Developments of shared walking-cycling infrastructure in Singapore

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ABSTRACT

Cycling was a popular transport mode in post-World War II Singapore but bicycle usage had dropped drastically since the 1970s. The road infrastructure had been focused on motorised transport that transformed Singapore into a highly-urbanised motor vehicle-centric island nation. Revival of cycling began in the 1990s, mainly as recreational cycling, and to date, there are over 200km round-island park connectors. In recent years, utilitarian cycling is seeing a huge resurgence, starting from a very low base for Singapore's case. The tight lane-arrangement on road carriageways coupled with large speed differential between motorised traffic and vulnerable cyclists result in many cyclists riding on pedestrian side-walks, and cross-walks at signalised junctions. This provides strong impetus to develop serviceability standards to give guidance on developing shared/co-located off-road walking/cycling facilities in accommodating the increasing number of cyclists.

Two set of serviceability standards based on human-centred approach were developed in this study, one for side-walk, the other for signalised cross-walk. For developing the standard, pedestrians gave their ratings of acceptability level as they walked in mixed pedestrian-cyclist stream along observation segments (side-walk or signalised cross-walk); for the same segments, pedestrian and cyclist movements were video-recorded for obtaining pedestrian as well as cyclist flow rates. The pedestrians' ratings together with flow rates of pedestrians and cyclists were integrated to produce serviceability (acceptability) standards for a range of pedestrian-cum-cyclist trafficking level. All in all, serviceability rating and traffic flow data were collected from a series of sites over a wide geographical area that included 10 stretches of side-walks (and 679 pedestrian respondents) near to transit stations, and 17 signalised cross-walks (and 893 pedestrian respondents). The application of the serviceability standards is illustrated. The serviceability standards are useful for auditing the adequacy of existing facilities or when designing new integrated (shared) facilities for cyclists and pedestrians.

Keywords: shared walking-cycling facility, user-centric serviceability/acceptability schematics.

1 INTRODUCTION

Cycling was a popular transport mode in post-World War II Singapore. In 1960, there were 268,000 bicycles, compared to 63,000 cars and 19,000 motorcycles [1, 2], and there were bicycle tracks alongside footpaths along several major roads. However, bicycle usage had dropped drastically since the 1970s. The road infrastructure was focused on motorised transport that transformed Singapore into a highly-urbanised motor vehicle-centric island nation. Cycling relegated to an insignificant transport mode, and cycling facilities such as cycle tracks were removed to widen roads. Revival of cycling began in the 1990s, mainly as recreational cycling, and to date, there are over 200km round-island park connectors while intra-town cycling path network is being put in place. In the last few years, utilitarian cycling is seeing a huge resurgence, albeit starting from a very low base for Singapore's case, nominally at 1-2% of current transport modes [3].

Singapore is a city in a garden (nearly half of 716 km^2 land area is covered in greenery) and over 80% of its 5.4 million residents live in high-rise cluster housings (mostly 15-20 stories tall) in compact townships scattered across the island nation. Road network (of 3,400 km) comprises expressways (mostly 90 km/h) for fast round island travel; arterials (mostly 60-70 km/h) linked to developed sectors (downtown, residential townships, business parks, industrial zones, etc.); and streets (mostly 50 km/h) within developed sectors [4]. There are pedestrian footpaths (mostly 1.5 m wide) alongside almost all roads/streets; to date, there is no on-road bicycle lane anywhere, and park connectors' aside, few cycling tracks for utilitarian cycling. The urban rail network (of 180 km) is strung across the developed sectors and serves as mass rapid transit (MRT) for the population at large, with MRT stations at the townships and the activity centres. There is a pervasive first/last mile walking mode in the connection with MRT stations in multimodal trips, while cycling is assuming a growing share of the first/last trips, particularly in residential townships.

The tight lane-arrangement on vehicle-centric road carriageways (see Figure 1) coupled with large speed differential between motorised traffic and vulnerable cyclists result in many (more than 2 in 3) utilitarian cyclists riding on pedestrian side-walks, and cross-walks at signalised junctions. This is despite the fact that cyclists are forbidden by traffic regulations to ride along pedestrian footways. This defacto off-road cycling phenomenon has spawned extensive mixed pedestrian-cyclist streams on the side-walks and signalised cross-walks at sites in vicinity of the MRT stations and major activity centres. The intensity of first/last mile walking-cycling trips to/from the MRT stations shall continue to intensify as the present MRT network (of 180 km) shall double in coverage (to 360 km) over the next 15 years to become the predominant people mover system.

Figure 1. Street (left) and junction (right) in vicinity of transit station

Given the burgeoning popularity of utilitarian cycling, with most cycling being along pedestrian footways, the authorities may allow greater provisions for cyclists to share path with pedestrians. Tampines town was made the first cycling town in 2010 with legalised sharing of pedestrian footways with cyclists, following a period of trial [5,6]. By next year (2015), there shall be a total of about 50km of intra-town off-road cycling path networks in 7 townships [7]. More and more mixed pedestrian-cyclist traffic streams are thus travelling on hitherto pedestrian footways, which are aptly becoming non-motorised transport (NMT) pathways (see Figure 2).

Figure 2. Widened non-motorised transport (NMT) pathway

2 DEVELOPING SERVICEABILITY STANDARDS FOR NMT FACILITIES

The advent of institutionalised NMT facilities poses new challenges in their planning and design. Cyclists and pedestrians travel at inherently different speeds which results in greater conflicts during encounters as well as safety concern. Whereas there are well established engineering design procedures for pedestrian facility or for cycling facility [8, there is hardly any design information established for mixed-stream NMT facilities. This situation provides strong impetus to develop serviceability standards to give guidance on developing shared/co-located walking/cycling facilities in accommodating the increasing number of cyclists. On the one hand, existent infrastructure needs to be upgraded or new facility be built for NMT applications but what is the extent?

One can consider pedestrian/cycling network that emanates from the transit station (see Figure 3) as being the most significant NMT network. In vicinity of transit hub, the network is a concentrated zone with dual channels physically segregated or demarcated into footways and cycle-ways (where land space is sufficient); further on, as NMT traffic is distributed across the intermediate zone, pedestrians and cyclists shall travel on shared pathways by way of widened footpaths; further afield, there shall not be sufficient demand to warrant upgraded NMT facilities as the traffic shall be sparse due to spatial spread while the greater distance (from transit station) is also not conducive for NMT. This NMT network provides the basis to develop two set of serviceability standards based on human-centred approach, one for side-walk, the other for signalised cross-walk, so as to provide guidance to planners and engineers to know the extent of upgrading and up-building NMT facilities.

2.1 Methodology to develop serviceability standards

For developing serviceability standard, pedestrians gave their ratings of acceptability level after walking in mixed pedestrian-cyclist stream along observation segments (side-walk or sinalised cross-walk), as illustrated in Figure 4. Respondents were pedestrians as they are the more vulnerable user group, and also they being the 'priority' users in terms of infrastructural facilities being shared. The pedestrian respondents were interviewed on their acceptability level (four levels: not acceptable (1); tolerable (2), acceptable (3), comfortable (4)) of the actual ground situations based on immediate personal experience. For the same segment, pedestrian and cyclist movements were video-recorded, and the footages were subsequently interrogated to obtain pedestrian as well as cyclist flow rates (determined at 10-minute pedestrian/cyclist counts). The pedestrians' serviceability ratings together with flow rates of pedestrians and cyclists were integrated, as shall be illustrated later, to produce serviceability (acceptability) standards in the form level-of-service-acceptability-matrix (LOSAM) for a range of pedestrian-cum-cyclist trafficking level. All in all, pedestrians' serviceability rating and pedestrian/cyclist flow data were collected from a series of side-walks and signalised cross-walks over a wide geographical area in residential towns.

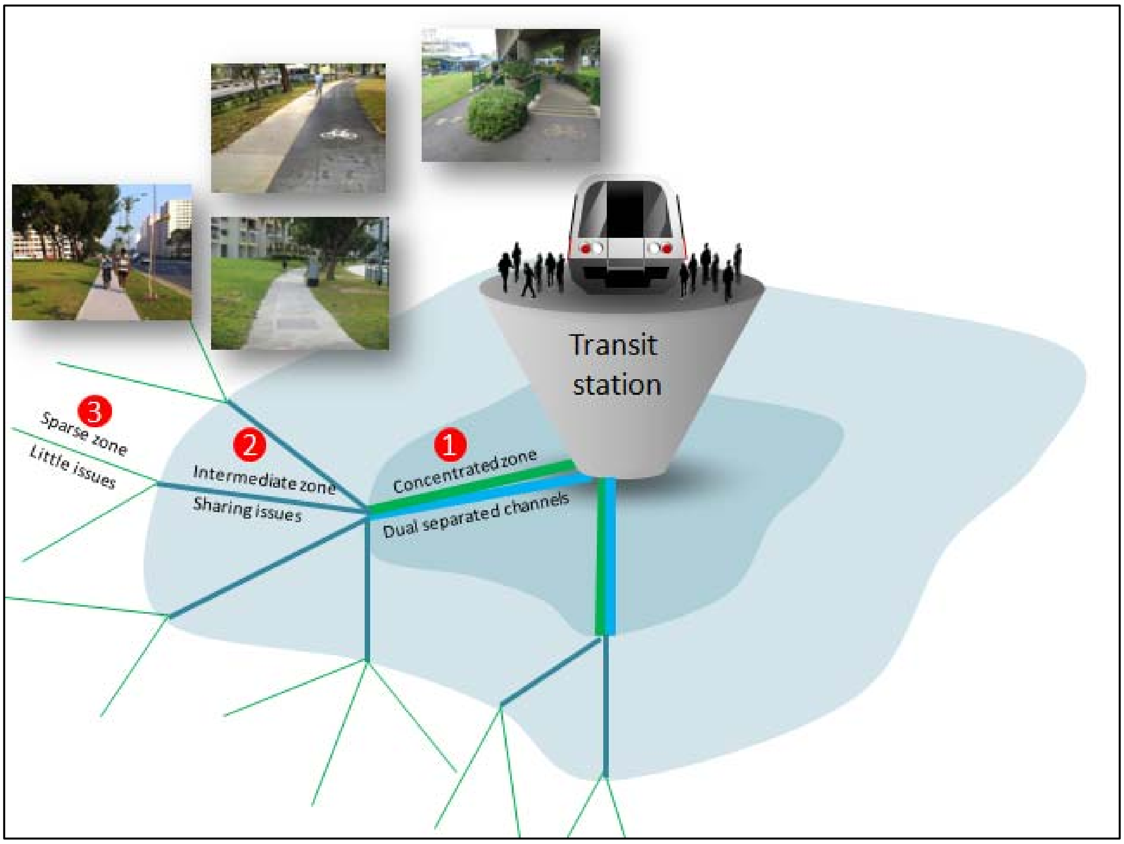

Figure 3. Non-motorised transport (NMT) network emanating from transit station

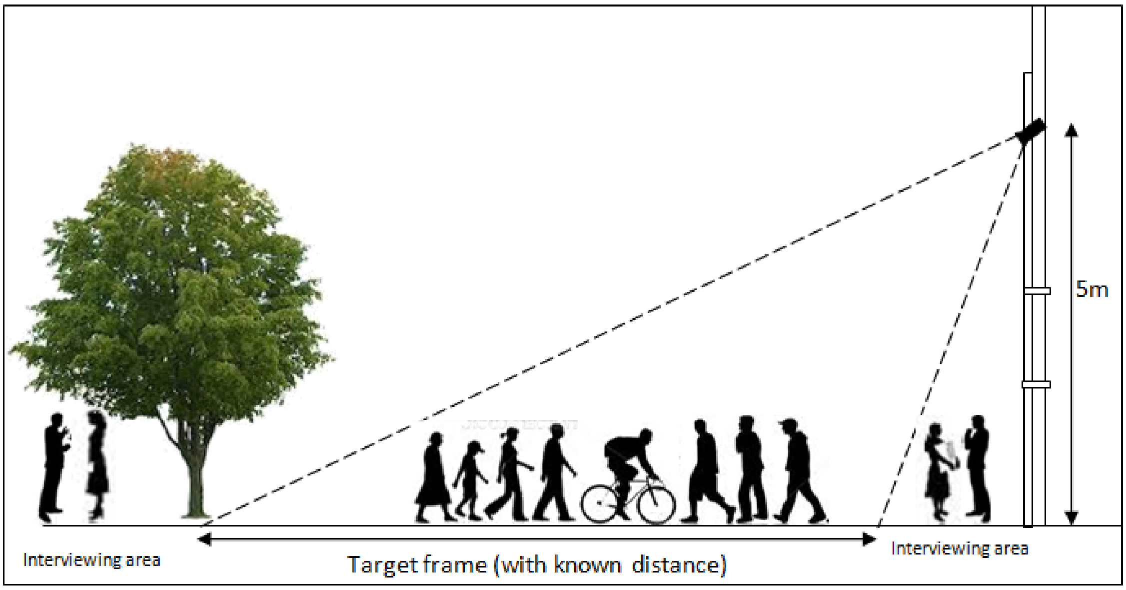

Figure 4. Target frame and positioning of interviewers

2.2 Level-of-service-acceptability-matrix (LOSAM) at side-walks

Data for a total sample of 679 pedestrian respondents along 10 stretches of side-walks and near to transit stations were applied to develop LOSAM for side-walks. The survey sample was gathered over 5pm-7pm evening peak, with about 60% walking in away-transit station direction. The sample was representative of national profile in terms of gender and age, and the majority were local or long-term residents going about their regular activities. More than 2 in 5 pedestrian respondents had at least one adult bicycle at home, and 1 in 3 also cycle (with two-thirds of these cyclists usually cycling on the footways). About 3 in 4 of the pedestrian respondents were supportive of sharing footways with cyclists, with 43% stating that wider footways are needed to facilitate sharing.

The respondents' serviceability ratings were plotted against corresponding 10-min pedestrian/cyclist flows (from video observations) to generate the *level-of-service-acceptability-matrix* (LOSAM) for side-walks as shown in Figure 5. The coloured bubbles depict the intensity of respective ratings and the size of the bubbles represent the number of respondents for that particular point of pedestrian and cyclist flows; whereupon loci of average acceptability index (AAI) are constructed by best-fit interpolation to constitute the LOS acceptability matrix which establishes the serviceability standard for side-walk. As to be expected, comfortable situations (upper left portion) correspond to low flow regimes, and the facility is not inadequate. The lower right portion corresponds to high flow regimes that warrant substantive widening of the side-walk. For a given combination of pedestrian and cyclist flow rates, the degree of widening is dependent on target AAI whereby the lower the AAI value (the greater the comfort), the greater the widening is required. When widening is greater than 3.5m, dual channels (in concentrated zone) comprising footway (≥1.5m) and cycle-way (≥2.0m) is recommended given that mono-stream flow is basically more efficient than mixed-stream flow [9,10,11].

2.3 Level-of-service-acceptability-matrix (LOSAM) at signalised cross-walks

Using a similar concept, 893 pedestrian respondents were interviewed at 17 stretches of signalised cross-walks located near to transit stations. The sample had fairly similar profiles to the sample gathered at the side-walks. About one in five reported that they also cycle (2 in 3 of them usually cycling on the footways). Two in three pedestrian respondents did not object to sharing signalised cross-walks with cyclists, with 39% viewing that it is alright to share if the channel is wider. Figure 6 shows the developed LOSAM for signalised cross-walks, using the same technique as afore-described, and with same meanings as that for side-walks.

3 APPLICATION OF LOSAM

The proposed threshold to trigger improvements works is set by the LOSAM users, and is a trade-off between serviceability of the facility and the amount of improvement works (i.e. amount of available budget). Essentially, providing a high serviceability level (or high AAI) in the facility shall equate to high amount of improvements works, and vice versa. With reference to the LOSAM for side-walks in Figure 5, it is observed that the average acceptability indices (AAIs) from 2.9 down to 2.5 are more tightly bunched; the '2.5 AAI' threshold provides a sensible peg for auditing side-walk serviceability. An AAI of 2.5 implies that 50% of the respondents felt that the LOS is "Acceptable" or better and the other 50% felt that the LOS is "Tolerable" or worse (the pink-shaded portion in Figure 5); on the other hand, an AAI at 2.2 indicates the majority (85%) respondents rating the facility as "Tolerable" or better, and the (lesser) improvement works are directed at solving the problems for the worst 15%. One can work from the bottom right of the LOSAM, and prioritise improvement works, in cognisant of available budget. With reference to Figure 6 for LOSAM of cross-walks, it is seen that pedestrian respondents provided more favourable ratings than for side-walks. Whereas side-walks are bounded by grass verges [12], the cross-walks are delineated by painted lines and without grassy areas, hence the lesser feeling of being physically helmed in for the latter. The AAI threshold at the signalised cross-walks can thus be set correspondingly higher, nominally at 2.7 as compared to 2.5 for side-walks.

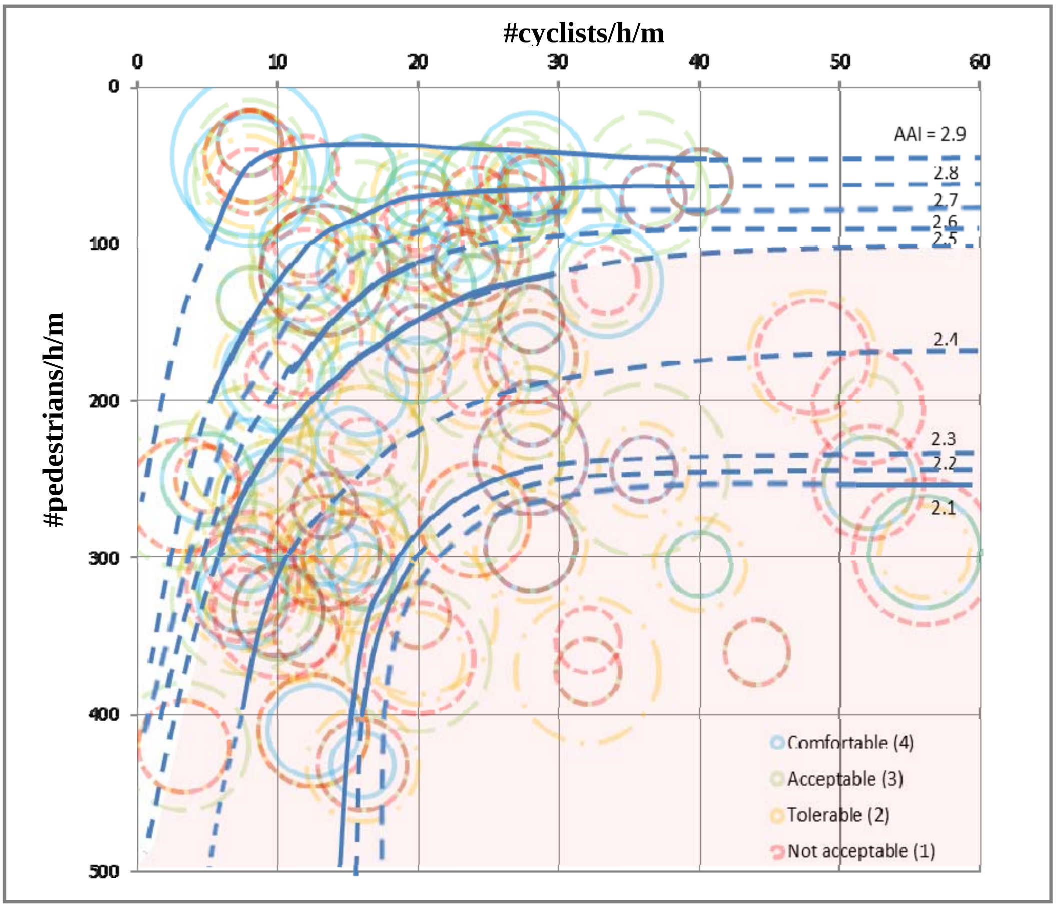

Figure 5. LOSAM bubble graph (for side-walk)

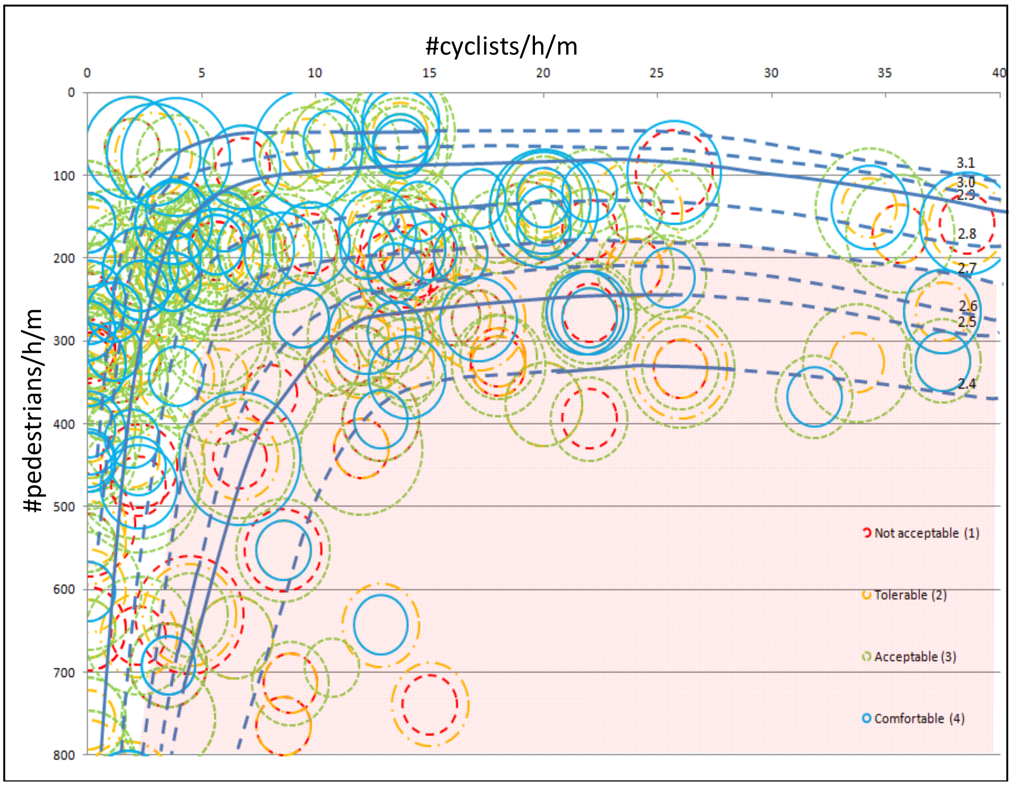

Figure 6. LOSAM bubble graph (for signalised cross-walk)

An application example in using LOSAM is provided here to illustrate the use of LOSAM (for case of side-walk). For example, there are feedbacks of crowdedness along a shared 1.5m-wide side-walk. An engineering evaluation shall entail obtaining on-site 10-min counts of pedestrians and cyclists during the peak period. Suppose the 10-minute counts were 75 pedestrians (or 450 per hour) and 5 cyclists (or 30 per hour) on the 1.5m-wide side-walk, which translate to respectively 300 pedestrians/h/m and 20 cyclists/h/m, and the acceptability index for this stretch of side-walk can be read off the LOSAM as being 2.2. For improvement works to bring the serviceability level to 2.5 (200 pedestrian/h/m; 13 cyclists/h/m), the side-walk needs to be widened to 2.3m (450/200=2.3; 30/13=2.3) by working along the "2.5 AAI" locus on the LOSAM in Figure 5.

The LOSAM for side-walks was applied to audit an NMT network. Pedestrian and cyclist counts were collected at 10-min interval during evening peak period along the network of side-walks around the Boon Lay MRT station. The 10-minute counts were then translated to AAI using LOSAM. The values were keyed in as attributes of the side-walk layer in GIS and displayed in Figure 7. There was a segment shown by the red line (AAI of 1.0-2.2, within the worst 15%) which calls for urgent improvement (e.g. widening side-walk or re-channelling). That location is the side-walk along the private shuttle bus drop-off area next to the MRT station. There were several segments next-in-line for improvement works, as denoted by the orange lines.

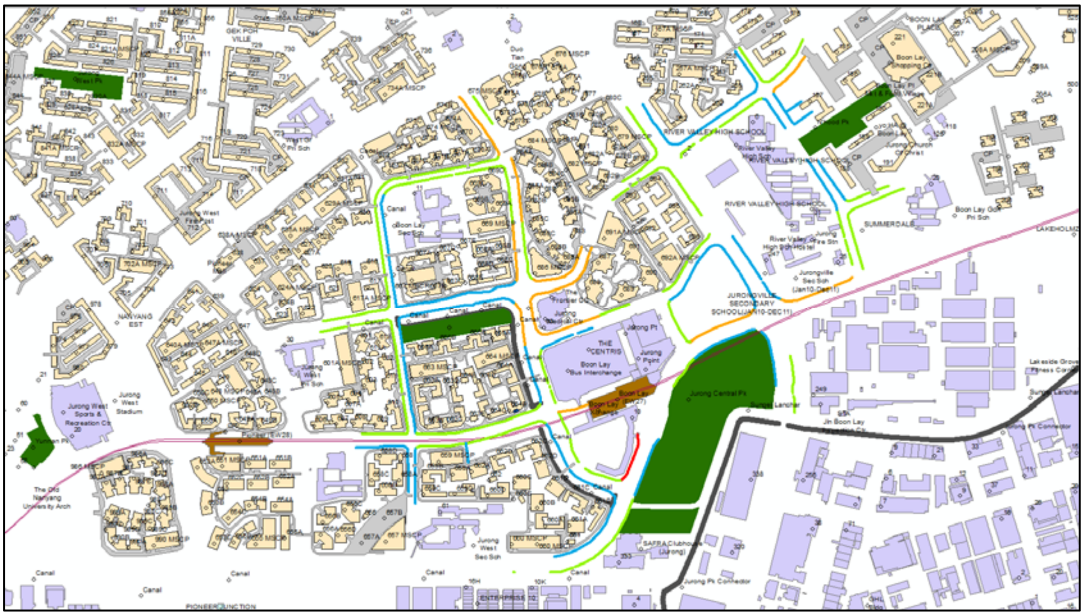

Figure 7. LOSAM-audited NMT network in vicinity of Boon Lay MRT station

4 DISCUSSIONS

The serviceability standards enshrined in LOSAM is seen to be a useful tool for auditing the adequacy of existing NMT facilities, or when designing new integrated (shared) facilities for cyclists and pedestrians. It is a tool that allows the user to plan improvements of facilities according to the desired level of serviceability for the NMT network, and is also valuable for prioritisation of improvement works. Singapore is ramping up its public transport facilities over the next 15 year [13], and there is great impetus to promote bike-and-ride as well as walk-and-ride. The LOSAM shall be invaluable in providing guidance in upbuild of NMT infrastructures.

There are several limitations in the LOSAM that should be noted. Firstly, the model is a pedestrian-centric model calibrated on the current operating conditions, whence cycling is still on the upsurge stage. It is a human-centred in approach and is calibrated upon the acceptability of the pedestrians which implies that the established schematics shall stand to change with changes in users' behaviour and value-set. In time, LOSAM shall need to be updated, especially with proliferation of cycling culture and users shall be more accustomed with shared/co-located NTM facilities. The current LOSAM for side-walks is calibrated only for side-walk of 1.5-2.4m width; many future side-walks shall be of wider widths and a separate model shall be applicable.

5 CONCLUSIONS

The resurgence of utilitarian cycling in Singapore in a motor vehicle-centric road network has resulted in many cyclists riding on pedestrian side-walks, and cross-walks at signalised junctions. This is also a result of perceived unsafe cycling conditions on the tightly arranged lanes on road carriageways coupled with large speed differential between motorised traffic and vulnerable cyclists.

Two set of serviceability standards based on pedestrian-centred approach have been developed in this study, one for side-walks, and the other for signalised cross-walks. The serviceability standards are found to be useful for auditing the adequacy of existing NMT facilities or when designing new integrated (shared) facilities for cyclists and pedestrians.

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