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Report of Research Results

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Cyclists' visual behaviour and its effects on walking/cycling trips

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1. Summary

Locally and internationally, active trips (walking/cycling) are being encouraged to improve transport efficiency. Therefore, it is expected that bicycle traffic in Singapore will increase at a fast rate, with most of these trips being made on off-road pathways. Considering the vulnerability of active trip-makers, extra consideration needs to be placed on their safety. Movement speed differential between pedestrians and cyclists relegate the pedestrians as the more vulnerable of the two user groups. Thus, it is crucial to understand active travel behaviour and how this affects active trips in general. This project, through perception surveys (481 subjects) and field experiments (37 subjects) examined travel path preferences, behaviours when encountering (seeing) another active mobility user, and common cyclists' visual behaviours (obtained via eye tracker). The research protocol was approved by the NTU Institutional Review Board.

It is found that both pedestrians and cyclists generally prefer delineated paths (adjoining walking and cycling paths demarcated with clear markings) by virtue of dynamic sharing of 'middle-ground' space, instead of physically segregated pathways. Moreover, users reported to commonly move to the left when encountering (seeing) another active mobility user to allow him/her to pass. This suggests that programmes aimed to encourage safe sharing of facilities can focus on providing cues to further enhance this (keep-left) behaviour. Regarding cyclists' visual behaviour, four main focal points are identified, of which "ground" focal point is observed to occur at the beginning of the cycling trip, indicating that at places where cyclists are required to stop, ground marking will be most suitable.

2. Aim of Research

This 12-month project aims to investigate cyclists' travel behaviour. The main focus is placed on visual behaviour and movement behaviour at shared off-road facilities. Behaviour of other off-road users (e.g. pedestrians) is also analysed. Alternatives (as applicable) to improve road safety and trip comfort for pedestrians and cyclists are recommended.

3. Method of Research

Phase 1. Literature review and naturalistic observation

This phase involved reviewing existing literature on active travel and visual behaviour, with emphasis on the special characteristics in Singapore. The literature affirmed the gap in knowledge regarding mobility behaviour when commuting facilities are shared among cyclists and pedestrians (whereas the usual layout considers shared facilities between motorised vehicles and cyclists). Naturalistic observation was conducted at footpaths, widened paths, adjoining paths, and segregated paths (see Figure 1). Observations covered mainly cyclists and pedestrians, with occasional presence of users of personal mobility devices (PMDs, such as electric scooters). The literature review and naturalistic observations serve to identify specific parameters to be studied, such as eye fixation points, interaction behaviour when meeting another active mobility user, and path preferences in walking/cycling.

Figure 1. Active mobility commuting facilities in Singapore

Phase 2. Perception survey data collection and analysis

This phase entailed data collection by the means of three street intercept surveys. The first survey was aimed at understanding the effect of cycling infrastructure on bicycle usage and overall active trips. The survey included questions to estimate respondents' awareness of cycling infrastructure in their town of residence, reasons for cycling (or not cycling), and cycling frequency with respect to perceived characteristics of the active mobility pathways. The first survey garnered responses from 202 participants (full survey response). The second survey used a mixed quantitative/qualitative approach, comprising selected quantitative questions from the first survey, plus qualitative questions. It was aimed at investigating active travel behaviour in relation to various "developments" aimed for pedestrians and cyclists in Singapore. The second survey had an analysis sample of 213 participants. Finally, the third survey was aimed at investigating where pedestrians and cyclists reported to look at when using various types of cycling facilities. The analysis sample in the third survey comprised 66 respondents. All three surveys collected demographic information of participants.

For data collection, road users were randomly intercepted while commuting along pathways in public spaces such as in the vicinity of food centres, transport hubs, and recreational facilities. They were invited to participate in the interview survey. Survey interviews took place during evening peak period (on non-rainy and non-school-holiday weekdays). Evening peak period was chosen such that there is a large population of both young and mature adults to take part in the interview survey. Young adults are generally the most active in terms of transport usage and activity level, thus, they are considered good "candidates" to commute by active transport modes; they are essentially the "mover-and-shaker group" who are leading changes in different areas, including transport-centric activities. Participants received honorarium for their participation. Data from all three surveys were digitalised, and were analysed using empirical data analyses.

Phase 3. Eye-tracking and travel-monitoring study

In this phase, eye-tracking and travel monitoring was conducted (see Figure 2). Young and mature adults were invited to participate in the field experiment. The eye-tracking experiment consisted of wearing an eye tracker device and cycling for a certain distance (2km – 3km). The eye tracker device recorded eye movement, fixation points, sight-level, characteristics of the path/road travelled, and interaction with other users. All participants utilised the same bicycle (provided by NTU) to reduce equipment bias. The bicycle was installed with an additional camera, to record path/road characteristics, as well as bicycle accessories (lights, bell, bicycle stand, brakes) to ensure participants' safety. Insurance was provided for the participants.

The travel-monitoring experiment consisted of following, with their consent, the pedestrians and cyclists from a designated origin (MRT station) to their destination (e.g. home). Most participants were young adults and adults. The journey was audited by the surveyor and covered aspects such as built environment characteristics (e.g. type of path, availability of shelter, use of informal network such as void-decks), and interaction with other active mobility users (e.g. behaviour when a cyclist was approaching). All participants received an honorarium (based on cycling/walking distance).

Figure 2. Eye tracking and travel-monitoring field experiment

Data were collected from more than 70 participants. After data cleaning and checking, the analysis sample comprised 25 cyclists and 12 pedestrians (37 participants).

4. Results of Research

The key findings of the surveys and field experiments are focused on active travel behaviour, travel preferences, and cyclists' visual behaviour. Detailed analysis, sample characteristics, and findings are presented in the different "media of official announcement" listed in Section 6 of this report.

Active travel behaviour and preferences

Majority of all surveys participants selected public transport as their most commonly-used mode of transport. Walking and cycling were reported to be used as main mode for shorter (full) trips and as modes of transport for first/last-mile trips connecting to/from public transport nodes. Most participants (40%, n=154) reported to have cycled for more than 10 years. On the other hand, a high proportion started cycling recently, with 9% of them cycling since less than 6 months ago and 5% less than one year ago. Most "new" cyclists reported to start cycling due to availability of bicycles from the advent of bicycle-sharing schemes, thereby highlighting the importance of such programmes in increasing cycling mode share. Two in three of those who have cycled for less than a year reported to most commonly do it for transport (utilitarian cycling), while almost the same proportion of those who cycled for more than one year reported to do it mostly for recreation and health purposes.

Six types of commuting facilities were considered in this study, four of which are off-road (footpaths, widened paths, delineated paths, and segregated paths) and two are on-road (on-road bicycle lane, and on road without bicycle lane). The two most preferred cycling facilities were delineated paths and segregated paths (see Figure 3; n=154). This was also true for the most preferred walking facilities. Dynamic use of 'middle-ground' space was mentioned (by pedestrians and cyclists) as the main reason for selecting delineated paths as preferred facility. Many argued it is best to commute along these facilities as the proportions of user groups vary spatially and temporally, with dominantly more pedestrians during certain times and vice versa. Pedestrians indicated that availability of cycling facilities has also impacted their walking trips; many (37%; n=211) mentioned improved trip safety, while nearly as many (32%) mentioned improved walking trip convenience. Also, as noted in Figure 3, majority of the cyclists preferred to share facilities with other active mobility users rather than with motorised vehicles. Some reported that mixed-stream traffic (*off-road* → pedestrians and cyclists sharing off-road pathways, or *on-road* → cyclists and vehicles sharing on-road facilities) reduces the perceived level of safety but does not reduce their willingness to commute by their usual active mode of transport. Moreover, it is found that pedestrians are more likely than cyclists to use informal commuting network such as void-decks of housing complexes and car parks.

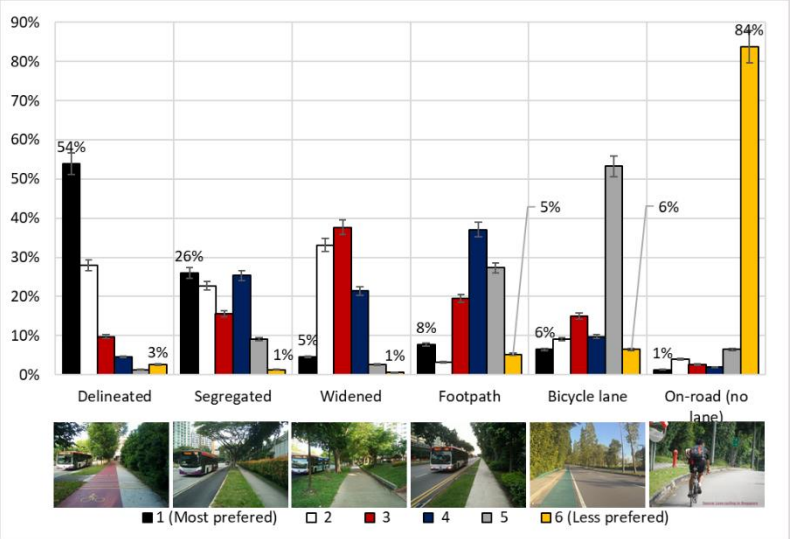

Figure 3. Cyclists preferred commuting spaces

Regarding interaction behaviour when encountering another road user, pedestrians reported to commonly keep to the left or step off the paths when meeting a cyclist, while cyclists reported to keep to the left and reduce cycling speed when meeting a pedestrian. These behaviours were corroborated with results from the site observations. Programmes aimed at promoting safe sharing of facilities can take these behaviours into consideration and provide appropriate pathway markings accordingly.

Cyclists' visual behaviour

From the visual behaviour study, four types of common focal points were identified as shown in Table 1. Some of these focal points are common in all cyclists (such as ground focal points at the beginning/end of cycling trips) while some are characteristic of experienced or newer cyclists (new cyclist defined in this study as someone who has started cycling less than a year ago and/or cycles less than once a month). Figure 4 depicts cyclists' visual behaviour based on the type of cyclists and their observed focal points. Focal point was mostly on the path, and shift to the surroundings was noted when the cycling trip was longer and traffic flow was low. Moreover, the constant shift between far (away) and near focal points as commonly observed in newer riders is attributed to the lack of experience in pacing distance against surrounding objects (e.g. street furniture, other users) and their bicycle.

Table 1. Types of focal points

Focal point	Ground	"Away" from participant	"Near" to participant	Surroundings
Photo				
Description	Street level, checking on pedals	On the path, far from participant's bicycle	On the path, closer to participant's bicycle, usually the participant can see the wheel	Out-side the commuting path, far from the participant's bicycle

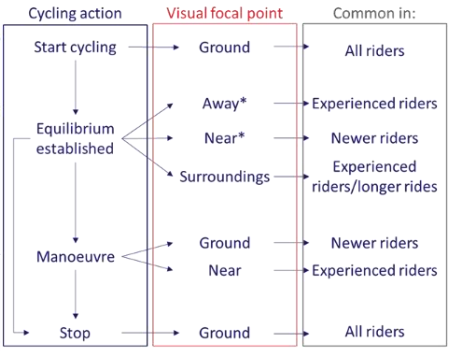

Figure 4. Cycling behaviour and visual model

Focal point was observed to change smoothly under normal conditions and when passing a pedestrian. However, a drastic change in focal point was observed when there were loud noises (e.g. car honk) or sudden movements (e.g. sudden change of position by the pedestrian in front). Focal point is found to be associated with travelling speed. Average cycling speed of the participants was 13.1 km/hr (which is slightly lower than the general average cycling speed, mainly because the experiment took place in areas with moderate to high traffic flow). Under "away" and "surrounding" focal points, cycling speed was generally higher. During "near" focal points, cycling speed was reduced. Speed change, as similar to focal point change, was observed to be generally smooth. Harsh speed reductions or stops were also observed due of sudden loud noises or movements. A lower cycling speed and more frequent "nearer" focal points were common in environment with many children.

These findings indicate the importance of ground markings for cyclists, especially those aimed at increasing safety and at places where cyclists start and finish their cycling trips such as at traffic lights (crossings). Informational signs can be placed at elevated levels corresponding to the "near" and "away" focal points.

5. Future areas to Take Note of, and Going Forward

There are certain limitations of this study. First, participation in an experiment (survey and experiment) may have resulted in a deviation of natural travel behaviour. Nonetheless, as similar behaviour was observed in naturalistic studies and across populations of similar characteristics, the findings from this study would reflect fairly the actual travel behaviour and preferences of young pedestrians and young cyclists in Singapore. Another limitation is the (intentional) over sampling of young adults and adults. While they are the main users of active mobility, it must be noted that population in Singapore is aging and behaviour of elder pedestrians and cyclists may differ from those of adults and young adults, be it for those who are in elder-hood today or elders of the future (generational gaps need to be taken into consideration). This can be overcome by conducting longitudinal/cohort studies. Future research may also consider the inclusion of personal mobility device (PMD) users and the effect of off-road safety hazards (e.g. illegally parked bicycles) on travel behaviour.

6. Means of Official Announcement of Research Results

Rojas Lopez, M. C. and Wong Y. D., Pedestrian and cyclists sharing facilities in Singapore. *Proceeding, International Velo-City 2017 Conference, The Freedom of Cycling, The Netherlands, Arnhem-Nijmegen* – 13-16 June 2017. https://goo.gl/2TEXKw

Rojas Lopez, M. C. and Wong Y. D., Users' preferences and determinants of active mobility in Singapore. *Transportation Research Part A: Policy and Practice*. (Submitted in November 2016 – Under review)

Poyil, P. R., Rojas Lopez, M. C. and Wong Y. D., Non - motorised transport prioritisation model using spatial intelligence. *Proceedings of ICE – Transport* (Submitted in November 2016 – Under review)