

Desire Lines User Behaviour Research: Initial Scoping and Feasibility

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Preface

The Victoria Department of Transport and Planning Strategy and Victoria Road Safety Strategy set out to improve the pedestrian and vulnerable road users' experience when using public transport (PT) systems. The goal of these strategies is to deliver people-focused connectivity to the PT system that enhances a simple, safe and connected journey for vulnerable and unprotected road users. Melbourne's population growth and high concentration of residences, businesses, and leisure and activity areas within walking distance of PT stations necessitate better active transport connectivity and safer infrastructure designs, particularly with respect to pedestrian connector routes to PT stations and terminals.

In line with this goal, this project aimed to study the street-crossing behaviour of pedestrians and the factors affecting the choice of desire lines at PT stations and interchanges instead of safe designated paths. Desire lines are the most direct and shortest walking route between modes of transport but not necessarily the safest option. Where the provided safer route is longer and deviates from the desire line then a proportion of users may not use it, electing instead to take the shortest route. In these circumstances, control measures are enforced on desire lines, such as fences or plants, to actively dissuade/prevent usage.

The objectives of this project were twofold:

1. Identify the behavioural and socio-demographic factors affecting the choice of desire lines versus the designated pedestrian routes at the PT stations and level crossing interchanges.
2. Recommend the pedestrian connector design requirements based on the in-field behavioural evidence and the literature review.

By conducting a field survey at two important tram stations in Melbourne, we collected data on the share of pedestrians using desire line at various times of day, different days and weather conditions as well as the perceived characteristics of pedestrians by the surveyors on the site. To complement the field observation survey, we also intercepted a random sample of individuals and conducted a web-based survey to examine the impact of hypothetical external factors on the choice of desire line versus designated route.

The findings of this study revealed that some location-specific factors such as the traffic volume and specifications of PT platform design layouts would affect the rate of using desire lines. Some other external factors such as severe cold and windy weather and afternoon hours could also make people more inclined to use desire lines. On the other hand, a number of control measures such as pedestrian signal countdown, CCTV cameras or highly visible line marking and pedestrian signage would lead to safer crossing behaviour. Male gender, younger age and higher income level were amongst individual factors that positively correlated with opting for crossing via desire line as opposed to safer crossing routes.

This study set out a set of pragmatic recommendations to improve pedestrians' safety and road users' experiences based on the above findings. The recommendations include design specifications for the PT stations and their surroundings to minimise conflicting flows of movement among transport modes, access modes and destinations, especially in cities with densely populated areas like Melbourne's central business districts (CBD).

1 Background

During the last decade, Melbourne has experienced significant growth in its population and number of jobs. There has also been a change in the ways that people travel [1]. It is estimated that the 17 million trips per day that are made across all modes of transport in Melbourne will increase to more than 30 million by 2050. Increasingly, people walk, ride bikes and take PT [2]. Since 2001, the number of vehicles entering the city centre has decreased by 14% and the share of car trips to work has been reduced by 25%. As the Victorian Government increases investment in PT infrastructure, such as the Metro Tunnel, car dependence will continue to decrease as more convenient transportation options become available [3].



Future transport strategies, such as [2], have given considerable attention to pedestrians and their transport needs. The importance of this aspect is underscored by the fact that within the Hoddle Grid, 89% of all trips begin and end on foot [2]. Thus, maintaining Melbourne's reputation and liveability depends on pedestrians' safety, security and comfort. However, pedestrians often face challenges. For example, footpath congestion is a serious problem in parts of the central city, particularly when switching modes of transportation [4]. Conflicts between pedestrians and vehicles can occur when they share the same roadway, particularly after exiting or entering tram stations. Pedestrians are usually put at high risk due to such conflicts [5]. It is common for road designers and planners to fail to fully consider the characteristics of road users, including pedestrians [6]. The Melbourne CBD has more than 290,000 railway station users on weekdays, contributing to congestion on footpaths and at intersections [7]. In such crowded areas, pedestrians may use the most direct route or so-called desire lines to switch modes of transport, some of which may not be the safest. Desire lines are defined as the most direct and shortest walking route between modes of transport but not necessarily the safest option. Where the provided safer route is longer and deviates from the desire line, then a proportion of users may not use it, electing instead to take the shortest route. In these circumstances, control measures are enforced on desire lines, such as fences or plants, to actively dissuade or prevent usage.

Statistics show that Melbourne has the highest pedestrian road trauma rate in Victoria [8]. The evidence listed above, as well as the fact that 1.4 million people will be moving around the Melbourne municipality each day by 2036, makes it necessary to study pedestrian behaviour in order to provide reliable and safe infrastructure for them.

A variety of reasons can lead people to choose a path other than a designated path. These factors must be explored in order to improve services for transportation users and pedestrians. For example, at many intersections in Melbourne, particularly in the CBD, the traffic lights are optimised for vehicular traffic and not pedestrian traffic. [2]. Many signals do not change frequently enough, causing delays for crowds around stations during peak hours. While signal cycle times are being reduced in cities all over the world to reduce delays for all users, long periods of green time are common at Melbourne's traffic intersections. Pedestrians, cyclists, and trams are hindered by this [2]. With an increase in train patronage, this problem will most likely worsen.

Further, pedestrian behaviour is affected by building environments and PT stations such as tram stops. To reduce overcrowding, transport interchange precincts should be designed as 'people places' with high-quality footpaths and increased permeability of stops [2]. Streets and interchanges in these precincts must be capable of handling the volume of people that uses these stations at peak patronage times. Train stations and their surrounding precincts must be designed to cater for patronage growth [9]. Tram stop design should address a lot of these requirements, such as providing users with a comfortable environment while they wait for a service or ensuring that the network infrastructure is designed in a way that is easy to use [10].

Furthermore, authorities have been working on improving transport infrastructure, specifically stations, and have defined many requirements such as those in the "PTV-NTS-002–Public Precincts Standard" [11]. Each of these standards emphasizes the role of pedestrians and their behaviour. For example, these standards require there to be direct, obvious, and safe access paths to the station for all users, including from external paths, bus stops, tram stops, and road crossings. Furthermore, the design of the station should take into account the local community's characteristics, exogenous factors, and cultural values. Future station designs should incorporate pre-existing urban design strategies and consider all adjacent approved development plans. In addition, stations and public precincts should adhere to the Crime Prevention Through Environmental Design (CPTED) principles. The standards also mention that pedestrians with mobility problems should be considered in station design.



Pedestrians' needs should be met by improving footpaths and crosswalk locations. Footpaths will need to be wider as PT patronage increases, kerb outstands will need to be extended, and streetscapes will need to be improved to cater for increased traffic. This includes space for improved amenities, such as green spaces, places for resting and meeting places. Transportation and land use planning are integrated under Victoria's principal transport statute [12].

Recognizing that streets serve multiple purposes is fundamental to thinking about movement and place. According to the Department of Transport's new approach described in the *Movement and Place Framework*, streets are not just places to move people and goods but also places to live, work, and entertain. There is a natural tension between these two aspects. Each link in a movement corridor aims to reduce travel time and keep people and goods moving. On the other hand, as a destination, it aims to increase visitor dwell time. A balanced approach to integrated transportation planning is essential. It is important to consider community needs, expectations, and aspirations when planning and developing the transportation network, particularly by studying the behaviour of pedestrians and the factors that may influence their decision-making when choosing a path. To achieve this goal, the Department of Transport and VicRoads work with transportation and planning agencies, local councils and stakeholders. We should also note some Melbourne-specific characteristics, as listed below:



Melbourne-specific characteristics and strategies

The PT infrastructure in Melbourne, a city with a population of over 8 million, needs to be comprehensively planned.

While many new Melbourne residents are not within walking distance of PT, many of their jobs are in the inner city. Furthermore, many new jobs are expected to be created in the Melbourne CBD in the upcoming years, which will significantly impact PT services. The planning of transport services can be significantly improved if passenger behaviour is considered simultaneously.

Climate change impacts on PT services

The Melbourne area is expected to experience more extreme weather events in the near future. Understanding pedestrians' reactions to these events may assist service providers in designing systems to meet their needs, such as by providing shelters in stations and on sidewalks, and altering transport services.

The role of education in behavioural change

Melbourne's diversity of cultures highlights the need for educational campaigns, nudge strategies, and PT station access areas that are tailored to a multicultural society.

Enhancing public safety in public places

To design and provide more convenient, safe, and comfortable infrastructure and services, it is necessary to understand pedestrians' and PT users' behaviours inside and outside of peak hours. As an example, lighting can be designed in harmony with the local environment, amenities can be installed and arranged according to the behaviour of their users, and the locations of security devices, such as closed-circuit television (CCTV), can be optimized.

Facilitating the implementation of emerging technologies in the transportation sector

Melbourne is preparing its infrastructure to accommodate emerging technologies in its transport systems, such as driverless vehicles. Analysing how pedestrians choose their paths and cross streets in congested areas can help to incorporate these modes of transportation into current transportation systems.

Improving the suitability of PT stations

Passengers waiting, boarding and alighting at PT stops must have enough space to move and rest. Passengers' perceptions of their journey and safety can be negatively affected by a lack of space at busy stops, leading to unsafe crossing behaviours. By understanding the behaviour of pedestrians at PT stations, features such as permeability can be improved.

Providing consistent and easy-to-follow visual messages that make PT station easier to use, especially when changing modes and taking unfamiliar journeys, is also essential to pedestrian safety. Across Melbourne's PT networks, many signs have already been installed, with further upgrades progressively being made [11]. Studying the behaviour of pedestrians can assist in designing signs, symbols and logos [13]. Due to the increasingly central role that pedestrians are playing in transport strategies, this project aimed to study the route choice behaviour of pedestrians and its influences at PT stations and interchanges when they choose a path, so-called desire line, other than a safe designated route.

2 Insights from the Literature about the Potential Influential Factors

In recent years, several studies have examined pedestrian behaviour using desire lines or crossing the road during the red traffic light. These studies postulated that many factors influence a person's path choice, such as weather, congestion, individual characteristics, and walking time. We conducted a systematic literature review to identify the relevant factors mentioned by previous studies. A close look at the influences on pedestrian behaviour reported in the literature reveals that the influential factors on pedestrian behaviour may vary across different cities, cultures and countries. For this reason, it was very important to examine pedestrian behaviour according to each city or even at smaller scales to make more effective policies and strategies. Table 1 summarizes the potential factors that were identified in the literature. The influencing factors were divided into five categories: (i) pedestrian-related, (ii) traffic-related, (iii) location-specific, (iv) weather and time-of-day, and (v) built environment. Detailed information on these categories is provided in the following subsections. Appendix A presents the detailed literature review.

Table 1: Potential factors influencing pedestrians' walking behaviours

Category	factor	References
Pedestrian-related factors	Gender	[14-22]
	Age	[22-32]
	Walking style	[33-38]
	Group size and herd behaviour	[17, 27, 38-42]
	Crowd avoidance	[43-48]
	Trip purpose	[49-52]
	Distraction	[30, 53]
	Clothing type	[54, 55]
	Carrying bag, pet, prams or walking with kids	[49, 56-59]
	Cultural influence	[53, 60, 61]
	Safety perception	[62-68]
Traffic-related factors	Volume of road traffic	[30, 31, 69-71]
	Speed of vehicles	[20, 25, 26, 32, 72-74]
	Presence of on-street parking	[30, 75, 76]
	PT service gaps and frequencies	[52, 77-79] [52, 80]
	Safety perception of driverless operations	[81-88]
Location-specific factors	Availability of central refuge islands	[89-93]
	Line marking and road signage	[49, 94-96]
	Traffic lights and signal cycle time	[38, 42, 75, 97, 98]
	Pedestrian countdown signals	[29, 99]
	Length of crosswalks	[27, 42, 92, 100, 101]
Weather and time-of-day factors	Street illumination	[102-104]
	Weather condition	[91, 105-109]
Built-environment factors	Time of day (peak vs. off-peak, day vs. night)	[102, 110, 111]
	Nearby land uses types	[112-115]
	Walkway width, slope and level of service	[114, 116-121]
	PT station facility accessibility	[122-124]
	Familiarity (or using google maps) path attractiveness	[114, 118, 125] [112, 117, 120, 125, 126]

3 Data Collection

The survey was conducted between Monday, January 30th, and Sunday, February 5th, through different timeframes that were selected based on busy hours in the survey sites, extracted from Google Maps. The survey aimed to collect data on the travel patterns and preferences of PT users in two selected locations in Melbourne. To ensure a representative sample, the survey was conducted for a total of 7 hours, covering various time slots such as the AM peak hour (7-9 am), AM off-peak (9-11 am), PM peak hour (4-6 pm), and late evening (7-8 pm). To gather data from a diverse range of commuters, the survey was conducted in two PT stations: (i) the Queensbridge at Crown; and (ii) the junction of Russell St. and Bourke St. (see Figure 1).

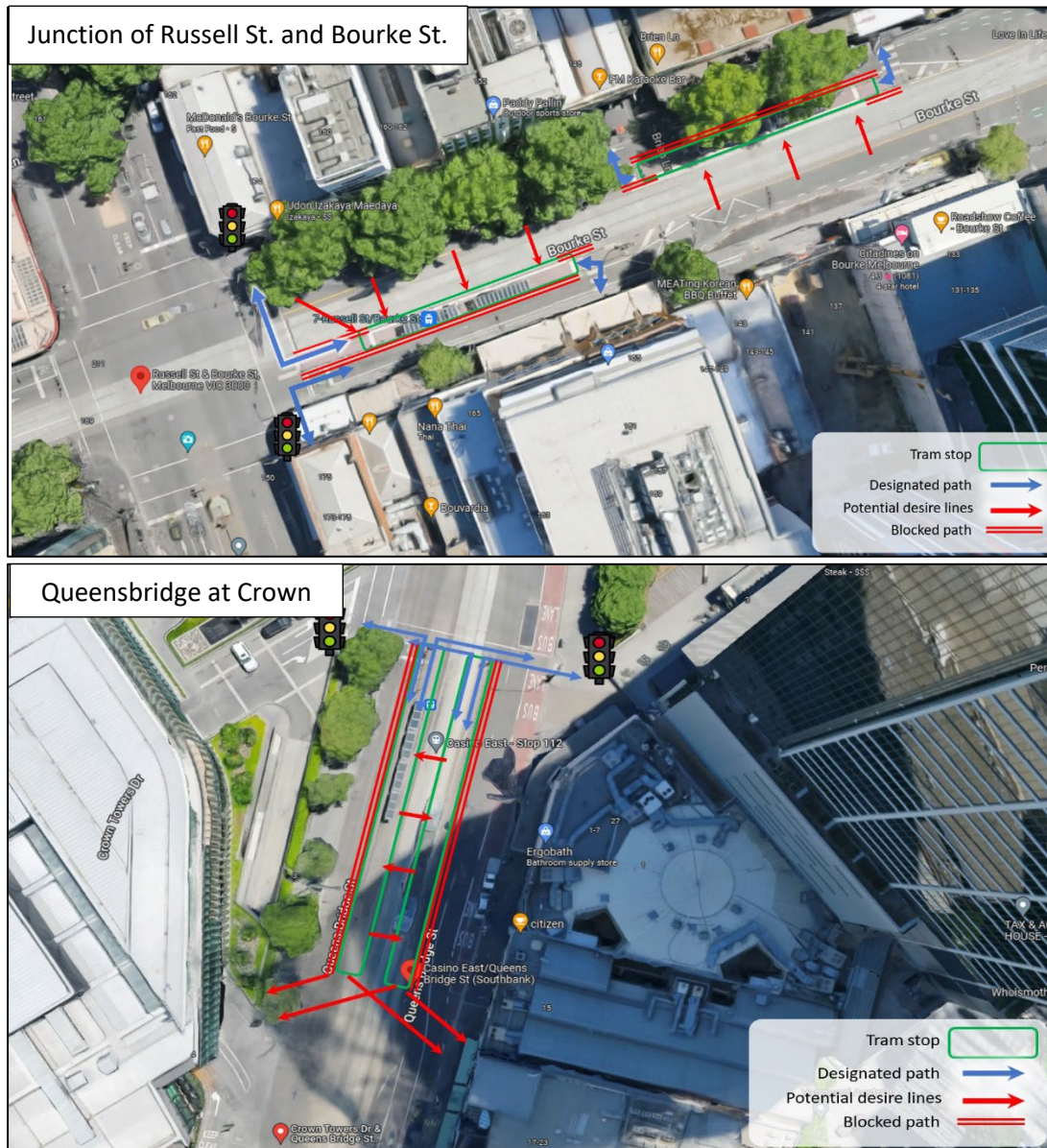


Figure 1: Survey locations

The survey team consisted of six survey staff in Bourke and Russell St. junction and four staff in Queensbridge tram station at Crown. The locations of the surveyors were clearly defined in a document provided to the survey team. Throughout the survey, we monitored the number of field observations and online survey participation rates. Due to less foot traffic and a lower online questionnaire participation rate at the Queensbridge site, two survey staff were transferred from the

Queensbridge site to the Bourke St site on Thursday and Friday. Data collection at the Queensbridge site was stopped early due to unforeseen unavailability of data collectors.

Posters were also placed at locations where surveyors stood to inform people about the ongoing research. Figure 2 presents the posters and signs that were utilised in the survey sites to inform the public about the survey and increase their participation.

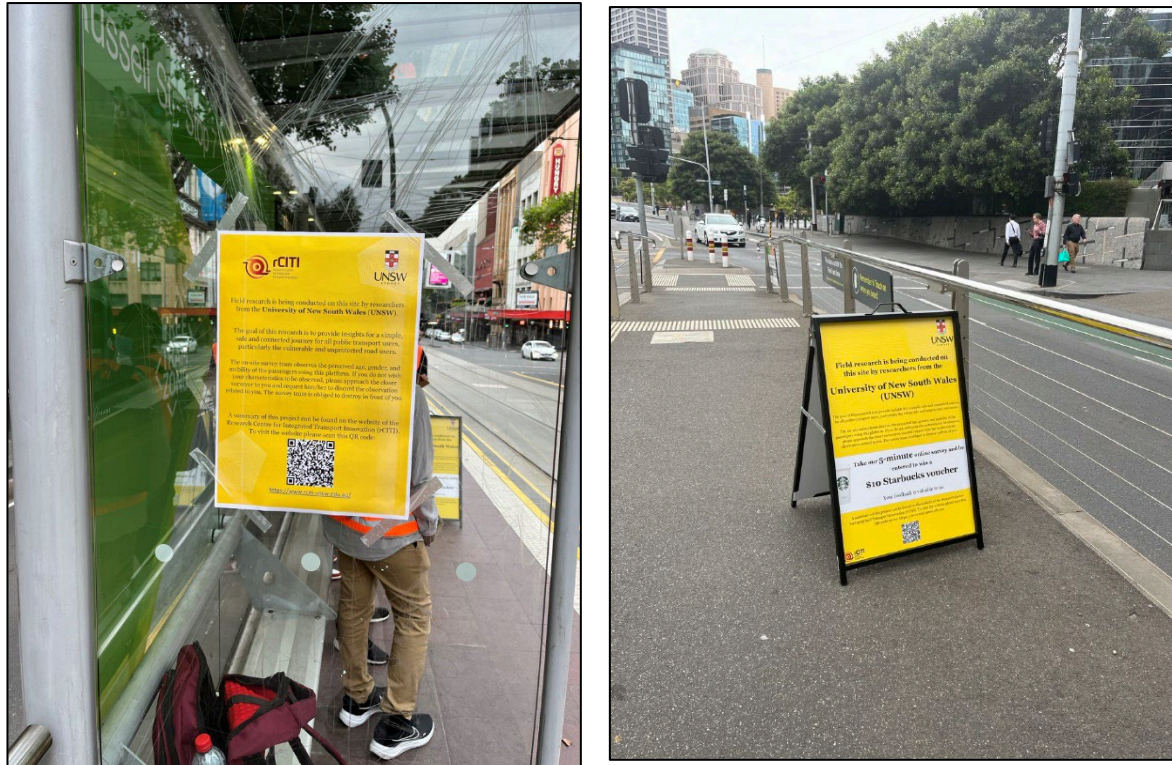


Figure 2: Strategies to inform public about the survey and to increase the survey participation rate

To collect data on pedestrian behaviour at the stations, two methods were employed: (i) field observation; and (ii) intercept survey. During the field observation, surveyors completed Form A (see Appendix C) to document various observable characteristics of pedestrian crossings, such as their perceived age, gender, walking direction and speed and more importantly the use of designated safe paths versus desire lines. Additionally, the surveyors recorded any distractions or use of mobile devices by pedestrians. These observations were conducted at different times of the day, both during peak and off-peak hours, to capture the full range of pedestrian crossing behaviour patterns.

In total, 4,544 complete field observation records were collected (after data cleansing). The observed information includes factors such as gender, age, weather conditions, time of day, disability or mobility impairments and most importantly the usage of safe and unsafe paths by pedestrians when crossing the street. Figure 3 presents the descriptive statistics of pedestrian characteristics and their street-crossing behaviours for two selected locations.

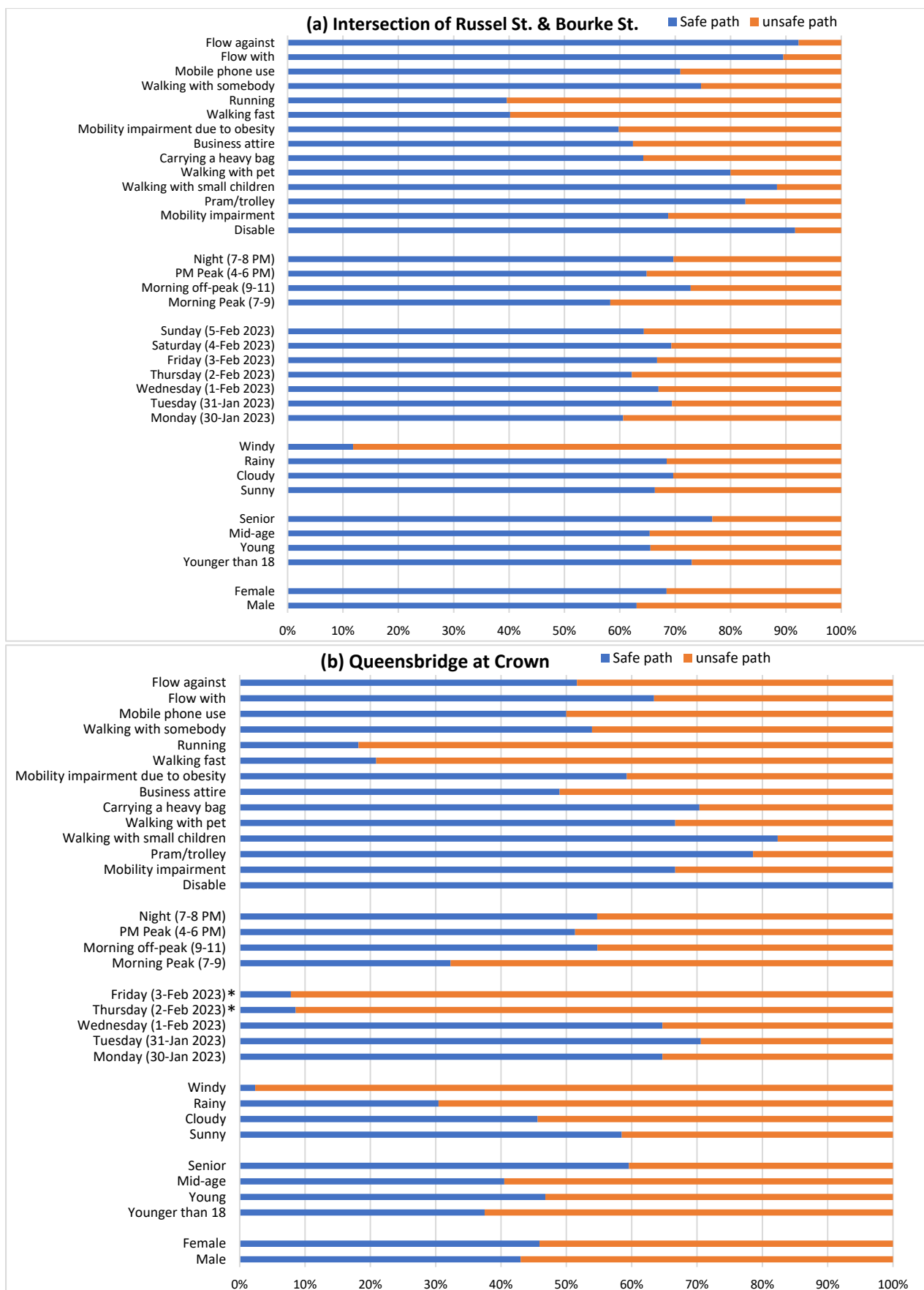


Figure 3: Descriptive statistics of crossing behaviours and socio-economic factors

To complement the field observation data, an intercept survey was also conducted. The survey team randomly selected pedestrians to participate in the survey. The web-based survey questionnaire was administered on tablets and the intercept surveyors explained the questions to the respondents (see Figure 4). The intercept web-based survey included questions about socio-demographic information, cultural background, trip purpose and hypothetical scenarios of street crossing (the questionnaire is presented in Appendix D). The survey took approximately 5-7 minutes to complete. To incentivize participation, respondents who completed the survey on-site received a \$10 Starbucks voucher. Alternatively, those who completed the survey later entered a random draw to win the coffee voucher.

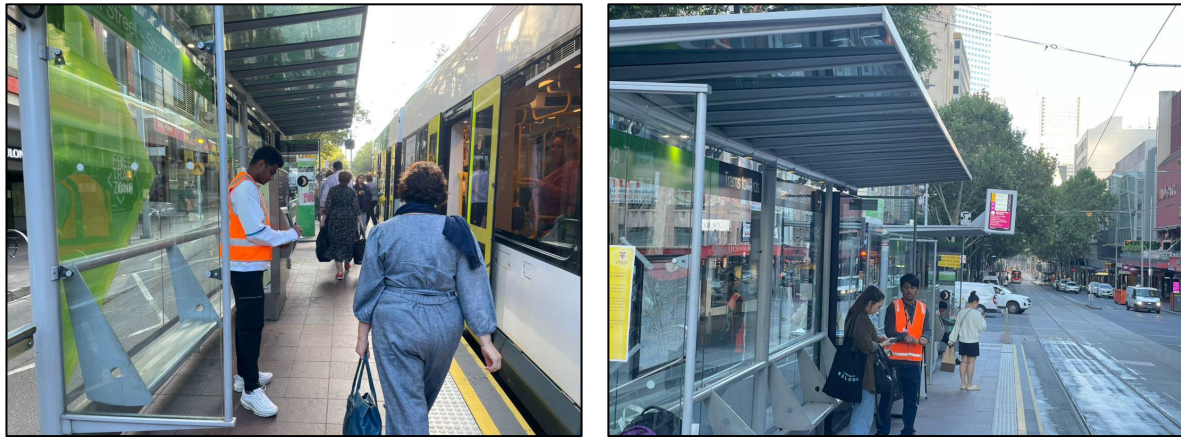


Figure 4: Survey staff intercepting people or distributing survey flyers

The intercept survey was designed to collect more detailed demographic and travel behaviour information from respondents that could not be obtained through observation. The questions aimed to determine the cultural background, educational level, income level, and frequency of PT use of the respondent. The questionnaire also included questions about the familiarity of the respondent with the surveyed area, the purpose of the trip to the surveyed location, and whether the respondent was in a hurry while travelling in the surveyed location.

Furthermore, the respondent was given a hypothetical situation (shown in Figure 5), featuring two street crossing options (path A or B). The respondent had to choose the likelihood of choosing either path A or path B in different scenarios involving specific factors of weather, traffic, etc. The survey respondents were presented with the following five options to indicate their path preference under different scenarios: "Definitely A", "Maybe A", "A or B equally possible", "Maybe B", and "Definitely B". Therefore, by using both field observation and an intercept survey, we gathered a more comprehensive understanding of pedestrian street crossing behaviour in PT stations.

In total, 424 complete and correct responses were collected through web-based survey (after data cleansing). Figure 6 presents a snapshot of descriptive statistics of responses to the hypothetical questions. More detailed descriptive statistics are provided in Appendix B. The responses to these hypothetical scenarios in relation to the respondent's socio-demographic characteristics were also investigated and presented in Appendix E.

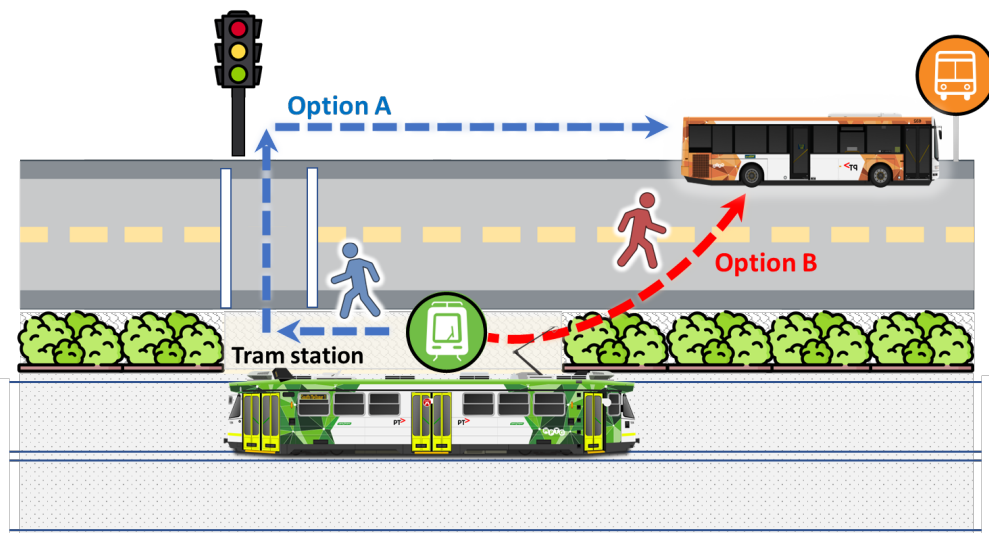


Figure 5: Hypothetical scenario presenting two options (A and B) in the online questionnaire.

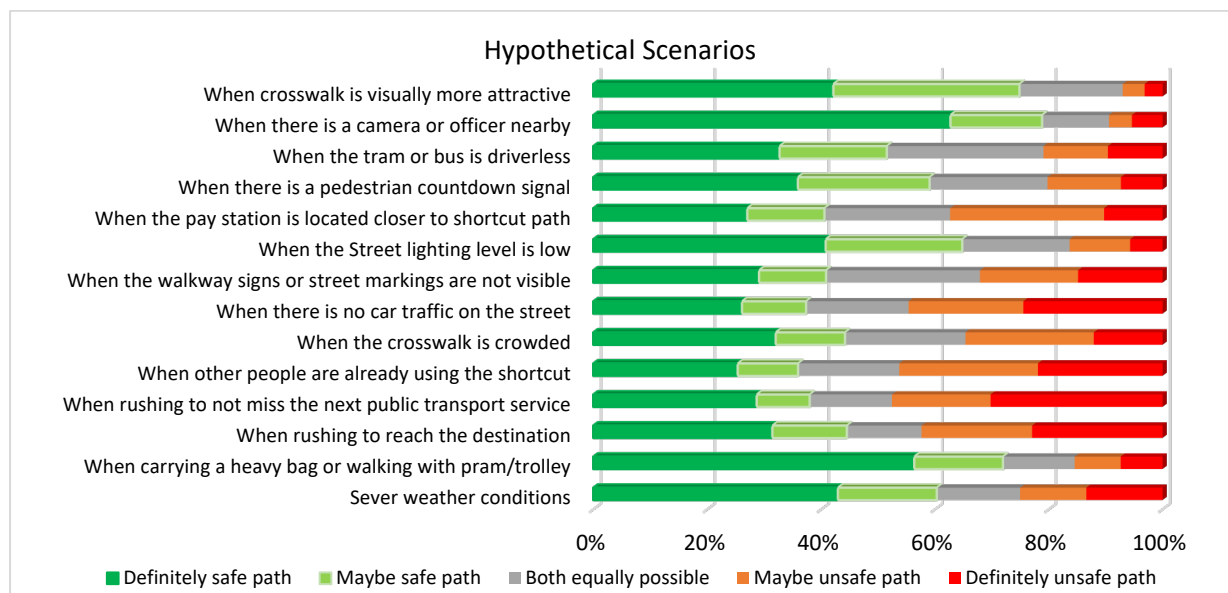


Figure 6: Responses to hypothetical scenarios in the online survey

4 Results

The influence level of factors was investigated by applying statistical models (see Appendix F for more details about the developed models). According to the field observation, in both Crown and Russell sites, on average around 67% of PT users use designated safe path while the remaining 33% used desire lines. However, the field observations data on two rainy and windy days suggest that pedestrians are more likely to choose a desire line at Crown site compared to Russell site in harsh weather conditions. To avoid a potential observation bias, we excluded these two days from the analysis. However, this pattern could be due to the low foot and vehicular traffic at Crown site, particularly on rainy, windy and cold weather. The previous studies also confirmed that congestion on roads significantly reduces risky pedestrian behaviour or the use of non-designated paths [69-71]. As depicted in Figure 7, the end side of the tram platform at Crown site does not have a zebra pedestrian crossing. This design layout enforces people to walk across the length of the platform (platform length:

60 meters) to be able to use the zebra crossing at the intersection. If the PT passengers encounter red traffic light, then they have to wait even further for the green signal. Whereas the design layout of the platform at the Russel site provides pedestrian access and a zebra crossing at both ends of the platform which itself is shorter (platform length: 44 meters), and results in less unsafe behaviours.

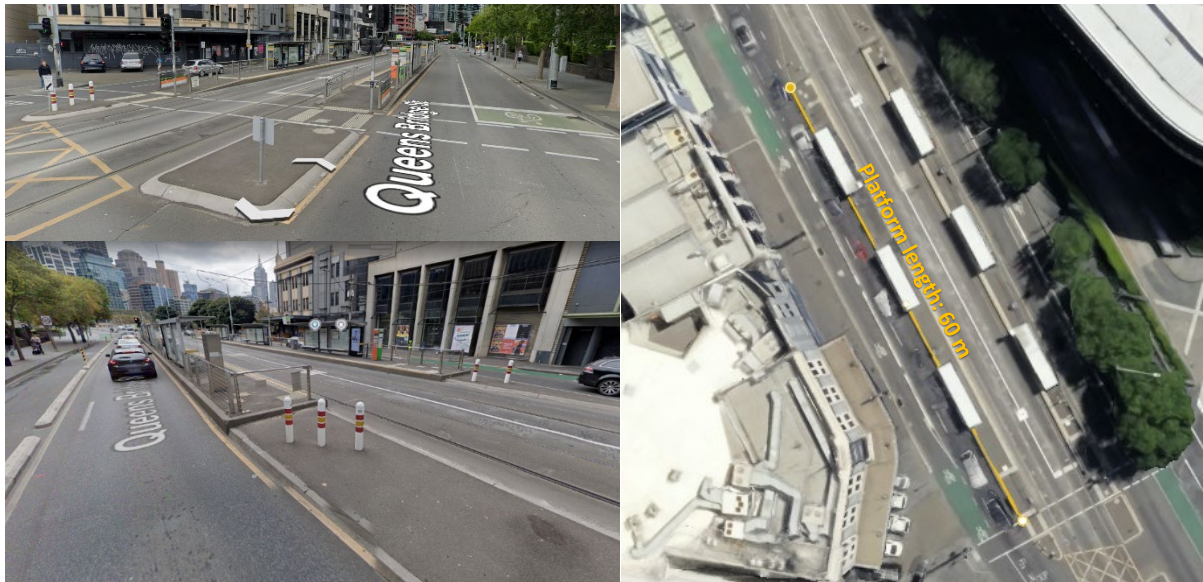


Figure 7: Queensbridge at Crown tram station



Figure 8: Russel St. and Bourke St. tram station

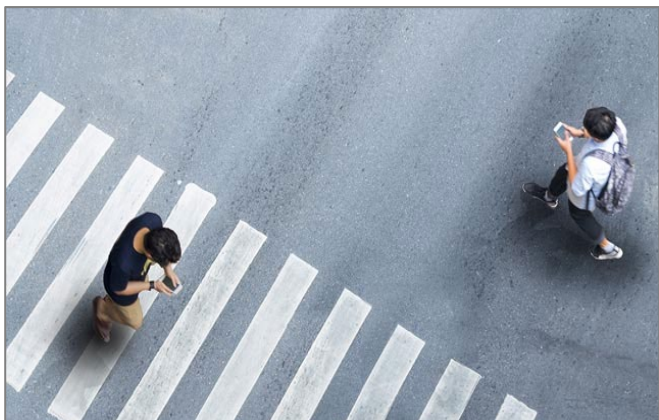
The observational data also showed higher percentage of unsafe behaviours during the afternoon hours compared to morning hours. This result was in line with the literature and suggests that pedestrians were more likely to use desire line during peak hours and when being in hurry to reach their destination [111].

The data collection covered periods of different weather conditions as two days of the data collection occurred during cold, windy as well as rainy weather. Our data suggest that cold windy weather is statistically a significant factor in prompting people to use desire line, as also suggested by the previous studies [91, 108, 109].



Similar to the findings of previous studies, male pedestrians are more likely to choose an unsafe path compared to female pedestrians [14-22] and senior pedestrians are less likely to choose an unsafe path compared to younger pedestrians [22-32]. Moreover, pedestrians who are carrying a pram, trolley, a heavy bag or walking with small children are less likely to choose an unsafe path compared to those who are not [56, 58, 59]. Similarly, less unsafe crossing behaviour was observed among people who are dressed in business attire, as also confirmed by the literature [54, 55].

While some previous studies suggest that distraction may result in illegal street-crossing [30, 53], our data suggests the opposite. Those who were observed walking with somebody else or using their mobile phones when crossing the street were less likely to use the unsafe desire line path. Interestingly, our data also suggest that people are less likely to choose the unsafe path when there is a high flow of people going in the same direction or when there is a high flow of people going in the opposite direction.



This result suggests that using the unsafe desire line is less likely to be influenced by the behaviours of a large group in our case study, and suggest that the majority of PT passengers use the safe path. It should be noted that this finding is yet to imply that the herd behaviour does not exist in our case study. As suggested by the literature, only a small percentage of informed individuals (e.g. 5%) can guide a larger group of uninformed individuals to use an unsafe path or cross the road during the red traffic light.

Overall, it appears that walking fast, walking with somebody else, and the flow of people crossing in the same direction (presented by the “*Flow with*” variable) have the strongest impact on the likelihood of people choosing the safe path. Gender, seniority, pram/trolley, walking with small children, and weather conditions also have some impact, but to a lesser extent. The impact of morning peak, morning off-peak, carrying a heavy bag, and mobile phone use may be less significant. Having business attire and the flow in the opposite direction of crossing appears to have a smaller impact but still has a significant effect on the likelihood of people choosing the safe path.



4.1 Impacts of hypothetical external factors

The results of presented hypothetical scenarios in the online survey suggest that a number of factors influence the swiftness of movement which is more likely to result in deviating from the designated safe crossing path and opting for desire line. We name this group of factors “*Impulsivity*”. The impulsivity factors confirm our prior hypothesis as well as the literature that severe weather conditions (windy, rainy, very hot sunny days), being in a hurry, herd behaviour, poor line marking and signs of walkways, and use the desire line to tap on the pay station as well as avoiding the crowd on the designated walkway could prompt people to deviate from the designated safe path and opt for the desire line. The estimates confirmed that these factors exacerbate unsafe and risky street-crossing behaviours and align well with the findings from the literature, as shown in Table 1 and described in Appendix A.

However, some other factors prompt people to use the designated safe path. We name them “*risk aversion*” factors. These factors include carrying a heavy bag or walking with a pram, trolley or scooter. Also, during dark hours of the day or when there is not enough street lighting, individuals are more likely to stick to the safe path. The presence of CCTV or police officers also has a positive impact on prompting people to follow the rules. It also appears that the public does not perceive the driverless tram or autonomous bus as safe, and individuals prefer to not take a risk of using an unsafe desire line. Interestingly, installing a pedestrian signal countdown and increasing the attractiveness of walkways or street zebra crossings (such as having a shade or vibrant high visibility pavement painting) can also prompt individuals to use the designated crossing path rather than the desire line. These results confirm the findings of the previous studies [29, 99, 112, 117, 120, 125, 126]. Notably, some respondents preferred the safe designated path in the presence of an autonomous tram or PT service, as also found in a number of studies suggesting that pedestrians may have a greater concern about interacting with driverless vehicles than they do with a human-operated vehicle due to the lack of meaningful eye contact or the absence of driver gestures that indicate their intention. [84, 85]. While as suggested by previous studies [88], pedestrians' crossing decisions are heavily influenced by their age and familiarity with driverless cars. Hence, in the next section, we present the relationship between the socio-demographic characteristics of respondents and choosing the desire line in the hypothetical scenarios. For example, we found a positive correlation between being a high-income earner and Melbourne resident and choosing the desire line which suggests more confidence in driverless technologies among this specific group of people.

4.2 Impacts of socio-demographic characteristics

We investigated the relationship between individual socioeconomic characteristics and if these characteristics influence using desire lines in various circumstances. Interestingly, very high-income earners (with an annual income of \$135K or more) lean towards selecting desire paths and deviate from the designated safe path in most hypothetical scenarios. Opting for desire line in this group of people could be a result of having a higher value of time. Notably, this group of people stated their preference for the desire line when carrying a bag or walking with a pram or trolley or when PT is autonomous and did not care about the visual attractiveness of the designated crosswalk path. This result may indicate a lesser level of rules obedience in this group or could simply be just a sample bias.

It appears that severe weather is more likely to influence individuals of non-Asian cultural backgrounds and regular PT users (i.e. those who use PT between two to four times per week) to use the desire line. While the results as well as the literature suggested that being in a hurry is an influential factor for using desire line, it appears that the impact is less among non-Melbourne residents, random PT users (those who use PT only once a week), mid-age individuals (i.e. 45-54 years old), and individuals with an Asian background.

We also postulated that when there is a significant number of people making the desire line to cross the street, this could prompt others to do the same. This kind of influence is called herd behaviour in the literature and is suggested to influence the pedestrian walking behaviour [17, 27, 38-42]. Our results indicate that herd behaviour exists, particularly for very high-income earners.

As suggested by the literature [43-48], some people may avoid using crowded walkways or crowded street crossings, particularly after the COVID-19 pandemic. It appears that those with a non-Asian or non-Australian cultural background are more likely to deviate from the designated safe path to avoid the crowd.



Those who are new to Australia (i.e. those who lived in Australia for less than 1 year or between 1 and 5 years) tend to stick to the designated walkways despite being crowded. In other words, they are more likely to follow others and opt for the designated path rather than deviating from it.

Another factor to prompt people to use a desire line is when there is not high vehicular traffic on the street [69-71]. The estimates proved this hypothesis to be valid, particularly for the regular PT users, average-income and very high-income earners.

As suggested by the literature [49, 94-96], high visible line marking could nudge the behaviours of individuals toward using the designated safe path. Our results suggest that the impact of walkway line marking visibility is likely to be stronger for very high-income earners and regular PT users and Melbourne residents. The location of the Myki-card reader (pay station) on the PT station is an important design factor that can induce unsafe street crossing behaviours. Overall, the model estimates confirmed this hypothesis, particularly for very high-income earners.

The second group of factors trigger the risk aversion attitude among pedestrians, namely carrying a bag, pushing a pram or walking with a children, poor street lighting, presence of signal countdowns,

CCTV or police officers. However, it appears these factors have a mixed effect on various groups of people. For example, carrying a load or pushing a pram or trolley prompts a few groups of individuals to use desire line such as mid-age people (55-64 years old), very high-income earners, and people with mobility impairment related to obesity. Other factors with the mixed effect are poor street lighting and pedestrian countdown signal. While overall, dark hours of the day and poor street lighting prompt people to take less risky actions, a few groups of individuals indicated the opposite. These groups include regular PT users, individuals with a postgraduate degree, young people aged in their early 20s and mid-age people who stated that they are more likely to opt for the desire line. In terms of the pedestrian countdown signal, it appears that senior people and individuals of Asian background are less likely to opt for the desire line while it prompts the individuals with postgraduate education to not wait and use the desire line instead. As noted, the presence of automated trams is more likely to trigger cautious pedestrian behaviours except for Melbourne residents and high-income earners who appear to have more trust in autonomous technologies.

Expectedly, the presence of a CCTV camera or police officer nearby induces safe crossing behaviours, particularly among individuals with disability or mobility impairments. It appears the visual attractiveness of designated safe paths may also prompt people to use them more, particularly individuals with an Asian background.

Notably, other socioeconomic variables did not have a statistically significant impact on the respondents' choices in hypothetical scenarios. Moreover, we considered the actual crossing behaviour of pedestrians (who completed the online survey) as a dependent variable and examined the influence of socioeconomic factors answered by the respondents. No socioeconomic variable was found statistically significant. Hence, we can conclude that the choice of desire line is by and large associated with external factors rather than socio-demographic characteristics.

5 Design Implications and Insights

Implementing measures such as pedestrian-friendly crossings, improving the accessibility of PT, and enhancing the safety of walking and cycling paths are necessary steps toward achieving safety goals in cities. This section of the report emphasises the importance of comprehending the intricate interplay between various factors that influence pedestrian behaviour and the use of unsafe pathways. PT managers and policymakers can develop more effective interventions to promote safer pedestrian behaviour and reduce the risk of accidents and injuries by taking these insights into account.



5.1 Location-based implications

The patterns of pedestrian behaviour can vary across different locations, as evidenced by comparing the observations from the CBD site and the Crown tram stop. It appears that pedestrians exhibit fewer instances of unsafe crossing behaviour in the CBD stations compared to the less crowded area such as the Crown tram stop. The observations also revealed that pedestrians are more likely to deviate from safe crossing behaviours (e.g. by using desire line or crossing the street during red signal) when there is less vehicular traffic on the street, during off-peak periods when traffic is less, or if the crosswalk is crowded due to actual reduction in perceived risk. These influential factors highlight the importance

of design interventions such as clear and highly visible road markings and signage, wide footpaths and pedestrian crossings, and pedestrian signal countdowns.

Addressing unsafe pedestrian behaviour around Melbourne's stations may be addressed by conducting an audit of PT stations to identify areas that require enhancement of infrastructure and signage. The collected information can then be used to prioritise the pedestrian infrastructure projects, such as widening footpaths and crosswalks and installing new signals, cameras, or artistic design of crosswalks to nudge people towards the safe designated path. Furthermore, the design of the station also plays a critical role in guiding pedestrians. Hence, city managers need to collaborate with local authorities to ensure that new developments include pedestrian infrastructure in their planning process.

5.2 Traffic signal implications

It appears that time constraints are a significant contributing factor to pedestrians taking unsafe paths. When in a hurry, people tend to choose desire line to save time, especially in areas with high foot traffic. This was proved as a correlation between walking fast or running and the number of unsafe street crossings in our observations. Herd behaviour was also proved to influence the street crossing behaviour of people because PT users were more likely to opt for a desire line when there were already other people on that unsafe path.



Given the majority of PT stations are located in the vicinity of intersections, signal timing becomes important in street-crossing behaviours. Traditionally the traffic signal timings are optimised based on the directional vehicle traffic, and the pedestrian flow is not taken into account. Therefore, the traffic signals at the intersections often give priority to vehicles and ignore the number of pedestrians, particularly the PT passengers who board or alight PT services.

Not only sufficient time for pedestrians has to be provided to cross the road safely but also the priority should be given to all road users equally if not more to active road users. One recommendation would be revisiting the signal optimisation guidelines and prioritising pedestrians and other active road users over vehicles. Reducing the traffic signal cycles to allow more frequent signal changes in crowded areas could also be influential.

Currently, the adaptive traffic signals only consider vehicle traffic through the sensors installed on the pavement and do not adapt (i.e. increase or decrease the green light according to the volume) to the pedestrian flow. One mitigating strategy could be installing passenger counters (or sensors) at the tram, bus doors or stations, predicting the pedestrian traffic at the intersections and adapting the signal timing according to the volume of both vehicles and pedestrians. Furthermore, push button data could be useful to determine the approximate level of use, particularly at signalised crossing points.

The Vic DoT has already implemented intelligent pedestrian detection sensors¹ at several walkways in Melbourne CBD to detect the crowded walkways to trigger controlling measures when pedestrian spillage on the street occurs. This technology can be used at major PT stations to trigger the pedestrian green signal.

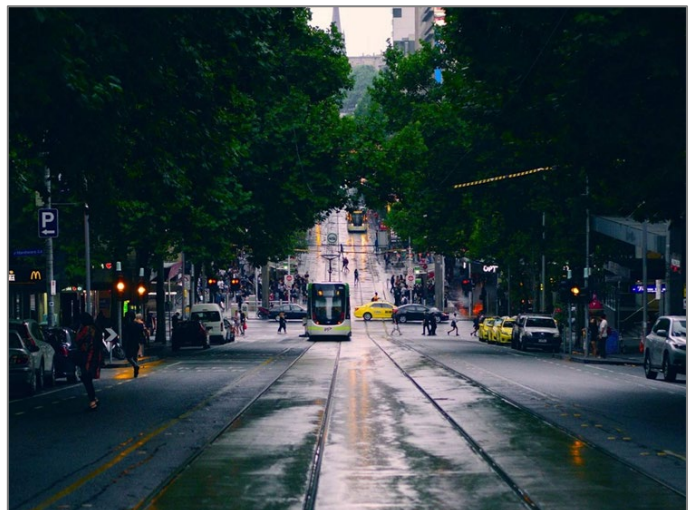
Another strategy could be coordinating the pedestrian green signal with the PT services. It appears that when people are hurrying to catch the next PT service across the road are more inclined to use the unsafe desire line or cross the road during the pedestrian red light. Given the PT travel pattern remains relatively stable, the number of PT passengers boarding or alighting at each station can be estimated and considered in the traffic signal optimisation. Then, the traffic engineers can design two optimum scenarios of signal timing, one without PT arrival/departure and another with PT-induced foot traffic at the intersection. A vehicle to infrastructure (V2I) equipment such as DSRC or 5G communication sensor can be installed on the PT services and trigger the PT signal timing scenario to provide priority to the pedestrian phase. This strategy can significantly prevent risky street-crossing behaviours and provide seamless pedestrian movements across the PT stations and intersections.

It also seems that if people know how long they have to wait, e.g. through a pedestrian countdown signal, may encourage them to wait and use the safe crosswalk. Therefore, installing pedestrian signal countdowns can mitigate the impulsivity and risky behaviours of passengers at intersections with high traffic volume and long traffic cycles.

5.3 PT schedule implications

A well-coordinated and integrated PT system not only reduces the number of private vehicles and congestion but also contributes to safer and more seamless pedestrian movements. On the other hand, an irregular or unreliable PT service can have adverse effects on PT users and pedestrian crossing behaviours. If the PT schedule is unpredictable or unreliable (deviating from the original schedule by being early or delayed), pedestrians may feel compelled to hurry, leading to riskier street-crossing behaviours.

Therefore, PT planners must coordinate the adjacent PT service schedules and allocate proper time intervals for passengers who have to transfer between different PT modes (e.g. tram and bus, train and tram, train and bus) or different PT routes across the same mode (e.g. two bus routes). Looking at the travel patterns, the PT transfer rates can be identified between each pair of PT services. This information alongside the distance between the stations, and the walking time required to make the transfer can then be used to match the service times. One



recommendation would be then optimising the schedule of the integrated PT system rather than individual services, and taking the walking links between the stations as a constraint in the scheduling optimisation problem. The use of information variable message signs to inform the next PT service

¹ <https://www.agd-systems.com/>

could also reduce the impulsive behaviour of PT users, particularly if it is readable from the other side of the road.

Notably, major PT interchanges in Melbourne are being equipped with multi-modal digital information displays. Further, such displays are placed at appropriate locations and information is displayed to discourage unsafe behaviour (e.g., when a service is two minutes away, the display is removed to prevent passengers from running). Melbourne is also working to improve the legibility of areas surrounding PT stations. In a legible space, passengers are able to orient themselves and reach their destinations without excessive directional signage. Complicated or unfamiliar environments can cause anxiety, so logical spaces assist in making movement easier.

5.4 Design considerations

5.4.1 Attractive design and high visibility of line marking and signage

While severe weather conditions push people to use unsafe desire lines to shorten their walking distance, using visually attractive designs of crosswalks may encourage people to stay on the designated safe path. Therefore, pedestrian-friendly design aspects can be considered such as shaded crosswalks, coloured pavements, or artistic pavement marking on the pedestrian pathways, adding pleasing elements like greenery, ensuring clear signage, and creating a user-friendly layout. Moreover, climate change is predicted to result in Melbourne having less rainfall but with more frequent and intense downpours, as well as more hot days and heat waves. As a result of these changes, tram stop shelters and shading is becoming more important for passengers and staff. Methods for mitigating heat retention include reducing hard surfaces and increasing tree canopy coverage.



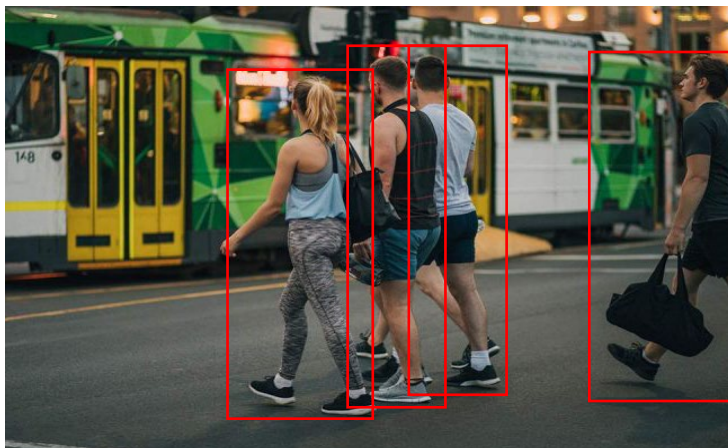
The use of pedestrian-friendly land can have an impact on where pedestrians walk based on their trip purpose.

The Vic DoT have already evaluated the effectiveness of various painting at crosswalks. One trial project at Thornbury aimed to increase the visibility of crosswalks for senior pedestrians by using bright yellow paint, as two white lines in parallel on a grey road background does not provide a clearly visibility.

5.4.2 Safety perceptions

The behaviour of pedestrians can be substantially influenced by their perception of safety. Pedestrians may deem certain areas to be unsafe, regardless of the absence of actual safety concerns. A poorly lit alleyway, for instance, may be perceived as a safety hazard, despite the absence of criminal activity. Some measures can be implemented to address the safety concerns such as improving streetlights, reflective line-markings, CCTV cameras, and maintaining a clean and well-groomed walking pathway.

Pedestrian safety is one of the most critical concerns for authorities in Melbourne, who use technologies such as CCTV cameras and pay careful attention to lighting. In particular, outside of peak hours, appropriate lighting can provide a safe, comfortable, and functional environment for PT users. Lighting on a sidewalk or reflecting off a canopy can contribute to the safety of pedestrians. Engaging with the local community to establish a sense of ownership can also contribute to improving the perception of safety. Furthermore, the regular maintenance of infrastructure and landscaping can assist in creating a more appealing and hospitable pedestrian environment.



5.4.3 Enforcement levels

There are always some impatient pedestrians who cross at traffic lights before the green signal, regardless of whether they are breaking basic road rules. Most Australian states have laws against jaywalking with fines issued to those caught. People break this rule daily as pedestrians cross whenever they see a suitable gap. There is no harsh penalty for crossing during the red light, but the police presence in the crowded intersections in CBD in rush hours reinforces the correct crossing behaviour. Different states and territories of Australia have different levels of fines and police may issue pedestrians a fine of up to \$154 if they cross the street illegally (see the Table 2).

Table 2: Penalty fee in the Australian States and Territories for illegal street-crossing actions

State or territory	Fine
New South Wales	\$76
Victoria	\$91
Queensland	\$53
Western Australia	\$50
South Australia	\$145
Tasmania	\$43
Australian Capital Territory	\$154

5.4.4 Station layout

In the morning and evening rush hours in Melbourne, many people are going to work and higher use of desire line was observed in our survey. In such conditions, pedestrians frequently use safety zone stops, which are located in the centre of the road and separated from other traffic by metal railings and traffic bollards.

The Melbourne network is moving away from kerbside boarding with a new stop design for trams. It features a pole holding a stop flag, a route timetable and, occasionally, a small screen showing tram arrival times and disruptions. In some instances, these stops also have a bench and/or small shelter. Placement of these amenities varies, as some are situated in the safety zone area itself (centre of the roadway), while most are located on the footpath due to a lack of space in the safety zone area. For access to a stop, passengers must cross an intersection and wait near the metal railings, although most safety zone fences have gaps to prevent crush loading. Upon tram arrival, passengers may cross the road at non-designated crossing points where a shelter is located on the footpath.

The PT platform designers and road authorities can also conduct walkability assessments to identify areas where pedestrians are more likely to take unsafe paths. This would enable them to work on improving the design of walking or PT infrastructure, such as adding more shaded sidewalks or crosswalks, to encourage pedestrians to use safe paths, particularly during severe weather conditions.



Permeability of public transportation stations may influence pedestrian behaviour.

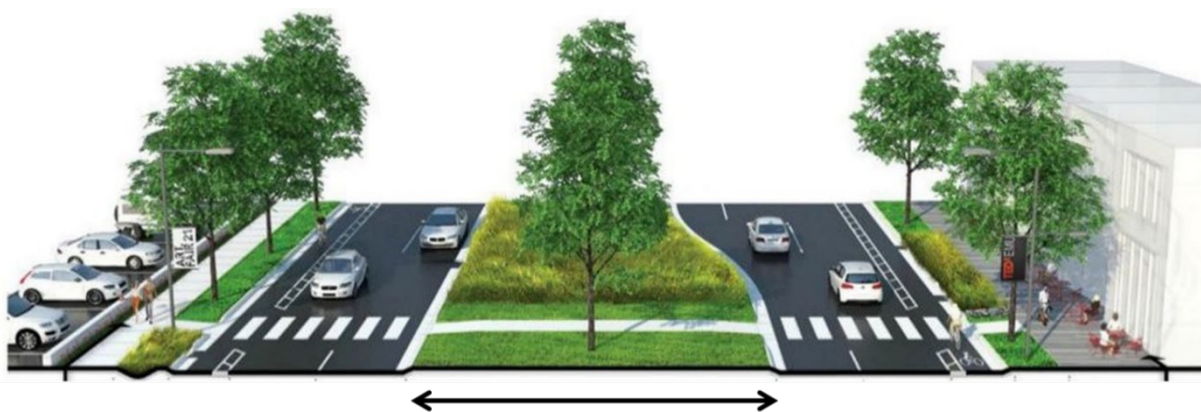
Furthermore, the location of pay fare stations also plays a significant role in promoting safe pedestrian behaviour. If pay fare stations are located in convenient and safe areas, pedestrians are more likely to use designated crossings and follow established safety protocols. Therefore, it is necessary to carefully consider the placement of pay fare stations to ensure that they do not inadvertently encourage unsafe pedestrian behaviour.

Looking at the Australian context, it becomes important to consider how a PT station should be incorporated into the design of the built environment. Melbourne tram stops, for example, can be classified into two categories: (i) integrated kerb extensions with surroundings (in narrow movement corridors with high permeability requirements), (ii) side platforms with raised shared zones (in wide corridors with high permeability needs), and (iii) island platforms (e.g. Nicholson Street trams station). Both designs aspire to improve pedestrian movement to and from the stop, as well as to enhance the surrounding public realm in an integrated way. Specific elements within these designs can then be selectively applied to less busy stops (e.g., adjusting the numbers of shelter and/or access points) through a Movement and Place approach. Movement and Place is a cross-government framework for planning, designing and managing our transport networks to maximise benefits for the people and places they serve. The locations of top-up stations and fare collection points can also influence pedestrians' choice of unplanned paths. All of the factors mentioned above can affect pedestrian behaviour.



5.4.5 Pedestrians with specific needs

Navigating paths can be a challenge for pedestrians with prams/trolleys, small children, wheelchairs or heavy bags. These individuals are more vulnerable to accidents and injuries, making it crucial to encourage them to use safe paths. Although the observational data has indicated that pedestrians with disabilities, or those accompanied by strollers or young children, are more likely to utilise safe paths, these areas demand increased attention to accessibility. Accessibility is a pivotal aspect in encouraging pedestrians to use designated safe paths, particularly for individuals with mobility challenges. Designers should ensure that safe paths are accessible to all pedestrians, which can be accomplished through the incorporation of ramps, elevators, and other accessibility features. Furthermore, the needs of diverse pedestrian groups, such as children, seniors, and individuals with disabilities, must be considered when developing pedestrian infrastructure. This can entail the provision of wider footpaths, central refuge, clear and readable signage, and tactile paving for visually impaired pedestrians.



Each 1% increase in central median width increases the likelihood of pedestrian violations by 15% ([Cao et al. 2016](#)).

However, the main issue arises from non-compliance with the design standards. Hence, the first step towards promoting safe path usage is to conduct a safety audit of the existing infrastructure. This audit should identify the unsafe areas and assess the associated risks, particularly for those with specific needs such as those with prams/trolleys or carrying heavy bags. This information can be used to prioritise improvements and safety features that make safe paths accessible to everyone. For example, installing handrails on steep inclines, repairing cracked pavements, clearing debris, and ensuring proper lighting. To increase the visibility of safe paths, signage can be placed at their entrances. These signs can indicate that the path is safe and accessible to pedestrians with prams/trolleys or small children. Additionally, they can provide information on the distance and the estimated time it would take to reach a destination using the designated path. To make safe paths accessible to everyone, ramps can be installed near their entrances. This makes it easier for people with prams/trolleys or small children to access the path without struggling to lift them. Seating areas can also be provided along safe paths to give people a place to rest, especially those with prams/trolleys, wheelchairs or carrying heavy bags. This can make using the path more comfortable, knowing that there is a place to take a break if needed. Directional signage can be installed along safe paths to make them easier to navigate. This is particularly useful for people with less or no familiarity with the area. The signage should indicate the direction of travel and the distance to the destination.

5.4.6 Different times of day

The use of unsafe and undesignated crossing paths can be a significant safety concern, particularly at dark hours of the day and in low visibility areas, such as the evening and night. Observations suggest

that people may be less patient after a long day at work and are more likely to take risks to reach their destination faster by taking the desire line. The darkness may make it harder for them to perceive hazards in their path.



As discussed in the previous section, the level of illumination in the surrounding environment can influence pedestrians' behaviour. Pedestrians are more likely to use well-lit and well-maintained paths than those that are poorly lit and in disrepair. Therefore, improving the visibility through reflective line markings of crosswalks and illuminating walking infrastructure can be an effective strategy to encourage pedestrians to use designated safe routes. Adequate street lighting and illumination can improve visibility and reduce the risk of accidents. This will also help pedestrians to perceive hazards in their path, such as potholes or debris, and avoid them. By providing clear and concise directions through reflective line markings, pedestrians will be less likely to become disoriented and take unsafe paths.

Another effective strategy is increasing police patrols in areas with high foot traffic, especially during specific hours of the day when pedestrian traffic is high. Pedestrians are more likely to feel safe and also stick to traffic rules when they see law enforcement officials patrolling the area. The use of monitoring technologies such as CCTV cameras and pedestrian sensors can also help reduce unsafe street-crossing behaviours.

5.4.7 Driverless vehicles

As autonomous vehicles (AVs) are becoming increasingly prevalent in major cities throughout Australia, it is crucial to raise public awareness regarding their safety. The survey responses suggest that overall, the public would not take risky street-crossing behaviours in the presence of driverless PT or AVs. It appears that only high-income earners still are willing to opt for unsafe desire lines around the driverless PT services or vehicles. Therefore, it is an option to educate the public about the safety of



driverless vehicles in relation to pedestrians and create public trust through AV trials. Moreover, the government should take steps for the safe co-design of infrastructure for both passengers and AVs. This could include installing 5G and infrastructure-to-vehicle (I2V) communication technologies that can detect the presence of pedestrians and adjust the vehicle's speed accordingly. Ultimately, the successful integration of AVs into our transportation system will require a collaborative effort between policymakers, the public, and industry to raise awareness and create trust and safety perceptions.

5.5 Educational campaigns

Pedestrian behaviour can be influenced by social norms prevalent in their community. For instance, some pedestrians may choose to take unsafe routes because that is the norm in their social circle or community. Therefore, to promote safe pedestrian behaviour, educational campaigns and engagement with the community would be necessary. This can be achieved through a range of initiatives such as community education campaigns, fun and creative social media campaigns, and

other communication channels such as collaborating with local businesses to promote safe pedestrian behaviour.

A large portion of Melbourne's population comprises immigrants from around the world. More than 140 cultures are represented in Victoria, from the original indigenous inhabitants to recent immigrants from Europe, Asia, and Africa. Early migrants to Melbourne contributed significantly to the development of its identity. Others are more recent arrivals, like international students who have added to the city's multicultural fabric. As a result of this diversity of cultures, this factor is becoming increasingly important and highlights the importance of educational campaigns.

Local authorities can organise seminars, workshops, and awareness campaigns in schools and public places, highlighting the risks associated with taking unsafe paths. They can use social media and other digital platforms to reach out to young pedestrians and raise awareness. Local authorities can work with schools to promote safe pedestrian practices. This could include organising safety talks, safety walks, and campaigns aimed at encouraging students to use safe paths. Schools can also be encouraged to integrate pedestrian safety into their curriculum. Technology can be used to encourage young pedestrians to use safe paths. This could include developing mobile apps that provide real-time information about safe paths, or virtual reality simulations that demonstrate the dangers of using unsafe paths.



Creating a peer-to-peer network of young pedestrian safety ambassadors could encourage more young people to use safe paths. These ambassadors could be trained to promote safe pedestrian practices in their communities. Furthermore, parents and caregivers play a crucial role in encouraging young pedestrians to use safe paths. Local authorities could organise workshops and seminars for parents and caregivers, highlighting the importance of safe pedestrian practices. They could also provide information on safe routes to school and encourage parents and caregivers to use these routes with their children.



The combination of the carrot and stick policy can also be implemented. Rewarding campaigns could be an effective strategy in encouraging and institutionalising the correct behaviour in which the compliant street-crossing behaviours get rewarded with a small token or goodie. On the other hand, law enforcement agencies could increase the number of patrols in high-risk areas and introduce warning notes or stricter penalties for those who disobey pedestrian safety rules and create unsafe situations for themselves or other road users. This may help to create a culture of compliance with pedestrian safety rules, including street-crossing behaviours.

Moreover, involving community members in the planning process can foster a sense of ownership and responsibility. By seeking input and feedback from the community, city managers and urban planners

can ensure that safe pedestrian paths meet the unique needs of the community. This, in turn, can promote a sense of ownership and responsibility, thereby enhancing compliance with safe pedestrian behaviour.

5.6 Socio-economic Considerations

The field observations suggest that various socio-economic backgrounds may affect street-crossing behaviours. For example, men, young individuals, people with casual clothing and high-income earners are most likely to use the unsafe desire line. The individuals' behaviours under various circumstances may also vary. For example, our field observations confirmed that windy and cold weather would increase the chance of using unsafe crossing paths. Our survey particularly indicated that individuals with a non-Asian background would use the desire line under severe weather conditions. Therefore, it may be necessary to provide more education for people from specific cultural backgrounds to adjust their behaviour and use safer paths.

Furthermore, the frequency of using PT has a significant impact on the use of unsafe paths during severe weather. Although there may be various reasons for this, people who use PT between 2 to 4 times a week may have a negative perception of the service's schedule reliability during bad weather, therefore choose to use the desire line.

When faced with crowded areas, people tend to avoid them, particularly in public places such as transportation stations. However, this behaviour can lead to changes in navigation and result in people taking potentially unsafe routes to avoid crowds. For instance, people might choose shorter or less crowded paths to reach their destination. Our data suggest the duration of being in Australia may also affect crowd avoidance behaviour. Additionally, analyses confirm cultural background can influence crowd avoidance behaviour. Individuals from other cultures rather than Asian or Australian may be more inclined to avoid crowds and take the desire line. In order to improve pedestrian flow and prevent overcrowding, it is imperative to widen the designated safe pathway. However, it is equally important to educate and raise awareness about the benefits of using the safe path, while also highlighting the potential hazards of using unsafe routes, particularly for certain groups.

Pedestrian countdown signals serve as a valuable means of informing pedestrians about the remaining time before the traffic signal changes, thereby aiding in reducing the risk of pedestrian-vehicle collisions and improving pedestrian safety. Our observations suggest that countdown signals are more effective for elderly people and individuals with Asian backgrounds while having an inverse effect on people with higher educational levels. It appears that this specific group of people may feel compelled to cross the street rapidly before the timer runs out, even if it means crossing when it is not safe to do so. As such, it is crucial to recognise the potential impact of these signals on diverse pedestrian groups and adopt measures to address any negative effects. Such actions could include providing further education and outreach to vulnerable populations, adjusting the countdown timer's duration based on local conditions, or implementing other initiatives that promote safe and accessible pedestrian crossings.

Lastly, it is worth noting that cultural background can play a crucial role in pedestrian behaviour, as different cultural norms and values may influence the way people perceive and use public spaces. Therefore, it is essential to take a nuanced approach when designing and promoting safe pedestrian routes, taking into account the unique needs and preferences of diverse communities. By doing so, we can create safer and more inclusive public spaces for all pedestrians.

6 Conclusions

This study aimed to identify the percentage of unsafe street crossings by PT users at two stations and the underlying causes and influential factors on these behaviours. Various potential factors were extracted from previous studies and were examined through field observation as well as web-based intercept surveys in two sites with different geometric design specifications of PT platforms and different foot traffic.

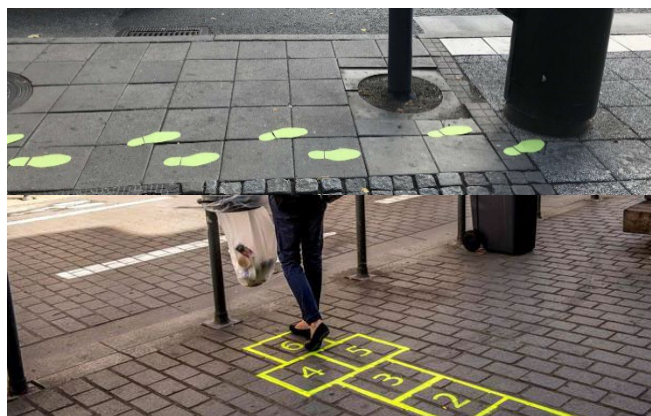
To avoid biases in the responses, the respondents were asked to state the five Likert scale likelihood of opting for an unsafe path in hypothetical scenarios. To examine the potential correlation between the actual behaviour and the stated response, a unique code was used to match the observed behaviour with the responses from the web-based survey. However, no statistical correlation was found between the indicated likelihood of choosing unsafe street-crossing and the actual observed behaviour. The lack of correlation between stated and revealed behaviour could be due to differences in hypothetical scenarios from the actual situation.

The influence of pedestrian characteristics on the revealed and stated behaviours was also examined. Some characteristics turn out to be influential in opting for unsafe paths and these characteristics were by and large in line with the literature. The field observation was undertaken at different time of day and for the duration of one week. Over the course of survey, the observations covered all different weather conditions such as cold windy, rainy, and sunny days. This enabled examining the impact of time of day, day of week and weather on pedestrian behaviours.

Moreover, this study attempted to test the hypothesis about herd behaviour in opting for an unsafe desire line. Overall, it appears that walking fast, walking with somebody else, and the flow of people crossing in the same direction have the strongest impact on the likelihood of people choosing the safe path. Male gender, seniority, pram/trolley, walking with small children, and weather conditions also have some impact, but to a lesser extent. The impact of morning hours, carrying a heavy bag, and mobile phone use may be less significant. Having business attire and the flow in the opposite direction of crossing appears to have a smaller impact but still has a significant effect on the likelihood of people choosing the safe path.

The results revealed that some active and passive controlling measures may be effective in encouraging pedestrians to use an unsafe pathway or desire line, while others may prevent them. For example, improving signage, increasing street lighting, widening the crosswalks, installing pedestrian signal countdowns or cameras, or locating Myki-card readers closer to the safe crosswalk can gauge pedestrians to navigate safe pathways during peak traffic hours or in adverse weather conditions. The collected data from field observations and an online survey at two locations in Melbourne also provided insights into socioeconomic factors, trip purpose or characteristics that would interplay with external factors such as weather or the design of the PT stations and affect the street crossing behaviours at the PT stations.

While some of the implications may be specific to the case study locations, most of these insights can be applied to other locations to improve the safety and experience of vulnerable road users, particularly PT users. To develop a comprehensive safety roadmap for PT services, however, further investigations in other sites with different characteristics would



be advised. Hence, we underscore the need for conducting experimental research to examine nudge strategies and various interventions and to identify effective design solutions that are tailored to the needs of diverse communities, people, or different built environments. Through this process, policymakers, designers and urban planners can develop comprehensive strategies that address the unique challenges faced by different communities and promote equitable access to safe, efficient, and sustainable transportation systems. Future studies can utilise the observed behavioural data to improve the simulation softwares and emulating the real behaviours.

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Appendix A: Literature Review

A set of criteria for article inclusion was developed as the first step. The Scopus and Web of Science databases were used to find articles using the following search criteria. (i) Article titles, abstracts, or keywords must contain the words (or alternates) "Pedestrian" or "Walking," "Route" or "Path," and "Choice". (ii) Studies must be published in English. (iii) Articles from peer-reviewed journals and grey literature, i.e., government resources, were considered. Articles meeting the inclusion criteria were reviewed and categorized using a systematic classification scheme. The influencing factors were divided into five categories: (i) pedestrian-related, (ii) traffic-related, (iii) location-specific, (iv) weather and time-of-day, and (v) built environment. Detailed information on these categories is provided in the following subsections.

Pedestrian-related factors

There is growing evidence that the behaviour of pedestrians on paths differs according to their demographic characteristics, such as gender and age [14, 127-130].

Gender

Most studies indicate that men are more likely to increase their safety risk by using non-designated paths [14]. In Canada, road accidents injure or kill more male pedestrians than female

ones [15]. Several studies have indicated that, compared with women, men are less likely to follow pedestrian rules [16], spend less time waiting before crossing the road [17], cross in the red traffic light and non-designated walking path on the street [17, 97], walk faster [131], interact with vehicles more frequently [18], cross with a reduced margin of safety [19], perceive less danger and accept more risk [20]. According to observations from Montreal, 66% of women and 56.6% of men adhered to road signs and markings [21]. Similarly, there are differences between men and women in their reactions to specific variables in a situation [22]. Men are more affected by traffic volume and speed than women, but women are more affected by the behaviour of other pedestrians [132].

Age

Most research shows that young and middle-aged pedestrians are least likely to adhere to road rules and are more likely to be involved in risky crossings than older pedestrians [22]. Similarly, Dommes, Granié [23] and Sucha, Dostal [24] found that older pedestrians were more willing to tolerate longer waiting periods and cross at designated intersections. Pedestrian accidents are more common among younger pedestrians because they are more likely to cross in non-designated areas, to not obey traffic lights, and to ignore traffic signals [27]. Although older adults are more respectful of road rules, advanced age negatively affects mobility. Therefore, older adults find it more difficult to cross with adequate safety margins. Moreover, older adults have difficulty estimating their surroundings, which makes them more likely to make inappropriate crossing decisions [28]. However, a few studies have found that age has no impact on illegal behaviour or non-designated path use [27, 29].

Pedestrian-related factors:

- Pedestrian-related factors have a significant impact on pedestrian behaviour.
- Pedestrian behaviour varies significantly by gender and age.
- Many pedestrians follow other pedestrians when walking in crowded areas.
- Pedestrian behaviour has changed because of the recent pandemic and its associated rules.

Herd behaviour

Behavioural research shows that people's path-selection decisions are heavily influenced by the social information they gather from those around them [133, 134]. According to Dyer, Johansson [39], a small percentage of informed individuals (5%) can guide a larger group of uninformed individuals to a target location. Pedestrians who follow other pedestrians blindly on non-designated paths provide examples of this behaviour [41]. Those who follow non-designated paths or cross the roads without checking the traffic lights can cause accidents and injuries since they may trust incorrect or unreliable information. Compared to individual pedestrians, groups of pedestrians are more likely to participate in illegal behaviour [17, 27, 42].

The study by Guo, Gao [38] confirmed this herd behaviour by observing that pedestrians walking alone spent 3.6 times longer waiting at signalised intersections than those walking in groups. Walking in groups causes pedestrians to follow the first impatient pedestrian who crosses, instead of waiting for a dedicated green signal. Illegal behaviour is more likely to occur if other pedestrians are already crossing the street illegally [135]. In situations where personal information and social information conflict, a pedestrian's behaviour may change. Deb, Strawderman [40] found that groups cause pedestrians to pay less attention to the road due to having conversations with each other. It is also possible for pedestrians to change their speed by walking in a group. A delay occurs when pedestrians walk in a group because they must wait until the pedestrians ahead of them step off the sidewalk before entering a crosswalk (Highway Capacity Manual, 2016).

Crowd avoidance

Even though walking in a herd may alter the behaviour of a pedestrian, pandemics such as the COVID-19 pandemic have increasingly changed pedestrian behaviour in recent years [43]. Zhang and Fricker [44] reported that COVID led to a decline in non-motorized activities in densely populated cities, while walking and bicycling increased in less densely populated ones. Compared with pre-COVID periods, Askarizad, Jinliao [45] found that pedestrians' social space requirements had increased. Contrary to the pre-COVID period, pedestrians' preference for commercial spaces has diminished. Many countries and authorities, including the Victorian Government in Australia, implemented strict rules to combat the virus' spread. As a result of new regulations such as social distancing, or the threat of exposure to a COVID carrier, some pedestrians may try to avoid congestion and choose less-crowded paths to prevent congestion.

Romero, Stone [46] examined how traffic patterns within buildings impact virus exposure levels. They modelled and analysed various configurations of one-way and two-way pedestrian traffic inside hallways. Short exposures to a large number of people are similar to significant exposures to a small group of people, so exposure levels should be minimised in all aspects. To control the spread of the pandemic, authors like Combs and Pardo [47] suggested adjusting signal timing to minimise pedestrian queues.

Australian cities have experienced strict rules, such as social distancing, that have also affected pedestrian behaviour in recent years. When a carriage is busy, many PT users may try another door or wait for the next service. It has also been observed that many people use less-crowded carriages despite having to walk further to reach them [136].

Clothing and physical fitness

The clothing worn by pedestrians can also reflect their destination which, in turn, can affect their route choice [54]. Some clothing and footwear, such as business attire, are not comfortable for fast walking, especially in areas with cars. In addition, pedestrians have difficulty walking on gravel paths with high heels or business shoes [55].

Furthermore, a pedestrian's fitness level may also affect their behaviour. A more physically fit person is more likely to choose a non-designated path than an unfit one, because they can cross streets more quickly or jump guardrails designed to prevent crossing. Many studies have shown that the passengers who rush in crossing the road, are more likely to present illegal traffic behaviour or use non-designated paths. Younger, stronger, and faster walkers are more likely to cross using undesignated paths [33, 35, 137].

Carrying bags and pets

People may behave differently when walking with a bag when choosing non-designated paths than when without a bag. In some cases, carrying a backpack may hinder someone from using non-designated paths containing obstacles; however, a heavy bag may cause them to choose the shortest path. For example, carrying bags is directly related to pedestrians' decisions to use zebra crossings in Malaysia, according to Al Bargi and Daniel [56]. Based on the observation of 2089 pedestrian red-light crossings across eight Kolkata city crosswalks, Raoniar, Maqbool [57] reported that pedestrians with luggage were more likely to violate traffic signal rules. A case study in India showed that pedestrians without belongings were less patient at red signals [59].

Along with the things that pedestrians carry, like bags, it is common for Australian pedestrians to walk with their dogs. Leashed dogs may cause pedestrians to behave entirely differently than regular pedestrians, such as to avoid traffic jams. According to Lanza, Burford [58], dog walkers may prefer a cycling path to a sidewalk due to its greater width and distance from other pedestrians.

Trip purpose and activity points

Trip activity points may affect street-crossing behaviours. A *trip activity point* is a stopping point on a pedestrian route, regardless of whether it is the final destination or another point along the route (e.g., a coffee shop). Walking to a coffee shop for leisure may not cause rushed behaviour, while walking to work may do so, particularly if switching between transportation modes is necessary. The shortest path is used more often than a designated path in these situations due to time constraints.

The purpose of a pedestrian's trip also influences their decisions. When people rush, they tend to jaywalk or cross undesignated paths, which means that they take greater risks than pedestrians walking for pleasure [49, 50]. Hamed [51] found that pedestrians who are not travelling to work wait 1.8 times longer at the curbsides of undivided roads before crossing than those who are. When crossing a divided road, pedestrians travelling for a non-work trip may wait up to three times longer than pedestrians going to work. Zhang, Wang [52] similarly observed that, compared with pedestrians walking to work/school, strollers are more likely to demonstrate safe crossing behaviour. People going to work or school usually want to minimise their travel time, so are more likely to ignore traffic rules when crossing the street.

Crossing style

Walking and running are two broad categories of pedestrian gait. Some pedestrians run while crossing the street to avoid a collision with oncoming vehicles. Pedestrians must sometimes increase their speed to avoid missing PT. Walking on non-designated paths is often accompanied by running behaviour. Goh, Subramaniam [36] showed that pedestrians who crossed illegally at non-signalled crosswalks walked 1.1 times faster, on average, than other pedestrians. Additionally, Guo, Liu [37] found that pedestrians crossing an intersection at the end of a "walk" phase crossed much faster than those crossing at the beginning of this phase.

Distractions

Distracting activities, such as using a mobile phone, may also influence people's decisions to use non-designated paths. When distracted, pedestrians may unintentionally follow other pedestrians on non-designated paths. For example, Zhuang and Wu [30] observed that nearly half of pedestrians were distracted while crossing the street. Distractors consist of talking on the phone, drinking, smoking, and carrying bags, which all slightly affect crossing behaviour. However, a few studies have found this factor to be negligible. For example, Shaaban, Muley [53] found that risky pedestrian crossing behaviour on a significantly divided arterial road in Qatar did not differ considerably between pedestrians carrying bags and those using cell phones.

Cultural influence

Cultural background may affect pedestrian decision-making and street-crossing behaviours. There may be a greater influence of this factor in some countries like Australia where, according to the 2021 census, 29.1% of the population was born overseas². Sueur, Class [60] examined the influence of culture on an individual's perception of risk when crossing a road by analysing the expected crossing duration. A study was conducted in two cities in Japan and France to observe pedestrian behaviour. It was observed that French pedestrians were more risk-averse than Japanese ones, with males being more risk-averse than females in Japan. Shaaban, Muley [53] classified foreign and non-foreign pedestrians according to their clothing in Qatar. People wearing traditional clothing were assumed to be Qatari nationals, while all others were assumed to be foreigners. Observations revealed that foreigners and natives had different crossing behaviours, perhaps due to their different cultural backgrounds. According to Hirschi and Gottfredson [61], social punishment may have a stronger effect on behaviour than formal punishment, which is closely related to culture.

Safety perception

For many pedestrians, the fear of crime is a more significant problem than the crime itself [62]. The fear of crime may affect people's behaviour more than actual crime and restricts their mobility [63]. Crime-reducing features aren't necessarily the same as those that reduce fear [64], and places with the highest crime rates are not necessarily places where people feel most safe. There may be a feeling of safety when walking along more crowded paths to railway stations, yet crime is likely to be more prevalent. In Sweden, 42% of young women changed their routes or travel means due to fear of being victimised by crime, according to the Swedish National Council for Crime Prevention (2019). Due to the direct impact of safety perceptions on travel behaviour, ensuring people's safety is essential. There has been an extensive study of the effects of demographics on fear of crime, and it has been noted that people with physical illnesses or disabilities, and women and the elderly are all more worried about their safety [65-67]. People are more likely to feel unsafe travelling to PT stations than riding PT; this implies that path characteristics are essential [68]. Most studies have examined the characteristics of the paths to stations. Still, Schneider, Krueger [48] suggested that passengers are more likely to leave the safety zone and the safe walkways in order to avoid the uncomfortable feeling in the crowded stations. This may cause passengers to take risks due to an uncomfortably high density of passengers.

In addition to the characteristics discussed above, which almost all relate to pedestrian behaviour, some factors that may influence pedestrian behaviour are under the control of authorities such as urban designers and traffic controllers [94, 95]. It is, therefore, very important to consider factors that can be controlled to improve the services provided to PT and infrastructure users. Many factors can

² <https://www.abs.gov.au/statistics/people/population>

play a role in this, including traffic signs [96], the use of traffic calming measures to prevent speeding and other unsafe driving behaviours [138] and stop lights [49] and their timing.

Traffic-related factors

Besides the factors discussed previously, other factors are closely related to traffic, including the number and speed of vehicles in the street. Additionally, vehicle size and congestion level may also influence pedestrians' perception of street safety.

Traffic-related factors:

- Road congestion causes pedestrian violations to decrease significantly.
- Pedestrians avoid crossing roads illegally when large and heavy vehicles are present.
- Public perception may affect pedestrian behaviour in the presence of driverless cars.
- Services provided by the PT system may influence pedestrian behaviour.

Congestion and pedestrian gap acceptance behaviour

In most previous studies, it has been shown that congestion on roads significantly reduces risky pedestrian behaviour or the use of non-designated paths [69-71]. Insufficient gaps between vehicles in congested conditions hinder pedestrians from crossing illegally. According to other studies, the probability of crossing in a traffic gap depends on the pedestrian's age and how long they wait before crossing [30, 31]. Oxley, Ihsen [25] explored illegal behaviour in three age groups based on the gaps available in a one-way street. They found that pedestrians aged 60–69 years were more likely to jaywalk when there was a significant gap between approaching vehicles. In more than 70% of the cases, pedestrians older than 75 years accepted gaps that were riskier, raising questions about their visual ability, processing speed, and reaction time.

Vehicle speed

The frequency of risky pedestrian behaviour or use of non-designated paths has also been assessed in relation to vehicle speed [20, 72, 73]. Most studies have noted that average vehicle speed is another traffic-related factor influencing pedestrian behaviour. Several experiments have revealed that the pedestrian behaviour used in choosing a non-designated path or crossing illegally in relation to vehicle speed varies by age [26, 32]. For example, Lobjois & Cavallo (2007) found that elderly people chose larger gaps than younger ones, perhaps due to their slower walking speed, allowing them to compensate for their longer crossing times. In contrast, other studies found no correlation between vehicle speed and risky pedestrian behaviour or use of non-designated paths according to age [25, 74]. Consequently, there are conflicting results, meaning that in different conditions and locations, pedestrians may exhibit different behaviours. This highlights the importance of case studies in studying pedestrians' behaviour.

Street fleet composition and on-street parking

Studies have also explored whether vehicle type affects pedestrian behaviour. The findings of such studies show that pedestrians avoid a risky crossing in the presence of heavy and large vehicles by waiting longer on the curbside [30, 75]. Furthermore, previous studies indicate that parked vehicles near crosswalks cause pedestrians to violate the rules. On-street parking near crosswalks increases risky behaviour or non-designated paths use, largely because approaching vehicles are less visible to pedestrians. Mukherjee and Mitra [76] found that the presence of a parked vehicle or other obstacles will more likely make pedestrians to walk across them.

PT services

Those travelling by PT, particularly in Australia, are frequently required to change travel modes or services. As pedestrians switch from one service to another depending on the available time, they may behave differently. As an example, a train passenger arriving in the CBD from the outer suburbs may have to switch to a light rail line to get to their destination, so a non-designated path may be chosen to avoid missing their next service. Pedestrians have been shown by Zhang, Wang [52] to accept riskier crossings to avoid missing a bus. In most cases, using non-designated paths is associated with higher speed and not paying attention to traffic [52]. At a busy intersection in Vancouver, Canada, 67% of those who used non-designated paths were trying to catch buses at a bus stop located at the southwest corner of an intersection [80]. Mukherjee and Mitra [77] observed that the use of non-designated paths was not affected by the presence of bus stops at intersections. According to other studies, the number of bus stations within a predefined buffer zone is positively related to risky pedestrian behaviour or non-designated path use. According to Pulugurtha and Repaka [78], the significant buffer value was 30 m, while Ghomi and Hussein [79] found it to be 50 m. According to Ghomi and Hussein [79], bus frequency has positive impacts on both non-designated path use or red-light crossings and the severity of collisions caused by illegal behaviour or non-designated path use. In an environment where buses are more frequent, pedestrians are less stressed about catching a bus as the wait for the next bus is shorter. Furthermore, this factor can be examined from a different perspective. The possibility of illegal crossing behaviour or the use of a high-risk non-designated path may be avoided when the time interval between two consecutive services is relatively short. However, when there is a lengthy gap between services, pedestrians may take a risky path to avoid missing the next service.

The presence of driverless cars

The emerging technologies like driverless cars have opened new opportunities in transportation research. However, their influence on pedestrian behaviour in choosing a non-designated path to avoid such vehicles, or trusting these vehicles for safety when they are crossing the street illegally, has not been adequately explored thus far. It becomes important when many large cities in developed nations, particularly those in Australia, are implementing emerging vehicle technologies, such as automated bus shuttles and driverless trams, into their transportation plans. Driverless cars are predicted to become commercially available in the near future, with promises of increased traffic safety and traffic flow efficiency. Fully automated vehicles are anticipated to have fewer collisions than human-driven vehicles, since human error will be eliminated [81-83]. There may be, however, unsafe situations where road users, including pedestrians, interact with driverless cars. For instance, if driverless cars fail to behave as expected or are misunderstood by pedestrians and others.

Several studies suggest that pedestrians may have a greater concern about interacting with driverless vehicles than they do with a human-operated vehicle due to the lack of meaningful eye contact or the absence of driver gestures that indicate their intention. A stated preference survey found that cyclists and pedestrians are more likely to prefer segregated facilities in the presence of autonomous vehicles [84]. An earlier study by Merat, Louw [85] supports these findings. Some 665 pedestrians were interviewed about their demographics, perception of safety and priority in shared spaces, acceptance and use of technology, and communication style when interacting with driverless cars. Pedestrians wanted to know how driverless cars behave and to be sure that they are detected by them. They observed that traditional signals, like horns and lights, are desired by pedestrians over text messages or verbal remarks by driverless cars.

A study conducted by Rothenbücher, Li [86] investigated 67 pedestrian interactions with a driverless vehicle. It was surprising to find that pedestrians were able to react normally despite believing the car was fully automated. During the interview, pedestrians used words such as "safe", "deliberate", and "smooth" to describe the behaviour of the vehicles. There were only a few pedestrians who hesitated to cross when a vehicle behaved unusually. Furthermore, Palmeiro, van der Kint [87] found no difference between pedestrians' critical acceptance gap and reported stress levels when interacting with driverless cars. According to Razmi Rad, Homem de Almeida Correia [88], pedestrians' crossing decisions are heavily influenced by their age, familiarity with driverless cars, communication with the driverless cars, and whether the approaching vehicle is an AV, in addition to the distance from the approaching vehicle and the existence of a zebra crossing. Despite this, Rothenbücher, Li [86] and Palmeiro, van der Kint [87] found that pedestrian reactions to fake driverless cars were surprisingly 'normal' and identical to those to conventional vehicles. Thus, more research is required to extend our understanding of crossing behaviour in the presence of driverless cars.

Location-specific factors

Location-related factors may also affect pedestrian behaviour significantly. This group of factors includes the characteristics of roads and neighbouring areas. For example, the number of risky pedestrian behaviours or non-designated path uses has also been found to decrease significantly at roads with more lanes [79, 139, 140]. Various explanations have been provided for these findings. Based on Petritsch, Landis [141], pedestrian

Location-specific factors:

- There is evidence that pedestrians' behaviour is influenced by location-specific factors.
- Pedestrian behaviour in using undesignated paths is correlated with signal timing.
- A higher number of lanes may reduce unsafe pedestrian manoeuvres.
- Unilluminated locations have less illegal behaviour and non-designated path use.

perceptions of intersections vary according to the number of lanes, with more lanes making them seem more hazardous and unsafe. It is, therefore, preferable for pedestrians to obey the traffic rules and only cross such intersections during designated times. The likelihood of illegal behaviour by pedestrians is lower at locations with more traffic lanes, which are generally major roads with high traffic volumes. Despite this, Ren, Zhou [27] did not find a significant correlation between the number of lanes and the number of illegal pedestrian crossings.

Central refuge islands

For many pedestrians, crossing the street is a complex task. Vehicle speeds must be estimated, walking speeds adjusted, gaps sized properly, vehicle paths predicted, and crossing times determined by pedestrians. Pedestrian can pause half-way across a road with a refuge island and raised medians. As a result, crossing becomes significantly simpler. Medians are areas between opposing lanes of traffic; they can either be open (pavement markings only) or channelized (raised medians or islands). There is a 46% reduction in crashes with pedestrians when raised medians are provided at marked crosswalks. The number of accidents involving pedestrians at unmarked crosswalks is reduced by 39% [89]. The availability of median strips may influence pedestrians' behaviour in using non-designated paths. Although studies that have found that central refuge islands provide significant safety benefits, they have also shown that pedestrians exhibit riskier crossing behaviours when they are present. A central refuge island at a location where pedestrians need to wait for a long period to cross the road may drastically reduce compliance with traffic signals [90]. Pedestrians don't have to wait for an

adequate gap in both directions if they can wait in a median for a gap in a single direction [91]. According to Cao, Ni [92], median width increases the likelihood of illegal pedestrian behaviour by 15% for every 1% increase in median width. Also, Xu, Li [93] found that pedestrian infrastructure at intersections, such as medians, prevented rule-breaking.

Street Illumination

Risky pedestrian behaviour and road lighting have also been found to be directly related. In contrast to locations with illumination, Zhang, Tan [102] found that pedestrians' illegal behaviours or non-designated path use were lower at unilluminated locations.

Signal timing

Many studies, all reported that proper signal design reduces pedestrian delays, which decreases risky pedestrian behaviour and non-designated path use [38, 97, 98]. Several signalized two-stage intersections in Hong Kong were analysed by Zhu and Sze [34]. Using a logit model, the study investigated whether refuge islands are associated with risky pedestrian behaviour or non-designated path use. When a green signal for the second stage of the crossing is displayed, pedestrians' tendency to cross the first stage during a red signal rises considerably. Further, other studies have demonstrated that increasing pedestrian walk times (signal clearance) reduces the frequency of illegal behaviour or non-designated path use [27, 42]. There is also controversy in the literature regarding the impact of countdown signals at intersections on pedestrian behaviour. Countdown signals have been shown to improve pedestrian behaviour and increase safety in several studies [99]. When pedestrians know the time remaining in a signal phase, they can adjust their walking pace so that they can cross during that time without causing conflicts with vehicles moving in the next phase. Another study found that countdown signals promoted risky pedestrian behaviour [29]. Pedestrians were more likely to cross illegally if the time remaining for the "Do Not Walk" phase was displayed.

It is widely documented that waiting time is a significant factor in crossing behaviour [142]. Two perspectives can be considered when choosing a non-designated path. One is the waiting time for a red signal. A number of researchers have investigated pedestrian behaviour when waiting for red signals. Nevertheless, pedestrians sometimes cross the street via a non-designated path rather than wait for a red signal.

Another type of waiting time occurs when there are no traffic lights or zebra crossings and pedestrians must pass through gaps between vehicles. The pedestrians' perception of crossing risk and the speed of the vehicles may influence the waiting time in these conditions. Several studies have suggested that pedestrians' illegal behaviour or non-designated path-use decisions at signalized intersections are greatly affected by the actual waiting time (i.e., between when they arrive at a crosswalk and start crossing it) and the maximum waiting time (i.e., between arriving at a crossing and when the red signal ends). Prior studies have demonstrated a higher likelihood of risky pedestrian behaviour or non-designated path use when there are longer curbside waiting times.

Several studies show that pedestrians who wait longer to cross often accept smaller traffic gaps between oncoming vehicles, contributing to collision risk. Using logistic regression, Koh and Wong [143] investigated pedestrian crossing behaviour in Singapore. It was reported that the gaps between oncoming vehicles accepted by violators were much shorter than those of non-violators. A study conducted by Russo, James [131] in New York and Arizona utilized an ordinal regression model to study the behaviour of pedestrians at four signalized intersections. A longer waiting time was associated with a higher rate of recurrence of illegal behaviour or non-designated path use. Pedestrian crossing behaviours at seven signalized intersections in Delhi, India, were evaluated by Tiwari, Bangdiwala [98]. Pedestrian illegal behaviour or non-designated path use increased with waiting times

for prolonged red phases. In another study, Brosseau, Zangenehpour [42] examined pedestrian illegal behaviour or non-designated path use at thirteen signalized intersections in Montreal, Canada using a logistic regression model. According to the results, risky pedestrian behaviour or non-designated path use and maximum waiting time had strong direct relationships. Guo, Gao [38] study of seven crosswalks in China found the same illegal behaviour and use of non-designated paths.

The signal timing factor can be viewed from a different perspective. Pedestrians' behaviour may be affected by the timing and distance of a street crossing. A pedestrian's perception of avoiding a non-designated path increases as distance and exposure to risk increase. According to several studies, such as [100], longer crosswalks result in more spatial and illegal behaviour or non-designated path use. In Changchun, China, Cao, Qu [144] collected video recordings of pedestrians' spatial illegal behaviour or non-designated path use at seven signalized crosswalks. They found a strong correlation between crosswalk length and pedestrian spatial illegal behaviour or non-designated path use.

A small number of studies, however, found no correlation between crosswalk length and illegal pedestrian behaviour or non-designated path use. The study by Ren, Zhou [27] analysed pedestrian behaviour at signalized intersections with crosswalk lengths ranging from 8.5 to 23 m. They did not find any correlation between crosswalk length and the frequency of illegal behaviour or non-designated path use. An analysis of video data collected at two signalized intersections with different crosswalk lengths in Nanjing city, China, was conducted by Wu, Guo [101]. Using a Bayesian Poisson-lognormal model, the study found that longer crosswalks may increase illegal behaviour or intentions to use non-designated paths.

It is, however, difficult to conclude that crosswalk length definitely influences illegal crossing behaviour, mainly because other factors, such as enforcement level or cultural behaviour, have not been identical across the two groups of studies.

Weather and time-of-day factors

Weather conditions are another factor that may influence the behaviour of pedestrians. In rainy weather, pedestrians may choose to use non-designated paths to avoid becoming wet. The severity of the weather conditions has been associated with the frequency of risky pedestrian behaviour or non-designated path use in many studies [105, 106]. As a result of

adverse weather conditions, drivers decrease their speed and increase attention on the road; however, pedestrians show riskier behaviour.

Weather and time-of-day factors:

- Significantly more pedestrians choose undesignated paths or cross the road illegally during peak hours than in off-peak hours.
- Non-designated path use and illegal crossing are positively correlated with adverse weather conditions.

A study by Li and Li and Fernie [91] found that pedestrians were much more likely to obey pedestrian signals during clear weather than during harsh weather. In extremely cold weather or during a thunderstorm, one may have to wait for a long time to cross an intersection. Pedestrians may use non-designated spaces or phases of an intersection to reduce their waiting time or reach their destination faster. The risk of a collision with a vehicle increases due to reduced visibility and tyre grip.

Based on Bargegol, Najafi Moghaddam Gilani [107] findings, pedestrians in normal weather conditions and those in rainy weather have different walking speeds. Liang, Leng [108] studied how weather and climate affect pedestrian walking speeds during cold and cool seasons in severely cold areas using computer vision technology. According to them, weather conditions affect pedestrian

behaviour significantly; therefore, designs of urban spaces that involve pedestrians should consider this. As weather conditions affect driver behaviour, such as by making them reduce speed, the behaviour of pedestrians may be impacted as well. For example, the risk of single-vehicle collisions increases significantly in Australia due to increased aggressiveness and impatience among drivers during extreme heat [109].

A few studies have examined pedestrians' illegal behaviour or non-designated path use at different times of day. Wang, Guo [111] studied pedestrian crossing behaviour at five intersections in Beijing, China. Pedestrians were more likely to violate the law during peak hours. Zhang, Tan [102] showed that, compared with night-time when there is inadequate road illumination, there is Zhang et al. (2016a) a lower probability of risky pedestrian behaviour or non-designated path use during the day. Pedestrians' crossing decisions can also be influenced by seasonal factors such as time of day and day of the week. According to data from the Federal Highway Administration (2004), 62% of pedestrian injury accidents happen at night. Also, pedestrian red-light violations are higher on weekends and holidays [110].

Furthermore, brightness may be a factor to consider, depending on the time of day. Researchers have shown that both brightness and viewability can enhance the quality of public spaces or change the behaviour of pedestrians, particularly when it comes to safety perception and path selection. During the night, lighting and its brightness play very important roles in subjectively experiencing safety and security. As a result, light makes public spaces feel welcoming and creates a positive experience. In three public districts in the UK, Painter [103] demonstrated this by improving street lighting. At night, pedestrians used these public streets significantly more frequently than before in all three settings (the numbers of women and men increased from 45% to 71% and from 34% to 101% respectively), suggesting that subjective safety perceptions increased and crime decreased. Donker, Kruisheer [104] examined the effect of lighting conditions on pedestrian walking speed. They found that walking speed increased as a result of low lighting, which indicates pedestrian discomfort.

Built environment factors

Non-designated path use may occur when the alternative route has certain desirable properties, or when the shortest-path route has undesirable properties [112, 117, 120]. In previous research, a variety of variables have been considered that might explain pedestrian route choice.

It has been shown that environmental factors such as sidewalk width, pedestrian density and flow, turn number, and climate comfort influence pedestrian route choice most of the time [112, 113, 121, 122, 125, 145].

Built environmental factors:

- Pedestrian behaviour may be influenced by the features of PT stations, such as permeability.
- Pedestrian-friendly land use can influence where pedestrians walk according to their trip purpose.
- The majority of pedestrians in big cities choose familiar routes.
- The availability of sheds may alter route choices.

It is also important to consider infrastructure variables such as the number of road crossings, the number of ascending steps, the presence of crosswalks or overpasses, and traffic speed and volume, as they reflect potential conflict points between pedestrians and motorists and also affect the safety perceptions of pedestrians [112-114, 121, 122]. There may be characteristics that influence the likelihood of a route being chosen by virtue of its attractiveness, such as the number of shops or amenities along the route, vegetation or parks, transit accessibility, or exposure to public places [112-114].

In addition to neighbourhood terrain, individuals are less likely to walk on hilly routes with significant elevation gains [114, 116]. In warmer climates, this is particularly true. Weather can also moderate pedestrian activity by increasing the propensity to take shorter trips or use sheltered routes during adverse weather conditions, such as extreme heat, rain or snow. Moreover, the path that a pedestrian takes can be influenced by a number of subjective factors that are highly correlated with the built environment, such as the perceived safety of the area, the level of comfort and familiarity, and the presence or absence of noise [114, 125].

Pedestrian behaviour is also affected by the features of PT stations. PT stations must offer enough space for waiting passengers, as well as those boarding and alighting. It is also possible for poor provision of space during peak periods at busy stops to impact passengers' perception of their journey and safety, as it can lead to unsafe behaviour. Permeability is an important factor that may influence pedestrian behaviour. All PT stops are intended to provide a minimal effort path between PT services and the adjacent public realm (e.g., with minimal barriers, walls or changes in level).

Besides the factors that are frequently discussed in the literature regarding the impacts of the surrounding station area on PT users' behaviour, some other factors are also important but have not been fully researched.

Features of sidewalks

According to most studies, pedestrians prefer routes that have wide, continuous sidewalks on both sides [117]. Shatu and Yigitcanlar [118] observed that students most often choose routes with good sidewalks. In addition, pedestrians prefer streets with sidewalks on both sides for convenience and safety [119]. According to Liu, Yang [120], pedestrians prefer a wider sidewalk. Additionally, pedestrians tend to take a slightly longer path if the sidewalk is wider than the usual 1.5 m width and is reasonably separated from traffic [121].

Flat routes may be preferred by pedestrians in general. It appears that older adults prefer to avoid walking routes with gradients as they are more physically demanding [112]. Very steep and uphill terrain is perceived as a barrier.

A study by Muraleetharan and Hagiwara [121] found that pedestrians choose routes not only based on distance but also based on the overall level of service (LOS) provided by sidewalks and crosswalks. Pedestrians use sidewalks and crosswalks with a high LOS when travelling longer distances away from the shortest path. A pedestrian on a short route is less likely to avoid sidewalks or crosswalks with a low LOS.

Olszewski and Wibowo [122] investigated influences on passengers' choice of walking route to Mass Rapid Transit (MRT) stations and developed a method of assessing nearby walking conditions in Singapore. Aside from the actual distance, factors such as road crossings, traffic conflicts, and ascending steps significantly influenced the choice of access mode.

A study by Shatu, Yigitcanlar [146] revealed that pedestrians in Brisbane, Australia prefer routes that require the least amount of directional change. A study by Koh and Wong [147] compared segments of the actually taken and shortest possible routes, finding that comfort, shops, and scenery were significant factors in choosing a favourite walking route.

Studies have also shown that urban areas with larger residential blocks promote jaywalking. Jaywalking behaviour was studied by Chu, Guttenplan [123] at 48 blocks in Florida by surveying pedestrians and conducting observational studies. Risky pedestrian behaviour or non-designated path use was found to increase when larger blocks were present, particularly near major bus stops. A study

conducted by Oakes, Forsyth [124] in Minneapolis, Minnesota, found that longer block sizes resulted in a 40% greater possibility of jaywalking in residential areas.

The density of trees appears to be positively correlated with pedestrian walking distance [126] and safety perception [148]. Zhu, Sze [149] evaluated the effect of tree density and canopy cover on pedestrian injuries based on comprehensive pedestrian count data from Melbourne, Australia. The results show that pedestrian casualties decreased when pedestrian crosswalk number and canopy density increased. Bafatakis, Duives [115] noticed that young pedestrians were more likely to take routes passing modern commercial and residential structures.

Familiarity and pathfinders

Pedestrians' familiarity with the environment has not been notably discussed in the literature. Google Maps and similar platforms may provide non-familiar users with official routes rather than non-designated routes. Furthermore, it has been shown that pedestrians are more inclined to walk familiar routes. For example, Guo and Loo [145] stated that pedestrians in New York City and Hong Kong city mostly choose familiar routes.

Appendix B: Descriptive Survey Statistics

Online Survey

In this section, the detailed descriptive statistics of the online survey are presented. The collected data were compared with the Australian Bureau of Statistics 2021 Census³, and as presented in Table B. 1, has relatively a good representation of the population of Greater Melbourne.

Table B. 1: Sample data compared with the Census 2021 of the Greater Melbourne area

		Census 2021	Field observations	Online survey
Gender	Female	51%	52%	54%
	Male	49%	48%	46%
Age	15-19 years	7%	47%	7%
	20-24 years	8%		22%
	25-34 years	20%		41%
	35-44 years	18%		13%
	45-54 years	16%	48%	8%
	55-64 years	13%		5%
	65-74 years	10%		3%
	75-84 years	6%		Less than 1%
	85 years or older	2%	3%	Less than 1%

Age and Gender

The survey has responses from individuals in 9 age groups ranging from 15-19 years to 85 years or older. The 25-34 years age group had the highest representation among the respondents, accounting for 41.27% of the total responses. This was followed by the 20-24 years age group, which represented 21.70% of the respondents. The remaining age groups had the following percentages of respondents, 15-19 years: 7.08%, 35-44 years: 13.44%, 45-54 years: 7.55%, 55-64 years: 4.95%, 65-74 years: 3.07%, 75-84 years: 0.47%, 85 years or older: 0.47% . In terms of gender, 52.83% of the respondents identified

³ <https://www.abs.gov.au/census/find-census-data/quickstats/2021/2GMEL>

themselves as female, 45.75% identified as male, and 1.42% identified as others. The results suggest that the survey was reasonably diverse in terms of gender representation (see Figure B. 1).

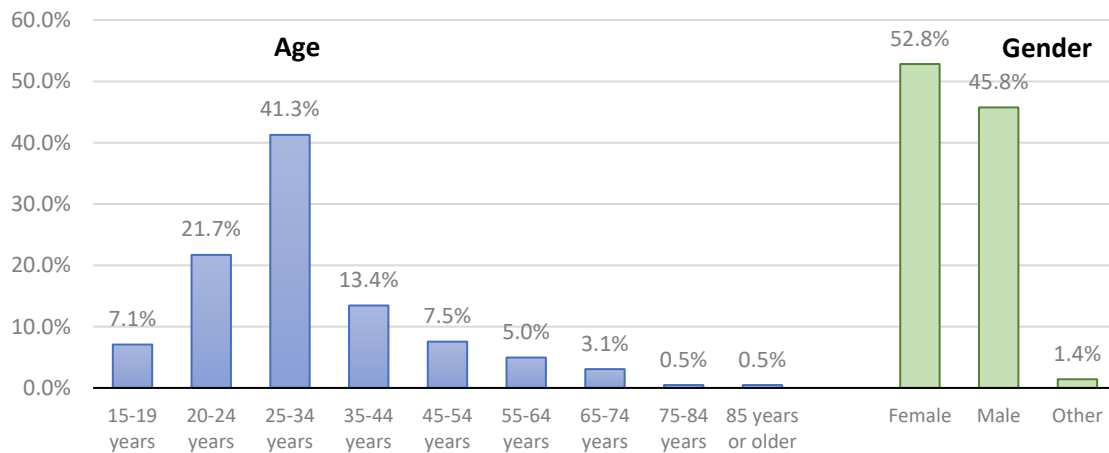


Figure B. 1: Age and gender distribution of survey respondents

Cultural background

Out of all the respondents, 62.03% reported that they were Melbourne residents, while 27.59% were not Melbourne residents. The remaining 10.38% of respondents were tourists from other countries who were visiting Melbourne. Figure B. 2 presents the breakdown of the surveyed population by ethnicity. The majority of the respondents identified as Australian (34.43%), followed by Asian (40.33%), European (12.03%), and New Zealanders (4.72%). Other ethnicities, including African, Indigenous Australian or Aboriginal Torres Strait Islander, Middle Eastern or West Asian, North American, and South American, each made up less than 3% of the surveyed population.

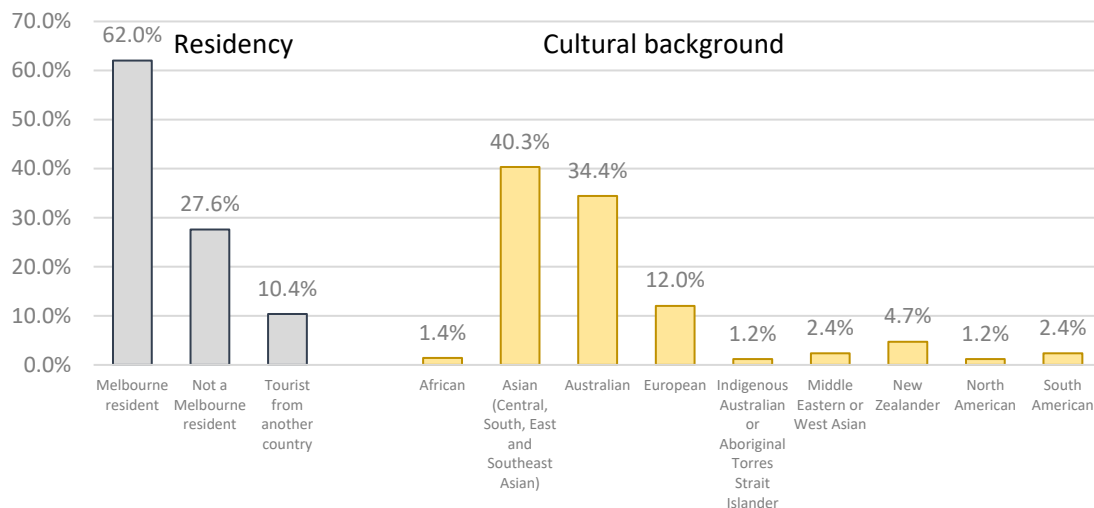


Figure B. 2: Residency and cultural distribution of survey respondents

Education, PT use frequency, and mobility characteristics

Among the respondents, 35.61% held a postgraduate degree, 39.15% held an undergraduate degree, 7.55% held a TAFE qualification, and 17.69% held a Year 12 certificate or lower. In addition, the

respondents revealed their frequency of using PT as: 48.58% used it daily, 37.50% used it between two to four days per week, 6.37% used it once a week, and 7.55% used it once a month. Out of all the pedestrians, 92.69% reported having no disability or mobility impairment, while 4.01% reported having a disability, and 3.30% reported experiencing reduced mobility due to walking, visual, or hearing impairment. Figure B. 3 presents the breakdown of percentages.

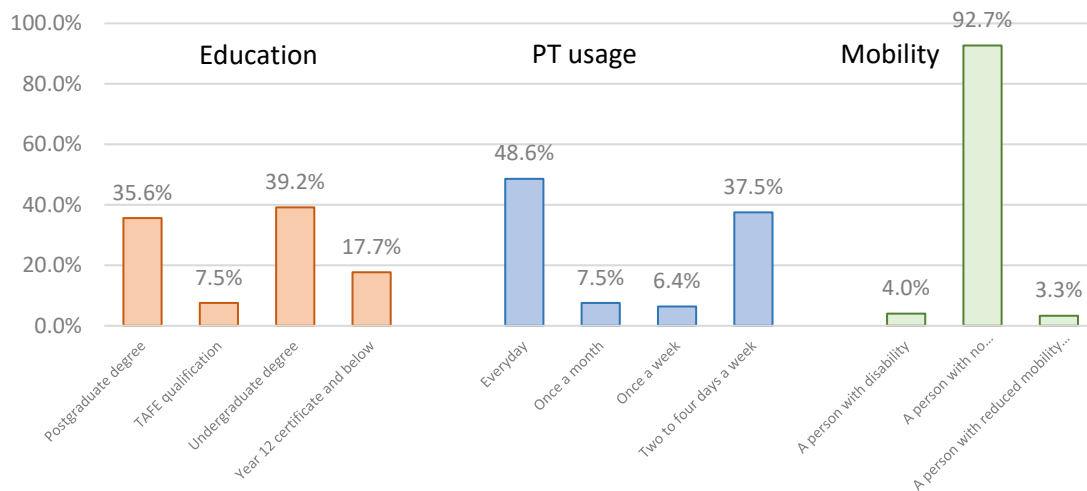


Figure B. 3: Education, PT usage and mobility

Familiarity, trip purpose, the value of time assessments

Of all the respondents, 83.73% reported that they were familiar with the area, while 16.27% reported the opposite. This question aimed to assess the respondents' knowledge of the area being surveyed.

The respondents reported their trip purposes as follows: 52.83% reported going to work or study, 20.52% going for shopping, restaurant, or recreation purposes, 19.81% getting back home, and 6.84% making a short visit to a nearby location before continuing with their original trip, such as grabbing a coffee.

Out of all the respondents, 53.77% reported that they were not in a hurry when travelling in the surveyed location, while 46.23% reported that they were in a hurry (Figure 8.c).

The respondents reported their income levels as follows: 25.24% earned between \$1,200 - \$1,810 per week (equivalent to \$60K - \$95K per year), 21.23% earned between \$750 - \$1,200 per week (equivalent to \$40K - \$60K per year), 17.22% earned between \$376 - \$750 per week (equivalent to \$20K - \$40K per year), 15.09% earned \$2,645 or more per week (equivalent to \$135K or more per year), 9.91% earned \$375 or less per week (equivalent to \$20K or less per year), and 11.32% reported earning no income. Figure B. 4 presents the breakdown of shares in each category.

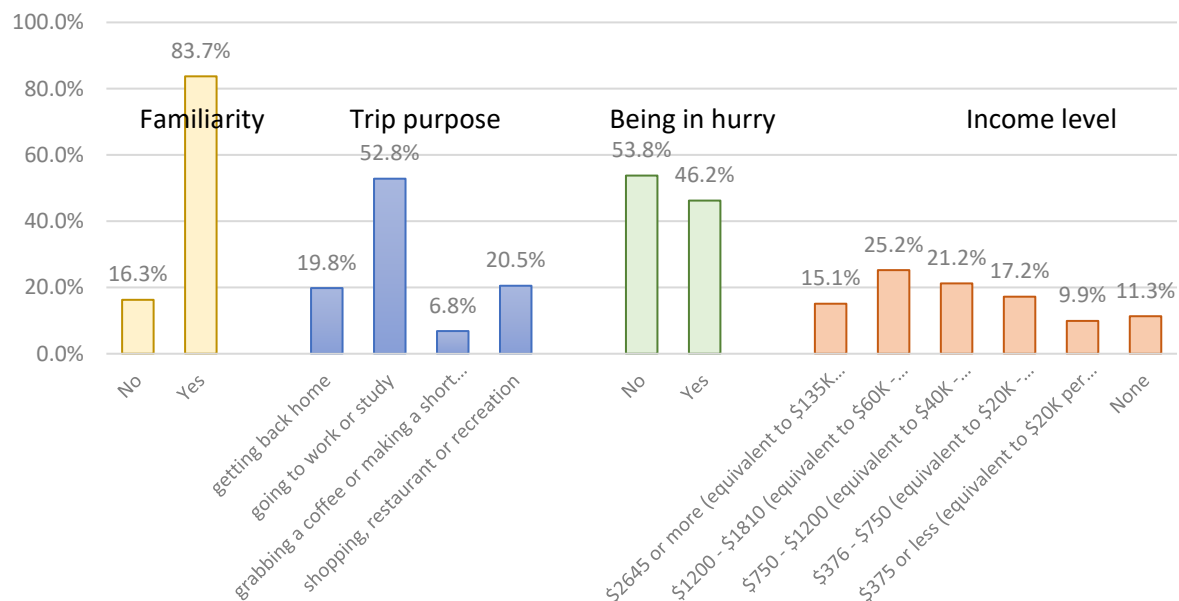


Figure B. 4: Familiarity with the surveyed area, trip purpose, being in hurry, income level distribution of the survey respondents

Table B. 2 presents all of the descriptive statistics for respondents' characteristics.

Table B. 2: Descriptive statistics of the pedestrian characteristics.

variable	Classification	Count	Proportion (%)
Which of the following age groups do you belong to?	15-19 years	30	7.08%
	20-24 years	92	21.70%
	25-34 years	175	41.27%
	35-44 years	57	13.44%
	45-54 years	32	7.55%
	55-64 years	21	4.95%
	65-74 years	13	3.07%
	75-84 years	2	0.47%
	85 years or older	2	0.47%
How do you describe your gender?	Female	224	52.83%
	Male	194	45.75%
	Other	6	1.42%
Which group do you belong to?	Melbourne resident	263	62.03%
	Not a Melbourne resident	117	27.59%
	Tourist from another country	44	10.38%
Which cultural background do you belong to?	African	6	1.42%
	Asian (Central, South, East and Southeast Asian)	171	40.33%
	Australian	146	34.43%
	European	51	12.03%
	Indigenous Australian or Aboriginal Torres Strait Islander	5	1.18%
	Middle Eastern or West Asian	10	2.36%
	New Zealander	20	4.72%
	North American	5	1.18%
	South American	10	2.36%
What is the highest level of education you have completed?	Postgraduate degree	151	35.61%
	TAFE qualification	32	7.55%
	Undergraduate degree	166	39.15%
	Year 12 certificate and below	75	17.69%
How often do you use public transport?	Everyday	206	48.58%
	Once a month	32	7.55%
	Once a week	27	6.37%
	Two to four days a week	159	37.50%
How do you describe yourself?	A person with disability	17	4.01%
	A person with no disability/mobility impairment	393	92.69%
	A person with reduced mobility (e.g., walking, visual or hearing impairment)	14	3.30%
What is your average weekly income?	\$1200 - \$1810 (equivalent to \$60K - \$95K per year)	107	25.24%
	\$2645 or more (equivalent to \$135K or more per year)	64	15.09%
	\$375 or less (equivalent to \$20K per year or less)	42	9.91%
	\$376 - \$750 (equivalent to \$20K - \$40K per year)	73	17.22%
	\$750 - \$1200 (equivalent to \$40K - \$60K per year)	90	21.23%
	None	48	11.32%
Are you familiar with this area?	No	69	16.27%
	Yes	355	83.73%
What is your trip purpose?	getting back home	84	19.81%
	going to work or study	224	52.83%
	grabbing a coffee or making a short visit to a nearby location before continuing to my original trip	29	6.84%
	shopping, restaurant or recreation	87	20.52%
When travelling in the surveyed location, were you in hurry?	No	228	53.77%
	Yes	196	46.23%

Field Observations

In this section, the detailed descriptive statistics of field observation are presented. Table B. 3 presents the descriptive statistics of pedestrian characteristics for two selected locations.

Table B. 3: Descriptive statistics of the pedestrian characteristics.

		Burke and Russel St. junction				Queensbridge at Crown			
		Safe path	unsafe path	Safe path	unsafe path	Safe path	unsafe path	Safe path	unsafe path
		No	No	%	%	No	No	%	%
Gender	Male	1195	701	63%	37%	120	159	43%	57%
	Female	1438	663	68%	32%	123	145	46%	54%
Age	Younger than 18	46	17	73%	27%	15	25	38%	63%
	Young	1253	659	66%	34%	102	116	47%	53%
	Mid-age	1255	664	65%	35%	98	144	40%	60%
	Senior	79	24	77%	23%	28	19	60%	40%
weather	Sunny	802	407	66%	34%	69	49	58%	42%
	Cloudy	1607	700	70%	30%	166	198	46%	54%
	Rainy	202	93	68%	32%	7	16	30%	70%
	Windy	22	164	12%	88%	1	41	2%	98%
Day	Monday (30-Jan 2023)	320	208	61%	39%	77	42	65%	35%
	Tuesday (31-Jan 2023)	522	230	69%	31%	72	30	71%	29%
	Wednesday (1-Feb 2023)	542	267	67%	33%	77	42	65%	35%
	Thursday (2-Feb 2023)	332	202	62%	38%	9*	96*	9%	91%
	Friday (3-Feb 2023)	343	171	67%	33%	8*	94*	8%	92%
	Saturday (4-Feb 2023)	287	127	69%	31%	-	-	-	-
	Sunday (5-Feb 2023)	287	159	64%	36%	-	-	-	-
Time	Morning Peak (7-9)	545	390	58%	42%	72	151	32%	68%
	Morning off-peak (9-11)	653	244	73%	27%	46	38	55%	45%
	PM Peak (4-6 PM)	991	537	65%	35%	96	91	51%	49%
	Evening (7-8 PM)	444	193	70%	30%	29	24	55%	45%
Mobility	Disable	11	1	92%	8%	1	0	100%	0%
	Mobility impairment	22	10	69%	31%	6	3	67%	33%
	Pram/trolley	43	9	83%	17%	11	3	79%	21%
	Walking with small children	61	8	88%	12%	14	3	82%	18%
	Walking with pet	4	1	80%	20%	2	1	67%	33%
	Carrying a heavy bag	124	69	64%	36%	19	8	70%	30%
	Business attire	335	202	62%	38%	48	50	49%	51%
	Mobility impairment related to obesity	58	39			16	11		
				60%	40%			59%	41%
Walking speed	Walking fast	129	192	40%	60%	47	178	21%	79%
	Running	97	148	40%	60%	12	54	18%	82%
	Walking with somebody	911	309	75%	25%	48	41	54%	46%
	Mobile phone use	244	100	71%	29%	34	34	50%	50%
Flow with/against	Flow with	873	102	90%	10%	104	60	63%	37%
	Flow against	108	9	92%	8%	16	15	52%	48%

*Note: The field observations were biased towards unsafe crossing behaviours at the Queensbridge site on Thursday and Friday due to changes in the number of survey staff on that site on those two dates.

Gender

According to the data provided, 63.03% of male pedestrians used safe paths on Russel St, while 36.97% used unsafe paths. This suggests that a majority of male pedestrians on Russel St are using safe paths to cross the street. Observations show that on Russel St, 68.44% of female pedestrians used safe paths while crossing the St, and 31.56% of female pedestrians used unsafe paths. On the Crown site, 43.01% of male pedestrians used safe paths while crossing the street, and 56.99% of male pedestrians used unsafe paths. For female pedestrians on the Crown site, 45.90% used safe paths while crossing the St, and 54.10% used unsafe paths (see Figure B. 5).

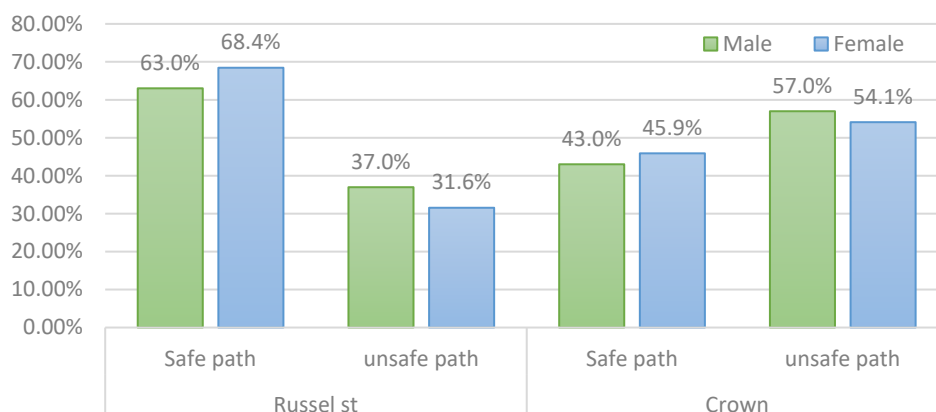


Figure B. 5: Comparison of safest and unsafe path usage across gender categories

Age

On the Russel site, the data shows that the percentage of pedestrians using safe paths varied by age group. The highest percentage of safe path usage was among senior pedestrians, with 76.70% using safe paths while crossing the street. The next highest percentage of safe path usage was among pedestrians younger than 18, with 73.02% using safe paths. The percentage of safe path usage was similar for young and mid-age pedestrians, at around 65%. Among pedestrians younger than 18, 37.50% used safe paths while crossing the street on the Crown site. The percentage of safe path usage was higher for young pedestrians, with 46.79% using safe paths. Senior pedestrians had the highest percentage of safe path usage, with 59.57% using safe paths (see Figure B. 6).

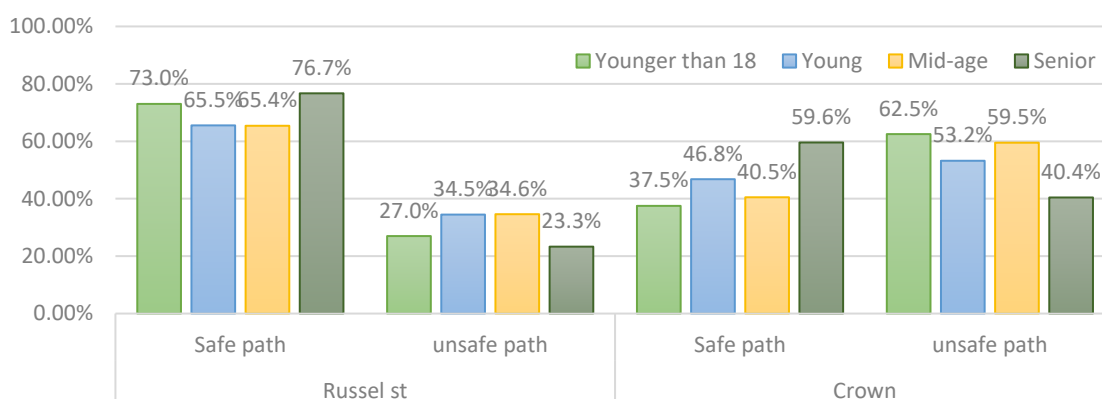


Figure B. 6: Comparison of safest and unsafe path usage across age categories

Weather conditions

A summary of unsafe path usage on both sites for different weather conditions is presented in figure 8. On the Russell site, unsafe path usage was highest on windy days, with 88.17% of pedestrians using unsafe paths, and lowest on sunny days, with 33.66% of pedestrians using unsafe paths. On the Crown site, unsafe path usage was highest on rainy days, with 69.57% of pedestrians using unsafe paths, and lowest on sunny days, with 41.53% of pedestrians using unsafe paths (see Figure B. 7).

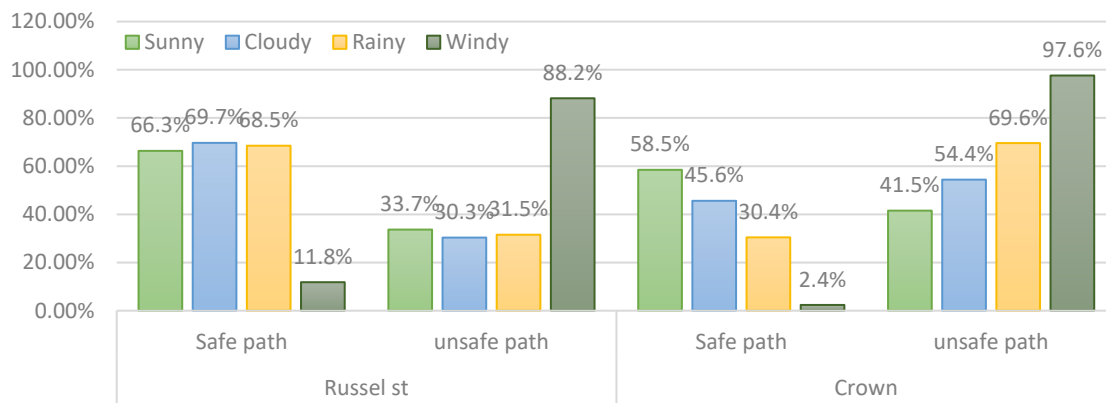


Figure B. 7: Weather condition distribution of the observation

Time of day

Based on the data observed, the safest path usage at the Russell site varies across different time periods. In the morning peak hours (7-9 am), only 58.29% of pedestrians use the safest path, with the highest proportion of unsafe path usage (41.71%) at this time period. In the morning off-peak hours (9-11 am), the safest path usage increases to 72.80%, with a corresponding decrease in unsafe path usage (27.20%). During the PM peak hours (4-6 pm), the safest path usage is 64.86%, with 35.14% of pedestrians still choosing to use the unsafe path. Finally, in the evening hours (7-8 pm), the safest path usage is 69.70%, with 30.30% of pedestrians still using the unsafe path. The highest proportion of unsafe path usage was observed during the morning peak hours at the Russell site, with 41.71% of pedestrians choosing to use the unsafe path. On the other hand, the lowest proportion of unsafe path usage was observed during the morning off-peak hours, with only 27.20% of pedestrians using the unsafe path (see Figure B. 8).

In the Morning Peak time period (7-9 AM), the safest path is used 58.47% of the time at the Crown site, while the unsafe path is used 41.53% of the time. In the Morning off-peak time period (9-11 AM), the safest path is used 66.22% of the time, while the unsafe path is used 33.78% of the time. In the PM Peak time period (4-6 PM), the safest path is used 52.58% of the time, while the unsafe path is used 47.42% of the time. In the evening (7-8 PM), the safest path is used 54.72% of the time, while the unsafe path is used 45.28% of the time. Overall, we can see that the safest path is used more often during the morning off-peak time at the Crown site, followed by the evening time. However, the usage of the unsafe path is still high during the morning peak and PM peak time periods. The maximum usage of unsafe paths at the Crown site is 47.42% during the PM Peak time period, while the minimum usage of the unsafe path is 33.78% during the morning off-peak time period. On the other hand, the minimum usage of the safest path is 52.58% during the PM Peak time period (see Figure B. 8).

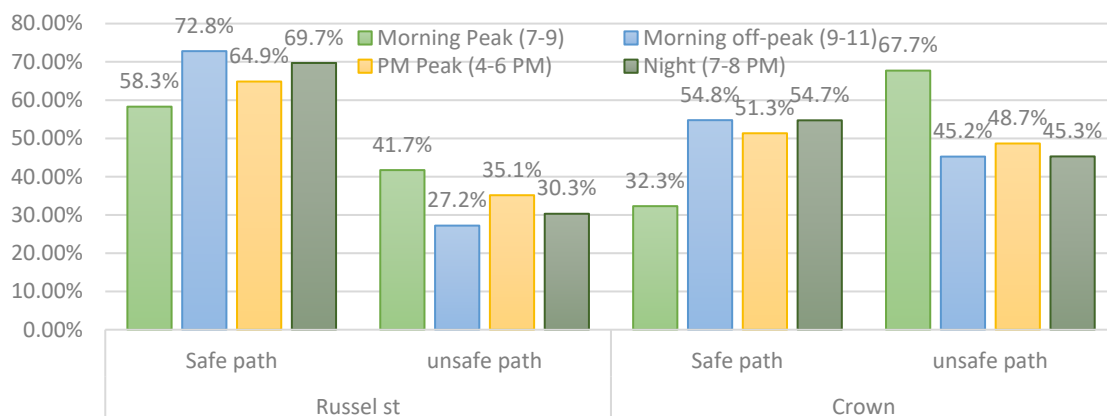


Figure B. 8: Comparison of safest and unsafe path usage across different time periods

Disability and mobility impairment

At the Russell site, the safe path is used by 91.67% of people with disabilities, while the unsafe path is used only 8.33% of the time. At the Crown site, 100% of people with disabilities use the safe path, and none use the unsafe path. For people with mobility impairments, the safe path is used by 68.75% of people at Russell St, while the unsafe path is used by 31.25% of people. At the Crown site, the safe path is used by 66.67% of people with mobility impairments, while the unsafe path is used by 33.33% of people (see Figure B. 9).

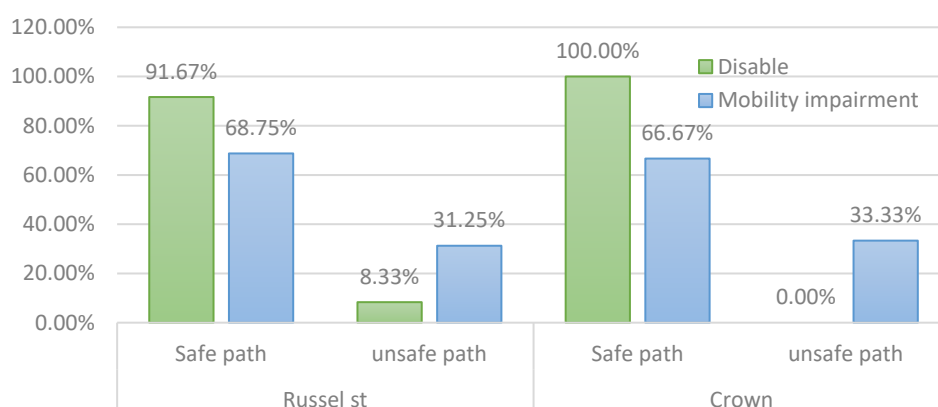


Figure B. 9: Comparison of safe and unsafe path usage by people with disabilities and mobility impairments

Walking speed

At the Russell site, only 40.19% of pedestrians who were walking fast used the safe path, while 59.81% used the unsafe path. Similarly, only 39.59% of runners at the Russell site use the safe path, while 60.41% use the unsafe path. At the Crown site, the safe path is used by only 20.89% of pedestrians walking fast, while 79.11% use the unsafe path. Similarly, only 18.18% of runners at the Crown site use the safe path, while 81.82% use the unsafe path (see Figure B. 10).

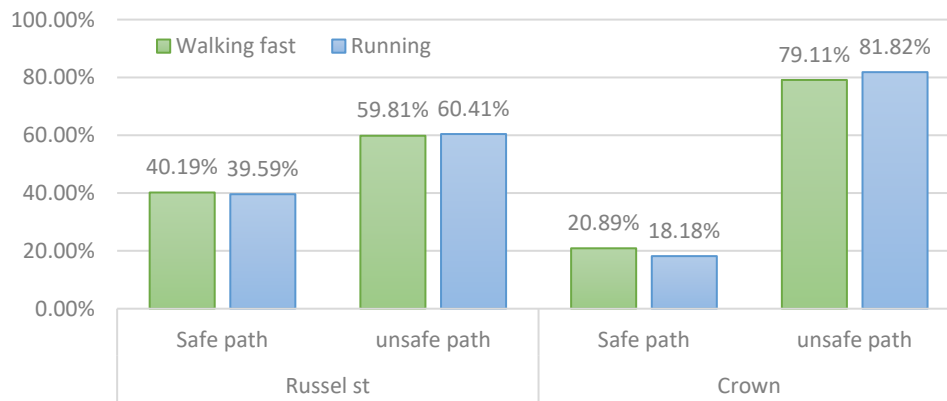


Figure B. 10: The proportion of pedestrians using safe and unsafe paths while walking fast or running

Herd behaviour and crown avoidance

At the Russell site, 89.54% of pedestrians flow with the traffic and use the safe path, while only 10.46% use the unsafe path. When flowing against the traffic, 92.31% of pedestrians use the safe path, while 7.69% use the unsafe path. At the Crown site, 63.41% of pedestrians flow with the traffic and use the safe path, while 36.59% use the unsafe path. When flowing against the traffic, 51.61% of pedestrians use the safe path, while 48.39% use the unsafe path (see Figure B. 11).

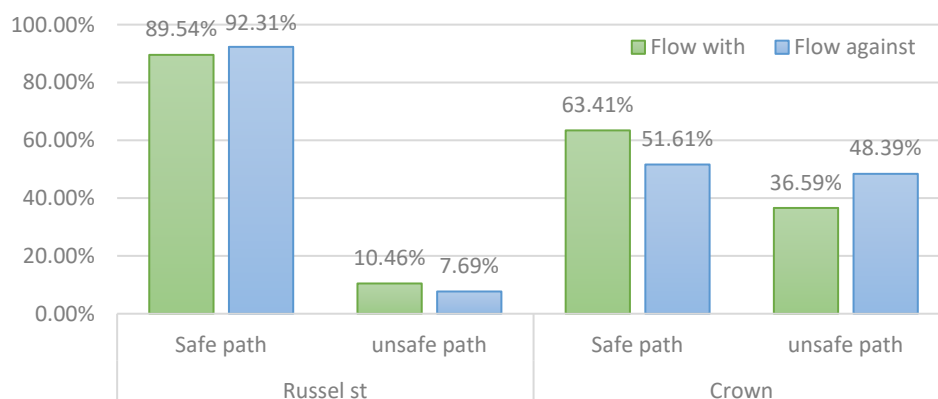


Figure B. 11: The proportion of pedestrians using safe and unsafe paths based on the direction of flow (with or against the traffic).

Other factors

Figure B. 12 to Figure B. 19 show the percentage of pedestrians using the safe and unsafe paths for various scenarios at Russell St and Crown sites. At Russell St, the safe path is used by 82.69% of people with prams or trolleys, 88.41% of those walking with small children, 80% of those walking with pets, and 64.25% of those carrying heavy bags. The safe path is used by 62.38% of people in business attire and 59.79% of physically fit individuals. When walking with someone, 74.67% use the safe path, while 70.93% use it while using mobile phones. At the Crown site, 78.57% of people with prams or trolleys use the safe path, while 82.35% of those walking with small children use it. The safe path is used by 66.67% of those walking with pets and 70.37% of those carrying heavy bags. For those in business

attire, 48.98% use the safe path, while 59.26% of physically fit individuals use it. When walking with someone, 53.93% use the safe path, while 50% use it while using mobile phones.

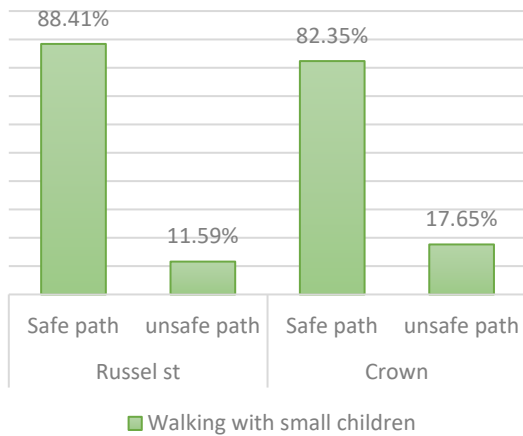


Figure B. 12: The proportion of pedestrians using safe and unsafe paths when walking with small children.

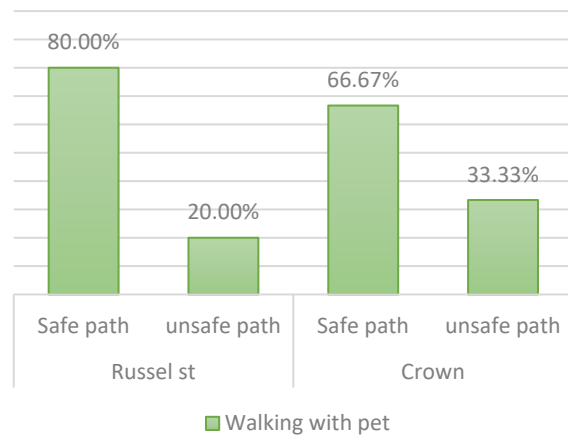


Figure B. 13: The proportion of pedestrians using safe and unsafe paths when walking with pets.

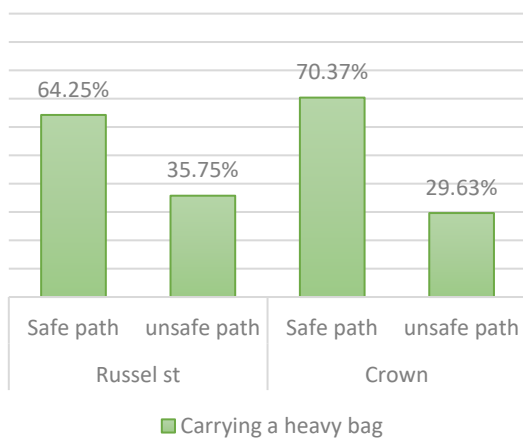


Figure B. 14: The proportion of pedestrians using safe and unsafe paths when carrying heavy bags

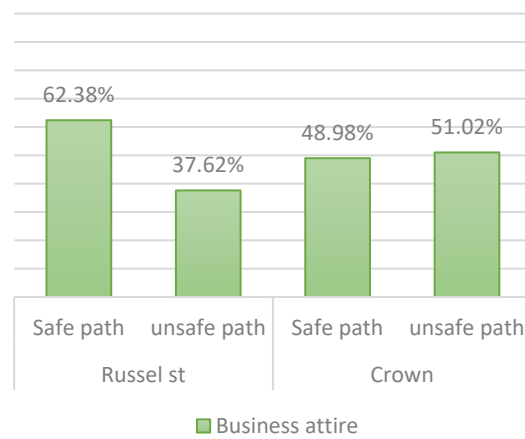


Figure B. 15: The proportion of pedestrians using safe and unsafe paths when having business attire

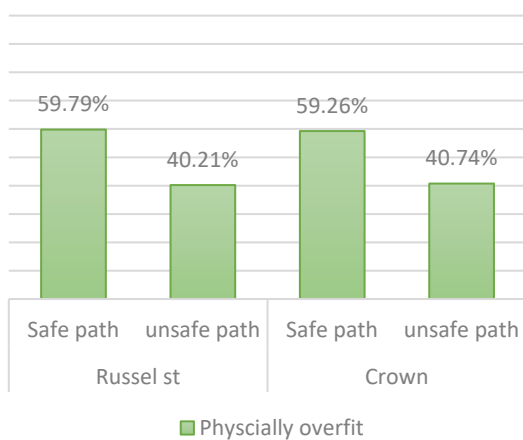


Figure B. 16: The proportion of pedestrians using safe and unsafe paths of being physically fit

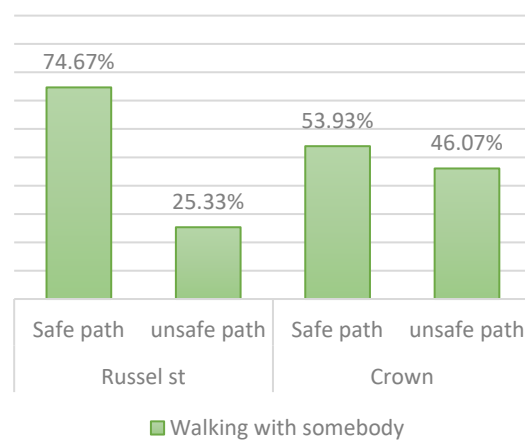


Figure B. 17: The proportion of pedestrians using safe and unsafe paths when walking with somebody

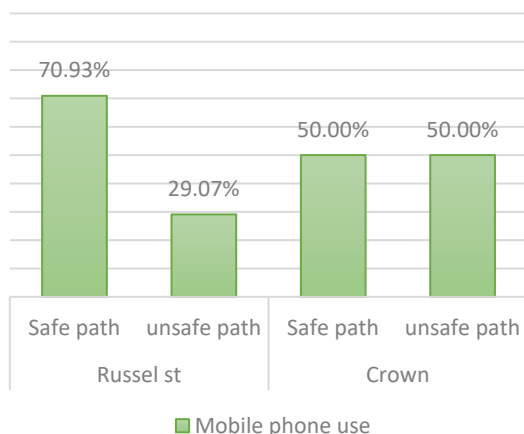


Figure B. 18: The proportion of pedestrians using safe and unsafe paths at Russell St when using mobile phone

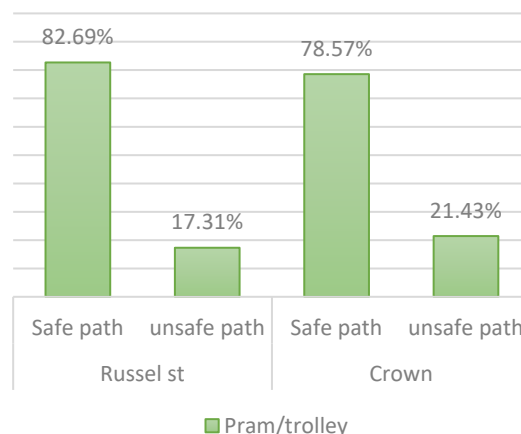


Figure B. 19: The proportion of pedestrians using safe and unsafe paths when carrying pram or trolley

Hypothetical street crossing scenario

In the hypothetical scenario, respondents were asked to choose between the designated safe path (A) versus the unsafe shortest path (B), depicted in Figure 5. The distributions of responses under various circumstances are presented in Figure B. 20. The following subsections discuss descriptive statistics.

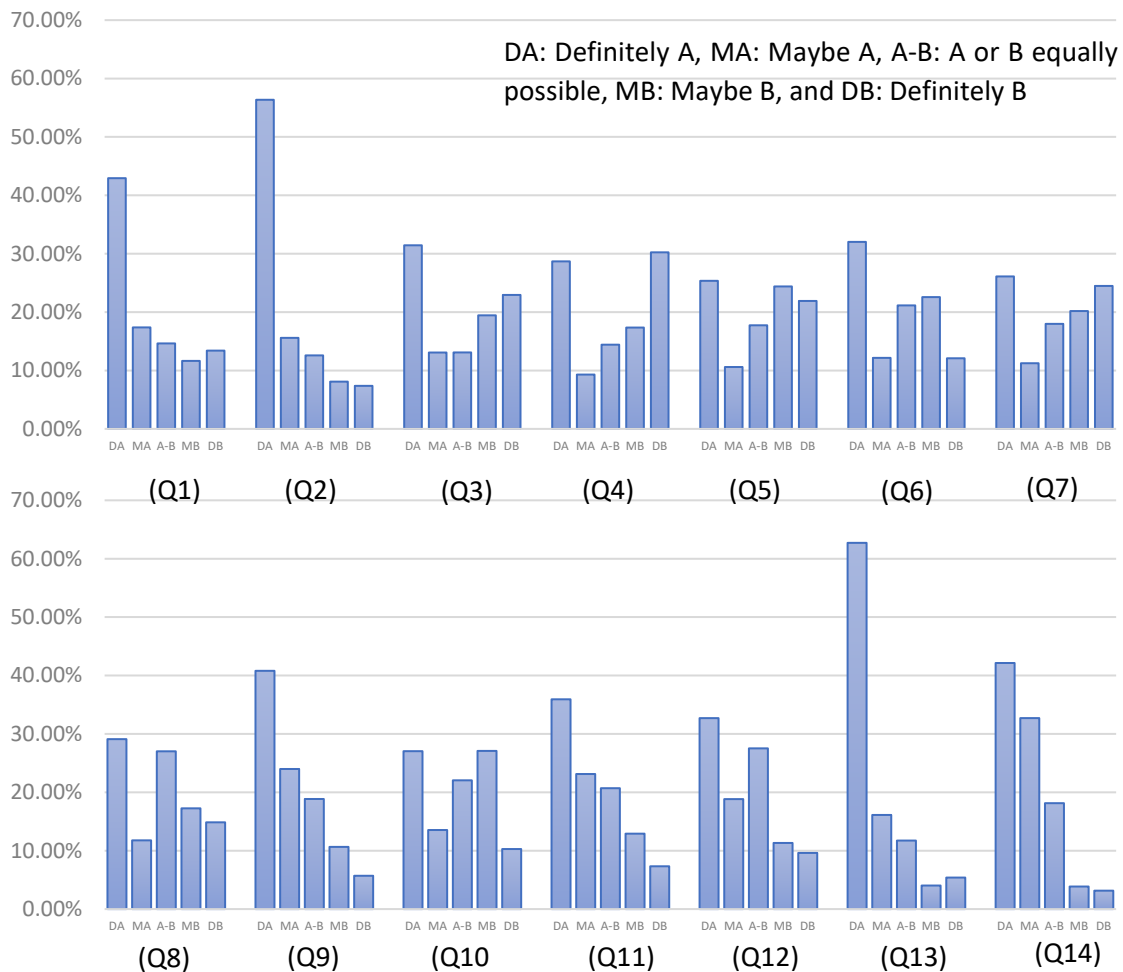


Figure B. 20. Hypothetical street crossing scenario

Scenario 1: Severe weather conditions

The largest group of respondents (42.94%) chose "Definitely A" as their response, meaning they would definitely choose path A in the case of severe weather conditions (see Figure 9). The second-largest group (17.38%) chose "Maybe A," indicating some uncertainty in their decision. The "A or B equally possible" category had a relatively low percentage (14.64%), suggesting that severe weather conditions are not seen as a factor that creates a lot of ambiguity in the decision-making process. The remaining two categories, "Maybe B" and "Definitely B," together made up 25.04% of the responses, meaning that less than 1/4 of the respondents would choose path B in the case of severe weather conditions.

Scenario 2: Carrying a heavy bag or walking with a pram or trolley

The majority of respondents (56.36%) chose option A, indicating that they would prefer path A when carrying a heavy bag or walking with a pram/trolley. Only 7.27% of respondents chose option B, indicating a strong preference for path A. About 28% of respondents were unsure and considered

either option A or B to be equally possible. Overall, the responses suggest that the majority of people would choose path A when carrying a heavy bag or pushing a pram or trolley.

Scenario 3: Rushing to destination

More than half of the respondents (42.38%) chose option B (maybe or definitely), indicating that they would prefer path B when rushing to reach their destination. However, almost the same number of respondents (44.52%) chose option A (maybe or definitely), indicating a preference for path A when not in a rush. About 13% of respondents considered both paths to be equally possible.

Scenario 4: Rushing to get on the PT service

When a person is rushing to not miss the bus (or the next PT service), they are more likely to choose path B. More than 47% of respondents (maybe or definitely) preferred path B, indicating that they consider it to be a quicker or more direct route to the bus or PT service. On the other hand, about 38% of respondents (maybe or definitely) preferred path A, indicating a preference for a more leisurely or comfortable route. About 14% of respondents considered both paths to be equally possible.

Scenario 5: Herd behaviour

Scenario 6: Crowd Avoidance

The largest percentage of respondents chose "A or B equally possible", indicating that in a situation where option A is crowded, some people would choose to use option B instead. However, a significant percentage of respondents (around 55%) still leaned towards using option A (either definitely or maybe), while a little over a third of respondents leaned towards using option B (either maybe or definitely).

Scenario 7: Vehicular traffic impact

The majority of respondents (45.59%) believe that option B is more likely to be chosen when there is no car traffic on the St (Maybe B and Definitely B combined). However, a significant percentage (37.34%) believe that option A is more likely to be chosen (Maybe A and Definitely A combined). The remaining 17.99% think that both options are equally possible. Overall, there is no clear consensus on which option is more likely to be chosen when there is no car traffic on the street.

Scenario 8: Poor sign and line marking visibility

In terms of the impacts of signs visibility, the respondents showed different preferences for paths A or B. The most common response is "Definitely A" with 29%. About 27% chose "A or B equally possible". Others are "Maybe B" with 17.25% and "Definitely B" with 14.86%. This suggests that some people are more likely to choose option A, even when the signs or markings are not visible, while others are more likely to choose option B.

Scenario 9: Poor street lighting

In terms of the impacts of street lighting, the most common response is "Definitely A" at 40.80%, indicating that a significant portion of the respondents would choose path A if the street lighting is low. The second most common response is "Maybe A" at 23.99%, suggesting that some respondents are more inclined towards path A, but may also consider path B depending on the situation. The response "A or B equally possible" received 18.85%, indicating that some respondents do not have a clear preference between the two options. The response "Maybe B" received 10.65%, suggesting that some respondents are more inclined towards path B, but may also consider path A depending on the situation. Finally, the response "Definitely B" received the lowest percentage at 5.70%, suggesting that only a small portion of respondents would choose path B in this situation.

Scenario 10: Vicinity of Myki-card reader (pay station)

Question 10 asks the preferred path if the Myki-card reader (pay station) is located closer to option B. The most common response is "Maybe B" at 27.09%, followed closely by "Definitely A" at 27.04%. This suggests that the proximity of the Myki-card reader to option B may be a significant factor for some people, but not for others. Around 22% of respondents think that either option is equally possible, indicating that the distance to the Myki-card reader may not be a deciding factor for them.

Scenario 11: Presence of a pedestrian countdown

Question 11 asks how a person would choose a path (A or B) when there is a pedestrian countdown signal on option A. From these results, we can see that a majority of respondents (59.05%) would consider taking option A when there is a pedestrian countdown signal, with 35.92% of respondents indicating that they would definitely choose option A. However, there is still a sizeable portion (32.95%) of respondents who would either consider both options equally or choose option B, with 12.92% indicating that they might choose option B and 7.33% indicating that they would definitely choose option B.

Scenario 12: Driverless PT service

In question 12, respondents were asked how they would choose a path (A or B) when the tram or bus is driverless (autonomous). The highest percentage of respondents (32.70%) answered "Definitely A," meaning they would choose option A without considering option B. The second-highest percentage of respondents (27.52%) chose "A or B equally possible," indicating that they would be indifferent between the two options in this situation. A significant percentage of respondents (18.83%) chose "Maybe A," suggesting that they would be more likely to choose option A but not completely sure. On the other hand, a smaller percentage of respondents (11.32%) chose "Maybe B," indicating they would be more likely to choose option B, but not completely sure. Finally, 9.62% of respondents answered, "Definitely B," meaning they would choose option B without considering option A.

Scenario 13: Presence of CCTV or police officer

In question 13, pedestrians were asked how they would choose a path (A or B) in the presence of a camera or officer nearby. As we can see, the majority of respondents (62.72%) answered "Definitely A", indicating that the presence of a camera or officer nearby would make them more likely to choose path A. Additionally, 16.12% of respondents answered, "Maybe A", while 11.73% responded "A or B equally possible", suggesting that the presence of a camera or officer might not have a strong impact on their decision. A smaller proportion of respondents (4.03%) answered "Maybe B", while 5.4% answered "Definitely B", indicating that the presence of a camera or officer nearby would possibly make them to choose path B.

Scenario 14: Visual attractiveness of crossing path

Question 14 asked respondents how they would choose between path A and B when option A is visually more attractive, such as being greener. The majority of respondents (74.85%) indicated that they would choose option A (Definitely A + Maybe A), which is visually more attractive. Only a small percentage of respondents (7.01%) indicated they would choose option B (Maybe B + Definitely B). However, a relatively high percentage of respondents (18.14%) indicated that they would be indifferent and consider both options equally possible.

Appendix C: Field observation Form (Form A)

Name of Surveyor: _____								
Location: _____								
Date: ____/____/____								
Morning peak ☐		Morning off-peak ☐		Afternoon peak ☐		Evening ☐		
Sunny ☐		Cloudy ☐		Rainy ☐		Windy ☐		
Designated safe path	☐	Designated safe path	☐	Designated safe path	☐	Designated safe path	☐	
Shortest path	☐	Shortest path	☐	Shortest path	☐	Shortest path	☐	
Female	☐	Female	☐	Female	☐	Female	☐	
Male	☐	Male	☐	Male	☐	Male	☐	
Younger than 18	☐	Younger than 18	☐	Younger than 18	☐	Younger than 18	☐	
Young (18-30 years)	☐	Young (18-30 years)	☐	Young (18-30 years)	☐	Young (18-30 years)	☐	
Mid-age (30-65 years)	☐	Mid-age (30-65 years)	☐	Mid-age (30-65 years)	☐	Mid-age (30-65 years)	☐	
Senior (65 years and over)	☐	Senior (65 years and over)	☐	Senior (65 years and over)	☐	Senior (65 years and over)	☐	
Disable	☐	Disable	☐	Disable	☐	Disable	☐	
Mobility impairment	☐	Mobility impairment	☐	Mobility impairment	☐	Mobility impairment	☐	
Pram/trolley	☐	Pram/trolley	☐	Pram/trolley	☐	Pram/trolley	☐	
Walking with small children	☐	Walking with small children	☐	Walking with small children	☐	Walking with small children	☐	
Walking with pet	☐	Walking with pet	☐	Walking with pet	☐	Walking with pet	☐	
Carrying a heavy bag	☐	Carrying a heavy bag	☐	Carrying a heavy bag	☐	Carrying a heavy bag	☐	
Business/formal attire	☐	Business/formal attire	☐	Business/formal attire	☐	Business/formal attire	☐	
Physically overfit	☐	Physically overfit	☐	Physically overfit	☐	Physically overfit	☐	
Walking fast	☐	Walking fast	☐	Walking fast	☐	Walking fast	☐	
Running	☐	Running	☐	Running	☐	Running	☐	
Walking with somebody	☐	Walking with somebody	☐	Walking with somebody	☐	Walking with somebody	☐	
Mobile phone use	☐	Mobile phone use	☐	Mobile phone use	☐	Mobile phone use	☐	
Flow with	☐	Flow with	☐	Flow with	☐	Flow with	☐	
Flow against	☐	Flow against	☐	Flow against	☐	Flow against	☐	

Appendix D: Online questionnaire (Form B)

Q1

Dear respondent,

This study adheres to the guidelines of the ethical review process of the University of New South Wales (#HC220725). This study attempts to collect information about factors affecting the street crossing behaviours of public transport users. The survey will take approximately 5 minutes. Questions are designed to determine the effective policies to influence safe crossing behaviours of pedestrians around public transport stops.

Benefits

Upon completion of this survey on-site, the participants will be rewarded with a \$10 coffee voucher. Respondents who complete the survey off-site will be entered into random draws in which 20% of respondents will be rewarded with \$10 coffee voucher.

Risk and Confidentiality

Risks are minimal for involvement in this study. The survey is anonymized and no IP or personal information will be collected. All data obtained from participants will be kept confidential and will only be reported in an aggregate format by reporting only combined results and never reporting individual ones.

Participation

Participation in this research study is completely voluntary. You have the right to withdraw at any time or refuse to participate entirely. As soon as you withdraw, all your previous responses will be deleted from our database. If you would like to know more about your participation in this survey or withdraw your response after the survey completion, please access the online Participation Information Statement on our website here.

Questions about the research

If you have questions or concerns regarding this survey, please feel free to contact the research project manager [Elli Irannezhad](mailto:e.irannezhad@unsw.edu.au) via email (e.irannezhad@unsw.edu.au) or call 0432 712 822. **Thank you very much** for your time and contribution.

Q2 I have read and understood the above information. I consent to participating in this study.

☐ Yes (1)

☐ No (0)

Skip To: End of Block If Q2 = No

Q3 What is the code on the flyer?

Q4 We would like to know a little bit about you in this section.

Q5 Which of the following age groups do you belong to?

- ☐ 14 years or younger (1)
- ☐ 15-19 years (2)
- ☐ 20-24 years (3)
- ☐ 25-34 years (4)
- ☐ 35-44 years (5)
- ☐ 45-54 years (6)
- ☐ 55-64 years (7)
- ☐ 65-74 years (8)
- ☐ 75-84 years (9)
- ☐ 85 years or older (10)

Q6 How do you describe your gender?

- ☐ Male (1)
- ☐ Female (2)
- ☐ Other (3)

Q7 Which group do you belong to?

- ☐ Tourist from another country (1)
- ☐ Not a Melbourne resident (2)

☐ Melbourne resident (3)

Display This Question:

If Q7 != Tourist from another country

Q8 How many years have you been living in Australia?

Q9 Which cultural background do you belong to?

- ☐ Australian (1)
 - ☐ Indigenous Australian or Aboriginal Torres Strait Islander (2)
 - ☐ New Zealander (3)
 - ☐ Asian (Central, South, East and Southeast Asian) (4)
 - ☐ European (5)
 - ☐ Middle Eastern or West Asian (6)
 - ☐ North American (7)
 - ☐ South American (8)
 - ☐ African (9)
-

Q10 What is the highest level of education you have completed?

- ☐ Year 12 certificate and below (1)
 - ☐ TAFE qualification (2)
 - ☐ Undergraduate degree (3)
 - ☐ Postgraduate degree (4)
-

Q11 How often do you use public transport?

- ☐ Everyday (1)
 - ☐ Two to four days a week (2)
 - ☐ Once a week (3)
 - ☐ Once a month (4)
-

Q12 How do you describe yourself?

- ☐ A person with no disability/mobility impairment (3)
 - ☐ A person with disability (1)
 - ☐ A person with reduced mobility (e.g. walking, visual or hearing impairment) (2)
-

Q13 What is your average weekly income?

- ☐ None (1)
 - ☐ \$375 or less (equivalent to \$20K per year or less) (2)
 - ☐ \$376 - \$750 (equivalent to \$20K - \$40K per year) (3)
 - ☐ \$750 - \$1200 (equivalent to \$40K - \$60K per year) (4)
 - ☐ \$1200 - \$1810 (equivalent to \$60K - \$95K per year) (5)
 - ☐ \$2645 or more (equivalent to \$135K or more per year) (6)
-

Q14 Are you familiar with this area?

- ☐ Yes (1)
 - ☐ No (0)
-

Q15 What is your trip purpose?

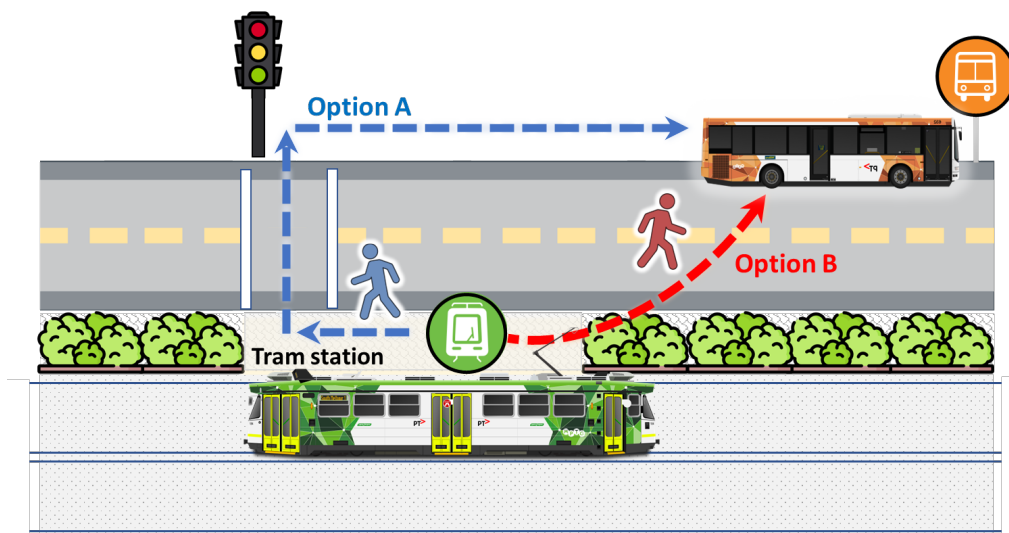
- ☐ going to work or study (1)
- ☐ getting back home (2)
- ☐ shopping, restaurant or recreation (3)
- ☐ grabbing a coffee or making a short visit to a nearby location before continue to my original trip (4)

Q16 When travelling in the surveyed location, were you in hurry?

- ☐ Yes (1)
- ☐ No (0)

In this section, we would like you to use a third-person view, and answer the following questions. Suppose in a hypothetical scenario, there are two options for crossing the road from the tram stop to a nearby bus stop.

In the case of the following factors, how would a person choose a path (A or B)?



	Definitely A (1)	Maybe A (2)	A or B equally possible (3)	Maybe B (4)	Definitely B (5)
Sever weather condition (e.g. rain, hot or sunny) (Q1)	☐	☐	☐	☐	☐
When carrying a heavy bag or walking with pram / trolley (Q2)	☐	☐	☐	☐	☐
When rushing to reach the destination (Q3)	☐	☐	☐	☐	☐
When rushing to not miss the bus (or the next public transport service) (Q4)	☐	☐	☐	☐	☐
When other people are already using the option B (Q5)	☐	☐	☐	☐	☐
When the option A is crowded (Q6)	☐	☐	☐	☐	☐
When there is no car traffic on the street (Q7)	☐	☐	☐	☐	☐
When the walkway signs or street markings are not visible (Q8)	☐	☐	☐	☐	☐
When the street lighting level is low (e.g. too dark) (Q9)	☐	☐	☐	☐	☐
When the Myki-card reader (pay station) is located closer to the option B (Q10)	☐	☐	☐	☐	☐
When there is a pedestrian countdown signal on the option A (Q11)	☐	☐	☐	☐	☐
When the tram or bus is driverless (autonomous) (Q12)	☐	☐	☐	☐	☐

When there is a camera or officer nearby (Q13)

☐
☐
☐
☐
☐

When the **option A** is visually more attractive (e.g. being greener) (Q14)

☐
☐
☐
☐
☐

We sincerely thank you for your participation. If you would like to receive a \$10 coffee voucher, please scan this QR code or click on [this link](#) to enter your email address (optional)
(In this way, we can maintain the anonymity of your responses as the new form is not linked to the current form)

		Q1		Q2		Q3		Q4		Q5		Q6		Q7		Q8		Q9		Q10		Q11		Q12		Q13		Q14				
		Count	Percentage	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S	MA	A.S			
Which of the following are you doing to help the environment?	15-20 years	7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	20-24 years	92	22%	51%	11%	12%	0%	64%	15%	0%	7%	3%	15%	15%	23%	11%	30%	10%	18%	10%	47%	20%	17%	13%	0%	17%	16%	11%	1%			
	25-34 years	175	41%	47%	13%	13%	10%	33%	15%	11%	9%	3%	33%	15%	23%	25%	7%	33%	15%	23%	30%	40%	23%	22%	10%	7%	17%	14%	11%	5%		
	35-44 years	104	24%	57	13%	13%	10%	25%	12%	7%	25%	12%	10%	10%	10%	10%	21%	21%	21%	21%	21%	21%	21%	21%	10%	7%	17%	14%	11%	5%		
	45-54 years	32	8%	53%	9%	10%	1%	16%	0%	23%	10%	19%	22%	9%	24%	9%	22%	13%	13%	14%	34%	10%	19%	22%	1%	13%	10%	13%	10%	6%		
How do you describe your pet?	55-64 years	10	2%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
	65-74 years	13	3%	80%	0%	15%	0%	17%	15%	0%	15%	0%	15%	0%	8%	10%	15%	23%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%		
	75-84 years	7	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
	85 years or older	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
	How do you describe your pet?	Female	224	52%	87%	14%	14%	13%	59%	17%	0%	8%	7%	30%	15%	12%	18%	24%	0%	17%	27%	24%	20%	13%	1%	67%	14%	11%	7%	87%	27%	13%
Which group do you belong to?	Male	194	45%	84%	10%	11%	11%	60%	12%	14%	9%	0%	31%	15%	14%	23%	15%	23%	24%	11%	17%	20%	12%	7%	67%	14%	11%	6%	84%	14%	11%	6%
	Other	6	1%	33%	0%	33%	33%	0%	50%	50%	0%	0%	0%	17%	0%	17%	0%	17%	0%	17%	17%	17%	17%	0%	17%	17%	17%	17%	17%	17%	17%	17%
	Maritime resident	263	62%	42%	14%	17%	14%	61%	11%	11%	8%	5%	48%	11%	14%	22%	24%	25%	9%	17%	25%	25%	30%	21%	12%	24%	24%	24%	24%	24%	24%	24%
	Not a Maritime resident	117	28%	58%	13%	13%	10%	38%	15%	13%	10%	8%	28%	15%	13%	10%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
	From another country	44	10%	64%	10%	10%	10%	33%	13%	13%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
Which country do you belong to?	African	6	1%	0%	50%	17%	0%	33%	13%	13%	17%	0%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
	Africa (East, South, East and Southeast Asia)	171	40%	54%	19%	11%	10%	61%	17%	9%	8%	5%	37%	15%	16%	20%	15%	10%	11%	13%	12%	23%	31%	12%	12%	0%	44%	18%	18%	18%	18%	18%
	Asia	484	11%	39%	13%	20%	13%	14%	62%	10%	12%	7%																				

Appendix F: Statistical Models

Field observations

In this research, the binary logit model is used to model pedestrian decision-making when it comes to choosing safe or unsafe paths. The model will estimate the probabilities of choosing the unsafe path for different combinations of independent variables, and the coefficients will indicate which independent variables are most strongly associated with this outcome. This information can be used to identify interventions that could be implemented to improve pedestrian safety and reduce the likelihood of pedestrians choosing unsafe paths. The binary logit model uses a logistic function to model the probability of the dependent variable taking one of the two possible values. The formula for the logistic function is as follows:

$$\mathcal{P}(y = 1 | x) = e^{(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p)} / (1 + e^{(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p)}) \quad (1)$$

Where:

- $\mathcal{P}(y = 1 | x)$ is the probability of the dependent variable (y) taking a value of 1 given the values of the independent variables (x).
- e is the base of the natural logarithm.
- β_0 is the intercept term, which represents the log odds of the dependent variable being equal to 1 when all independent variables are equal to 0.
- $\beta_1, \beta_2, \dots, \beta_p$ are the coefficients associated with each independent variable, which represent the change in log odds of the dependent variable being equal to 1 for a one-unit increase in the respective independent variable, holding all other independent variables as constant.
- $x_1, x_2, \dots, x_p$ are the values of the independent variables.

To estimate the coefficients of the model, maximum likelihood estimation is used. This involves finding the values of the coefficients that maximize the likelihood of the observed data given the model. The likelihood function is the probability of observing the data given the model parameters, and it is maximised by taking the derivative of the function with respect to each parameter and setting it equal to zero. Once we have estimated the coefficients of the model, we can use them to predict the probability of the dependent variable being equal to 1 for any combination of values of the independent variables. We can also use the coefficients to test hypotheses about the relationships between the independent variables and the dependent variable, as well as to identify which independent variables are most strongly associated with the dependent variable.

When the number of records for certain independent variables in the observed data is low, it is often necessary to group or merge them with other similar categories. To make sure that no information is lost due to merging the variables, we undertook non-parametric F-tests to examine if the impact of two groups on the dependent variable (the likelihood of choosing desire line) are statistically different from each other or not. If the distribution of two variables had the same characteristics and effect, we merged two variables to have a higher number of observations in the combined categories. For example, "*Walking with pet*" was merged with "*Walking with Pram/trolley*" due to their similarity of impact on crossing behaviours. Similarly, "Mobility impairment" and "Pedestrian with Disability" was merged into a single group. This type of grouping or merging helped to increase the sample size and reduce the likelihood of statistical bias. Furthermore, the variable "day" was grouped into two categories: weekdays and weekends.

In this research, dummy binary coding was used to prepare the data for analysis using the binary logit model. Dummy binary coding is a technique used to convert categorical variables into numerical variables, allowing them to be used in statistical models. Table F. 1 presents explanatory variables that were tested.

Table F. 1: Explanatory variables

Explanatory variable		Explanatory variable	
x1	CBD site (<i>Russel St. site</i>)	x13	Disability
x2	Weekday	x14	Pram/trolley
x3	Morning peak (7-9 am)	x15	Walking with small children
x4	Morning off-peak (9-11 am)	x16	Carrying a heavy bag
x5	Pm peak (4-6 pm)	x17	Business attire
x6	Windy weather	x18	Mobility impairment related to obesity
x7	Rainy weather	x19	Walking fast
x8	Sunny weather	x20	Running
x9	Male	x21	Walking with somebody
x10	Senior	x22	Mobile phone use
x11	Young	x23	Flow with
x12	Mid-age	x24	Flow against

Table F. 2 displays the primary result of the binary logistic regression analysis, taking into account all explanatory variables.

Table F. 2: The outcome of the binary logistic regression model with account for all explanatory variables

Variables	Coefficient	p-Value
Intercept	0.5384	5.977E-02
CBD site (<i>Russel St. site</i>)	-0.8825	8.117E-13
Weekday	-0.0592	5.717E-01
Morning peak (7-9 am)	-0.2203	8.520E-02
Morning off-peak (9-11 am)	-0.4436	3.714E-04
Pm peak (4-6 pm)	0.1240	2.525E-01
Windy weather	3.1072	4.122E-35
Rainy weather	-0.1371	3.433E-01
Sunny weather	-0.0171	8.433E-01
Male	0.2204	1.960E-03
Senior	-0.5968	5.431E-02
Young	0.0045	9.850E-01
Mid-age	0.0091	9.696E-01
Disability	-0.4120	2.271E-01
Pram/trolley	-1.0266	3.200E-03
Walking with small children	-1.3446	1.695E-04
Carrying a heavy bag	-0.3448	5.137E-02
Business attire	-0.2562	1.357E-02
Mobility impairment related to obesity	-0.0382	8.588E-01
Walking fast	1.0190	7.025E-19
Running	1.2863	2.363E-21

Walking with somebody	-0.3299	1.579E-04
Mobile phone use	-0.2106	9.539E-02
Flow with	-1.7507	1.342E-63
Flow against	-1.8183	4.972E-13

In Table F. 2, each row represents a variable in the model, with columns for the estimated coefficient and p-value. The estimated coefficient represents the expected change in the response variable for a one-unit increase in the corresponding predictor variable, holding all other predictor variables constant. The p-value represents the probability of observing a t-statistic as extreme or more extreme than the one observed, assuming the null hypothesis is true. Smaller p-values provide evidence against the null hypothesis and suggest that the corresponding predictor variable is associated with the response variable.

Based on this output, we can see that many of the predictor variables have statistically significant associations with the response variable (assuming a significance level of 0.05), as indicated by their small p-values. It's also worth noting that some of the predictor variables have large p-values, indicating weak evidence against the null hypothesis that their coefficients are zero.

The Backward Elimination method is a technique commonly used in statistical modelling to improve the accuracy of a model by systematically removing predictor variables that are not contributing significantly to the model's performance. The goal of model selection is to choose the best set of predictor variables (independent variables) that explain the dependent variable (outcome variable) while keeping the model as simple as possible. Backward elimination is a stepwise approach that starts with a full model that includes all predictor variables and iteratively removes the least important variable based on a pre-defined criterion. This process continues until the remaining variables in the model are all statistically significant or until the criterion is satisfied.

In the case of this research, backward elimination is used to select the best subset of independent variables that predict the dependent variable. The full model includes all 24 independent variables mentioned earlier. The backward elimination process starts by fitting the full model and then removes the least significant variable (high p-value) based on a criterion such as Akaike Information Criterion (AIC). The AIC is a measure used to compare the goodness of fit of statistical models. It provides a balance between the quality of the fit and the complexity of the model. The AIC value is calculated as follows:

$$AIC = 2k - 2\ln(L) \quad (2)$$

where k is the number of model parameters and L is the likelihood function of the model.

When comparing two or more models, the one with the lower AIC value is considered to be a better fit for the data. Therefore, in the context of model selection using backward elimination, the AIC can be used as a criterion to decide which variables to remove from the model.

In backward elimination, the model starts with all the independent variables included and then iteratively removes the variable with the least contribution to the model until the AIC cannot be improved any further. The contribution of a variable is assessed by the change in the AIC value when it is removed from the model. If the AIC decreases significantly when a variable is removed, it suggests that the variable is important for the model and should be kept. Conversely, if the AIC does not change much when a variable is removed, it suggests that the variable is not important and can be safely

removed from the model. The process continues until the AIC cannot be further improved by removing any variable from the model.

The results of backward elimination provide information on the most important independent variables that predict the pedestrian path. These variables can then be used to build a more parsimonious model with fewer variables, which is easier to interpret and more robust. It is important to note that backward elimination is not the only method for model selection and other methods such as forward selection, stepwise selection, or Lasso regression may be used. The results of the model after performing model selection using backward elimination are displayed in Table F. 3.

Table F. 3: The outcome of the model after performing model selection using backward elimination.

Variables	Coefficient	Standard Error (SE)	t-Stat	p-Value
Intercept	0.5619	0.0255	22.0330	0
CBD	-0.1453	0.0213	-6.8104	0
Morning Peak (7-9 AM)	-0.0566	0.0170	-3.3288	0
Morning off-peak (9-11 AM)	-0.0993	0.0164	-6.0525	0
Windy weather	0.4888	0.0320	15.2680	0
Male	0.0391	0.0128	3.0668	0
Senior	-0.1157	0.0359	-3.2198	0
Pram/trolley	-0.1411	0.0505	-2.7918	0
Walking with small children	-0.1874	0.0468	-4.0070	0
Carrying a heavy bag	-0.0525	0.0297	-1.7674	0
Business attire	-0.0430	0.0188	-2.2897	0
Walking fast	0.2126	0.0216	9.8588	0
Running	0.2787	0.0257	10.8410	0
Walking with somebody	-0.0579	0.0149	-3.8918	0
Mobile phone use	-0.0412	0.0226	-1.8217	0
Flow with	-0.2815	0.0152	-18.5780	0
Flow against	-0.3051	0.0361	-8.4574	0

The coefficient for *CBD* is -0.1453, indicating that participants are less likely to choose an unsafe path at *Russel St.* compared to *Crown St.*, controlling for all other variables in the model. The p-value for the coefficient is less than 0.05, indicating that the relationship between *CBD* and the response variable is statistically significant.

The coefficient for *Morning Peak (7-9)* and *Morning off-peak (9-11)* are -0.0566 and -0.0993, respectively. These estimates indicate that participants are less likely to choose an unsafe path during the morning hours, controlling for all other variables in the model. The p-values for these two coefficients are less than 0.05, indicating that the relationship between these variables and the response variable is statistically significant. We compared the estimates of these two variables to examine if they have a statistically different impact on the crossing behaviour. The results show that they have the same impact on the utility function of crossing behaviours and are not statistically significant from each other.

The coefficient for *Windy weather* is 0.4888, indicating that participants are more likely to choose an unsafe path during windy weather conditions, controlling for all other variables in the model. The p-value for the coefficient is less than 0.05, indicating that the relationship between *Windy weather* and the response variable is statistically significant.

The coefficient for *Male* is 0.0391, indicating that male participants are more likely to choose an unsafe path compared to female participants, controlling for all other variables in the model. The p-value for the coefficient is less than 0.05, indicating that the relationship between *Gender* and the response variable is statistically significant.

The coefficient for *Senior* is -0.1157, indicating that senior participants are less likely to choose an unsafe path compared to *younger participants*, controlling for all other variables in the model. The p-value for the coefficient is less than 0.05, indicating that the relationship between *Senior* and the response variable is statistically significant.

The coefficient for *Pram/trolley* is -0.1411, indicating that participants who are carrying a pram or trolley are less likely to choose an unsafe path compared to those who are not, controlling for all other variables in the model. The p-value for the coefficient is less than 0.05, indicating that the relationship between *Pram/trolley* and the response variable is statistically significant.

The coefficient for *Walking with small children* is -0.1874, indicating that participants who are walking with small children are less likely to choose an unsafe path compared to those who are not, controlling for all other variables in the model. The p-value for the coefficient is less than 0.05, indicating that the relationship between *Walking with small children* and the response variable is statistically significant.

The coefficient for *Carrying a heavy bag* is -0.0525, indicating that participants who are carrying a heavy bag are less likely to choose an unsafe path compared to those who are not, but the p-value for the coefficient is close to 0.05, indicating that the relationship between *Carrying a heavy bag* and the response variable is statistically significant for 0.1.

The coefficient for *Business attire* is negative (-0.0430), indicating that people who are dressed in business attire are less likely to choose the unsafe path. The t-statistic is moderately large (2.2897) and the p-value is relatively small (2.208E-02), indicating that this variable has a significant impact on the response variable. The SE is relatively small (0.0188), indicating that the coefficient is precise.

The coefficient for *Walking with somebody* is negative (-0.0579), indicating that people who are walking with somebody else are less likely to choose the unsafe path. The t-statistic is large (3.8918) and the p-value is zero, indicating that this variable has a significant impact on the response variable. The SE is relatively small (0.0149), indicating that the coefficient is precise.

The coefficient for *Mobile phone use* is negative (-0.0412), indicating that people who are using their mobile phones are less likely to choose the unsafe path. The t-statistic is moderately small (-1.8217) and the p-value is relatively large (6.857E-02), indicating that this variable may not have a significant impact on the response variable. The SE is relatively small (0.0226), indicating that the coefficient is precise.

The coefficient for *Flow with* is negative (-0.2815), indicating that people are less likely to choose the unsafe path when there is a high flow of people going in the same direction. The t-statistic is very large (-18.5780) and the p-value is zero, indicating that this variable has a significant impact on the response variable. The SE is relatively small (0.0152), indicating that the coefficient is precise.

The coefficient for *Flow against* is negative (-0.3051), indicating that people are less likely to choose the unsafe path when there is a high flow of people going in the opposite direction. The t-statistic is moderately large (-8.4574) and the p-value is zero, indicating that this variable has a significant impact on the response variable. The SE is relatively large (0.0361), indicating that the coefficient may not be as precise as other variables.

Overall, it appears that walking fast, walking with somebody else, and the flow of people crossing in the same direction (presented by the “*Flow with*” variable) have the strongest impact on the likelihood of people choosing the safe path. Gender, seniority, pram/trolley, walking with small children, and weather conditions also have some impact, but to a lesser extent. The impact of morning peak, morning off-peak, carrying a heavy bag, and mobile phone use may be less significant. Having business attire and the flow in the opposite direction of crossing appears to have a smaller impact but still has a significant effect on the likelihood of people choosing the safe path.

Online survey

An ordinal regression model is utilised to analyse survey data and predict the likelihood of various responses based on a set of independent variables (X). The dependent variable (Y) includes five potential choices, each representing a different level of likelihood regarding the selection of a safe or unsafe path.

Ordinal regression, also known as ordered logistic regression, is a statistical model used to analyse the relationship between an ordinal dependent variable and one or more independent variables. An ordinal variable is a variable where the values have an inherent order, but the distance between the values is not necessarily equal. Examples of ordinal variables include Likert scale items, grades, and levels of agreement or disagreement.

In an ordered choice model, the dependent variable is modelled as a function of the independent variables using a logistic regression framework, as:

$$y_i^* = \alpha + \beta'x_i + \varepsilon_i, i = 1, \dots, n \quad (3)$$

where β' are the coefficients for each independent variable, α is the intercept, ε_i is the error term, and y_i^* is the observed choice of individual i in discrete form through a censoring mechanism, as (also shown in Figure F. 1):

$$y_i = 1 \quad \text{if } -\infty < y_i^* \leq \tau_1 \quad (4)$$

$$y_i = 2 \quad \text{if } \tau_1 < y_i^* \leq \tau_2$$

$$y_i = 3 \quad \text{if } \tau_2 < y_i^* \leq \tau_3$$

$$y_i = 4 \quad \text{if } \tau_3 < y_i^* \leq \tau_4$$

$$y_i = 5 \quad \text{if } \tau_4 < y_i^* < \infty$$

The model estimates the cumulative log odds of being in a higher category for each level of the independent variable, with a separate intercept for each category. The probabilities of the dependent variable falling into each category are estimated separately as:

$$Prob[y_i = j | x_i] = Prob[\varepsilon_i \leq \tau_j - \beta'x_i] - Prob[\tau_{j-1} - \beta'x_i], j = 1, \dots, 5 \quad (5)$$

where x_i are the independent variables, j is the category of the dependent variable (1 for the option “most definitely safe path”, and 5 for the option “most definitely unsafe path”), y_i is a label and β' are the coefficients for each independent variable for the j th category.

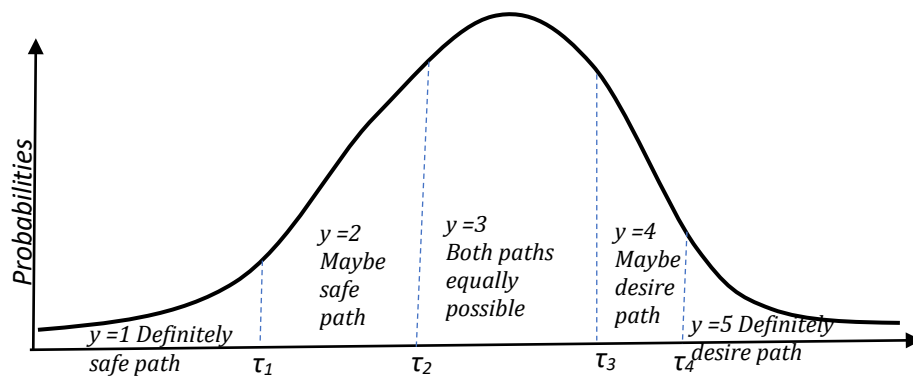


Figure F. 1: Underlying probabilities for an ordered choice model

To estimate the model, maximum likelihood estimation is used to find the values of the coefficients that maximise the likelihood of observing the dependent variable given the independent variables. The coefficients represent the change in the log odds of being in a higher category for each unit increase in the independent variable, holding all other variables constant.

To fit an ordinal regression model with these variables, it is first needed to code the response variable (y) as a set of ordered integers, with 1 representing "definitely choose the safe path" and 5 representing "definitely choose the unsafe path". Then the model is estimated using the cumulative odds model described above, with the response variable coded as ordinal.

The estimated coefficients (β) would reflect the impact of each independent variable on the odds of being in a higher or lower category of the response variable. After estimating the ordinal regression model, the probabilities of each category for new observations can be predicted by inputting the values of the independent variables into the formula and calculating the probabilities using the logistic function.

The variables for ordinal models are presented in Table F. 4, which include illegal crossings that were observed and recorded by surveyors. It should be noted that the field surveyors observed pedestrians' crossing behaviour first and then approached them and intercepted them for the online questionnaire. If they had crossed the street on zebra crossings and during a green pedestrian signal, a code with an even number was assigned to the person. Otherwise, a code with an odd number was assigned. If a person was willing to complete the questionnaire on the site, the code was entered by the surveyor in the first question of the online survey. Otherwise, it was written into the flyer and handed over to the pedestrian to be entered by the respondent later. Without this code, the respondent was not able to proceed with the survey. These codes were entered into the online questionnaire, hence linking the actual crossing behaviour with the stated crossing preference.

Other variables included age, gender, residency status, cultural background, years lived in Australia, education level, disability status, income, familiarity with the area, the trip purpose, and being in hurry, as well as PT usage.

Table F. 4. Variables for ordinal models

Variables	Description
X1	Actual Illegal Crossings
X2	Age (20-24 years)
X3	Age (25-34 years)
X4	Age (35-44 years)

X5	Age (45-54 years)
X6	Age (55-64 years)
X7	Age (65 years or older)
X8	Gender (Male)
X9	Gender (Other)
X10	Not a Melbourne resident
X11	Tourist from another country
X12	Residency (less than 1 year)
X13	Residency (1 year - 5 years)
X14	Other cultural backgrounds (non-Asian or non-Australian)
X15	Cultural background (Asian)
X16	Education (Postgraduate degree)
X17	Education (TAFE qualification)
X18	Education (Undergraduate degree)
X19	Use PT (Once a month)
X20	Use PT (Once a week)
X21	Use PT (Two to four days a week)
X22	A person with no disability
X23	Income (\$135K or more per year)
X24	Income (\$60K - \$95K per year)
X25	Income (\$40K - \$60K per year)
X26	Income (\$20K - \$40K per year)
X27	Income (\$20K per year or less)
X28	Familiarity with the area
X29	Trip purpose (getting back home)
X30	Trip purpose (going to work or study)
X31	Trip purpose (grabbing a coffee ...)
X32	Being in Hurry

Before creating models for various questions, we perform a factor analysis to identify which questions exhibit comparable patterns of behaviour (see Table F. 5). Factor analysis is a statistical technique used to identify underlying latent variables or factors that explain the patterns of correlations among a set of observed variables. In other words, it helps to reduce the complexity of a large set of variables by grouping them into smaller, more manageable sets based on their interrelationships. In the given context, factor analysis is being used to identify which variables exhibit similar patterns of behaviour. This can help in creating more effective models for different questions by reducing the number of variables needed to be considered.

In the process of conducting factor analysis, various methods can be used to determine the optimal number of groups or factors to use. One such method is to examine the eigenvalues of the correlation matrix and select the number of factors with eigenvalues greater than 1. Another method is to use a scree plot, which plots the eigenvalues against the number of factors and selects the point where the slope of the plot changes most dramatically. After trying different numbers of groupings, it was found that grouping the variables into two factors yielded better results. This suggests that the variables can be simplified and represented by two major factors, named *Impulsivity* and *Risk aversion*. The chi-square test yielded a statistic of 188.8 on 64 degrees of freedom. Table F. 5 presents the results of the factor analysis.

Table F. 5. The results of the factor analyses

Factors	Impulsivity	Risk aversion
Severe weather conditions	0.600	

Carrying a heavy bag or walking with a pram or trolley		0.424
Rushing to destination	0.805	
Rushing to get on the PT service	0.852	
Herd behaviour	0.785	
Crowd avoidance on the designated walkway	0.640	
Lack of vehicular traffic	0.751	
Poor sign and line marking visibility	0.630	
Poor street lighting		0.595
Vicinity of Myki-card reader (pay station) to desire line path	0.641	
Presence of a pedestrian signal countdown		0.621
Driverless PT service		0.623
Presence of CCTV or police officer		0.648
Visual attractiveness of crossing path		0.706

The first group present the factors influencing the swiftness of movement which is more likely to result in deviating from the designated safe crossing path and opting for a desire line. We name this group of factors “Impulsivity”. The impulsivity factors confirm our prior hypothesis that severe weather conditions (windy, rainy, very hot sunny days), being in a hurry, herd behaviour, poor line marking and signs of walkways, and making the desire line to tap on the pay station as well as avoiding the crowd on the designated walkway could prompt people to deviate from the designated safe path and opt for the desire line. The estimates confirmed that these factors exacerbate unsafe and risky street-crossing behaviours.

Whereas, some other factors prompt people to use the designated safe path. For example, when they are carrying a heavy bag or walking with a pram, trolley or scooter. Also, during dark hours of the day or when there is not enough street lighting, individuals are more likely to stick to the safe path. The presence of CCTV or police officers also has a positive impact on prompting people to follow the rules. It also appears that the public does not perceive the driverless tram or autonomous bus as safe and individuals prefer to not take a risk of using an unsafe desire line. Interestingly, installing a pedestrian signal countdown and increasing the attractivity of walkways or street zebra crossings (such as having a shade or interesting pavement painting) can also prompt individuals to use the designated crossing path rather than the desire line.

We also investigated the relationship between individual socioeconomic characteristics and if these characteristics influence using desire lines in various circumstances. A stepwise method is employed for selecting variables that are most relevant to predicting the use of the desire line. Estimates for these two distinct categories of *Impulsivity* and *Risk aversion* are presented in Table F. 6 and Table F. 7, respectively.

The threshold parameters adjust to allocate the mass of the distribution to mimic the sample, as shown in Figure F. 1. Looking at the thresholds, the likelihood distribution of the *Impulsivity* factors is skewed towards choosing the desire line instead of the designated safe path, which confirms our hypothesis that these factors increase the chance of opting for the desire line, regardless of the socioeconomic characteristics.

Interestingly, very high-income earners (with an annual income of \$135K or more) lean towards selecting desire paths and deviate from the designated safe path.

It appears that severe weather is more likely to influence individuals of non-Asian cultural backgrounds to use desire line and cross the street on a desire line whereas regular PT users (i.e. those who use PT between two to four times per week) are more likely to take the desire line paths even during cold, windy and rainy winter days or hot summer days.

Opposed to Melbourne residents, a few groups did not opt for the desire line when being in a hurry to arrive at the destination or get on the next PT service. These groups include random PT users (those who use PT only once a week), mid-age individuals (i.e. 45-54 years old), and individuals with an Asian background.

We postulated that when there is a significant number of people taking desire line to cross the street, this could prompt others to do the same. This kind of influence is called herd behaviour. Our results indicate that herd behaviour is strongly influential for very high-income earners.

We also postulated that some people may avoid using crowded walkways or crowded street crossings. It appears that those with a non-Asian or non-Australian cultural background are more likely to deviate from the designated safe path to avoid the crowd. However, those who are new to Australia (i.e. those who lived in Australia for less than 1 year or between 1 and 5 years) tend to use designated walkways more despite being crowded. In fact, they are more likely to follow others and opt for the designated path rather than deviating from it.

Another factor that was postulated to prompt people to use a desire line is when there is not high vehicular traffic on the street. So, people easily take a risk by using desire line and crossing the street on a desire line. Overall, the estimates proved this hypothesis to be valid, particularly for the regular PT users, average-income and very high-income earners.

In terms of the walkway sign or line marking visibility, we postulated that high visibility could nudge the behaviours of individuals toward using the designated safe path. This hypothesis was confirmed by the results. Particularly, the impact of walkway line marking visibility is likely to be stronger for very high-income earners and regular PT users and Melbourne residents.

Lastly, we hypothesised that the location of the Myki-card reader (pay station) on the PT station is an important design factor that can induce unsafe street crossing behaviours. Overall, the model estimates confirmed this hypothesis, particularly for very high-income earners.

Table F. 7 presents the estimates of socioeconomic factors that influence the choice of desire line under risk-aversion factors identified in group 2.

We had postulated that the *risk-aversion* factors prompt people to use the designated safe path and the estimates of the thresholds and their intervals by and large confirm this hypothesis. Notably, very high-income earners still opted for the desire line when carrying a bag or walking with a pram or trolley or when PT is autonomous and did not care about the visual attractiveness of the designated path. This result may indicate an honest response or could simply be just a sample bias.

The estimates indicate that mid-age people (55-64 years old), very high-income earners, and people with mobility impairment related to obesity tend to use desire line when carrying a heavy bag or pushing a pram or trolley.

When there is not enough street lighting, risk-averse attitudes should prompt people to use the designated safe path. Looking at the thresholds, the results confirm this hypothesis overall. However,

regular PT users, individuals with a postgraduate degree, young people aged in their early 20s and mid-age people still opted for the desire line.

The presence of pedestrian countdown signals has various impacts on people. It appears that senior people and individuals of Asian background are less likely to opt for the desire line while it prompts the individuals with postgraduate education to not wait and use the desire line.

If the tram or bus is driverless (autonomous), most people rather choose the designated safe path, particularly non-Melbourne residents who appear to have less trust in autonomous PT vehicles. However, very high-income earners appear to trust driverless vehicles and opt for the desire line.

Lastly, in the presence of a CCTV camera or police officer nearby, the majority of people forget about the desire line and obey the rules, particularly individuals with disability or mobility impairments. It appears the visual attractiveness of designated safe paths may also prompt people to use them more, particularly individuals with an Asian background.

Table F. 6. The coefficient estimates and p-values for group 1 (Impulsivity of movement)

	Severe weather	Rushing to destination	Rushing to get on PT	Herd behaviour	Crown avoidance	Street traffic	Poor line marking	Vicinity of pay station
Mid-age (45-54 years)	-	-	-0.809 (0.022)	-	-	-	-	-
Melbourne resident	-	0.498 (0.012)	0.510 (0.01)	-	-	-	0.613 (0.002)	-
Very new migrants (less than 1 year living in Australia)	-	-	-	-	-0.747 (0.006)	-	-	-
New migrants (1 year - 5 years living in Australia)	-	-	-	-	-0.445 (0.037)	-	-	-
Cultural background (non-Asian or non-Australian)	-	-	-	-	0.592 (0.005)	-	-	-
Cultural background (Asian)	-0.598 (0.001)	-	-0.459 (0.011)	-	-	-	-	-
Random PT users (Once a week)	-	-0.666 (0.069)	-0.758 (0.039)	-	-	-	-	-
Regular PT users (2 -4 days a week)	0.475 (0.011)	-	-	-	-	0.373 (0.043)	0.507 (0.006)	-
Very high-income earners (\$135K or more per year)	0.652 (0.008)	0.635 (0.01)	0.776 (0.003)	0.628 (0.01)	-	0.688 (0.008)	0.600 (0.015)	0.889 (0)
Average income earners (\$60K - \$95K per year)	-	-	-	-	-	0.394 (0.062)	-	-
τ_1	-0.17 (0.08)	-0.816 (0)	-0.816 (0)	-0.988 (0)	-0.665 (0)	-0.324 (0.001)	-0.85 (0)	-0.838 (0)
Threshold 1 ($y = 2$)	0.662 (0)	0.55 (0)	0.424 (0)	0.437 (0)	0.542 (0)	0.48 (0)	0.477 (0)	0.505 (0)
Threshold 2 ($y = 3$)	0.762 (0)	0.531 (0)	0.575 (0)	0.76 (0)	0.852 (0)	0.654 (0)	1.08 (0)	0.946 (0)
Threshold 3 ($y = 4$)	0.947 (0)	0.99 (0)	0.791 (0)	1.02 (0)	1.35 (0)	0.936 (0)	1.18 (0)	1.420 (0)

** The coefficient estimates are represented by the numbers without parenthesis, while the p-values are represented by the numbers inside the parenthesis

Table F. 7. The coefficient estimates and p-values for group 2 (Risk aversion)

	Carrying a heavy bag	Poor street lighting	pedestrian countdown	Driverless PT	CCTV / Police	Attractive crossing path
Age (20-24 years)	-	0.402 (0.065)	-	-	-	-
Age (55-64 years)	1.14 (0.02)	0.962 (0.017)	-	-	-	-
Age (65 years or older)	-	-	-1.29 (0.006)	-	-	-
Melbourne resident	-	-	-	0.544 (0.005)	-	-
Cultural background (Asian)	-	-	-0.482 (0.01)	-	-	-0.639 (0.001)
Education (Postgraduate degree)	-	0.433 (0.021)	0.497 (0.01)	-	-	-
Random PT user (Once a week)	-0.841 (0.065)	-	-	-	-	-
Regular PT user (2-4 days a week)	-	0.529 (0.004)	-	-	-	-
Having mobility impairment	0.829 (0.017)	-	-	-	-1.112 (0.001)	-
High-income earners (\$135K or more per year)	0.539 (0.058)	-	-	0.528(0.02)	-	0.631(0.009)
τ_1	0.521 (0)	0.14 (0.35)	-0.622 (0)	-0.646 (0)	0.602 (0)	-0.348 (0.008)
Threshold 1 (y = 2)	0.691 (0)	0.96 (0)	0.925 (0)	0.703 (0)	0.856 (0)	1.43 (0)
Threshold 2 (y = 3)	0.749 (0)	1.02 (0)	1.12 (0)	1.32 (0)	1.05 (0)	1.40 (0)
Threshold 3 (y = 4)	0.915 (0)	1.17 (0)	1.3 (0)	1.04 (0)	0.733 (0)	0.736 (0)

** The coefficient estimates are represented by the numbers without parenthesis, while the p-values are represented by the numbers inside the parenthesis



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