



# Technical Memorandum

## Re: Tewin Integrated Mobility Model Memo

### 1 Introduction

Tewin is being designed as a sustainable, connected, 15-minute community in southeast Ottawa with a transformative design approach for its land use and its supporting transportation network. Traditional transportation planning embodies a “predict and provide” approach that modelled demand based on past experience and recommended physical infrastructure to meet that demand. Tewin, however, will use the “decide and provide” approach, where the preferred future transportation network is designed based on the principles of sustainability and reliability. One key goal is to increase the use of sustainable modes of travel to decrease auto dependency and influence single vehicle auto trips. The Tewin Integrated Mobility Model (TIMM) was developed to embody this principle into the land use and transportation design process.

Travel modes compete with one another. Mode choice is a complicated process where individuals decide their mode of travel based on many factors, such as proximity of land uses, access to transit by active modes, and personal economics. By examining the competitiveness of each travel mode, TIMM will consider the trip maker’s decision factors, with the end goal of ensuring that each trip maker has at least one viable alternative travel mode option, instead of an auto trip. While there are many different factors to consider, they generally fall under the categories of travel time, cost, and infrastructure quality/comfort. The mode choice is also affected by environmental and personal health implications. While the structure of the factors affecting mode choice are the same for all modes, the sub-factors and their weights may vary. Through various processes involving research, expert consultation, workshops, and engineering judgment, the following report provides insight into the factors that influence mode choice and their use to develop the Tewin land use structure.

The following summarizes and integrates the significant research undertaken to support how the developers of Tewin have chosen land uses and a supporting transportation system to provide the desired qualities of the community.

### 2 Local Trips

For local trips under 3.5 km, understanding the factors influencing mode choice becomes particularly relevant to city planning, public health, and environmental sustainability. Short-distance trips provide an opportunity to encourage more sustainable, active modes of transport like walking and cycling, which can help reduce congestion and improve urban air quality. Drawing insights from research can help tailor strategies to promote these beneficial modes. Here’s an analysis based on the findings from relevant studies:

- 1. Quality of City Infrastructure/Comfort:** A conducive green-mode travel environment significantly increases the likelihood of choosing more sustainable travel modes for short distances. Infrastructure improvements such as safe, dedicated bike lanes, and pedestrian-friendly streetscapes can encourage walking and cycling (Li et al., 2015).

2. **Travel Time:** While for longer distances, travel time plays a dominant role, its influence slightly diminishes for short distances where the difference in travel time between modes (e.g., car vs. cycling or walking) is less pronounced. However, it remains a significant consideration for travelers (He et al., 2022).
3. **Health Impact:** The potential health benefits from active transportation modes are more directly perceivable over short distances, making health considerations a significant factor in mode choice. According to Jacob et. al., changes from sedentary to more active modes of travel through government encouragement provides benefits to both physical and mental health (Jacob et al., 2021). Promoting the health benefits of walking and cycling can influence decisions, especially for routine or daily trips (Kim & Ulfarsson, 2008). Additionally, a study by Paré, Leaver, and Bourget detailed the relationship between an increasing amount of wearable medical devices managing personal health data and tracking physical activity, alluding to the perceivable affects of active transportation modes on health ([Paré et al., 2018](#)).
4. **Travel Cost:** For short trips, the cost difference between modes may be less impactful, especially when considering the minimal or nonexistent cost of walking or cycling compared to the fixed and variable costs associated with car use (Meng et al., 2016).
5. **Environmental Impact:** Environmental concerns can influence mode choice, particularly among those aware of the carbon footprint associated with car use. For short distances, choosing more sustainable modes like walking or cycling has a clear positive environmental impact, which can motivate environmentally conscious individuals (Bai et al., 2020).

These concepts are defined based on the findings of the provided studies, tailored to the specific context of short local trips under 3.5 km. They reflect the nuanced factors influencing mode choice for these distances, emphasizing the role of infrastructure quality and the potential for active transportation to address health and environmental goals.

Search results did not provide direct studies on the environmental awareness of individuals in Ottawa and its impact on mode choice for local trips under 3.5 km. However, based on the available literature on environmental awareness and mode choice, it is generally acknowledged that environmental values and political ideology can affect public support for sustainable and renewable energy policies, which indirectly influence mode choices by promoting environmentally friendly transportation options (Fobissie, 2019).

Considering the importance of environmental awareness in influencing transportation mode choices and the lack of specific data for Ottawa, it is reasonable to suggest that these considerations may still play a significant role in mode choice decisions, especially in the context of a city known for its high levels of education, income, and quality of life, which are factors often correlated with environmental consciousness.

As such, these factors can reliably be used in 'deciding' what the Tewin local transportation infrastructure will be, to accommodate the desired land use plans.

### 3 Regional Trips

Based on TRANS 2022 survey, the average regional trip distance from South Gloucester excluding K-12 School and Return Home trips in the AM Peak Period is 19,072 metres. The average regional trip distance from South Nepean excluding K-12 School and Return Home trips in the AM Peak Period is 21,101 metres. The average regional trip distance for Ottawa excluding K-12 School and Return Home trips in the AM Peak Period is 19,463 metres. Based

on the 2022 TRANS survey, it was assumed that an average regional trip distance in Ottawa is 19.5 km, for the purposes of TIMM.

The factors influencing mode choice decisions for cross-district trips vary among travelers, with research pointing towards the significance of various attributes such as travel time, travel cost, quality of infrastructure, and to a lesser extent, the impact of the trip on achieving daily health goals and environmental impact.

- 1. Travel Time and Cost:** Studies consistently show that travel time and cost are among the most critical factors influencing mode choice decisions. A study examining mode choice behavior for long-distance travel found that travel costs, distance, transit station accessibility, service frequency, and parking costs are significant determinants of mode choice, emphasizing the importance of time and cost factors (Moeckel et al., 2015).
- 2. Quality of City Infrastructure:** The quality of infrastructure, including city makeup and the quality of mode-specific infrastructure, plays a crucial role in mode choice decisions. For instance, students traveling to school are more likely to walk or bike if the infrastructure supports it, indicating that infrastructure quality can influence mode choice (Ewing et al., 2004).
- 3. Health Impact:** Research indicates that active travel modes, such as walking and cycling, are chosen not only for their environmental benefits but also for their health benefits. This suggests that the health impact of a trip may be more important to some travelers than previously considered (Whalen et al., 2013).
- 4. Environmental Impact:** Research suggests that environmental awareness and pro-environmental behavior can influence mode choice, especially among specific traveler segments with a high degree of environmental consciousness. This might indicate that the environmental impact of a trip is a more significant factor for some travelers than estimated (Hergesell & Dickinger, 2013).

Given these insights, it appears that while travel time and cost are indeed paramount, the quality of infrastructure also plays a significant role, and the impacts on health and the environment might be more important for certain segments of travelers. Similarly, regional transportation infrastructure need not be based on predictive models but instead be based on these researched trends.

Through the choices of Tewin's land uses and their arrangement, the regional transportation network was developed.

## 4 Parking

When evaluating travel time for local auto trips, drivers do indeed consider factors beyond just the driving time, including the time it may take to find and use parking. Research has shown various aspects of how parking, especially the search for parking, influences travel time and behavior:

- 1. Impact of On-Street Parking on Travel Time:** On-street parking significantly impacts vehicle travel time. Factors such as effective lane width, the number of parking maneuvers, and occupancy influence travel time, with a quantitative analysis demonstrating that on-street parking increases overall travel time for motor vehicles (Guo et al., 2012).
- 2. Search Time for Parking in Urban Areas:** The search time for parking, especially in urban areas where parking spaces are scarce, is a considerable component of overall travel time. A new concept of parking

reliability has been defined, reflecting the probability that a driver's average search time for parking will be below a certain threshold (Lam & Tam, 2003).

3. **Effect of Parking Charges and Time Limits on Car Usage and Parking Behavior:** Parking charges and time limits influence both car usage and the choice between on-street and off-street parking. Policies can manage the demand for parking and encourage shifts in travel behavior (Simićević et al., 2013).
4. **Cruising for Parking:** A significant portion of urban traffic is attributed to drivers cruising for parking, with studies showing that cruising can constitute a large share of traffic and extend travel times significantly. The behavior of cruising drivers, including search times, has been closely studied to understand its impact on traffic flow and travel time (Zhu et al., 2020).
5. **Parking Time Model Analysis:** An analysis of the relationship between travel time and on-street parking suggests a strong influence of parking availability and behavior on travel times, reinforcing the significance of considering parking in travel time evaluations (Putri, 2021).

In conclusion, parking, particularly the time taken to find a parking spot, plays a critical role in the perception and calculation of travel time for local auto trips. The evidence suggests that drivers do consider parking time, alongside driving time, when evaluating the total time commitment of a trip.

The average time drivers spend searching for parking in constrained locations with limited or hard-to-find parking can vary significantly depending on the specific location, time of day, and other factors. However, empirical studies provide some insights into this issue:

1. In dense urban areas, the search time for parking can be considerable. For example, a study conducted in the central business district (CBD) of Brisbane, Australia, found that while 25% of participants did not cruise for parking, 40% spent less than five minutes, and 35% spent more than five minutes to find parking. The average search time for those who parked every day in the CBD was less than three minutes, whereas nearly 50% of those who parked occasionally in the CBD had to search for more than five minutes (Assemi et al., 2020).
2. Another study indicated that between 9 and 56 percent of the traffic was cruising for parking, with the average search time being about 6.03 minutes. This indicates a significant impact of cruising for parking on overall travel time in areas where parking is scarce (Zhu et al., 2020).
3. A different approach, utilizing a Monte Carlo simulation, highlighted the importance of parking reliability, defining it as the probability that drivers' average searching time for parking is less than a given threshold, especially in urban areas where parking spaces are scarce. Although not providing a specific average search time, this study underscores the variability and uncertainty drivers face when searching for parking (Lam & Tam, 2003).

These studies highlight the variability in parking search times in different urban contexts, with averages ranging from a few minutes to longer periods depending on various factors such as location, time of day, and parking demand vs. supply. The search for parking significantly contributes to overall travel time, underscoring the importance of efficient parking management and information systems to alleviate this challenge.

These factors have contributed to the policy choices about parking throughout Tewin (as documented in the community design plan).

## 5 Traveller Preference

Research indicates that travelers generally have a dislike of uncertainty in trip making, which can significantly affect their mode choice decisions, including whether to use transit modes that do not present on platforms like Google Maps. The presence of uncertainty in travel times, particularly for auto modes compared to transit modes, influences travelers' decisions due to the perceived reliability and ease of planning with auto modes over transit.

1. **Uncertainty Expectation Influences Mode Choice:** A study by Tian and Huang (2015) found that commuters' uncertainty expectations significantly influence their modal split and trip scheduling decisions, revealing that uncertainty could lead to distinctive flow patterns. Based on this conclusion, it is believed that uncertainty in travel times for auto modes might drive commuters to opt for these modes if they perceive them as more reliable or predictable compared to transit modes not shown on Google Maps (Tian & Huang, 2015).
2. **Impact of Transit Service Disruptions on Mode Choice:** Research by Saxena, Rashidi, and Auld (2019) on the effects of transit service disruptions in Chicago found that travelers significantly alter their mode choice behavior in response to disruptions, preferring modes that offer more certainty and reliability. This suggests that when transit modes are absent on Google Maps or perceived as unreliable, travelers might be more inclined to choose auto modes, which they can more easily plan around and anticipate travel times for (Saxena et al., 2019).
3. Information on travel time reliability, when modeled using Cumulative Prospect Theory (CPT), reveals that travelers exhibit varying degrees of risk aversion and preference based on the reliability of travel modes. This indicates the significant role of perceived travel time uncertainty in mode choice decisions (Ghader et al., 2019).
4. Travelers' preferences for certain modes of transport, such as preferring auto modes over transit modes not shown on platforms like Google Maps, are influenced by their dislike of uncertainty in trip-making. The absence of transit mode information on such platforms, coupled with the perceived reliability of auto mode travel times, encourages travelers to opt for auto modes to avoid the uncertainty associated with transit modes (Gan, 2015).

Travelers' dislike of uncertainty in trip making significantly affects their preference for certain travel modes over others. The absence of transit mode information on platforms like Google Maps, coupled with the perceived reliability of auto mode travel times, makes it more likely for individuals to opt for auto modes to avoid the uncertainty and potential delays associated with transit modes. This preference underscores the importance of providing reliable and comprehensive travel time information across all modes to support informed decision-making by travelers.

The use of a central mobility spine, where transit and active modes will be concentrated was decided to be a pillar of Tewin's land use plan and structure to provide all residents with certainty about the availability of these sustainable modes.

## 6 Cost

The research literature suggests that drivers often have a skewed perception of the costs associated with driving, tending to focus more on immediate, variable costs such as fuel and parking at the destination, rather than long-term fixed costs such as vehicle ownership, insurance, and maintenance.

1. **Immediate vs. Sunk Costs:** Drivers have a clearer perception of immediate costs, such as parking fees and fuel costs, because these expenses are encountered directly and require out-of-pocket payments at

the moment or shortly before the driving occurs. This immediate financial impact makes such costs more salient in the decision-making process (Feiler & Soll, 2010).

2. **Feiler and Soll (2009)** discussed how individuals often neglect the financial costs associated with driving, especially those that are not immediately apparent, such as the cost of vehicle upkeep and insurance. Their research suggests that when people are made explicitly aware of these costs, they are more likely to reduce driving (Feiler & Soll, 2010).
3. The concept of “sunk cost fallacy” in driving decisions further supports the idea that immediate costs are perceived more acutely than longer-term costs. A study by Ho et al. (2018) found evidence of the sunk cost fallacy influencing the usage of durable goods such as cars, implying that drivers might focus on the immediate costs of driving trips rather than considering the full economic implications of car ownership and usage over time (Ho et al., 2018).
4. In a different context, **Southern et al. (2017)** developed and deployed a system to make the total cost of each driving trip visible to users, including depreciation, maintenance, insurance, and fuel. They found that after this intervention, participants were able to more accurately estimate the costs of their commutes, suggesting that without such interventions, drivers might not fully account for the long-term costs associated with driving (Southern et al., 2017).

These studies collectively suggest that drivers are more attuned to immediate, variable costs associated with driving, such as fuel and parking fees, than to fixed, long-term costs like vehicle maintenance and insurance. This discrepancy highlights the importance of making all costs of car ownership more visible to drivers to encourage more informed transportation decisions.

For the purposes of TIMM, it has been assumed that a technology component will be available to trip makers to make a better educated decision in terms of costs associated with a particular mode of travel. In case of auto travel, technology could add up the costs of owning a parking spot, vehicle upkeep, and insurance per mile, and add it to fuel and parking at destinations costs to show a more realistic picture of what it costs for someone to travel using a car. It is important to consider that these are general trends, and actual costs can vary based on specific circumstances, such as free parking availability, vehicle efficiency, and local rates for fuel, electricity, and insurance.

As such, this research demonstrates and justifies the focus on transit, both locally and regionally, in order to provide an affordable transportation system for Tewin residents.

## 7 Vehicle Ownership

The decision to own a vehicle is influenced by various factors, including but not limited to, the distance to key destinations, the need to transport goods or children, especially in contexts like North America where lifestyle and urban planning significantly contribute to car dependency. Here are some factors based on research that influence the choice of owning a vehicle:

1. **Distance to Key Destinations:** Distance to work, schools, grocery stores, recreational, and shopping centers plays a crucial role in deciding to own a vehicle. Longer distances and inadequate public transport options often necessitate car ownership for convenience and time efficiency ([Frank & Pivo, 1994](#)).

2. **Need to Transport Goods or Children:** The necessity to carry heavy shopping loads, sports equipment for children, or transporting children to various activities significantly influences the decision to own a car. In North American cities, where suburban lifestyles prevail, this need becomes more pronounced due to larger distances between residential areas and amenities or activity centers (McCarthy et al., 2017).

These factors, among others, contribute to the complex decision-making process around vehicle ownership, reflecting the interplay between individual needs, societal norms, and the physical and policy environments.

For the purposes of TIMM, a traveler who lives close to key destinations may still own a vehicle due to the need to transport goods or children. Likewise, if on-demand grocery delivery and school pick-up / drop-off services are available, one may still choose a vehicle as they live far from key weekly destinations. Regardless, Tewin's land use structure has been established to facilitate a lower vehicle ownership.

## 8 Transit Quality and Reliability

Quality of transit goes hand in hand with ease of access. If transit services are excellent, but first last/mile is extremely poor, then transit competitiveness will be low regardless of services provided. The same applies to excellent first/last mile, but poor services. Research supports the statement that the quality of transit and ease of access, particularly in first/last mile connections, are crucial for the competitiveness of transit systems. Here's a summary of relevant findings:

1. The first and last mile (FLM) of the public transport trip significantly impacts the overall quality experienced by transit users. Improved security from crime during the FLM trip and aspects of travel time and cost of the access trip need enhancement to elevate passenger satisfaction and transit competitiveness (Venter, 2020).
2. Transit agencies in the United States have developed FLM plans with the goal of increasing ridership by addressing spatial gaps, incorporating emerging mobility services, developing active transportation infrastructure, and focusing on transportation equity. These initiatives aim to improve pedestrian and bicycle infrastructures surrounding transit stations to enhance transit competitiveness (Mohiuddin, 2021).
3. The lack of adequate connectivity between transit stops and trip origin or termination points significantly affects mode choice decisions of commuters. Improvements in transit availability, job accessibility, parking costs, the quality of the pedestrian environment, and safety from vehicular traffic and crime can significantly increase transit use (Tilahun et al., 2016).
4. Out-of-vehicle environments such as access, transfer, and egress significantly influence customer satisfaction and loyalty more than in-vehicle and system-related factors. This highlights the importance of ensuring safety and a positive transfer experience in the FLM segments to maintain high transit service competitiveness (Park et al., 2021).
5. The first-mile/last-mile problem is notably addressed by integrating passenger and freight transport, which can lead to reductions in distances traveled and externalities produced, showcasing a potential approach to enhance FLM connectivity and, by extension, transit competitiveness (Bruzzone et al., 2021).



These studies collectively emphasize that addressing first/last mile issues effectively can significantly enhance the competitiveness of transit systems by making them more accessible, safe, and convenient for users.

To rank the factors of reliability, headway, ease of ticketing, safety, and comfort in terms of user perception of transit service quality, various studies have been reviewed:

1. **Reliability:** Reliability is often ranked as the most critical factor affecting user satisfaction with transit services. Users value consistent and predictable service, as it affects their ability to plan trips and arrive at destinations on time. Bordagaray et al. (2014) highlight reliability, journey time, available information, and driver kindness as aspects where improvements have the greatest impact on quality, suggesting that reliability is a top priority for users (Bordagaray et al., 2014).
2. **Comfort:** Comfort, including seating availability, vehicle cleanliness, and temperature control, is another crucial factor influencing user satisfaction. Comfort impacts the overall travel experience and can determine the likelihood of transit being chosen over other modes of transport. The study by Eboli and Mazzulla (2011) considers comfort as a key characteristic that affects the perception of service quality (Eboli & Mazzulla, 2011).
3. **Safety:** Safety, including personal security from crime and accidents, significantly influences user perception of transit service quality. Users need to feel safe during their journeys, especially during night-time or in less populated areas. Cao and Cao (2017) discuss the importance of safety and security measures in transit systems, indicating its critical role in determining user satisfaction (Cao & Cao, 2017).
4. **Headway:** While headway, or the frequency of service, is a significant factor, it may rank slightly lower than reliability, comfort, and safety. Headway affects wait times and the overall convenience of using transit, but its impact may be considered part of the broader reliability concern. Users value shorter wait times, but the predictability and consistency of service (reliability) might be more critical (Soza-Parra et al., 2022).
5. **Ease of Ticketing:** Ease of ticketing is important for user satisfaction, especially in terms of convenience and reducing barriers to use. However, it may be ranked lower than the other factors because once users are accustomed to a ticketing system, its daily impact on satisfaction may be less pronounced compared to service reliability, comfort, and safety. Nonetheless, modernizing ticketing systems to be more user-friendly can significantly enhance the overall user experience (Obsie et al., 2020).

In summary, based on the available research, the ranking from most to least critical in user perception of transit service quality would be: 1) Reliability, 2) Comfort, 3) Safety, 4) Headway, and 5) Ease of Ticketing. It is important to note that these factors are interrelated, and improvements in one area can positively affect perceptions of others.

Tewin has been designed to enable these factors to enhance the support the transit system.

## 9 Accessibility and Information Availability

Ease of access by first / last mile can be subdivided into trip distance and quality. These two factors go hand in hand. If the transit coverage is poor, ability to access transit will be poor despite high quality sidewalk infrastructure. If the distance is short, but the user feels unsafe to walk the short distance due to lack of infrastructure and public surveillance, transit may become an unattractive option. Here's a summary of insights from the research:



1. **Distance as a Barrier:** Distance is a fundamental barrier to active commuting, including walking and cycling for first/last mile connectivity. Nelson et al. (2008) emphasize that distance is a critical perceived barrier to active commuting and a predictor of mode choice. If the first/last mile distance exceeds certain thresholds (e.g., 2.5 miles for cycling), individuals are less likely to choose active modes of transportation, highlighting the importance of proximity in transit planning (Nelson et al., 2008).
2. **Quality of Infrastructure:** The quality of pedestrian and cyclist infrastructure significantly impacts the attractiveness and safety of active commuting. Zuo et al. (2020) demonstrate that improving bicycle-transit modal solutions, including the quality of cycling infrastructure, can triple the transit access distance compared to walking, significantly increasing transit job accessibility and promoting transportation equity. This suggests that high-quality infrastructure can extend the effective range of active commuting, making distance less of a barrier (Zuo et al., 2020).
3. **Safety and Comfort:** Safety and comfort, critical components of infrastructure quality, play a significant role in determining the willingness to engage in active commuting for first/last mile trips. Park et al. (2021) found that safety concerns and the quality of transfer experience significantly influence customer satisfaction and loyalty more than in-vehicle and system-related factors, indicating that the quality of the first/last mile experience is crucial (Park et al., 2021).

In summary, while both distance and the quality of pedestrian/cyclist infrastructure are important for first/last mile connectivity, the quality of infrastructure may have a significant impact on extending the viable distance for active commuting by addressing safety, comfort, and accessibility concerns. Effective first/last mile solutions likely require a balanced approach that considers both proximity and the quality of infrastructure to support active commuting modes.

Tewin's structure, particularly with the Mobility Spine concept, will maximize active modes through its design.

## 10 Fare Integration

The impact of not having transit fare integration on the usage of regional transit, especially when accessed by local buses, can be significant. Lack of fare integration can act as a deterrent for people choosing to travel using regional transit systems. Here are some insights from research that support this statement:

1. **Increased Transit Ridership and Positive Travel Behavior Change:** Fare integration has been found to positively influence transit ridership and travel behavior. For example, a study conducted in Haifa, Israel, which moved from a complex per-boarding fare system to a simplified zone-based fare system with free transfers, showed a significant increase in transit ridership. The fare-box data indicated up to a 25% increase in single ticket sales in the year following the implementation of the new fare policy. This change also led to an increase in passenger trips by 7.7% and boardings by 18.6%, demonstrating how fare integration can encourage more people to shift from private cars to public buses, thereby increasing overall transit usage (Sharaby & Shiftan, 2012).
2. **Simulation Studies on Fare Integration:** Simulation studies, such as one conducted on the regional transit services in an Italian regional area, also highlight the positive effects of implementing an integrated fare system. These studies indicate that fare integration can lead to variations in demand levels and management revenues, implying that passengers are sensitive to fare changes and are more likely to use transit services when there is a seamless fare system in place (Gattuso & Musolino, 2007).

In conclusion, the absence of fare integration between local buses and regional transit can act as a significant deterrent to the use of public transportation. Fare integration not only has the potential to increase ridership by making transit systems more accessible and financially attractive but also plays a crucial role in promoting equity by ensuring that the benefits of public transit are accessible to all segments of society, including lower-income groups. Considering OC Transpo continues to study advancing technologies, there is no doubt that Tewin residents will have access to good fare integration, as this is common in Ottawa today.

## 11 Biking

When making a travel mode choice, particularly for biking, both safety considerations and user experience play crucial roles, albeit in different capacities. Here's an analysis based on the synthesis of the available research findings:

### 11.1 Safety Considerations

Safety considerations include bike facility quality, separation from vehicular traffic, well-lit paths, and natural surveillance. These factors are fundamental in determining the likelihood of biking as a chosen mode of travel. Safety is paramount for cyclists, influencing both the perception of cycling as a viable mode of transport and the actual risk associated with cycling activities.

- **Safety as a key barrier to cycling:** Safety is recognized as a critical factor affecting cycling mode choice, with perceived safety encompassing aspects such as contaminant exposure, collision risk, street conditions, weather conditions, and crime risk. Studies found that injury risk and street conditions are particularly significant in determining the perceived safety of cycling, highlighting the need for infrastructure that ensures cyclist safety to encourage cycling as a mode of transportation (Duren et al., 2023).
- **Perception of Cycling Safety:** Cyclists' safety perceptions in urban areas are influenced by both the behavior of other road users and the infrastructure in place. Negative interactions with motorists and inadequate infrastructure contribute to a perception of cycling as unsafe, which can deter cycling as a mode choice (Lawson et al., 2013).

### 11.2 User Experience

User experience encompasses neighborhood permeability, availability of secure bike parking at origin and destination, access to nature, and aesthetics. These factors enhance the attractiveness of cycling by improving the overall experience of the rider.

- **User experience and mode choice:** While safety is a crucial factor, the overall user experience, including comfort, plays a significant role in mode choice. Factors contributing to comfort include bicycle components, environmental conditions, and the cyclist's position. Ensuring comfort alongside safety can make cycling a more appealing mode of transport (Ayachi et al., 2015).
- **Environmental Awareness on Mode Choice:** Riders' environmental awareness, which can be part of the user experience, impacts their mode choice decisions. Those with a higher level of environmental consciousness are more likely to choose biking, highlighting the role of user experience in mode choice. The decision to bike can be reinforced by positive experiences related to environmental benefits and personal well-being (Bai et al., 2020).

In conclusion, while both safety and user experience, including comfort, are essential factors influencing cycling mode choice, the evidence suggests that ensuring cyclists' safety is paramount. Safety can be seen as a prerequisite for cycling, without which potential cyclists might be deterred regardless of how pleasant the experience could be. Conversely, positive user experiences, facilitated by convenient access to infrastructure, scenic routes, and community connectivity, can motivate individuals to choose biking more frequently. The City of Ottawa's policies and design practices for cycling has evolved tremendously over the last decade. These advancements have been integrated into Tewin's planning principles and will be further enhanced, mirroring the City's design standards in the future.

## 12 Cycling Facilities

The research provides insights into how various infrastructure factors influence cyclists' perceptions of safety when choosing to travel by bike. They offer valuable findings on the importance of bike facility continuity, cyclist separation on high-speed and volume roads, bike signals, well-lit paths, and natural/public surveillance.

1. **Bike Facility Continuity on Non-Local Roads:** The presence and quality of separated bicycle facilities are crucial for encouraging cycling. Disturbances from other modes on off-street facilities can affect cycling speeds minimally in some cases, but significantly in areas with more disturbances, highlighting the importance of facility continuity for maintaining cyclist speed and safety perceptions (Bernardi et al., 2016). Continuous bike facilities are also essential for ensuring cyclist safety. Disruptions in bike lanes, such as those caused by construction or parked cars blocking the cyclist's path, increase the risk of accidents. Ensuring continuous and unobstructed bike paths can significantly reduce cyclist injuries (Cicchino et al., 2020).
2. **Cyclist Separation on High-Speed and Volume Roads:** Protected bike lanes with substantial physical barriers offer a lower risk of collisions or falls leading to emergency department visits compared to conventional bike lanes or mixed traffic conditions. However, the level of protection varies with the type of separation, with heavier separation providing more safety benefits (Cicchino et al., 2020).
3. **Bike Signals on Non-Local Roads:** While specific research on bike signals was not directly highlighted in the reviewed studies, the overall safety at intersections and the role of traffic control devices in enhancing safety for cyclists suggest that bike signals, as part of a comprehensive infrastructure design, could significantly impact safety perceptions and actual safety. Chapter 5 of the TAC Geometric Design Guide (2017) states that bicycle-specific traffic signals can help cyclists safely operate through intersections. The bicycle signal provides temporal separation of bicycles and motor vehicles, eliminating conflicts with right-turning motor vehicles.
4. **Well-Lit Paths:** Lighting is indirectly mentioned as a factor that could enhance cyclist safety, especially in terms of visibility and comfort on separated and on-street bicycle facilities. While direct evidence from the studies is limited, the mention of the physical environment playing a major role on cyclist's perception of safety makes it reasonable to infer that well-lit paths would contribute positively to safety perceptions (Li et al., 2012). Improving street lighting can decrease the likelihood of cyclist injuries by enhancing visibility at night. Good lighting conditions allow cyclists to be more visible to drivers and help them navigate safely through their environment (Chen & Shen, 2016).
5. **Natural/Public Surveillance:** The impact of natural surveillance on the willingness to use active travel modes like walking and cycling is subtly addressed through studies focusing on related aspects, such as

the effects of the built environment, infrastructure, and perceived safety on active transportation choices. While direct quantitative research specifically isolating natural surveillance is scarce, the existing literature suggests that elements associated with natural surveillance—like pedestrian-friendly infrastructure, well-lit paths, and community visibility—can influence active travel behaviors indirectly by enhancing perceived safety and comfort. A study focusing on children's active school travel in the Netherlands found that the road geometry and surrounding conditions significantly influence bicyclists' perception of comfort on physically separated paths. This suggests that environments which facilitate natural surveillance could impact the willingness to engage in active travel by enhancing perceptions of safety (Helbich et al., 2016).

These concepts have been included in Tewin's community design plan policies and land use structure.

### 12.1 Supporting Infrastructure

Research on the importance of various factors on cyclists' perception of user experience when choosing to travel by bike emphasizes neighborhood permeability, availability of secure bike parking at both origin and destination, and access to nature and aesthetics throughout the ride. Here are some findings:

1. **Neighborhood Permeability and Accessibility:** Neighborhood permeability, often measured by street connectivity and the presence of shortcuts or direct routes for cyclists, is crucial for promoting cycling. Higher street connectivity reduces travel distances and times, making cycling a more attractive option for short to medium distances. It enhances the convenience and speed of cycling compared to other modes of transport in urban environments (Saelens et al., 2003).
2. **Availability of Secure Bike Parking:** The availability and quality of secure bike parking facilities at both origin and destination play a significant role in the cycling mode choice. Secure and convenient bike parking reduces the risk of theft and damage, directly influencing the decision to cycle. Especially in urban centers, where space is limited, the provision of adequate bike parking can significantly encourage cycling (Van der Spek & Scheltema, 2015). Furthermore, the presence of bicycle parking facilities at public transport stations can encourage combined bicycle-public transport use, expanding the catchment area of transit stations and facilitating longer distance commutes (La Paix et al., 2021).
3. **Presence of Trees:** The effects of the presence of trees was added per request of the City of Ottawa. While no studies currently link the presence of trees with improved cycling mode shares, there is existing research supporting the positive influence of trees on the experience of those using active modes of travel. Vich, Marquet, & Miralles-Guasch found a positive correlation between the presence of street trees and individual walking levels. This suggests that the presence of trees can encourage outdoor modes of travel, which can be extrapolated to support the idea that the presence of trees is a factor affecting cycling mode shares (Vich et al., 2019).

In summary, while all three factors contribute to the cycling mode choice, neighborhood permeability and the availability of secure bike parking at home and destinations are more directly influential because they address practical concerns related to convenience, security, and accessibility.

Neighborhood permeability has a more direct influence on the daily cycling experience by affecting route choice, travel time, and the overall ease of cycling. In contrast, the availability of secure bike parking primarily influences the decision to cycle based on security concerns and convenience at the trip's start and end points. Enhancing neighborhood permeability can significantly improve the cycling experience by making it faster and more convenient, potentially attracting more users.

These concepts have been included in Tewin's community design plan policies and land use structure.

## 12.2 Cyclists Behaviours

General insights on cycling behavior and the factors influencing cycling mode choice can provide some context for understanding the potential impact.

1. **Weather and Cycling Behaviours:** Nosal and Miranda-Moreno (2014) investigated the effect of weather on the use of urban bicycle facilities, including the impact of precipitation and temperature on cycling flows. While the study did not specifically address snow clearance, it highlighted that adverse weather conditions, such as precipitation, significantly reduce cycling activity. This suggests that lack of snow clearance, which worsens cycling conditions, could deter cyclists, especially those who are less confident or inexperienced (Nosal & Miranda-Moreno, 2014).

A relevant framework that categorizes cyclists by confidence levels is the "Four Types of Cyclists" identified by researcher Roger Geller, which includes:

1. **Strong and Fearless:** A small percentage of the population willing to bicycle under almost any urban condition.
2. **Enthusied and Confident:** Cyclists comfortable riding on streets with bike infrastructure.
3. **Interested but Concerned:** A significant portion of the population that would cycle if safe infrastructure were available.
4. **No Way No How:** Individuals who are not interested in cycling under any urban condition.

The concept of the "Four Types of Cyclists," which includes the "Strong and Fearless" category, was developed by Roger Geller, Bicycle Coordinator for the City of Portland. According to Geller's typology, the "Strong and Fearless" cyclists are those who are comfortable cycling in almost any urban condition and represent a very small minority of the overall population, often estimated at less than 1% (Dill & McNeil, 2013). This categorization has been influential in understanding the diversity within the cycling community and guiding infrastructure and policy decisions to make cycling more accessible and appealing to a broader segment of the population.

After transit, active modes, particularly cycling, will play a significant role in Tewin's mobility strategy. As such, these concepts have been included in the community design plan policies and land use structure.

## 13 Walk Trips

The decision to walk as a mode of transportation involves considering various factors related to both safety perceptions (e.g., sidewalk continuity, well-delineated crossings, pedestrian separation, well-lit paths, and natural surveillance) and user experience (e.g., neighborhood permeability, frequency of crossings, access to nature, and aesthetics). While the research retrieved doesn't provide a direct quantitative analysis comparing these factors' importance, it offers insights into how they influence walking behavior:

1. **Safety Perceptions:**
  - **Sidewalk Continuity and Crossings:** The presence and quality of sidewalks and crossings are crucial for pedestrians' safety. Studies have shown that well-maintained sidewalks and clearly marked crossings encourage walking by enhancing the perceived safety of the environment.

- **Pedestrian Separation:** Separation from vehicular traffic through physical barriers or designated pedestrian zones can significantly increase the likelihood of choosing to walk by improving perceived safety.
- **Well-Lit Paths:** Adequate lighting along walking routes is essential for night-time safety, increasing pedestrians' comfort and willingness to walk during darker hours.
- **Natural Surveillance:** The presence of other people and open, visible areas can enhance the sense of security, making walking a more attractive option.

## 2. User Experience:

- **Neighborhood Permeability:** The ease with which pedestrians can navigate an area, including the directness of routes and the connectivity between destinations, is a key factor in the decision to walk.
- **Frequency of Crossings:** Regular opportunities to safely cross streets reduce barriers to continuous walking and can make walking more efficient and enjoyable.
- **Presence of Trees:** Access to nature and the aesthetics provided through nature allow for a more enjoyable walking experience.

When considering walking as a trip mode, both users' perception of safety and user experience significantly influence their choice to walk. Safety aspects such as sidewalk continuity, well-delineated crossings, pedestrian separation, well-lit paths, and natural surveillance are fundamental for ensuring that individuals feel secure when walking. User experience factors like neighborhood permeability, frequency of crossings, and access to nature and aesthetics enrich the walking experience, making it more enjoyable and likely to be chosen as a mode of transport. While both safety and user experience are critical, safety could be considered as having a foundational importance. If individuals do not feel safe, the enhancements in user experience may not sufficiently encourage walking.

1. **Safety as a Primary Concern:** Safety is a crucial determinant for walking mode choice. Factors such as traffic conditions, the presence of sidewalks and crossings, lighting, and the perception of crime significantly influence individuals' decisions to walk. Studies have shown that interventions aimed at improving pedestrian safety, such as Safe Routes to School programs, can effectively increase walking rates by addressing safety concerns (Boarnet et al., 2005). This underscores the idea that safety concerns can override other considerations when individuals make mode choice decisions.
2. **User Experience:** While safety is critical, the quality of the walking experience also plays a significant role in encouraging walking as a mode choice. Factors contributing to a positive user experience include walkability, aesthetic environments, access to nature, and the overall pleasantness of walking routes. Improvements in these areas can make walking more attractive and enjoyable, thereby encouraging its choice as a mode of transportation. Enhancements in micro-level walkability, for example, have been shown to influence transit users' mode choices, indicating that aspects of user experience that make walking more convenient and enjoyable can motivate people to walk more often to transit stations (Park et al., 2015). Koh and Wong (2013) discuss how infrastructural compatibility factors like rain shelter, security, comfort, shops, and scenery are crucial for walking and cycling route choices. This research

demonstrates the significance of user experience elements in making walking an attractive mode of transport (Koh & Wong, 2013).

In conclusion, while both safety and user experience are essential factors influencing walking mode choice, safety may be considered more critical because it addresses the fundamental needs of pedestrians to feel secure when walking. Once safety concerns are adequately managed, enhancements in the user experience can further motivate individuals to choose walking by making it a more enjoyable and desirable mode of transportation.

These concepts have been included in Tewin's community design plan policies and land use structure.

## 14 Pedestrian Facilities

Drawing insights from the research, we can infer a general order of importance, acknowledging that actual prioritization might vary based on specific urban environments, pedestrian needs, and local conditions:

1. **Pedestrian Separation on High-Speed/Volume Roads:** The separation of pedestrians from high-speed and high-volume vehicular traffic through dedicated pathways significantly enhances pedestrian safety and their perception of it. This is critical in areas with heavy traffic where the interaction between pedestrians and vehicles is higher, posing greater risks (Sucha et al., 2017).
2. **Well-Delineated Crossings:** Clearly marked and visible pedestrian crossings are vital for safe pedestrian movement across roads. These crossings signal to drivers to yield to pedestrians, reducing the likelihood of accidents and enhancing pedestrians' confidence in their safety (Sucha et al., 2017).
3. **Well-Lit Paths:** Adequate lighting improves visibility for both pedestrians and drivers, particularly during night-time or in low-light conditions, significantly reducing the risk of accidents and enhancing the perceived safety of pedestrian paths (Fotios et al., 2015).
4. **Natural Surveillance:** The concept of "eyes on the street" through natural surveillance increases the perceived safety of pedestrians. A study by Dameria and Fuad, while focusing on women's safety, does imply that urban environments that facilitate visibility and social interaction can deter potential criminal activities and provide a sense of security for pedestrians (Dameria & Fuad., 2021).

These concepts have been included in Tewin's community design plan policies and land use structure.

## 15 Network-Level Considerations

When choosing to walk as a mode of travel, neighborhood permeability, the frequency of crossings, and the presence of trees are significant factors that influence a person's experience of walking. While these elements are crucial, their importance might vary depending on the specific context and personal preferences.

1. **Neighbourhood Permeability:** Neighborhood permeability refers to the ease with which individuals can move through an area, heavily influenced by the layout and connectivity of streets. High permeability typically allows for more direct routes to destinations, potentially making walking a more attractive and convenient option. Shigematsu et al. (2009) explored age-related differences in associations between perceived neighborhood environment and physical activity, underscoring the importance of environmental attributes, including permeability, in promoting walking across various age groups (Shigematsu et al., 2009).



2. **Frequency of Crossings:** The frequency of safe and accessible pedestrian crossings can influence walking by facilitating easier and safer street crossing. Frequent crossings can reduce the barriers to continuous walking, especially in areas with busy traffic, enhancing the overall walking experience. The study by Mason et al. (2011) on neighborhood walking and regeneration in deprived communities hints at the importance of the built environment, including features like crossings, in supporting walking (Mason et al., 2011).
3. **Presence of Trees:** While no research has been found to support that the presence of trees influence a person's experience of walking, this was added per request of the City of Ottawa.

Both neighborhood permeability and the frequency of crossings contribute to making walking a viable and preferred mode of transport by enhancing directness to destinations. While each factor plays a specific role in shaping the walking experience, permeability reduces travel time more significantly than frequency of crossings as crossings are a smaller part of a whole trip. Additionally, there is only the need for crossings at desire lines, hence frequency of crossings can be considered less significant.

These concepts have been included in Tewin's community design plan policies and land use structure.

## References

- Assemi, B., Baker, D., & Paz, A. (2020). Searching for on-street parking: An empirical investigation of the factors influencing cruise time. *Transport Policy*, 97, 186-196.
- Ayachi, F. S., Dorey, J., & Guastavino, C. (2015). Identifying factors of bicycle comfort: An online survey with enthusiast cyclists. *Applied ergonomics*, 46, 124-136.
- Bai, L., Sze, N. N., Liu, P., & Haggart, A. G. (2020). Effect of environmental awareness on electric bicycle users' mode choices. *Transportation research part D: transport and environment*, 82, 102320.
- Bernardi, S., Krizek, K. J., & Rupi, F. (2016). Quantifying the role of disturbances and speeds on separated bicycle facilities. *Journal of Transport and Land Use*, 9(2), 105-119.
- Boarnet, M. G., Day, K., Anderson, C., McMillan, T., & Alfonzo, M. (2005). California's Safe Routes to School Program: Impacts on Walking, Bicycling, and Pedestrian Safety. *American Planning Association. Journal of the American Planning Association*, b71(3), 301-317. <https://doi.org/10.1080/01944360508976700>
- Bordagaray, M., dell'Olio, L., Ibeas, A., & Cecín, P. (2014). Modelling user perception of bus transit quality considering user and service heterogeneity. *Transportmetrica A: Transport Science*, 10(8), 705-721.
- Bruzzone, F., Cavallaro, F., & Nocera, S. (2021). The integration of passenger and freight transport for first-last mile operations. *Transport policy*, 100, 31-48.
- Cao, J., & Cao, X. (2017). Comparing importance-performance analysis and three-factor theory in assessing rider satisfaction with transit. *Journal of Transport and Land Use*, 10(1), 837-854.ca
- Chen, P., & Shen, Q. (2016). Built environment effects on cyclist injury severity in automobile-involved bicycle crashes. *Accident Analysis & Prevention*, 86, 239-246.
- Cicchino, J. B., McCarthy, M. L., Newgard, C. D., Wall, S. P., DiMaggio, C. J., Kulie, P. E., ... & Zuby, D. S. (2020). Not all protected bike lanes are the same: Infrastructure and risk of cyclist collisions and falls leading to emergency department visits in three US cities. *Accident Analysis & Prevention*, 141, 105490.
- Dameria, C., & Fuad, A. H. (2021, February). Enhancing female pedestrians' safety perceptions through the permeability of building frontages (case study: blok M area). In *IOP Conference Series: Earth and Environmental Science* (Vol. 673, No. 1, p. 012040). IOP Publishing.
- Dill, J., & McNeil, N. (2013). Four types of cyclists? Examination of typology for better understanding of bicycling behavior and potential. *Transportation Research Record*, 2387(1), 129-138.
- Duren, M., Corrigan, B., Kennedy, R. D., Pollack Porter, K. M., & Ehsani, J. (2023). Identifying and assessing perceived cycling safety components. *Safety*, 9(4), 75.
- Eboli, L., & Mazzulla, G. (2011). A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view. *Transport Policy*, 18(1), 172-181.
- Ewing, R., Schroeder, W., & Greene, W. (2004). School location and student travel analysis of factors affecting mode choice. *Transportation research record*, 1895(1), 55-63.
- Feiler, D. C., & Soll, J. B. (2010). A blind spot in driving decisions: how neglecting costs puts us in overdrive: A letter. *Climatic change*, 98(1), 285-290.

- Fobissie, E. N. (2019). The role of environmental values and political ideology on public support for renewable energy policy in Ottawa, Canada. *Energy Policy*, 134, 110918.
- Fotios, S., Unwin, J., & Farrall, S. (2015). Road lighting and pedestrian reassurance after dark: A review. *Lighting Research & Technology*, 47(4), 449-469
- Frank, L. D., & Pivo, G. (1994). Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit, and walking. *Transportation research record*, 1466, 44-52.
- Gan, H. (2015). To switch travel mode or not? Impact of Smartphone delivered high-quality multimodal information. *IET Intelligent Transport Systems*, 9(4), 382-390.
- Gattuso, D., & Musolino, G. (2007, September). A simulation approach of fare integration in regional transit services. In *Algorithmic Methods for Railway Optimization: International Dagstuhl Workshop, Dagstuhl Castle, Germany, June 20-25, 2004, 4th International Workshop, ATMOS 2004, Bergen, Norway, September 16-17, 2004, Revised Selected Papers* (pp. 200-218). Berlin, Heidelberg: Springer Berlin Heidelberg
- Ghader, S., Darzi, A., & Zhang, L. (2019). Modeling effects of travel time reliability on mode choice using cumulative prospect theory. *Transportation Research Part C: Emerging Technologies*, 108, 245-254.
- Guo, H., Gao, Z., Yang, X., Zhao, X., & Wang, W. (2012). Modeling travel time under the influence of on-street parking. *Journal of Transportation Engineering*, 138(2), 229-235.
- He, M., Pu, L., Liu, Y., Shi, Z., He, C., & Lei, J. (2022). Research on Nonlinear Associations and Interactions for Short-Distance Travel Mode Choice of Car Users. *Journal of Advanced Transportation*, 2022(1), 8598320.
- Helbich, M., van Emmichoven, M. J. Z., Dijst, M. J., Kwan, M. P., Pierik, F. H., & de Vries, S. I. (2016). Natural and built environmental exposures on children's active school travel: A Dutch global positioning system-based cross-sectional study. *Health & place*, 39, 101-109.
- Hergesell, A., & Dickinger, A. (2013). Environmentally friendly holiday transport mode choices among students: the role of price, time and convenience. *Journal of Sustainable Tourism*, 21(4), 596-613.
- Ho, T. H., Png, I. P., & Reza, S. (2018). Sunk cost fallacy in driving the world's costliest cars. *Management Science*, 64(4), 1761-1778.
- Jacob, N., Munford, L., Rice, N., & Roberts, J. (2021). Does commuting mode choice impact health?. *Health economics*, 30(2), 207-230.
- Kim, S., & Ulfarsson, G. F. (2008). Curbing automobile use for sustainable transportation: analysis of mode choice on short home-based trips. *Transportation*, 35, 723-737.
- Koh, P. P., & Wong, Y. D. (2013). Influence of infrastructural compatibility factors on walking and cycling route choices. *Journal of Environmental Psychology*, 36, 202-213.
- La Paix, L., Cherchi, E., & Geurs, K. (2021). Role of perception of bicycle infrastructure on the choice of the bicycle as a train feeder mode. *International journal of sustainable transportation*, 15(6), 486-499.
- Lam, W. H., & Tam, M. L. (2003). Reliability assessment on searching time for parking in urban areas. In *The network reliability of transport* (Vol. 1, pp. 61-78). Emerald Group Publishing Limited. (Needs purchase)
- Lawson, A. R., Pakrashi, V., Ghosh, B., & Szeto, W. Y. (2013). Perception of safety of cyclists in Dublin City. *Accident Analysis & Prevention*, 50, 499-511

- Li, M., Song, G., Cheng, Y., & Yu, L. (2015). Identification of prior factors influencing the mode choice of short distance travel. *Discrete Dynamics in Nature and Society*, 2015(1), 795176.
- Li, Z., Wang, W., Liu, P., & Ragland, D. R. (2012). Physical environments influencing bicyclists' perception of comfort on separated and on-street bicycle facilities. *Transportation Research Part D: Transport and Environment*, 17(3), 256-261.
- Mason, P., Kearns, A., & Bond, L. (2011). Neighbourhood walking and regeneration in deprived communities. *Health & place*, 17(3), 727-737.
- McCarthy, L., Delbosc, A., Currie, G., & Molloy, A. (2017). Factors influencing travel mode choice among families with young children (aged 0–4): a review of the literature. *Transport reviews*, 37(6), 767-781.
- Meng, M., Koh, P. P., & Wong, Y. D. (2016). Influence of socio-demography and operating streetscape on last-mile mode choice. *Journal of Public Transportation*, 19(2), 38-54.
- Moeckel, R., Fussell, R., & Donnelly, R. (2015). Mode choice modeling for long-distance travel. *Transportation Letters*, 7(1), 35-46.
- Mohiuddin, H. (2021). Planning for the first and last mile: A review of practices at selected transit agencies in the United States. *Sustainability*, 13(4), 2222.
- Nelson, N. M., Foley, E., O'gorman, D. J., Moyna, N. M., & Woods, C. B. (2008). Active commuting to school: how far is too far?. *International journal of behavioral nutrition and physical activity*, 5, 1-9.
- Nosal, T., & Miranda-Moreno, L. F. (2014). The effect of weather on the use of North American bicycle facilities: A multi-city analysis using automatic counts. *Transportation research part A: policy and practice*, 66, 213-225.
- Obsie, A., Woldeamanuel, M., & Woldetensae, B. (2020). Service quality of addis ababa light rail transit: Passengers' views and perspectives. *Urban Rail Transit*, 6, 231-243.
- Paré, G., Leaver, C., & Bourget, C. (2018). Diffusion of the digital health self-tracking movement in Canada: results of a national survey. *Journal of medical Internet research*, 20(5), e177.
- Park, K., Farb, A., & Chen, S. (2021). First-/last-mile experience matters: The influence of the built environment on satisfaction and loyalty among public transit riders. *Transport policy*, 112, 32-42.
- Park, S., Choi, K., & Lee, J. S. (2015). To walk or not to walk: Testing the effect of path walkability on transit users' access mode choices to the station. *International Journal of Sustainable Transportation*, 9(8), 529-541.
- Putri, S. B. K. (2021). Analysis of the relationship between travel time and on street parking. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 12(3), 5252-5264.
- Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. *Annals of behavioral medicine*, 25(2), 80-91.
- Saxena, N., Rashidi, T. H., & Auld, J. (2019). Studying the tastes effecting mode choice behavior of travelers under transit service disruptions. *Travel behaviour and society*, 17, 86-95.
- Sharaby, N., & Shiftan, Y. (2012). The impact of fare integration on travel behavior and transit ridership. *Transport Policy*, 21, 63-70.

- Shigematsu, R., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Cain, K. L., ... & King, A. C. (2009). Age differences in the relation of perceived neighborhood environment to walking. *Medicine and science in sports and exercise*, 41(2), 314.
- Simićević, J., Vukanović, S., & Milosavljević, N. (2013). The effect of parking charges and time limit to car usage and parking behaviour. *Transport Policy*, 30, 125-131.
- Southern, C., Cheng, Y., Zhang, C., & Abowd, G. D. (2017, May). Understanding the cost of driving trips. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 430-434). Needs purchase
- Soza-Parra, J., Raveau, S., & Muñoz, J. C. (2022). Public transport reliability across preferences, modes, and space. *Transportation*, 49(2), 621-640.
- Sucha, M., Dostal, D., & Risser, R. (2017). Pedestrian-driver communication and decision strategies at marked crossings. *Accident Analysis & Prevention*, 102, 41-50.
- Tian, L. J., & Huang, H. J. (2015). Modeling the modal split and trip scheduling with commuters' uncertainty expectation. *European Journal of Operational Research*, 244(3), 815-822.
- Tilahun, N., Thakuriah, P. V., Li, M., & Keita, Y. (2016). Transit use and the work commute: Analyzing the role of last mile issues. *Journal of Transport Geography*, 54, 359-368.
- Van der Spek, S. C., & Scheltema, N. (2015). The importance of bicycle parking management. *Research in Transportation Business & Management*, 15, 39-49.v
- Venter, C. J. (2020). Measuring the quality of the first/last mile connection to public transport. *Research in Transportation Economics*, 83, 100949.
- Vich, G., Marquet, O., & Miralles-Guasch, C. (2019). Green streetscape and walking: exploring active mobility patterns in dense and compact cities. *Journal of Transport & Health*, 12, 50-59.
- Whalen, K. E., Páez, A., & Carrasco, J. A. (2013). Mode choice of university students commuting to school and the role of active travel. *Journal of Transport Geography*, 31, 132-142.
- Zhu, Y., Ye, X., Chen, J., Yan, X., & Wang, T. (2020). Impact of cruising for parking on travel time of traffic flow. *Sustainability*, 12(8), 3079.
- Zuo, T., Wei, H., Chen, N., & Zhang, C. (2020). First-and-last mile solution via bicycling to improving transit accessibility and advancing transportation equity. *Cities*, 99, 102614.

# Attachment 1