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What do pedestrians consider when choosing a route? The role of safety, security, and attractiveness perceptions and the built environment during day and night walking

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ABSTRACT

Increasing the use of non-motorized modes of transport, such as walking, is a worldwide objective aimed at improving the sustainability of cities. However, pedestrians may not choose to walk if the infrastructure fails to meet their needs or if they hold unfavourable perceptions regarding the built environment (BE). The current study aims to identify the significance of route attributes and perceptions of attractiveness, safety, and security at the route level, which influence pedestrians' preferences for last-mile route choices. A cross-sectional design was employed, utilizing a questionnaire comprising a stated preference (SP) experiment and a perception survey. The study considered theory-informed attributes influencing pedestrian route choice preferences, including: (1) individual-level determinants, (2) physical-level determinants, and (3) time of day. Two separate models were developed, considering the time of day, to examine the differences in trade-offs within pedestrians' route choice preferences between day and night. The results revealed that both the BE and perceptions of the BE play a crucial role in determining pedestrian route choice behaviour. Pedestrians showed a preference for routes fully encompassed by mixed or residential land uses during the daytime. The presence of vacant land along the walking route significantly decreased the likelihood of choosing a route at night. Generally, pedestrians favoured shorter walking times, lower posted speed limits, and comfortable walkway grades in their routes. Female pedestrians tended to avoid routes that were not well-lit and pleasant at night. Lowering roadway speed limits emerged as a strategy to encourage walking in suburban areas. The findings of this study hold the potential to play an essential role in the development of effective policy initiatives targeted at pedestrians in cities.

1. Introduction

1.1. Background

Walking for transportation offers numerous environmental, social, and health-related benefits. Increased walking can help decrease emissions linked to fuel-based transportation, thus enhancing the sustainability of the transportation system (Liang et al., 2019). Furthermore, additional walking can yield health advantages tied to heightened physical activity and enhanced social interactions (Leyden, 2003). To harness the advantages of active travel, policymakers and practitioners need to consider strategies that shift individuals from fuel-based transportation to active modes of travel. A pivotal issue to address while formulating a sustainable transportation strategy is commuting, both to and from work.

In Australia, many cities heavily rely on fuel-based transportation for commuting purposes. Still, a significant number of commuters must walk to and from public transport stops (Zapata-Diomedi et al., 2017). At the residential end of the journey, traveling to public transport typically entails walking from home to the stop in the morning and from the stop back home in the evening (referred to as the "last-mile" route). Notably, last-mile travel differs from first-mile travel, as time constraints to reach home are generally less pressing. Consequently, commuters might consider longer routes with essential attributes like improved

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lighting, particularly important during nighttime. Furthermore, these commuters possess limited discretion in whether to undertake the last-mile trip, given the necessity of reaching home. If the last-mile route presents tangible hazards, individuals might opt against using public transport. Poorly designed or maintained last-mile routes act as barriers to achieving a sustainable transportation system. Considering that individuals opt to walk to and from public transport stops based on available pedestrian facilities (Tilahun et al., 2016), it is plausible that the attributes of existing pedestrian facilities along alternative last-mile routes influence route selection.

The analysis of walking decisions is complex and depends on various factors. Ferreira et al. (2016) found that the avoidance of walking is primarily influenced by social qualities, while the decision to walk is affected by spatial-physical qualities. Well-designed, continuous, and safe walking routes are essential to encourage walking for transportation (Ariffin & Zahari, 2013). Designing effective walking routes demands a thorough understanding of pedestrians' decision-making processes and the multiple attributes considered by pedestrians, such as trade-offs between walkway grade and route length, sidewalks, direct connections, traffic volume, and speeds. Enhancing comprehension of these trade-offs would contribute to the better utilization of all routes, which significantly impacts overall traffic management (Sener et al., 2009). The process of selecting a route from various options for a specific origin and destination is referred to as "route choice" (Bovy & Stern, 2012). The investigation of pedestrians' route choices can yield a comprehensive understanding of the factors within the built environment (BE) and perceptions that influence pedestrians' preferences, ultimately serving to promote walking for transport.

1.2. Theoretical framework

Pedestrians' route choice decisions can be conceptualised using the PASTA (Physical Activity through Sustainable Transport Approaches) framework of active travel behaviour (see for more information Gotschi et al. (2017)). The PASTA framework describes the determinants of active travel choices, including (i) social context determinants such as policy, social network, and norms; (ii) physical context determinants such as natural and built environment, topography, land use; and (iii) individual-level determinants such as socio-demographics, attitude, perception, habit. Additionally, the PASTA framework states that active travel behaviour is influenced by objective (e.g., built environment) and subjective variables (e.g., perceptions and values). The mechanism proposed by the PASTA framework is that pedestrians develop perceptions from the environment and that such perceptions impact their active travel choices. The environment and the perceptions of such an environment will influence active travel decisions. The current study operationalised the mechanism of the PASTA framework by considering the physical context variables, individual-level determinants, and perception variables for data collection and analysis of route choice preferences in Australia (which is the social context of the study).

We will now summarise the main findings in the literature concerning the determinants of pedestrian's route choice behaviour. More in-depth information can be found in the Basu, Oviedo-Trespalacios, King, et al. (2022), a recent systematic review paper of all pedestrians' route choice behaviour studies in the literature, which served as the basis of the present study.

1.3. Literature review

1.3.1. Physical context determinants

Pedestrians consider features of the built environment (BE) to make route decisions. Previous research found that crosswalk infrastructure, sidewalk amenities (such as trees), and small commercial shops along the route were consistently associated with pedestrians' route choice (PRC) decision-making (Galama et al., 2017; Rodríguez et al., 2015). In contrast, factors such as steep terrain, longer walking time, longer waiting time, presence of litter, and lack of pedestrian signs decrease the likelihood of choosing a route (Ghorveh, 2017; Gim & Ko, 2017; Guo & Loo, 2013). However, a recent systematic review (Basu, Oviedo-Trespalacios, Haque, et al., 2022) has found crucial gaps in PRC studies. They found that very few PRC studies (only four out of forty-four) considered the speed limit of motorized traffic, which is associated with the safety concerns of pedestrians (Lee & Lee, 2021; Sevtsuk et al., 2021). The impact of walking time to the destination, which is a crucial factor for pedestrians' route choice also not considered very often in previous PRC studies (only six out of forty-four). Although many studies used land use along the route as a factor of PRC, none of the earlier studies has considered the percentage of the presence of land use share along the route.

The effects of the natural environment (NE) are rarely studied in PRC studies. Few PRC articles evaluated topography (i.e., steep terrain or upslope linked with the NE of pedestrian routes) (Joseph & Zimring, 2007; López-Lambas et al., 2021). It is essential to consider that older pedestrians are more vulnerable to falls due to uneven topography (Rod et al., 2021). For example, pedestrians may trade-off between narrow and broader sidewalks due to hilly topography (Guo & Loo, 2013; Ozbil et al., 2016). A variable not explicitly mentioned in the PASTA framework but will impact pedestrians' decisions is the time of day. Tribby et al. (2017) reported that the time of day affects traffic safety when selecting a route. They observed that pedestrians are more likely to choose a route if there is less interaction with motorized traffic, which often happens at night-time. Previous research also reported that female pedestrians are less likely to walk at night because they perceive a higher risk of being assaulted/robbed/harassed than in the daytime (Basu, Haque, et al., 2021, Clifton & Livi, 2005, Foster et al., 2004). Additionally, the perception of security among female and male pedestrians was found to be higher with the presence of trees during the night (Basu, Haque, et al., 2021).

Individual determinants such as socio-demographic factors, e.g., age, gender, ethnicity, occupation, and income, are explored in most PRC literature. Since the relationship between demographic characteristics and PRC differed by age, gender, and ethnicity, a thorough study of these variables is required to establish an appealing urban walking environment for all groups. For example, pedestrians aged between 18 and 24 years (students) were likelier to choose a route that included modern residential and commercial environments (Bafatakis et al., 2015). In contrast, older pedestrians preferred the route that included both modern residential and commercial settings. Particular groups of people, such as children commuting to school, have gotten a lot of attention in the PRC literature. When parents of schoolchildren walk along a route with trees, they feel more at ease and safer (Evers et al., 2014). It was also found that the influence on PRC differed by gender. Male pedestrians were likelier to choose a shorter walking route, had fewer streets to cross, and were less crowded. On the other hand, female pedestrians valued the availability of shops (Wickramasinghe & Dissanayake, 2015). Only a few studies have considered the potential taste (sensitivity) variation across individuals to route attributes due to personal characteristics.

Pedestrians consider a range of factors to perceive their route environment, including accessibility, aesthetics, comfort, convenience, attractiveness, familiarity, connectivity, safety (traffic safety), and security (personal safety, fear of crime) (Alonso et al., 2021; Craig et al., 2002; Ferrer et al., 2015; Foster et al., 2014; Giles-Corti & Donovan, 2002; Johansson et al., 2016; Rod et al., 2023; Moura et al., 2014; Panter et al., 2014; Villaveces et al., 2012). These perceptions have an impact on how pedestrians choose their routes. A review paper found that pedestrians' perceptions of attractiveness, safety, and security are the most critical factors determining walkability (Arellana et al., 2020). For example, some studies found that pedestrians perceived the route as attractive with good scenery (such as parks or playgrounds, vegetation, sculptures, or fountains) because of aesthetics, which improves the likelihood of choosing that route (Dessing et al., 2016; Koh & Wong,

Table 1
Attributes considered for PRC analysis based on the PASTA Framework.

Determinants	List of attributes	Key references
Individual-level determinants		
Demographics	Age, gender	Bafatakis et al., 2015; Evers et al., 2014
Perception of the walking environment	Attractiveness, safety, and security perceptions of the route	Dessing et al., 2016; Koh & Wong, 2013; Rodríguez et al., 2015; Bafatakis et al., 2015; Evers et al., 2014
Physical level determinants		
Built environment	Land Use (i.e., residential, commercial, recreational, mixed land use, and vacant land)	Galama et al., 2017; Rodríguez et al., 2015
	Sidewalk continuity	Rodríguez et al., 2015; Shatu & Yigitcanlar, 2018
	Walkway grade (slope)	Borst et al., 2009; López-Lambas et al., 2021
	Posted speed limit	Lee & Lee, 2021; Sevtsuk et al., 2021
	Walking time	Yamamoto et al., 2018
Natural environment	Time of day (i.e., day/night)	Tribby et al., 2017

2013; Rodríguez et al., 2015). On the other hand, a route is less likely to be selected if there is a risk of crashes or injuries, the presence of blockages or tripping hazards, or a detour along the route (Bafatakis et al., 2015; Dessing et al., 2016; Evers et al., 2014). Pedestrians' safety perceptions are influenced by factors such as the availability of crossing aids and interactions with motorized vehicles. Such perceptions of built environment (BE) are thought to mediate the relationship between BE characteristics and PRC in the literature. Importantly, Basu, Oviedo-Trespalacios, Haque, et al. (2022) reported that very few PRC studies evaluated the impacts of attractiveness, safety, and security perception on PRC in their systematic review. In light of this gap in the literature, we included the BE variables that influence perceptions of a walking route's attractiveness, safety, security, and decisions to walk on that route, by day or night. Following Basu, Haque, et al. (2021), we considered two indicators of attractiveness, i.e., pleasantness and friendliness. The former is related to physical and the latter to social aspects of attractiveness.

The built environment (BE) has been considered an influential factor in an individual's travel behaviour. However, the collective impact of BE and the perception of pedestrians on route choice has not been studied widely. Previous studies examined the effect of BE characteristics on pedestrians and considered the aggregate and disaggregate levels of route selection. The aggregate level studies included choosing the route with either existing or after improvements of the BE facilities (Muraleetharan & Hagiwara, 2007; Ozbil et al., 2016). In contrast, disaggregated route choice preferences considered pedestrians' decision-making, i.e., the underlying pedestrian behaviour (Bafatakis et al., 2015; Dessing et al., 2016; Galama et al., 2017; Rodríguez et al., 2015). The present study analyses disaggregate-level route choice preferences due to its capacity to better capture the relationship between pedestrian route choices and walking route facility features.

Based on the literature review, a set of potential determinants of pedestrian route choice has been identified. See Table 1 for a comprehensive list of attributes used in this study.

1.4. The present study

The aim of this study is to investigate the last-mile route choice preferences of pedestrians based on route attributes and route level perception of attractiveness, safety, and security. We performed a route choice analysis because it can reveal the important features needed for walking the last part of a journey. By comparing these features, we can learn about the challenges in walking within the current transport system and the effects of people's perceptions. In this study, we uncover and assess how significant different design aspects and perceptions are when pedestrians decide on their route for the final part of their journey. The results of this research can inform recommendations to enhance the walking experience and to plan future facilities that encourage people to walk more.

The present investigation is highly comprehensive as it considers a wide range of physical and individual-level determinants, the perception of those physical level factors, and the time of day variables. The current study contributes to the existing literature by (1) including a set of attributes of the route in pedestrian route choice analysis, (2) focusing on land-use share along with the route, walkway physical characteristics as they impact pedestrian route choice, (3) analysing the perception of attractiveness, safety and security on the experimental facility attributes, and (4) using a multinomial analysis framework with sensitivity differences across pedestrians personal attributes for route choice analysis.

2. Methods

The present study utilizes a cross-sectional design with a questionnaire consisting of a stated preference (SP) experiment and a perception survey. The SP experiment was selected to collect the route preference data, and the perception survey was conducted to collect the perception of the specific walking environment designed using different land uses. The list of attributes considered in the present study is shown in Table 1.

The designed questionnaire contained a total of 33 questions. The first part of the questionnaire included questions about the socio-demographics of pedestrians, their typical travel habits (how often they walk and use public transport), and their attitude toward walking. The second part consisted of questions regarding respondents' perceptions of different walking scenarios. These questions presented ten hypothetical environmental scenarios, each depicting a unique route environment. These scenarios were categorized into day and night settings. More details about the perception data collection process can be found in the next section. In the third part of the questionnaire, respondents were asked about their preferred options in route-level scenarios (refer to Appendix A). The SP experiment used scenarios to gather data about preferences. Specifically, we designed hypothetical environmental situations using actual photographs of neighbourhoods in Brisbane, Australia. This approach aimed to make the study feel more authentic and relatable. Each scenario had its own distinct route setting. For the collection of stated preference (SP) data, we used three questions, each presenting a choice between three alternative routes. Participants were asked to choose one route out of the three in each question. More information about the stated preference data collection design can be found in Section 2.1. The online survey was accessible for data collection from 21/10/2019 to 20/06/2020.

2.1. Stated preference (SP) experiment

As a part of this study, we carried out an SP experiment. This was done because SP data help us efficiently grasp the important factors that greatly influence people's choices (Beelaerts van Blokland, 2008). These data also let us figure out the trade-offs between various attributes and

Table 2
Route attributes and levels for the SP experiments.

Determinants	PRCB attributes	Description of attributes	Attribute levels
Physical level determinants	1. Residential 2. Commercial 3. Recreational 4. Mixed land-use 5. Vacant land	The presence of various combinations of land uses along the route	1. 0 % share 2. 25%share 3. 50%share 4. 75%share 5. 100 %share (0 % to 50 % presence are considered for all land uses. 75 % and 100 % presence are considered for residential and mixed land use only)
	Sidewalk continuity	The sidewalk is considered continuous if the whole route has a sidewalk and is discontinuous otherwise.	1. Continuous- the sidewalk is continuous for the whole route 2. Discontinuous- the sidewalk is not continuous for the whole route
	Walkway grade (slope)	The terrain grade of the walking route	1. Flat - No hills 2. Some moderate hill 3. Some steep hills
	Speed limit	The speed limit on the roadways encountered on the walking route	1. 30 km/h 2. 50 km/h 3. 70 km/h
	Walking time	Time is taken to go to the bus stop from home	1. 8–10 min 2. 10–15 min 3. 15–20 min
		Time of day to walk	1. Daytime 2. Night-time

what people prefer when it comes to pedestrian routes.

2.1.1. SP experimental design

There are, overall, ten route attributes for the SP experimental design. The description of the attributes is shown in Table 2. The levels were designed based on a general understanding of existing conditions, and factors were presented from lower to higher levels to capture pedestrians' preferences based on the levels of the attributes. Based on existing information, the pedestrian walking time has been estimated for unit trip length (1 to 1.5 km). The experimental block design, i.e., for the time of day (day/night), was adopted to get the perception and preference variation data based on this factor. We designed a methodology based on the type of land use and the percentage of time a pedestrian spends on it to account for land use. Five land-use attributes are presented in the scenario design as the percentage share in the real-life route environment. There are five levels of residential and mixed land use[1]share (0 %, 25 %, 50 %, 75 % and 100 %), and three levels for commercial, recreational, and vacant land (0 %, 25 %, 50 %) are used based on intuitive judgment. Combining these levels was used to design a total 100 % presence of land uses along the route.

The D-optimal design was used to consider all ten route attributes in a manageable manner (Maitra et al., 2015). The traditional approach, full factorial design, would have resulted in an unfeasible number of experimental conditions. Specifically, an SP experiment that includes ten route attributes and their levels would have resulted in a total of 36,450 choices ($5 \times 3 \times 5 \times 3 \times 3 \times 2 \times 3 \times 3 \times 3$). Instead, the D-optimality method sought to do this. Like Majumdar and Mitra (2017), this paper used JMP statistical package to design optimal choice sets. A total of 45 choice situations were generated using the D-optimal design, which was then randomly divided into five blocks.

The survey presented three choice experiments (or choice questions) to each respondent. The choice sets offered three alternative routes, and the individual was asked to choose one of the three routes. Each survey respondent, for example, is provided with nine experiments. In each experiment, three hypothetical route scenarios were described, with walking time, presence of land-use share, sidewalk continuity, posted speed limit, and walkway grade. In each experiment, three scenarios were presented, and the respondent was asked which option s/he would choose if facing the choice in the real world. One example of instruction questions presented in the questionnaire as follows:

"*Imagine you are walking along a route from a bus stop/train station to your home. You have three alternative routes to walk home. The sidewalks of all routes are continuous, and you have to consider the following four features (land use, speed limit, slope, and walking time) to choose your route. Which route would you like to choose?*"

Three sample choice sets that are used to prepare the graphical design to present in the questionnaire are shown in Table 3.

The design aimed to extract as much information as possible about the influence of route features on the decisions of route choice. Any SP question design offered to a respondent was reviewed to clear the dominant alternative. The survey included pictures and graphical designs to present the experimental route scenarios. Fig. A1 shows only one choice set (sample choice set 1) out of three choice sets in questionnaire set 1 (see Appendix A).

2.2. Perception survey

The Perception of attractiveness (in terms of pleasantness and friendliness), safety (in terms of risk of injury due to car crash), and security (in terms of risk of assault/harassment/robbery) of the different walking environments were collected using photographs of Brisbane suburbs. Participants were then shown photos of ten (10) hypothetical environmental scenarios considering different land uses, including residential. Commercial, recreational, mixed land-use, and vacant land with/without trees or garbage to represent the specific walking environment. The locations of collected photographs of environmental scenarios are shown in Fig. A2. These data were collected using a 7-point Likert scale. Scenarios were taken at day and night times for similar environments during 2019. One respondent responded only on either day or night-time scenarios aligned with the SP experiment to reduce the time burden. In relation to each scenario, the respondents were asked to answer a number of questions regarding the pleasantness of the route environment as a measure of perceived environmental attractiveness (1 "extremely unpleasant"–7 "extremely pleasant"), friendliness of the route environment as a measure of perceived social attractiveness (1 "extremely unfriendly"–7 "extremely friendly"), the likelihood of injury due to a car crash as measures of perceived safety and likelihood of being assaulted/robbed/harassed as measures of perceived security (1 "extremely unlikely"–7 "extremely likely" for both perceived safety and security).

The perception data of the walking environment was processed to build a new perception dataset for the experimental routes designed for collecting stated preference data as described in Section 2.1. In the new

[1] Mixed-use development is a type of urban development strategy for living spaces that blends residential, commercial, cultural, or institutional uses, where those functions are physically and functionally integrated.

Table 3
Sample choice sets for questionnaire set 1.

Choices	Attributes					
	Land uses along the route	Sidewalk continuation	Posted speed limit	Walking time	Walkway grade (slope)	Tick your choice
Sample choice set 1						
Route 1	100 % residential	Continuous	30 km/h	8 to 10 min	Flat or no slope	
Route 2	50 % residential + 25 % commercial + 25 % recreational	Continuous	50 km/h	10 to 15 min	Flat or no slope	
Route 3	75 % residential + 25 % mixed land use	Continuous	30 km/h	10 to 15 min	Some moderate slope	
Sample choice set 2						
Route 1	50 % residential + 50 % mixed land use	Dis-continuous	50 km/h	15 to 20 min	Some steep slope	
Route 2	25 % commercial + 75 % mixed land use	Dis-continuous	30 km/h	15 to 20 min	Some steep slope	
Route 3	25 % residential + 50 % mixed land use + 25 % vacant land	Dis-continuous	30 km/h	15 to 20 min	Some steep slope	
Sample choice set 3						
Route 1	75 % residential + 25 % recreational	Dis-continuous	50 km/h	15 to 20 min	Flat or no slope	
Route 2	50 % residential + 50 % recreational	Continuous	50 km/h	15 to 20 min	Some moderate slope	
Route 3	75 % residential + 25 % commercial	Continuous	30 km/h	15 to 20 min	Flat or no slope	

dataset, the weighted average perception data was used for a specific route based on the land use presence along that particular route. The perception data of any specific walking environment was multiplied by the % share of the presence of particular land use along the route. To address this, we created a variable considering the proportion of land uses available, multiplied by the rate given by the participant for each of the three perceptions. For example, if the perception of pleasantness level for residential land use with/without trees was '5' out of '7', this number was multiplied by the score of 0.25 if 25 % residential land use was present along the route. Similar approaches were applied to calculate the perception of all land uses along the route. At the end, all land use perceptions were then added to obtain the overall perception of the route. The critical point to consider here was that all routes were not designed using the same land-use types and proportions. The total land use along the route was 100 %, and the weighted average perception level would always be on a scale of 1 to 7. These techniques were applied to calculate the perception of friendliness, perception of risk of injury due to a car crash, and perception of risk of assault/harassment/robbery for all routes separately.

2.3. Recruitment

The questionnaire was administered through a website hosted by the Queensland University of Technology (Brisbane, Australia). The questionnaire was disseminated using Facebook and electronic mail through QUT mailing lists and public face-to-face dissemination of survey links. A participant information sheet (PIS) also provided a brief overview of the study (pedestrian route choice behaviour in general) and a link to the survey. It took about 20 min to complete the whole questionnaire. It was assured that the participation was voluntary. The final version of the survey instrument is available on request from the authors. The Ethics Review Committee approved the protocol for the research of the Queensland University of Technology (QUT) (Approval Number: 1900000737), Australia.

2.4. Sample size

We followed Louviere et al. (2000) to calculate the sample size for SP data collection. To predict the route share in the range of 10 % probability ($p = .10$), a route accuracy of 10 %, and a 95 % confidence level, the minimum number of choice required is 3457, and with each respondent answering three choice scenarios', a sample of at least 1152 ($3457/3 = 1152$) respondents were needed. The share probability depends on the true population proportion (i.e., the % of pedestrians in Brisbane compared to the total population). According to the Australian Bureau of Statistics, the total population of greater Brisbane was 2.2 million on 30th June 2013. Based on the household travel survey report of the Department of Transport and Main Roads (2018), 10 % of the population of South East Queensland (SEQ) used walking as a transport mode by 2009. As mentioned in Section 2.1, 45 choice profiles were generated using a D-optimal design and divided into five questionnaires. Each questionnaire has three choice sets with three alternatives. As the experimental block design was followed to develop the questionnaire, all questionnaire sets have two versions; one was designed for daytime, and the other was for night-time. Considering these strategies, ten sets of questionnaires were disseminated to collect data. Given that the research needed a sample of 1152, each set of questionnaire needs at least 116 responses.

2.5. Dataset for analysis

During three months, 1174 participants fully completed the web-based questionnaire. The database screening has been done to ensure the respondent's survey completeness. The participants are eligible if their age is above 18 years old. Participation was voluntary, so the participants were entered into a draw to win one of 20 $50 gift vouchers (if they agreed).

Table 4 provides the descriptive statistics of the 1174 participants, of which 568 males (48 %) and 610 females (52 %). The Participants were 36.23 (SD = 14.79) years old in average (range 18–84 years). Among all participants, 42 % are young adults (age range 18–29 years), 49 % are middle-aged (age range 30–59 years), and the rest 9 % are old adults. As mentioned earlier, the experimental block design was adopted to get the perception and preference variation for time of the day (day/night), 608 (52 %) respondents received a daytime questionnaire, and the remaining 566 individuals (48 %) received a night-time questionnaire.

Table 4 shows summary statistics for variables relating to pedestrians' personal characteristics and route level attributes. Table 5 summarises the responses given by the participants to each of the ten route environment scenarios for four different perceptions.

2.6. Econometric modelling framework and estimation

A utility-maximising model of choice is considered in this investigation for route choice analysis. The multinomial logit (or MNL) model has been used to estimate the main and interaction effects of the vari-

Table 4
Summary of participants' responses.

Variable name	Frequency (%)	
	Day	Night
Pedestrians personal characteristics		
Age		
Young adults	254 (42.0)	239 (42.0)
Middle-aged adults	303 (49.0)	275 (49.0)
Older adults	51 (9.0)	52 (9.0)
Gender		
Male	278 (47.0)	277 (47.0)
Female	322 (52.0)	284 (52.0)
Other	8 (1.0)	5 (1.0)
Time of the day		
Day	608 (52.0)	–
Night	–	566 (48.0)
Route level attributes		
% share of residential land use		
0 % share	241 (40 %)	226 (40 %)
25 % share	54 (9 %)	50 (9 %)
50 % share	149 (25 %)	139 (25 %)
75 % share	83 (14 %)	76 (14 %)
100 % share	80 (13 %)	76 (13 %)
% share of commercial land use		
0 % share	432 (71 %)	402 (71 %)
25 % share	110 (18 %)	100 (18 %)
50 % share	67 (11 %)	63 (11 %)
% share of mixed land use		
0 % share	245 (40 %)	227 (40 %)
25 % share	14 (2 %)	12 (2 %)
50 % share	162 (27 %)	150 (27 %)
75 % share	122 (20 %)	113 (20 %)
100 % share	66 (11 %)	63 (11 %)
% share of recreational land use		
0 % share	486 (80 %)	452 (80 %)
25 % share	96 (16 %)	88 (16 %)
50 % share	27 (04 %)	25 (04 %)
% share of vacant land		
0 % share	500 (82 %)	466 (82 %)
25 % share	68 (11 %)	63 (11 %)
50 % share	40 (07 %)	37 (07 %)
Walkway facility characteristics		
Sidewalk continuity		
Continuous sidewalk	379 (62 %)	353 (62 %)
Dis-continuous sidewalk	229 (38 %)	213 (38 %)
Walkway physical characteristics		
Walkway grade		
Flat - No slope	192 (31 %)	177 (31 %)
Some moderate slope	240 (40 %)	226 (40 %)
Some steep slope	176 (29 %)	163 (29 %)
Roadway functional characteristics		
Posted speed limit		
30 km/h	241 (40 %)	227 (40 %)
50 km/h	150 (25 %)	138 (25 %)
70 km/h	217 (36 %)	201 (36 %)
Walkway operational characteristics		
Walking time		
8–10 min	214 (35 %)	201 (35 %)
10–15 min	216 (35 %)	201 (35 %)
15–20 min	178 (30 %)	164 (30 %)

ables in the route choice preferences:

$$U_{ijk} = \beta x_{ijk} + \varepsilon_{ijk} \tag{1}$$

where the *Uijk* is the utility of a route that is the choice of individual i from the alternative j on k numbers of choice scenarios. In the above equation, i ($i = 1, 2, \ldots, I$) used for the individual decision-maker, j ($j = 1, 2, \ldots, J$) for the alternative of route and k ($k = 1, 2, \ldots, K$) for SP scenarios. In this investigation, β is the vector of the mean effects of the preference coefficients of route attributes x_{ijk} (perception variables, and the interactions of route attributes among themselves and with pedestrian personal characteristics), that affects the utility of individual I (from $I = 1174$) for alternative j ($J = 3$) at the kth ($K = 3$) choice scenario. ε_{ijk} represents Gumbel distributed random error specific to the choice scenario. It is assumed that ε_{ijk} is independent of x_{ik}. There are no alternative-specific variables in the current context as the route alternatives are "unlabelled" and characterised by route attributes.

In the usual multinomial logit form, the probability of choosing route j at the *kth* choice scenario by individual i can be written as follows:

$$P_{ijk} = \frac{e^{\beta x_{ijk}}}{\sum_J e^{\beta x_{ijk}}} \tag{2}$$

The empirical model of pedestrian route choice used a total of 3522 choice scenarios (3 choices per respondent) from 1174 individuals as the final estimation sample. The route perception level data (Section 2.2), time of day, interaction effects of the route attributes (see Table 2) and perception data with pedestrian characteristics were factored into the route choice model used in this investigation. The specification of main effects variables was finalised by eliminating the statistically insignificant variables and parsimony in representing variable effects. The multinomial models were estimated using the software package LIMDEP 10.0/NLogit 5.0.

3. Results

The route attribute category discusses the main effects of route attributes and perceptions and related interaction effects in the following sections (Table 6). At first, all attributes of SP experiments and perceptions are used to finalise the main effects model, which is an essential reference point for analysing the importance of all route level variables and perceptions. The main effects model was obtained based on a systematic process of eliminating variables found to be statistically insignificant at a 5 % level.

3.1. *Physical level attributes influence PRC*

3.1.1. *Land uses along the walking route*

Five land-use categories are considered in the analysis of this study. All variables are captured as dummy variables. For residential and mixed land uses, 50 % presence of land-uses is considered the reference attribute level, whereas 25 % land-use share is considered the reference level for other land-use categories as shown in Table 6. In general, attribute levels of the land-use categories have a statistically significant effect on route choice preferences in the daytime, except for 75 % residential, 50 % commercial, and 25 % mixed land use attribute levels and for vacant land. However, only five attribute levels, including a 0 % share of vacant land, are statistically significant at night-time. It is to be noted that attribute levels of commercial and recreational land use have no significant effects at night.

The negative signs of coefficient values indicate less preferable attributes, whereas positive signs indicate preferable attributes compared with the reference level. For example, the model results show that pedestrian prefers to walk along the route with a 100 % presence of residential land use, whereas 0 % presence of residential land use is not preferred in the daytime. The model results for night-time indicate that the pedestrians do not prefer the route with the presence of vacant land at night-time. Furthermore, the relative magnitudes of land-use variables suggest that 100 % of mixed land use is the most preferred land-use type, followed by the 100 % presence of residential and 50 % of recreational land use. In summary, the increasing trends of the relative magnitude of the coefficient indicate that preference for a route increase

Table 5
Average responses per scenario.

Scenarios		Perceived attractiveness (pleasantness) M (SD)	Perceived attractiveness (friendliness) M (SD)	Perceived safety (injury due to a car crash) M (SD)	Perceived security (being assaulted/robbed/harassed) M (SD)
Combined built environment factors along the route					
1. Residential land-use with lots of trees	Day	6.06 (0.891)	5.96 (0.940)	2.15 (1.343)	2.48 (1.476)
	Night	4.36 (1.515)	4.04 (1.479)	2.30 (1.366)	3.97 (1.686)
2. Residential land-use with few or no trees	Day	3.57 (1.534)	3.84 (1.432)	3.15 (1.584)	3.51 (1.647)
	Night	2.54 (1.324)	3.57 (1.298)	3.40 (1.735)	4.80 (1.667)
3. Commercial land-use with lots of trees	Day	6.22 (0.953)	6.04 (1.018)	2.12 (1.390)	2.68 (1.509)
	Night	5.75 (1.106)	5.69 (1.060)	2.50 (1.491)	2.62 (1.454)
4. Commercial land-use with few or no trees	Day	2.80 (1.486)	3.14 (1.477)	4.09 (1.740)	3.70 (1.649)
	Night	2.93 (1.358)	3.02 (1.320)	3.89 (1.685)	4.27 (1.694)
5. Mixed land-use with lots of tree	Day	5.46 (1.161)	5.40 (1.149)	3.17 (1.614)	2.95 (1.487)
	Night	4.81 (1.291)	4.85 (1.242)	2.90 (1.497)	3.24 (1.466)
6. Mixed land-use with few or no trees	Day	4.03 (1.453)	4.12 (1.373)	3.41 (1.585)	3.46 (1.530)
	Night	3.63 (1.348)	3.73 (1.327)	3.32 (1.613)	3.86 (1.522)
7. Recreational land-use with lots of trees	Day	5.92 (1.167)	5.51 (1.289)	1.62 (1.141)	4.01 (1.708)
	Night	5.02 (1.622)	4.54 (1.657)	1.75 (1.157)	4.44 (1.661)
8. Recreational land-use with few or no trees	Day	5.41 (1.305)	5.33 (1.152)	2.43 (1.499)	3.48 (1.610)
	Night	3.41 (1.632)	3.27 (1.523)	3.27 (1.523)	4.74 (1.597)
9. Vacant land without garbage	Day	3.28 (1.368)	3.42 (1.342)	2.96 (1.553)	3.90 (1.629)
	Night	2.80 (1.311)	2.86 (1.297)	2.96 (1.598)	4.65 (1.606)
10. Vacant land with garbage	Day	2.24 (1.156)	2.59 (1.303)	3.19 (1.604)	4.28 (1.687)
	Night	2.36 (1.253)	2.48 (1.265)	3.04 (1.590)	4.83 (1.561)

Table 6
Pedestrian route choice model results with interaction effects.

Determinants	PRC attributes	Attribute levels	Daytime		Night-time	
			Coefficient	z value	Coefficient	z value
Physical level determinants	% share of residential land use (ref: 50 % share)	00 % share	−1.48***	−7.23	−0.607***	−4.44
		25 % share	−0.831***	−4.19	−0.636***	−3.15
		75 % share	–	–	–	–
		100 % share	1.04***	6.45*	–	–
	% share of commercial land use (ref: 25 % share)	00 % share	−0.450***	−4.73	–	–
		50 % share	–	–	–	–
	% share of mixed land use (ref: 50 % share)	00 % share	−0.508***	−2.89	–	–
		25 % share	–	–	–	–
		75 % share	0.655***	4.85	0.312**	2.48
		100 % share	1.53***	7.08	0.513***	3.00
	% share of recreational land use (ref: 25 % share)	00 % share	−1.11***	−10.22	–	–
		50 % share	0.712***	3.35	–	–
	% share of vacant land (ref: 25 % share)	00 % share	–	–	0.837***	6.28
		50 % share	–	–	–	–
	Sidewalk continuity (ref: Continuous sidewalk)	Discontinuous sidewalk	−1.15***	−8.17	−1.23***	−8.54
	Walkway grade (ref: Some moderate slope)	Flat - No slope	1.24***	7.59	0.927***	6.94
		Some steep slope	−0.523***	−4.23	−0.871***	−6.28
	Posted speed limit (ref: 50 km/h)	30 km/h	0.295***	2.70	0.327***	3.38
		70 km/h	−0.479***	−4.05	−0.489***	−4.07
	Walking time (ref: 10–15 min)	8–10 min	1.06***	15.18	0.802***	9.97
		15–20 min	–	–	−0.563***	−4.29
Individual-level determinants	Perception of attractiveness	Pleasantness	–	–	0.229***	3.25
		Friendliness	–	–	–	–
	Perception of Safety	Risk of injury due to car-crash	−0.116**	−2.05	–	–
	Perception of Security	Risk of being assaulted/robbed/harassed	–	–	–	–
Interaction effects						
Gender (female) * 0 % share of mixed land use			−0.337**	−2.15	–	–
Gender (female) * 0 % share of vacant land			–	–	0.981***	4.84
Gender (female) * Perception of pleasantness			–	–	−0.257***	−2.68
Age (young adult) * 0 % share of residential land use			0.557***	3.86	–	–
Age (older adult) * 0 % share of residential land use			–	–	−1.120***	−4.20
Log-likelihood function			−1559.57		−1430.65	
Number of parameters			18		16	
Number of route choice observations			1824		1698	
Akaike's information criterion (AIC)			3155.1		2904.9	

*** Significance at 1 % level.
** Significance at 5 % level.
* Significance at 10 % level.

with the increase of the land-use share of particular land use for both daytime and night-time.

3.1.2. Sidewalk continuity

Sidewalk continuity is captured in the form of two dummy variables. Sidewalk continuity is considered as the reference variable. The effect of walkway facility types on pedestrian route choice is as anticipated. The negative effects on discontinuous walking facilities indicate that pedestrians do not prefer a discontinuous route for both daytime and night-time.

3.1.3. Walkway grade

The variables associated with walkway grade indicate a preference for flat terrain with no slope and a low preference for ‘some steep slopes’ compared to the walkway with a moderate slope for both daytime and night-time. As anticipated, the relative magnitude of variables suggests that flat terrain is the most preferred walking grade for pedestrians.

3.1.4. Posted speed limit

The effects of posted speed limit on the adjacent road on pedestrian route choice are modelled for 30 km/h and 70 km/h with 50 km/h as the reference level. The results show a lower preference for a walking route with a 70 km/h posted speed limit on an adjacent road for both daytime and night-time. Pedestrians preferred speed limit is 30 km/h on an adjacent road for both daytime and night-time.

3.1.5. Walking time

The variables associated with walking time are statistically significant for the night-time model. However, only ‘8 to 10 minutes’ walking time is significant for the daytime model compared to ‘10 to 15 minutes’ walking time. The coefficients of ‘8 to 10 minutes’ walking time are positive and significant, reflecting a preference for shorter walking time for both daytime and night-time. The model result also shows that pedestrians do not prefer a route with a high walking time (15 to 20 min) at night.

3.2. Influences of perception of attributes on PRC

The perception of attractiveness (pleasantness and friendliness), safety, and security are considered for the analysis of this study. All variables are captured as ordered variables. Only two of four perception variables are significant for daytime and night-time models: the perception of pleasantness and safety. The model result shows that pedestrians prefer a route with a lower perception of risk of injury due to car-crash in the daytime and a higher perception of pleasantness at night-time.

3.3. Influences of pedestrians’ demographics on PRC

Pedestrians’ personal characteristics in terms of gender and age are used for sensitivity tests in PRC. The interaction effects specific to residential land use indicate that young adults prefer the route with no presence of residential land use in the daytime. And older adults have a lower preference for the route with no presence of residential land use at night-time. The coefficient of 0 % presence of residential land use along the route indicates that a route along with 0 % residential land-use is 0.607 utility units less preferred than with 50 % residential land use presence along the route for the young and middle-aged men pedestrians at night. For older pedestrians, the route with 0 % residential land use is $1.727 = (0.607 + 1.120)$ utility units less attractive than a route with 50 % residential land use at night. Similarly, a route with no mixed land use is 0.508 utility units less preferred during the daytime, and the same route is $0.845 = (0.508 + 0.337)$ utility units less preferred than a route with 50 % mixed land use for female pedestrians. However, a route with no vacant land is $1.818 = (0.837 + 0.981)$ utility units more preferred than a route with a 25 % presence of vacant land at night-time.

4. Discussion

The factors that influence decisions when selecting a last-mile route have received limited attention in academic literature. This study aimed to explore preferences for last-mile routes in suburban walking environments during both day and night by developing a multinomial logit model (MNLM) that incorporates built environment and perception factors. In this study, route preferences were evaluated based on the trade-offs between different route attributes while traversing diverse land-use settings. The scenarios examined in this investigation revealed that a variety of physical built environment factors, including land-use diversity, walkway facilities, and perceptions of route attributes, contribute to preferences for last-mile routes. Additionally, pedestrian characteristics played a significant role in shaping preferences for last-mile routes at various times of the day.

4.1. Land uses along the walking route

Pedestrians generally prefer routes through diversified land use over those passing through unoccupied or vacant land. Additionally, routes featuring vacant land are less likely to be selected as last-mile routes. Prior research has indicated that pedestrians tend to avoid areas near vacant land due to the perception of low human activity (Borst et al., 2008). Specifically, women pedestrians tend to avoid walking through areas with unoccupied land during nighttime due to concerns about security risks (Keizer et al., 2008). Vacant land in suburban areas can impact women’s psychological safety, as it may create a perception of low human activity, preventing them from fully utilizing walking opportunities (Basu, Haque, et al., 2021, Borst et al., 2008). As such, an effective strategy to increase foot traffic is to develop land considering the proportion of diversified land uses.

The percentage share of mixed land use significantly influences pedestrians’ route preferences. In this study, the model results demonstrated that a 100 % mixed land use is the most preferred choice for pedestrians, compared to a route with 50 % mixed land use. This preference aligns with research suggesting that mixed land uses make walking more enjoyable and provide a sense of security. This could be attributed to the vibrancy of mixed-use areas, which offer diverse amenities like shops and restaurants, reduce reliance on cars, and ensure safety due to activities occurring throughout the day (Hirt, 2016). Research focused on female pedestrians indicated that their sense of security is higher when walking through areas with mixed land use during the daytime, which contributes to increasing equity (Basu, Haque, et al., 2021).

The results also revealed that pedestrians’ second preference is to walk through areas with 100 % residential land use during the daytime. However, young adults prefer routes without a significant presence of residential land use during the daytime. This might be attributed to the general quietness of residential areas in Brisbane, Australia, during the day. Earlier Australian research demonstrated that young people prefer inclusive, walkable communities with nearby amenities like shops, services, and entertainment (Garrard, 2017). On the other hand, older adults exhibit a lower preference for routes lacking residential land use at night. This is likely because of their familiarity with residential areas, especially at night (Phillips et al., 2013). Additionally, Guo and Loo (2013) noted that pedestrians frequently choose familiar routes in their study conducted in New York and Hong Kong. These findings underscore the importance of designing routes that cater to the needs of both older and younger pedestrians.

Walking through recreational areas, such as parks, emerged as the third option for last-mile trips, both during the day and at night. One possible explanation is that parks are perceived as safe due to the minimal likelihood of conflicts with motorized vehicles. Additionally, parks often feature shade trees, which can reduce ultraviolet (UV) radiation exposure – a significant health concern in Australia due to its contribution to skin cancers (World Health Organization, 2003). Parks also offer seating spaces along the sidewalk that can be appealing to pedestrians. Moreover, parks serve as gathering spots for pedestrians, contributing to their perceived friendliness as a social and attractive environment.

The model's predictions also suggest that pedestrians prefer routes with a commercial land use component. Pedestrians favoured a 25 % presence of commercial land use along the route. This preference is supported by a previous Australian study showing that young pedestrians prefer living in walkable communities with nearby commercial and retail areas (Garrard, 2017). However, the model did not indicate significant effects for a 50 % presence of commercial land use, which was unexpected. The reasons behind this finding are not clear, as no previous studies have explored the percentage share of land use along routes in relation to pedestrian route choice preferences.

A crucial implication of these findings is that the distribution of land uses along a route significantly influences pedestrian route choice preferences. This highlights the need for professionals and policymakers to consider the proportion of land uses when designing last-mile walking routes. However, these considerations should be made while accounting for potential group differences, as certain groups may be disadvantaged by specific route attributes. Additionally, special attention should be given to pedestrian amenities like shaded areas, benches, and drinking water sources, as these elements can further enhance the overall route perception (Basu, Oviedo-Trespalacios, King, et al., 2022).

4.2. Sidewalk continuity

Pedestrians preferred continuous walking facilities during daytime and night-time. This is unsurprising considering that continuous footpaths/sidewalks are safe and convenient for walking. Previous studies also showed that discontinuous walkways might be unsafe since pedestrians could bypass the discontinuous parts of the sidewalk and walk on the streets (Osama & Sayed, 2017). This would expose pedestrians to vehicle movements and could result in pedestrian-vehicle crashes. Policymakers and practitioners should provide continuous footpaths in the suburban environment as these are key factors for promoting walking and last-mile route choices.

4.3. Walkway grade

Pedestrians tend to avoid routes with steep terrain. This is because routes with significant gradients can be physically demanding for pedestrians, especially older adults (Borst et al., 2009). Broach and Dill (2015) also noted that a steep incline in the uphill direction is perceived as a hindrance to walking. They further revealed that traversing a 10 % steep slope is twice as energy-intensive as walking on a less steep path. Meeder et al. (2017) found that a 1 % increase in slope leads to roughly a 10 % decrease in walking attractiveness. Future research should investigate the preference for route choices based on gradient measurements to understand how much walkway slope pedestrians prefer in selecting their last-mile routes. For instance, slopes ranging from 0 % to 10 % could experience a 1 % decrease in pedestrian route choice preference for every increment in slope. Additionally, the influence of weather should be explored in conjunction with walkway slope. It is anticipated that walking on a steep slope in extreme weather conditions (e.g., extreme heat or cold) might negatively impact pedestrian route choice preferences. However, this study highlights the importance of careful slope design when planning for increased active travel.

4.4. Posted speed limit

Pedestrians prefer walkways alongside roads with lower posted speed limits both during the day and at night. One potential explanation is that pedestrians may feel unsafe when vehicles are traveling at high speeds nearby. Previous research has indicated that walking along roads with lower posted speed limits is perceived as safer (Gårder, 2004). Gårder (2004) establishes a significant correlation between speed and the severity of crashes. It is essential to consider that higher speeds often mean that pedestrians are given lower priority compared to motorized transport. For instance, an 80 km/h posted speed limit along a walkway might imply the presence of traffic lights at intersections (where pedestrians must request a green light to cross), thereby granting less precedence to foot traffic. Hussain et al. (2019) discovered that the odds of a pedestrian fatality increase by 11 % as the estimated impact speed rises by 1 km/h. The risk of fatality reaches 5 % at an estimated impact speed of 30 km/h, 10 % at 37 km/h, 50 % at 59 km/h, 75 % at 69 km/h, and 90 % at 80 km/h. According to Rankavat and Tiwari (2016), the perceived safety of pedestrians is intertwined with the actual risk, and enhancing their risk perception can result in a reduction of actual risk. A key implication of this research is that policymakers should consider lowering speed limits to encourage walking in suburban areas.

4.5. Walking time

Pedestrians prefer a route with a short walking time (8 to 10 min) both during the day and at night. This preference can be explained by the fact that shorter walking times are less physically demanding, more comfortable, and convenient. This finding aligns with Munoz-Raskin's (2010) study, which suggested that pedestrians are generally willing to walk no more than 10 min to access public transit. A study focusing on perceived walking time to school also reported that a walking time of 5 to 10 min is considered comfortable (Curtis et al., 2015). Moreover, this study revealed that if the perceived walking time to school is less than 10 min, the likelihood of children walking to school increases by a factor of 15.24 compared to walking times exceeding 10 min.

The model's outcomes also indicate that pedestrians are less inclined to choose a route with a lengthy walking time (15 to 20 min) during the nighttime. Yamamoto et al. (2018) similarly found that pedestrians tend to opt for alternative routes to minimize walking time.

4.6. Perceptions of the route

Time of day has different effects on route choice preferences, considering the perception of the route. The model's results indicated that pedestrians preferred routes with a lower risk of injury due to car crashes during the daytime. This is somewhat different from previous research, which showed that men and women feel unsafe at night because traffic is perceived as a threat during nighttime (Rišová & Sládeková Madajová, 2020). The model results also showed that pedestrians preferred to walk along routes with a higher perception of pleasantness at nighttime. Women pedestrians do not want to walk along a route if it is not pleasant at night. This may manifest as pedestrians' preference to walk along an attractive route. Borst et al. (2008) reported that routes through parks (recreational areas) are perceived as attractive for walking. In contrast, Nasar and Fisher (1993) found that the concealed view due to vegetation in the park areas might hinder pleasant features and be perceived as insecure at night. This higher perception of attractiveness might depend on the presence of enough street lights along the routes in Brisbane suburbs at night and the natural surveillance ensured by Brisbane City Council's tree maintenance program (Brisbane City Council, 2020). Policymakers and practitioners should provide more trees for all land uses to increase attractiveness. Additionally, it is necessary to prevent conflicts between pedestrians and motorized transit. For example, pedestrians should be allowed to walk at a comfortable pace when crossing signalized intersections, and speed limits should be kept low. Previous research has demonstrated the importance of separating pedestrians from motorized vehicles without creating a burden for pedestrians (Hasan et al., 2020; Oviedo-Trespalacios and Scott-Parker, 2017).

4.7. Discussion on methodology

This research has brought valuable insights to the field of pedestrian route preferences. By combining data from both the Built Environment (BE) and route perception, a comprehensive model was developed. This model effectively explains why people choose certain routes by considering a wide range of socio-technical factors. This research emphasizes that when studying walking route preferences, it is important to look at factors like the route itself, how people perceive it, and who the pedestrians are. Furthermore, the model introduced in this study can help us weigh the pros and cons of different route features. This can lead to better decisions when planning walking routes.

Through the use of an experimental route design to collect stated preference (SP) data, this study contributes to the methods of data collection in PRC preferences. This approach simplifies understanding the trade-offs between different route features when making route decisions. Collecting SP data for PRC research is a time-consuming task that requires prompt respondent answers. Only an efficient SP design can aid data collection without overwhelming participants. The SP experiment in this study is constructed in a way that professionals can use it to design future surveys. However, this study solely employed a web-based survey to collect data. There's a possibility of bias since respondents might be more inclined toward using these forms of communication technology. Platforms like LinkedIn or other social media attract a limited section of society.

Another important aspect is that the present paper developed a new approach to obtain the overall perception of the route. Specifically, considering that a route might encompass various scenarios, we developed a methodology to assign weights to all land use perceptions of a particular route. We ensured that the entirety of land use along the route added up to 100 %. To achieve this, we carefully considered the proportion of each type of land use within the route. This meticulous attention to proportion allowed us to measure and represent the various components of land use within the route, providing a standardized scale for evaluating perceptions. Nonetheless, this is a preliminary approach, and future research can develop more sophisticated techniques to improve the accuracy of perception data collection and analysis.

The direct effects of perception factors have been analysed using the multinomial model in this study. An important question that arises when analysing the relationship between different factors and pedestrian route choice preferences is whether the associations are independent or mediated by perceptions. The development of mediation analysis and structured equation models that helps to analyse direct, indirect and total effects will be a promising methodological advancement (Hayes, 2009).

The study considered attractiveness in terms of pleasantness and friendliness, as outlined in Basu, Haque, et al. (2021). The rationale for not assessing the general attractiveness of scenarios is rooted in the aim of providing more precise insights specific to the studied scenario. For example, in a city like Brisbane with its diverse landscapes, asking a broad question like 'is this attractive?' could introduce biases, as people might focus on more prominent areas rather than the areas they typically traverse. The study employed a 7-point Likert scale to gather perception data on attractiveness, safety, and security. Opting for a comprehensive scale instead of separate dimensions to account for latent variables was motivated by the universality and ease of understanding of this data collection method. It proves to be a rapid, efficient, and cost-effective approach. The quantitative data generated from this scale are straightforward to categorize for data aggregation. More research is necessary concerning route choice behaviour across diverse circumstances and alternative data collection methodologies.

5. Limitations and future research directions

Modelling the relationships between the built environment (BE) and walking routes serves as a platform for increasing the utilization of walking routes. However, collecting data to track how changes in the BE affect pedestrian route choice behaviour (PRCB) requires longitudinal data to establish the causality of BE elements on route selection. Pedestrian route choice can be influenced by climate and weather-related attributes, such as seasonality and the presence of weather shelters. For this study, data on pedestrians' perceptions of attractiveness, safety, and security were collected for land uses with trees and garbage along the route. However, data on perceptions of walking time, speed limits, and roadway gradient were not considered for collection. Incorporating perceptions of these three route-level attributes could offer more insights into pedestrian route choice research. Limiting the focus to the last mile as a walking route restricts the generalizability of the results. Exploring a broader range of trip purposes in future research will be essential. Furthermore, considering different latent classes of pedestrians and developing a model for each class would provide more informative outcomes.

6. Conclusion

The present investigation identified pedestrians' preferences for last-mile routes based on physical-level determinants, individual-level determinants, and perceptions of the route environment. A conceptualisation and operationalisation of the PASTA framework have been provided to aid readers in understanding why perceptions were chosen to identify pedestrians' last-mile route preferences for this study. This will enable future investigations to expand upon these perceptions and potentially include others, while also attempting to evaluate their causal link to the physical determinants of the environment. It is also important to consider the crucial role played by emotional connections to place in people's perceptions. These emotional factors impact value, attitudes, and consequently, preferences toward sustainable transportation modes, such as walking, all of which are presented in the PASTA framework.

The study employed a web-based questionnaire using a stated preference experiment and perception survey to collect data from pedestrians in Brisbane (Australia). The findings highlight the influence of land-use distribution on pedestrian route choices. Primarily, pedestrians prefer routes fully integrated within mixed or residential land uses during the daytime. However, they exclusively favour routes within mixed land uses at night. An ideal pedestrian route would feature level terrain and uninterrupted walking paths with mixed land uses, both during the day and at night. An important variable that emerged in the study was posted speed limits. Pedestrians consistently selected routes with lower roadway speed limits. The study also shows the preference for continuous walking routes and lower walkway gradients along the route. It is also important to keep mind pedestrians' sensitivity to travel time; naturally, they prefer shorter routes, which supports the notion of enhancing access to public transportation. These findings carry implications for promoting walking within suburban environments.

A key conclusion drawn from this paper is that both the physical and perceptual attributes of routes must be taken into consideration, as they have distinct impacts on pedestrian behaviour. For instance, when three routes connect an individual's home to a bus stop or train station, the choice of route can depend on factors such as terrain, crosswalks, and the presence of a park. If a park feature is included in the assessment of the second and third routes, pedestrians who value green spaces may opt for route two due to the larger park. However, when safety considerations are factored in, the preference may shift. Route two, which initially seemed appealing due to its shorter distance, flat terrain, and park, may not be selected if there is a perceived risk of injury or danger. Pedestrians might instead choose route three, which appears slightly safer. Future research should investigate whether perceptions should account for isolated situations along a route or the entire route as a whole. Finally, the insights derived from this study can play a pivotal role in crafting effective policy initiatives targeted at pedestrians. For example, planners should employ attractiveness and safety indicators to evaluate pedestrian route choices. These perception-based indicators are particularly important to address transport disparities, as certain perceptions disproportionately influence the decisions of vulnerable groups, such as women and older adults. Policymakers and practitioners must specifically consider the safety and security of pedestrians' chosen routes, as these factors could act as barriers to walking.

CRediT authorship contribution statement

Nandita Basu: Conceptualization, Investigation, Data curation, Formal analysis, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft. **Oscar Oviedo-Trespalacios:** Conceptualization, Supervision, Investigation, Methodology, Writing – review & editing. **Mark King:** Conceptualization, Supervision, Writing – review & editing. **Md. Kamruzzaman:** Conceptualization, Supervision, Writing – review & editing. **Md. Mazharul Haque:** Conceptualization, Supervision, Investigation, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

Fig. A1. The experimental route scenarios for different times of day.

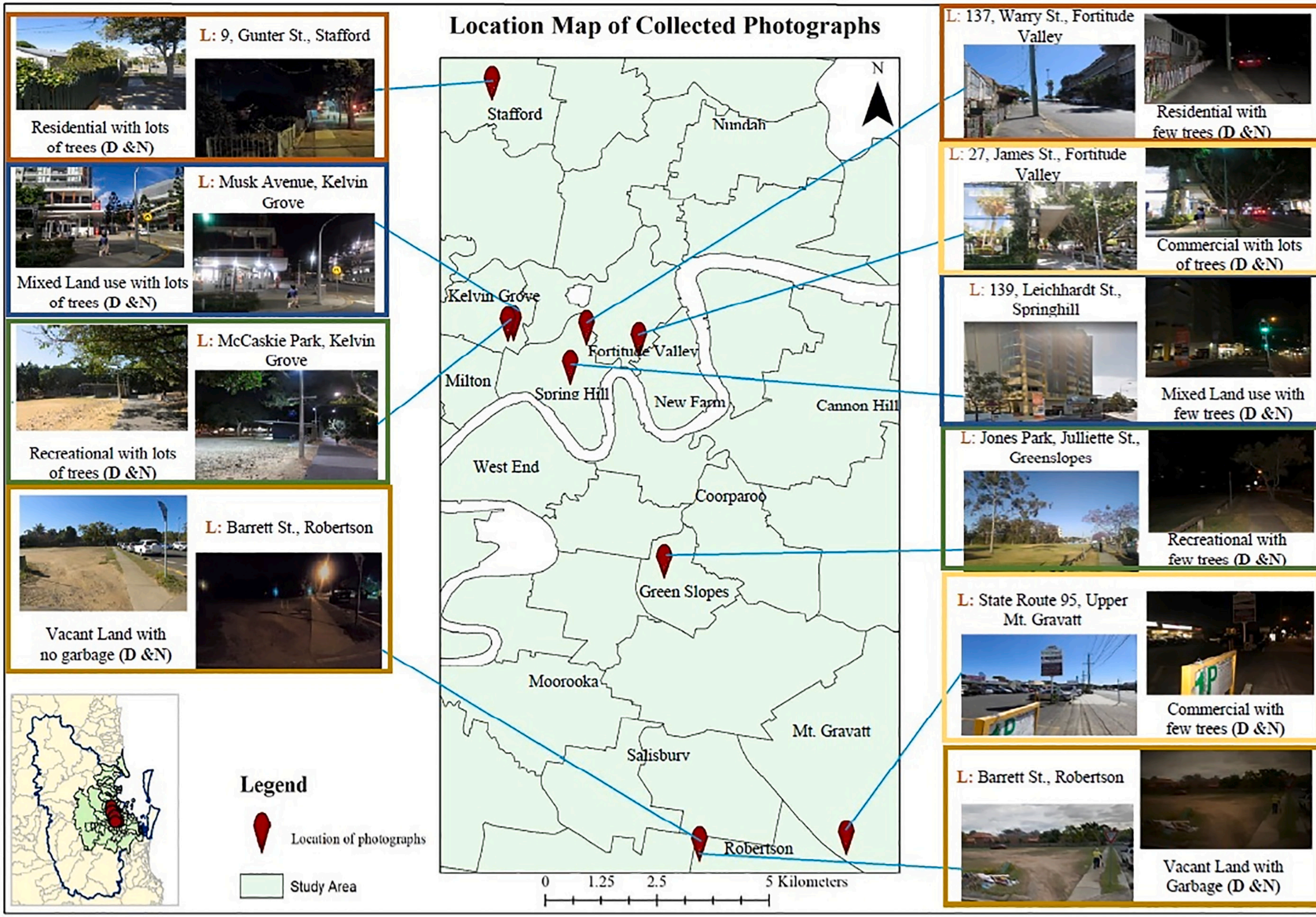

Fig. A2. Location (L) map of collected photographs for both day-time (D) and night-time (N).

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