access time-low variable corresponds to a 1.27 increase in the log-odds of transit, holding all other predictor variables constant. Simply put, the probability of using transit is higher when a person is living in close proximity to a transit stop compared to a person living further away. When looking at the odds ratios or Exp(B) values, it can be seen that commuters living in less than 8 mins of walking distance to transit stops are 3.5 times more likely to use transit over a car for work compared to a person with more than 11 mins of walking distance. Hence, the interpretation of B and Exp(B) leads to the same conclusion. Here on, estimated coefficients (B) will be used for interpretation.

Table 4.3 Model estimation results, effect of access and egress time on transit use

Variable	B	Exp(B)	Wald	Sig.
Constant	-3.056	.047	10.507	.047
Age	-.022	.979	5.038	.025
Education	-.253	.777	.409	.522
Income	-.179	.836	.513	.474
Country	-.294	.746	1.547	.214
Household size	-.052	.949	.567	.454
Access time - Low	1.269	3.558	7.337	.007
Access time - Mid	.752	2.120	2.760	.092
Access time - High	Reference			
Egress time - Low	1.563	4.775	16.002	.000
Egress time - Mid	.479	1.615	1.856	.520
Egress time - High	Reference			
Work Walkscore	.022	1.022	12.084	.001
Home Walkscore	.015	1.015	4.081	.043
Model Fit				
Nagelkerke R Square:.0314	Model Sig.: .000	Final LL: 472.471	Dataset N: 424	

The probability of using transit is higher when a person is living within moderate walking distances to transit stops than a person living further away. Nevertheless, access time-low is found to have a stronger impact than access time-moderate, as the difference of estimated coefficients is positive (1.269-.752=.517). The probability of using transit is higher when a person's workplace is in short walking distances to transit stop than when a person's workplace is situated further away. A similar effect is observed when a person's workplace is within moderate walking distance to a transit stop. A large positive difference (1.563-.479=1.084) is reported between low and moderate egress times, indicating that there is a strong increase in the probability of using transit when a person has a short egress time, rather than a moderate egress time. Along with proximity, a higher walkability index or walkscore of origin and destination areas are found to have an additional positive effect on the use of transit. An increase in age is found to decrease the probability of using transit. It is now clear that both access and egress time are influencing the use of transit when controlled for built environment characteristics, age, education, income.

Interpretation of model with interaction terms

Interaction terms of access and egress variables are included in Table 4.4 to report the influence of possible combinations of access and egress time. Using the coefficients presented in Table 4.4, contribution of each combination of access and egress time variables to transit use are presented in Table 4.5. In Table 4.5, based on the coding scheme (see Table 4.2) and the model outputs *total contribution* to the use of transit are calculated. This contribution defines the probability of using transit when controlled for socioeconomic characteristics of the traveler and built environment. For instance, to calculate the contribution of low access and low egress time only the variables relevant to these variables are taken into consideration (CFDR, 2006), this can be seen in Eq.1.

A-Low*E-Low = 2.263 * A-low (1) + 2.245 * A-mid (0) + 3.630 *E-low (1) + 0.6323 * E-mid (0) - 1.267 *(A-low (1) *E-low (1)) +0.458 *(A-low (1) *E-mid (0)) - 2.149 *(A-mid (0) *E-low (1)) = **4.620.** $Eq.1$

In Eq.1, coefficient of each variable (taken from Table 4.4) are multiplied with code of the variable (1 and 0) and the summation of the equation results in the total contribution to the transit use (see Table 4.5). ‘0s’ in each column of Table 4.5 indicate that there is no contribution of these variables for the specific combination. Similarly rest of the values are calculated. Using these values, probability of using transit is compared and the following interpretations are presented. Fourth combination, i.e., when both sides are moderately well connected (A-mid*E-mid) is also possible. This was tried in the analysis, but model did not produce any significant results by including this combination in the model, therefore this combination was excluded in Table 4.4. However, the model with all four combinations can be found in Appendix- B.

Table 4.4 Model estimation results, effect of access and egress time with interactions

Variable	B	Exp(B)	Wald	Sig.
Constant	-2.844	.058	5.057	.025
Access time – Low	2.263	9.610	3.606	.058
Access time - Mid	2.245	9.442	4.495	.034
Access time - High	Reference			
Egress time -Low	3.630	25.439	8.853	.003
Egress time - Mid	.632	1.882	2.203	.130
Egress time - High	Reference			
Home Walkscore	.531	1.701	4.602	.032
Work Walkscore	.644	1.905	5.353	.021
Household size	-.036	.965	.274	.600
Income	-.190	.827	.574	.440
Education	-.127	.881	.108	.743
Age	-.020	.980	4.537	.033
Country	-.316	.729	2.065	.151
Interaction Effects				
A-Low*E-Low	-1.267	.282	.917	.068
A-Low*E-Mid	.458	1.581	.449	.500
E-Low*A-Mid	-2.149	.117	3.198	.074
Model Fit				
Nagelkerke R Square:.0310	Model Sig.: .000	Final LL: 473.822	Dataset N: 431	

Table 4.5 Parameter of each combination of access and egress time

Access time	Egress time	Transit use contribution per term							Total contribution
		A-low	A-mid	E-low	E-mid	A-low*E-low	A-low*E-mid	A-mid*E-low	
Baseline combination									
High	High	0	0	0	0	0	0	0	**0 (a)**
When both sides are well connected									
Low	Low	2.263	0	3.63	0	-1.267	0	0	**4.626 (b)**
When one side is well connected, and other side is not well connected									
Low	High	2.263	0	0	0	0	0	0	**2.263 (c)**
High	Low	0	0	3.63	0	0	0	0	**3.630 (d)**
When one side is well connected, and other side is moderately well connected									
Low	Mid	2.263	0	0	0.632	0	0.458	0	**3.353 (e)**
Mid	Low	0	2.245	3.63	0	0	0	-2.149	**3.726 (f)**

Interpretation of the main effects is as follows, when both residence and workplaces are in close proximity to a transit stop, probability (b) of using transit is highest among all the combinations. This is expected and well-studied in the literature that transit is most likely to be the dominant mode choice when the access and egress side are both well connected. However, it is interesting to note, although model results show that total contribution to the utility for using transit is higher than rest of the combinations, this contribution is still lower than the expected (due to negative value of the interaction term), based on the main effects for access and egress time.

When only one side is well connected and another side is not well connected (A-low & E-High, E-Low & A-High). With (c) & (d) values in Table 4.5, we can see that contribution to transit use have increased to 2.263 (from baseline group) when access time is low and egress time is high. And the contribution to transit use is further increased to 3.630 when access time is high, but egress time is low. This indicates the probability of using transit is higher for individuals with low egress time and high access time than for individuals with low access time and high egress time.

Next, a step further than before, this study tries to compare the effect of access and egress when one side is well connected, and another side is moderately well connected (A-Low & E-Mid, E-low & A-Mid). With (e) & (f) values in Table 4.5, we can see that the probability of using transit is higher for an individual in both cases compared to an individual in the baseline category. Besides, the probability of using transit is higher for an individual with low egress and moderately high access time than for individuals with low access and moderately high egress time.

We can see that for all, low, mid and high access times if egress time is low, the probability of using transit is always higher than a car. While it is not the same case when access time is always low but varying egress times. To put it simply, there is a decrease in the probability of using transit when a person’s egress time is increasing. Although not all interaction variables are significant by reasonable standards, therefore it cannot be claimed with enough confidence that transit use is always higher when egress time is low for a work-based trip. It is to be noted that the differences in the use of transit presented above are all relative to high access time and high egress time. Living in higher walkscore areas is found to increase the odds of using transit for the work commute. Similarly, higher walkscores at work locations are also associated with an increase in the use of transit. The country variable indicates that living in the Netherlands is negatively affecting the use of transit, this does make sense because in the Netherlands transit use is lower due to biking, however, this cannot be claimed with enough statistical confidence.

4.1.5 Conclusion

The last three sections have focused on providing a brief overview of the objectives of the research, predictor variables and the coding scheme and interpretations of the logistics regression results.

Findings presented in the last section can be briefly summarized as follows:

- Both access time and egress time play a significant role in influencing the use of transit.
- Shorter egress time is a much more important factor in deciding to use transit for work commute than shorter access time.
- Home and workplaces situated in higher walkscores areas promote the use of transit for the work commute.
- The probability of using transit is highest when both access and egress distance are low.
- When only one side is well connected and the other is not well connected, it is found that having shorter egress time (or well connected) is associated with higher use of transit than having shorter access time.
- When one side is well connected, and another side is moderately well connected, the probability of transit is still higher for individuals with a well-connected workplace than for individuals with a well-connected residence.
- The probability of using transit is always higher for individuals with the egress side being well connected than for individuals with the access side of the trip is well connected.

It is to be noted that all of the above findings are reported in comparison to having high access time and egress time. Using the findings presented in this chapter, the study can be concluded in the next chapter by answering the main research questions.

5 Conclusion, Discussion, Recommendations

Using the results from the previous chapter, this chapter concludes the research. It answers the research questions posed in the introduction chapter and then discusses how the findings of this research relate to the research gap. Before answering the research questions and discussions, a brief overview about the research gap is provided. Lastly a few recommendations are made regarding future research directions and also to urban planners and future TOD developments.

5.1 Conclusion

5.1.1 Introduction to the study

In the literature review, it was apparent that transit-oriented development (TOD) increases the use of transit. TOD essentially brings housing, jobs, entertainment options, restaurants, groceries closer to the transit stop. By doing so the aim is to increase the diversity of land use, residential and job densities around the transit stop. Now day to day activities of people is all in close distance to transit stop along with their housing and work locations. The assumption is that the need to use a personal vehicle for completing daily chores will be drastically reduced as every activity is in close vicinity to their home and can be accessed by walking and for activities that are further away such as their jobs can be accessed via transit which is also closely situated. Despite limitations and obstacles, TOD areas have been fairly successful in increasing transit ridership and reducing automobile use.

But the success of a TOD area is only possible when people are living in TOD areas and more often than not, also their workplaces are in TOD areas. In that case, both workplaces and residence are close to transit stops, thereby making transit a dominant mode choice. But what happens when the only side of a work-based trip is well-connected will people still use transit for work? Does living closer to transit stop (access time), still play a key role in influencing people to use transit even if the workplace is further away from the transit stop?

In order to answer the research gap, the research question in this study is formulated as follows:

What is the role of proximity to transit stop in increasing the propensity to use transit for work?

The aforementioned research question overarches the effect of both access and egress time on the use of transit, especially for the work commute. To supplement the main research question, a few detailed sub-questions are also formulated, these sub-questions help answer the research gap mentioned and when to put together answers the main research question. To achieve the research objectives, this study uses the data that was collected in 2015 by an inter-disciplinary research group, Transport research at McGill, Montreal, Canada in collaboration with Delft University of Technology, Netherlands. This data was primarily collected from the people living in TOD areas in the Netherlands, USA and Canada.

Based on the previous studies on determinants of transit use and the data that has been made available for this research, the influence of access time, egress time, age, household size, education, income, country of residence, home and work Walkscores on the use of transit for work commute has been investigated. Descriptive analysis of the data set has revealed that the majority of the dataset represents a young adult, an average of 2.5members household size, highly educated-high income class, owning at least one car households. The above description of the data set is in line with findings in the literature regarding the type of population that would be attracted to a TOD. Guthrie and Fan (2016) found that developers perceive TOD to attract a small but distinct percentage of the population, a specifically younger household with high income and education levels.

The mainstream of the observations had a light rail stop (tram, metro, subway, Skywalk) in their close vicinities. Thus, the findings of this research can be extended to TOD areas with light rail stops. An interesting part of the descriptive analysis is that there was a considerable difference between the mean access time (~6mins) and mean egress time (~11mins). And there were relatively high standard deviations for both access and egress time variables. To use this wide range of access and egress time values, access and egress time variables were split into 3 categories. The access time variable is divided into low (0-4mins), middle (4-11mins) and high. Similarly, egress time is also divided into low (0-8mins), middle (8-30mins) and high. Categorization of these variables was made partly based on the guidelines, frequently reported findings in the literature regarding the average walking time (both access and egress) for rapid transit systems and partly derived from multiple trials to find the best cut-off points that are deemed to fit the data best. These variables along with the variable related to personal characteristics and Walkscores were included in the logistic regression model to find their effects on the use of transit.

5.1.2 Answers to research questions

The main aim of this research is to find the influence of access and egress time on the use of transit. In order to answer, first individual effects of proximity to transit stop from home and proximity to transit stop from destination are discussed, then the combined effect of access and egress time are discussed. Lastly the effects of other factors such as personal characteristics, built environment characteristics and country of residence are discussed.

Individual effect of access and egress time on the use of transit

The propensity to use transit is strongly influenced by proximity to the station. However, proximity to the station at both ends of a trip is important. Logistics regression results show that built environment characteristics, access time, egress time are all influencing the use of transit. People with access time lower than 4mins or under a quarter mile are 3.5 times more likely to use transit than people living further away from transit. While on the other hand people who have workplaces under 8 mins of walking distances to transit stops are found to be 5 times more likely to use transit than people who are working further away. Findings of these two variables show that indeed it is important to have both job and residences closer to a transit stop, but one step further, egress time or the time taken to walk from station to workplace, has a stronger influence on transit use than access time, especially for the work commute. There can be various explanations for this observation, plausible reason could be the familiarity of the area, i.e., people could be more familiar with the surroundings around their home locations than their workplace surroundings.

However, more interestingly, if a person resides a little further away from transit stop (4-11minutes) they are still 2 times more likely to use transit but if a person's workplaces are situated a little further away i.e., in the range of 8 to 30mins from transit, they are only 1.5 times more likely to use transit. There is undeniably a decrease in the use of transit by increasing access and egress distance. But there is a sharper decline in the attractiveness of transit when workplaces are situated further away from transit stops than people's residences. Although this rather strong decrease could be attributed to the fact that the author used a larger range for egress time than access time. But to back these findings, Guerra and Cervero (2013) have also reported that if there are additional jobs and residences in the same proximity to the transit stop, jobs are likely to be correlated with a greater number of additional transit trips than residences.

Combined effect of access and egress time on transit use

As mentioned earlier in the research gap, along with the individual effect of access and egress time, a person might alter their decision to choose transit based on both access and egress time. In order to capture this, possible combinations of access and egress time were chosen. First being when both sides of a trip are well connected; second, when only one side of a trip is well connected and the other not well connected and the third being when one side is well connected, and the other side is moderately well connected. The contribution of each combination to the utility i.e., transit use is used to compare (See section 4.1.4). Parameters of each combination of access and egress time are shown. It is evident that the use of transit is highest among all the combinations when both sides are well connected i.e., when access and egress times are low. This is understandable, as travelers are provided with comfort and ease that of a personal vehicle, where they step in and step out of transit to reach their workplaces.
When egress time is kept constant at and increasing the access time value, findings show that indeed there is a decrease in the use of transit, but this decrease is rather marginal. But, if access time is kept constant at low and increasing the egress time, there is a rapid decrease in the probability of using transit with an increase in the egress time. This finding is rather interesting to note, as it reiterates the importance of having shorter egress time than access time to increase the propensity of using transit, especially for the work commute. The same reason why egress is more important than access can be extended here to explain why low egress time is preferred over low access time. Additionally, perhaps by living in and around the TOD area, the built environment of these areas could be promoting people to walk further at home locations. Furthermore, respondents in the study mostly dwelled in inner suburbs with one major transit stop apart from bus service, so people may be inclined to walk longer durations to access this transit service if their workplace is closely situated to this transit line. Lastly, implications of these findings in practice can be of great use especially for current and future TOD developers, this will be revisited again in the policy recommendations section.

Effect of built environment characteristics, personal characteristics and country of residence

Personal characteristics of a traveler that were included in the research were found to have no significant effect on the use of transit except for the age variable. Transit use is found to reduce with the increasing age of the traveler. Habib et al. (2009) also reported that car usage is more likely to increase with increasing age. Built environment characteristics are found to further increase the propensity of using transit. Pointing out the additional advantage of living in TOD areas, these areas create a walking-friendly environment by having higher densities, pedestrian-friendly designs and land use mix. This in turn increases the affinity to walk to transit stops and reduce the necessity to use private vehicles. Finally, people living in TOD areas in North America are more likely to use transit than people living in the Netherlands. This is expected, as in the Netherlands transit use is lower compared to other countries. This is due to the fact that bicycles are strongly ingrained in the Dutch culture, and thus are strong competitors for transit modes, especially for transit trips with relatively shorter trip lengths such as light rail.

To conclude, this study has contributed to filling the research gap. On further studying the influence of access and egress time, it is found that proximity to a transit stop is an important determinant of transit use and it is essential for transport planners and urban designers to create an urban setting where a person's job and residence are close to a transit stop. For work commute trips, proximity to transit stop from the workplace is found to strongly influence transit use than at residences. In fact, there's no substantial decrease in transit use if a person's access time is increased from 4 mins to 11 mins as long as their egress times are lower than 8 minutes. But there's a sharp decline in the likelihood of using transit when egress time is increased even if access time is low. To put it simply a person is most likely to use transit if both residence and workplaces are closer to a transit stop. But if that's not possible, keeping workplaces at close proximities to transit stop can still encourage people to use transit.

5.2 Discussions

In this section findings of this study are compared to the findings of other related studies, then later scope and the limitations are discussed.

5.2.1 Comparison to literature

In order to increase the comprehension on how to construe the findings of this study, it is useful to reflect and compare the outcomes with the findings of related studies. Although there are a lot of studies who have researched access and egress time variables individually there are not many researchers who tried to understand the combined effect of these variables that too for transit modes such as light rail, subways, metros. Therefore, findings of this study can be compared both more on a general effect of access and egress time on transit and also, studies related to TOD and how it is influencing transit usage as well.

In order to study the effect of built environment characteristics of TOD's on train users in Randstad region, Hubers et al. (2015) have reported that living closer to railway station is associated with higher use of train and also proximity of employment location to railway station was also found to increase train ridership, in fact proximity of employment location was reported to have stronger association with train usage than residential location. This is very much in line with findings of this study. In Calgary, O'Sullivan and Morrall (1996) found average walking distance to light rail stops was 649m in the suburbs and in the central business district average walking distance was 840m, also to light rail stops, which is fairly in line with this study where access time in the range of 4-11mins (400-1000m) along with short egress time is found to have higher probability of using transit. Also, this study used a data representing a population living mostly in TOD areas with light rail stop, reflecting an additional advantage to promote people to walk longer than to a usual light rail stop. A consistent finding among walking distance research conducted by Agrawal et al. (2008) in California and Oregon, Alshalalfah and Shalaby (2007) in Toronto, Canada, and Ker and Ginn (2003) to access rail in Perth, Australia, is that people walk considerably farther to access public transport than commonly assumed "rules of thumb." This research also shows that people's willingness to walk further to transit stops depends on whether their work location is closer to transit stop or not.

Krygsman et al. (2004) reported that people were willing to walk longer durations at destination side than at access side of a trip, when using a train. As for Bus/tram/metro author found no differences in access and egress time. This study contradicts these findings, at least for light rail stops, shorter egress distances are associated with higher use of light rail. However, Shelat et al. (2018) have also found that transit users are willing to travel larger distance towards train and light rail stops at home end of the trip than at activity end. Guerra and Cervero (2013) in their study researched whether half a mile circle better explains transit ridership using the data collected from rapid transit stations in 21 cities across US reported that if there are additional jobs and residents in a quarter mile distance to transit stop, jobs are likely to be correlated with a greater number of additional transit trips than residents. In fact, additional trips are almost double for the same number of additional jobs than additional residents. Although this study has not directly researched the link between jobs/residents with transit ridership, findings of this study also indicate keeping work locations closer to transit stop in a TOD area is associated with higher use of transit than residential locations.

Apart from the effect of access and egress time on transit usage, this study has also reported that areas with higher walkability index are found to furthermore increase the likelihood of using transit. It indicates the additional benefit of living/working in a TOD area. This effect is found to be consistent at both home and work locations. Although in this study walkability index is taken as a de facto for built environment characteristics of a TOD areas. This finding is still consistent with findings in the literature (De Witte, 2013; Nasri & Zhang, 2019) where these studies have all reported that built environment characteristics at both ends of trips have a strong association with increasing transit ridership as well as increasing the walking distance to transit stop. To sum up, findings of this study are mostly in line with findings in the literature.

5.2.2 Limitations and scope of the study

Throughout the report, limitations of this study have conversed briefly, however, in this section an elaborate discussion is presented.

Firstly, regarding the dataset, it cannot be pointed out as a limitation rather speaking in terms of scope would be apt. In the literature review, it was evident that walking or non-motorized access modes are subjected to physical exertion and other external factors such as temperature and weather. When studying the effects of access and egress time it would be more appropriate to include factors related to temperature and weather. It was not possible to do it in this research due to a lack of enough data related to those variables. This should be addressed in future research, as will be discussed in section 5.3.2. Secondly, in this research, the influence of access and egress time is studied when controlled for socioeconomic factors and walkability index alone. However, several studies in the past have noted the effect of trip characteristics such as trip length, frequency, number of transfers, waiting time, number of transport lines stopping at the station; transit use as well as willingness to walk. These variables were not included in the study thereby questioning whether people would be still willing to walk the longer distance if they were to also wait longer for transit? However, it can also be argued that the study used data that represents a population already living in and around TOD areas so maybe a short waiting time is implicitly taken into account. Also, it was discussed in the data source chapter that the majority of the study areas has a frequent transit service. In that case findings of this study can be only limited to circumstances where transit service is up to reliable standards.

Thirdly, the dataset represents a population that is young adults, highly educated and of relatively higher income groups. There can be a number of limitations when studying such a relatively smaller section of a population (both USA and the Netherlands) because educated people may be inclined to walk long distances because of their awareness of environmental and health benefits thereby questioning whether the rest of the population would also walk longer distances to access transit? While on the other hand it is reported in the literature that higher-income people are more likely to locate themselves closer to transit stops and walk shorter distances. Then it could be that low-income groups walk even longer distances than what is found in this research because more often than not for these groups transit is the only option for commuting.

The fourth limitation would be that this research only considered walking as an access and egress mode. But this is not always the case, with growing private investment in shared bicycles and other non-motorized modes people are exposed to a greater number of options for access and egress modes. This may substantially differ how access and egress time influence transit use. This could also be addressed in future research. But the silver lining could be that walking is most likely to be slower than other access/egress modes so other modes can only reduce the access/egress time, facilitating transit further. Lastly, this study could not differentiate the

effect of access and egress time contextually i.e., in the Netherlands and North America. This study only controlled for the country of residence because of the aim of the study, although this might not strictly be a limitation to differentiate how access and egress time are influencing transit use in these two contexts, a smarter way would be to take an interaction effect of access/egress time variables with a country of residence.
Last limitation of this research is related to the modelling method. In this research MNL model is used for modelling transit use. Using MNL model comes with few limitations. Alternative specific variables such as in-vehicle travel time for transit and car cannot be introduced in the model. Excluding variables related to trip journey (in-vehicle time etc.) may not capture the entire effect of access and egress time. As, willingness to walk longer distances to access transit stops may vary based on the travel time, as discussed in the literature review.

5.3 Recommendations

Using the findings of this study related to access, egress time and built environment characteristics of an area, recommendations to practice are presented and later suggestions for future research are also discussed.

5.3.1 Recommendations for practice

From the perspective of space allocation for housing and workplaces in a TOD area, the first suggestion for future development is that every TOD area in central business districts has to be a residence as well as a commercial center. The finding of this research points out that having low access time as well as low egress time is an encouraging condition for transit to be the dominant mode choice for the work commute. Secondly, it is suggested not to develop a station area solely based on the thumb rule of a quarter mile or 400m catchment area. Rather, allocating a majority of the space that can be reached within 4 minutes (approx. 100 to 400m) by walk from transit stop for commercial/office space, retailers, restaurants or other services. Then housing in 4-11minutes (approx. 400-1000m) of walking time would be advised. By doing so developers can provide affordable housing beyond the 400m radius. It is important to note, built environment characteristics of a TOD area are pivotal as they promote people to walk further to access transit stops thereby retaining/increasing transit ridership, even when houses are placed a bit further. The benefits of these characteristics are recurrently reported in the literature and also echoed in this study. On the whole, as a consequence, TODs can expect two benefits, they can retain/increase transit ridership by providing more space for retail/office space. And secondly, it can also attract a wider mix of socio-economic groups, especially mid and lower-income groups, which might in turn further increase transit ridership.

In Figure 5.1, second suggestion for practice is illustrated. Two circles indicate a 4-minute walking time, or first quarter mile and the next circle is 4-11 minutes of walking time or 400-1000m.

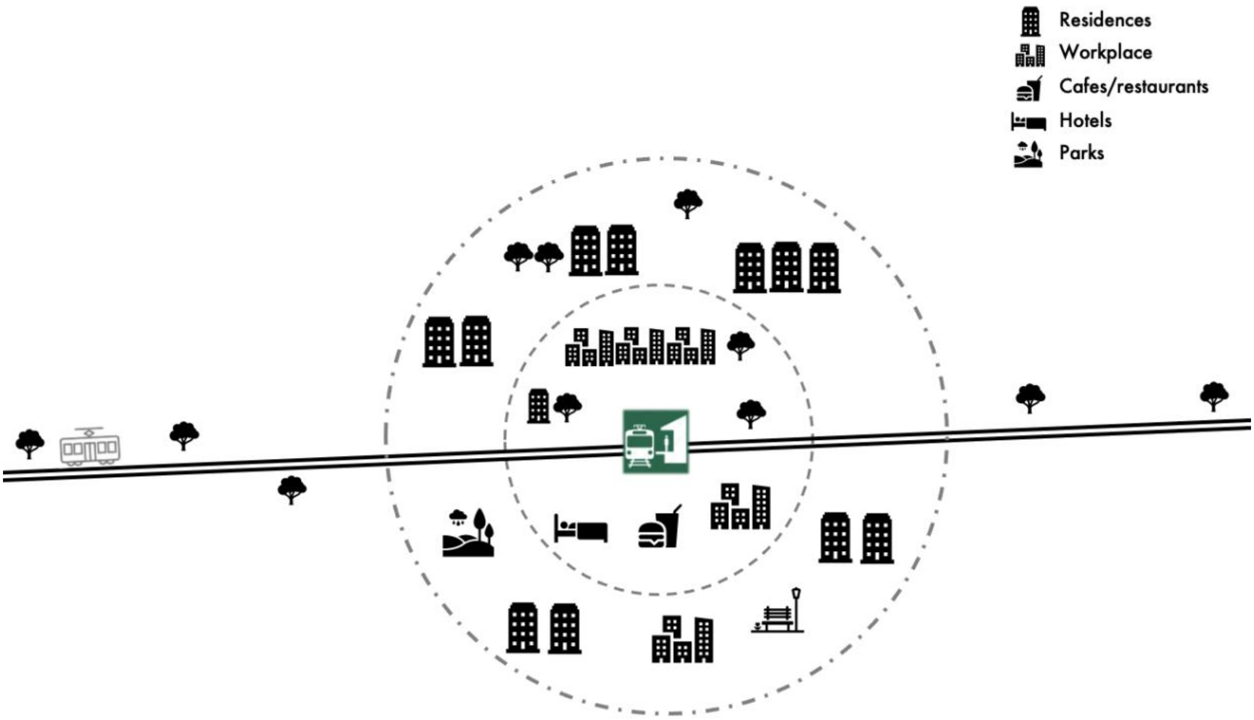

Figure 5.1 Proposed idea for space allocation to residences and workplaces in TOD area

The third recommendation is regarding TODs in suburbs of major cities with light rail stops, planners and urban designers need to focus on aligning workplaces/jobs along the transit corridor than developing dense residential areas around the suburban station. Findings of this study suggest shorter distances to workplaces from transit stops are important than from residences, to increase transit use. But it is necessary to make the station area a walker's paradise with ample green spaces and diverse land use, as this study shows that a high walkability index of an area can provide additional benefits and promote the use of transit further. In conjunction with supportive policies that discourage car use, such as limiting parking facilities and making them more expensive (Chava, 2018) are also important for suburban areas to make transit attractive.
Furthermore, soon new mobility services like Mobility-as-a-Service (MaaS) may help TOD areas by providing packages that can potentially link a plethora of non-motorized modes with transit services, thereby fixing the longer access times in inner suburbs. And also, at the egress side of the trip, if allocation/reallocation of workplaces along the transit corridor is expensive or is not possible, these modes and mobility services might potentially reduce the egress time as they are most certainly faster than walking, thereby still achieving short egress times. However, additional benefits of bike-sharing or MaaS in reducing the access and egress time cannot be suggested solely based on this study as there can be many other factors linked to it such as willingness to use such services.

The last recommendation would be for public transit design, findings of this study indicate people are willing to walk longer durations to access transit stops in TOD areas (this can be attributed to the fact that the findings of the study are based on the data collected from TOD areas). So, potentially stop spacing can also be increased for urban transit modes with stops in TOD areas. Increasing stop spacing would enable operators to provide a faster service which in turn can also increase the frequency of the line. Doing so, increases the reliability of the transit services and be beneficial for the traveler as waiting time and in-vehicle time can both potentially decrease with faster and more frequent transit service. In Figure 5.2, the transit stop in grey is at 600-700m from the transit stop in the TOD area, instead of increasing the stop spacing further to the transit stop in green (800-1000m) would be suggested. Placing a stop following the usual guidelines of 600-700m for a light rail would make this stop redundant when it is adjacent to a TOD area. In situations where there are multiple TOD areas on a single line, then the number of stops in such lines can be significantly reduced as the catchment area of TODs is much larger than a regular stop, achieving a coarser transit network.

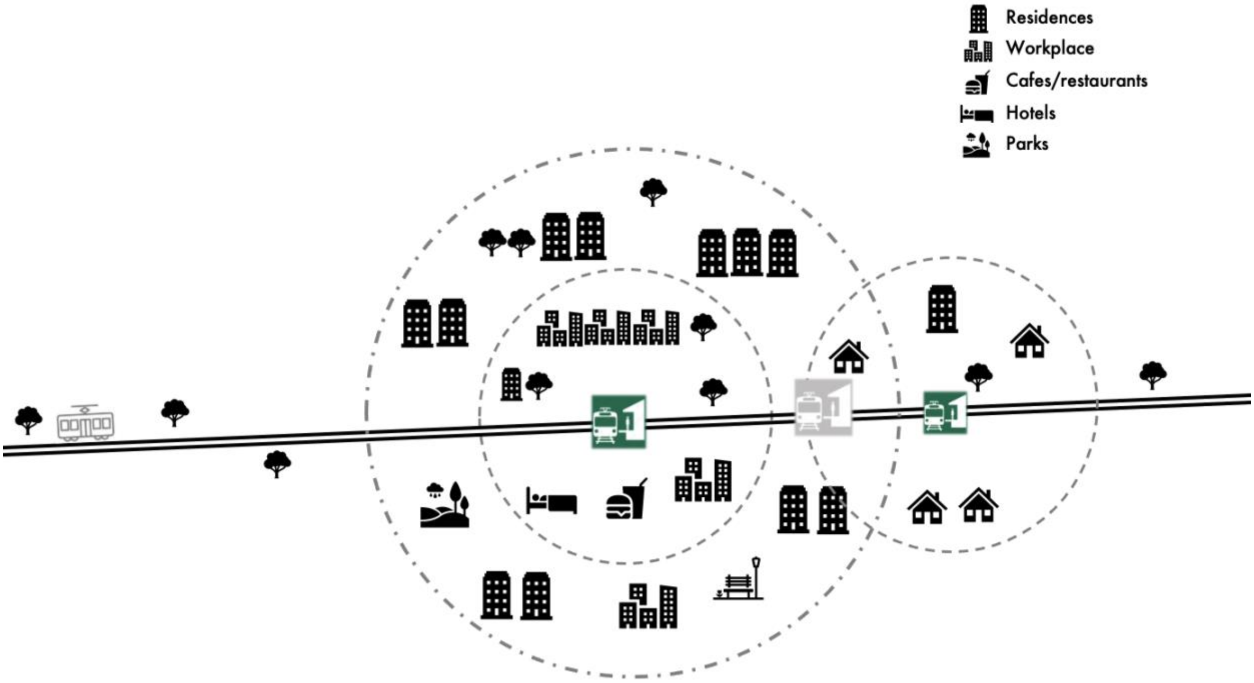

Figure 5.2 Illustration of possible increment in stop spacing due to presence of a TOD area

5.3.2 Discussion about recommendations for practice

TOD concept first appeared in the late 1980s, since then researcher and practitioners have believed TOD to be the way forward for delivering comprehensive solutions to urban problems, by integrating land use planning, urban design and transport studies (Ibraevaep et al., 2020). At the core of TOD is a transit stop and around it lies a surrounding that accommodates residence, jobs, spaces for recreation, green spaces. One of the main advantages of the TOD area is its proximity to a transit stop. Proximity can strongly influence whether people use transit. Consequently, high transit ridership influences the cost efficiency of transit as well as nearby land values (Guerra, 2013). As a result, one of the common problems faced by TOD areas is that the property value of surrounding areas of transit stop sees a significant rise, especially leading to higher-priced housing. As a result, TOD areas are believed to attract a type of population, to be specific young adults, highly educated, high-income class population (Guthrie, 2016).

However, there are other arguments why low-income groups are not attracted, Lund (2006) reports that industrial sites for low-paid jobs are likely to be easier to reach by bus or car, while TOD areas might be more appealing for medium or high-income residents whose jobs are located in central business districts (CBD). CBD and employment centers are likely to be well connected by rail or light rail. Nevertheless, making it unaffordable for low-income groups is not a healthy way forward for the future of TOD. It is important to not exclude these groups as they represent the majority of transit users. It is paradoxical as low-income groups are the ones who are more likely to benefit from shorter access to transit whereas high-income groups are less inclined to use transit as they are likely to own at least one vehicle. Also, many researchers and policymakers have reiterated the need to make TOD attractive for a mix of socio-economic groups through a development that can provide affordable housing for lower-income families (van Lierop, 2017).

To address this issue, as suggested in the previous section housing does not necessarily have to be in the first quarter mile or 400m radius of the transit stop instead they can also be situated in a 400m-1000m radius of the transit stop. In the first-quarter mile of the circle, it is suggested to allocate space for jobs, retailers, restaurants or other services which can be used and accessed easily by the commuters/travelers living around the transit stops. By doing so developers can provide affordable housing beyond the 400m radius. The above suggestion can be backed by the findings of Lund (2006), where the author performed a stated preference survey to analyze the residential location choices of TOD residents. The author reported that major reasons for their residential choices as Quality of housing, cost of housing, quality of the neighborhood. This shows that the aforementioned reasons can still be achieved even after allocating space for residences a bit further away from transit stops. But the important note is to create a walking-friendly environment in the whole neighborhood along with diversity in the land use in the initial 400m. To back the suggestion that housing can be made more affordable if it is placed at 400-1000m distance from a transit stop, Yu et al. (2018) evaluated price changes of properties around newly introduced rail and BRT system in Austin, the author reported TOD produced additional price premiums of $9/ft2 within 400 m from a station, $8.3/ft2 within 400–800 m, and $5.6/ft2 for properties within 800–1200 m. Indicating the price premium is decreasing with increasing distance from a transit stop. Although there is an increase in property values for properties within 400-1200m, travelers would be willing to compensate this additional price by saving on transport-related expenditures Also, Guerra and Cervero (2013) have estimated that "a 10 per cent increase in the number of jobs within a quarter-mile of a transit station corresponded with a 2 to 4.7 per cent increase in average weekday ridership while a 10 per cent increase in the number of residents within a half-mile of a transit station corresponded with a 0.9 to a 3.5 per cent increase in ridership". Pointing out the additional advantage of focusing on retail and office developments nearer to stations.

TODs in inner suburbs, compensating the cost of development by increasing density is not possible due to the backlash from local communities (Ibraeva et al., 2020). These long-established communities could be accustomed to low-density conventional auto-dependent suburbs. This is justifiable, however, there are several cases of satellite towns in Asia, Western Europe which were traditionally auto-dependent have now become successful TOD areas after introducing a frequent and reliable rail or light rail service connecting them to major cities (Knowles, 2020). Findings of this study suggest egress time have a stronger association with transit use than access time, so there is no immediate need to create a dense residential complex around TOD areas in inner suburbs but rather creating an environment that has a walking-friendly design, ample green spaces at the suburban stops and closely aligning jobs along the transit corridor would still promote transit ridership. As long as workplaces are closer to transit, people living a bit further away from transit stops are still likely to use transit. However, it is not attractive for developers as providing green spaces/walking-friendly atmospheres and mixed uses not only increases project costs also face the risk due to the uncertain demand for transit service (Knowles, 2020).

5.3.3 Recommendation for further research

It would be interesting for future studies to include a wider range of socio-economic groups; this research has fundamentally studied the effect of access and egress time for high-education

and relatively higher income classes. Like Lund (2006) has stated jobs/workplaces of individuals in these classes are more likely to be situated in CBD, therefore recommendation provided for practitioners may only be valid for TODs with a particular type of population. By including lower-income groups in the study, it would help to see how the effect of access and egress might change when jobs are easier to reach by car than transit.
Secondly, for access and egress modes, this study has only taken walking as a choice. But that might not always be the case, especially for people living in TOD areas they might be presented with a larger array of active modes that can be faster than walking. It could be interesting to investigate the effect of access and egress tine by including other access/egress modes. This can be instrumental in determining the potential for emerging modes as they may or may not be complementary to transit modes and if they are complementary to transit, they may help in solving the first and last-mile problem.
Thirdly, Active modes are more often than not influenced by weather and time of the day, it is recommended for future researchers to test the effect of access and egress time while controlling for time of the day and weather conditions also because people may be willing to walk, for instance, 10-12mins to access transit stops in pleasant weather conditions but the same may or may not be true in unpleasant weather conditions. Lastly, this research only investigated for work-based trips, but in reality, the work-based trip only constitutes 18-20% of the total trips, it would be interesting to study the effect of access and egress time using data representing a wider range of trip purposes because for work-based trips travelers are found to walk longer distances than for other trips, therefore findings of only work-based trips cannot be generalized. Also, in Figure 5.2, as this research only studied work-based trip, space allocation for residential and office space could only be discussed, but for instance, a TOD area may also have an educational institution in its vicinity, would a traveler be willing to walk a longer distance to access transit for a school-based trip? will it benefit transit ridership by placing it closer to a transit stop instead of an office space? These questions should be addressed in future research.

As an ending note, the author firmly believes in the concept of TOD and in its potential to redefine the way people move and carry out their daily activities in an urban and suburban area. However, as it goes for any good policies or concepts, TOD is only as good as its implementation. Planners should be cautious in implementing TOD such that people from all socio-economic background reap the benefits of TOD at the same time necessity to use car for the people living/working in and around TOD areas should be minimized as much as possible. TOD has the capacity to improve transit ridership and can also provide ample opportunities for emerging modes and other mobility services that are collectively pushing towards a sustainable future.

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Appendix

Appendix-A: Code used to get walkscores from Walkscore API

```
package main

import (
    "encoding/json"
    "fmt"
    "net/http"
    "net/url"
    "os"
    "strconv"

    "github.com/gocarina/gocsv"
)

type input struct {
    Homelat       string `csv:"homelat"`
    Homelon       string `csv:"homelon"`
    HomeAddress   string `csv:"home_address"`
    HomeWalkScore string `csv:"home_walk_score"`
    Worklat       string `csv:"worklat"`
    Worklon       string `csv:"worklon"`
    WorkAddress   string `csv:"work_address"`
    WorkWalkScore string `csv:"work_walk_score"`
}

type address struct {
    lat     string
    long    string
    address string
}

type addressApiResponse struct {
    Results []struct {
        Locations []struct {
            Street         string `json:"street"`
            AdminArea6     string `json:"adminArea6"`
            AdminArea6Type string `json:"adminArea6Type"`
```

```
        AdminArea5     string `json:"adminArea5"`
        AdminArea5Type string `json:"adminArea5Type"`
        AdminArea4     string `json:"adminArea4"`
        AdminArea4Type string `json:"adminArea4Type"`
        AdminArea3     string `json:"adminArea3"`
        AdminArea3Type string `json:"adminArea3Type"`
        AdminArea1     string `json:"adminArea1"`
        AdminArea1Type string `json:"adminArea1Type"`
        PostalCode     string `json:"postalCode"`
      } `json:"locations"`
   } `json:"results"`
}

type walkScoreApiResp struct {
   Walkscore int
}

func main() {

   data := []input{}
   if err := loadCsv("input.csv", &data); err != nil {
      fmt.Println("error reading file:", err)
      return
   }

   for i := range data {
      fmt.Printf("processing %v record...\n", i)
      if data[i].Homelat != "" && data[i].Homelon != "" {
         data[i].HomeAddress = getAddress(data[i].Homelat, data[i].Homelon)
         data[i].HomeWalkScore = getWalkScore(data[i].Homelat, data[i].Homelon, data[i].HomeAddress)
      }
      if data[i].Worklat != "" && data[i].Worklon != "" {
         data[i].WorkAddress = getAddress(data[i].Worklat, data[i].Worklon)
         data[i].WorkWalkScore = getWalkScore(data[i].Worklat, data[i].Worklon, data[i].WorkAddress)
      }
   }

   if err := writeCsv("output.csv", data); err != nil {
      fmt.Println("error writing file:", err)
      return
```

```
    }

}

func loadCsv(csvFile string, out interface{}) error {
    f, err := os.Open(csvFile)
    if err != nil {
        return err
    }
    defer f.Close()

    return gocsv.UnmarshalFile(f, out)
}

func apiCall(reqURL string, out interface{}) error {
    r, _ := http.NewRequest("GET", reqURL, nil)
    // fmt.Println(r)

    client := http.Client{}
    resp, _ := client.Do(r)
    // fmt.Println(resp.Status)

    return json.NewDecoder(resp.Body).Decode(out)
}

func getAddress(lat, lon string) string {
    getAddressApi :=
`http://www.mapquestapi.com/geocoding/v1/reverse?key=7ACOt23JGjbjJlvIH9eGlwLu39kGzvRW&location=%s,
%s`
    url := fmt.Sprintf(getAddressApi, lat, lon)
    addressResp := addressApiResponse{}
    if err := apiCall(url, &addressResp); err != nil {
        fmt.Println("error getting address using lat long:", err)
        panic(err) // TODO:
    }
    // fmt.Printf("address response: %#v\n", addressResp)

    var city, state, country string

    if len(addressResp.Results) == 0 {
```

```
        return ""
    }
    if len(addressResp.Results[0].Locations) == 0 {
        return ""
    }

    add := addressResp.Results[0].Locations[0]

    if add.AdminArea5Type == "City" {
        city = add.AdminArea5
    }
    if add.AdminArea3Type == "State" {
        state = add.AdminArea3
    }
    if add.AdminArea1Type == "Country" {
        country = add.AdminArea1
    }

    return fmt.Sprintf("%s, %s, %s, %s, %s", add.Street, city, state, add.PostalCode, country)
}

func getWalkScore(lat, lon, address string) string {
    getWalkScoreApi :=
`https://api.walkscore.com/score?format=json&address=%s&lat=%s&lon=%s&transit=1&bike=1&wsapikey=cf38e
148df3590ada982fa0d2751bf54`
    url := fmt.Sprintf(getWalkScoreApi, url.QueryEscape(address), lat, lon)
    walkResp := walkScoreApiResp{}
    if err := apiCall(url, &walkResp); err != nil {
        fmt.Println("error getting address using lat long:", err)
        panic(err) // TODO:
    }
    return strconv.Itoa(walkResp.Walkscore)
}

func writeCsv(csvFile string, data interface{}) error {
    f, err := os.Create(csvFile)
    if err != nil {
        return err
    }
    defer f.Close()
```

```
    err = gocsv.MarshalFile(data, f)
    if err != nil {
        return err
    }

    return nil
}
```

Appendix-B: Other models that were tried

Model with Active modes and transit as mode choice options. Variables related Dwelling type characteristics added to the model.

Independent Variables	Active modes				Transit			
	Country-The Netherlands		Country- USA & Canada		Country-The Netherlands		Country- USA & Canada	
	Exp(B)	*p-value*	*Exp(B)*	*p-value*	*Exp(B)*	*p-Value*	*Exp(B)*	*p-Value*
Constant	1.174	0.616	-5.174	0.008	0.542	0.841	2.742	0.125
Traveler socioeconomic characteristics								
Age	0.996	0.831	1.018	0.359	0.964	0.115	0.979	0.198
Household Size	1.581***	0.005	1.006	0.975	1.941***	0.002	1.271*	0.091
Own single car	0.63**	0.021	0.197**[2]	0.041	0.038**	0.012	0.176**	0.019
Own more than one car	0.008***	0.000	0.117**	0.017	0.008***	0.001	0.080***	0.002
Reduced Transit fare to work	2.035	0.114	1.736	0.359	6.238***	0.000	4.111**	0.011
Transit pass holders	2.883*	0.076	4.253**	0.018	10.717***	0.000	8.717***	0.000
Own bicycle	5.13**	0.020	3.013**	0.023	2.296	0.350	1.062	0.884
Built environment characteristics								
Free parking at work location	0.297***	0.002	0.211***	0.003	0.186***	0.002	0.102***	0.000
Home Walkscore	0.989	0.471	1.073***	0.000	1.006	0.749	0.997	0.848
Work Walkscore	1.001	0.879	1.002	0.852	1.024*	0.064	1.012	0.275
Proximity to transit stops and travel time								
Access time	1.054	0.340	0.844**	0.029	0.921**	0.027	0.810*	0.093
Egress time	0.955***	0.002	0.915***	0.002	0.961**	0.043	0.921**	0.039
Transit/Auto commute time ratio	1.445*	0.060	2.095***	0.002	0.574*	0.097	0.612*	0.053

[2] ***-Indicates variable is significant at 99% confidence level
**-Indicates variable is significant at 95% confidence level
*Indicates variable is significant at 90% confidence level

Independent Variables	**Active modes**		**Transit**	
	Exp(B) (Slow)	p-value	Exp(B) (Transit)	*p*-Value
Constant	-3.558	0.209	2.515	0.70
Traveler socioeconomic characteristics				
Age	1.019	0.109	0.977*[3]	0.066
Household Size	1.175*	0.75	1.233**	0.034
Own single car	0.162***	0.002	0.151***	0.002
Own more than one car	0.042***	0.000	0.057***	0.000
Reduced Transit fare to work	1.547	0.194	4.238***	0.000
Transit pass holders	2.926***	0.006	15.717***	0.000
Own bicycle	6.149***	0.000	1.096	0.775
Built environment characteristics				
Free parking at work location	0.307***	0.000	0.132***	0.000
Home Walkscore	1.014	0.113	0.995	0.633
Work Walkscore	1.000	0.998	1.011	0.141
Proximity to transit stops and travel time				
Access time	0.902**	0.017	0.942*	0.069
Egress time	0.955***	0.000	0.984*	0.092
Transit/Auto commute time ratio	1.563***	0.000	0.669**	0.024

[3] ***-Indicates variable is significant at 99% confidence level
**-Indicates variable is significant at 95% confidence level
*Indicates variable is significant at 90% confidence level

Independent Variables	Active modes		Transit	
	Exp(B) (Slow)	p-value	Exp(B) (Transit)	*p*-Value
Constant	-3.558	0.209	2.515	0.70
Traveler socioeconomic characteristics				
Age	1.037	0.227	0.970	0.213
Household Size	1.019	0.88	1.067	0.572
Own single car	0.187	0.038**	0.099	0.000***
Own more than one car	0.183	0.084*	0.107	0.014**
Reduced Transit fare to work	1.579	0.194	4.759	0.010**
Transit pass holders	1.112	0.868	8.610	0.000***
Own bicycle	4.879	0.004*	1.455	0.419
Built environment characteristics				
Free parking at work location	0.210	0.007**	0.073	0.000***
Home Walkscore	1.073	0.001***	1.004	0.765
Work Walkscore	0.992	0.61	1.003	0.791
I.E Work walkscore & egress time	1.000	0.64	1.001	0.032**
Proximity to transit stops and travel time				
Access time	0.949	0.622	0.880	0.100*
Egress time	0.902	0.006**	0.996	0.772
IE Access & Egress time	1.014	0.038**	1.001	0.858
Transit/Auto commute time ratio	1.677	0.023**	0.587	0.041**
Dwelling type characteristics				
Dwelling type-Apartment	0.590	0.507	1.134	0.853
Dwelling type-Townhouse	6.163	0.002**	4.749	0.100*
Year moved to the current house-Under 5 years	1.327	0.719	1.035	0.956
Year moved to the current house-5 to 10 years	0.331	0.202	0.499	0.287
Rent-current house	0.223	0.053**	1.112	0.859
Country of residence				
Country of residence- NL	1.860*	0.067*	0.829	0.625
Country of residence- CA	0.477	0.233	1.909	0.165

Model fit	
No. of observations	549
McFadden R-square	0.519
Likelihood ratio test: chisquare	313.138 (P value =0.000)
Log-likelihood	-145.325