REPORT OF RESEARCH RESULTS

(a) **Title**: An Elder-Friendly Pedestrian Crossing System for Singapore

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(c) **Summary**: This study profiled the green man timings of 198 pedestrian crossings across Singapore and measured the gait characteristics of 52 subjects under different loading conditions. When starting crossing from the onset of the steady green man, young and older pedestrians in their sixties would be able to cross more than 99% of the roads in time. Pedestrians aged 70 yrs and above would struggle at 8.1% of crossings while walking unloaded and up to 14.6% when pulling a shopping cart. Entering at flashing green was more problematic as pedestrians at their sixties would fail at 18.7% of the crossings while unloaded and up to 34.8% if loaded. Those above 70 yrs would not be able to cross without having to rush in more than 50% of the roads measured. Older pedestrians would benefit from having longer total green man time of up to 6.0 s unloaded and 8.0 s loaded. When entering the road at flashing green, the majority of crossings can be improved by having up to 10 s of additional flashing green man time, though certain crossings would need up to 29.9 s more.

(d) **Aim of Research**: This study aimed 1) to access whether the current pedestrian crossing system in Singapore was appropriate for elderly, and 2) to determine the time required for elderly pedestrians to cross the road safely with considerations of real life demands such as pushing a pram and pulling a shopping cart.

(e) **Method of Research and Progression:**

Phase 1: Profiling of the current green man time

Five districts in Singapore with the highest proportion of elderly residents were selected. In each district, a Mass Rapid Transit (MRT) station was chosen and a 1 km^2 area centred at the MRT station was mapped out. For all pedestrian crossings within the selected area, three measurements were taken: 1) length of the pedestrian crossing, 2) the steady green man time and 3) the flashing green man time (Table 1). Such information was used to calculate the walking speed required in order to cross the road safely.

Table 1 Road measurement of five selected districts with the highest proportion of elderly residents

District	MRT Station	No of Crossings	Crossing Distance (m)	Steady Green Man Time (s)	Flashing Green Man Time (s)	Total Green Man Time (s)
Outram	Outram Park	26	20.4 (11.1)	21.8 (24.1)	17.2 (8.1)	39.0 (21.7)
Downtown Core	City Hall	63	18.2 (6.7)	19.9 (19.6)	15.8 (5.0)	35.7 (19.2)
Rochor	Bugis	78	21.4 (7.4)	18.7 (21.8)	18.7 (8.7)	37.4 (21.0)
Queenstown	Queenstown	12	17.2 (9.3)	7.3 (1.1)	14.2 (6.9)	21.5 (7.1)
Toa Payoh	Toa Payoh	19	21.1 (6.2)	7.2 (1.4)	20.0 (4.6)	27.2 (4.7)

*Data are presented as mean (standard deviation).

Phase 2: Measuring start-up time and walking speed

In a laboratory setting, the start-up time and walking speed of young and elderly participants were measured (Table 2). Participants walked at their comfortable pace for 10m under four randomised conditions: 1) unloaded, 2) pushing a stroller loaded with 10 kg, 3) pulling a shopping cart loaded with 15 kg, and 4) carrying two shopping bags each loaded with 2 kg. Start-up time was determined from video recordings and walking speed measured using timing gates.

Table 2 Physical characteristics of young and elderly participants

Characteristics	Young (21 – 35 yrs)	Elderly 1 (60-69 yrs)	Elderly 2 (70 yrs +)
Total *n*	20	17	15
Males *n* (%)	10 (50%)	8 (47%)	6 (40%)
Age (yrs)	23.1 (2.0)	63.7 (2.8)	76.0 (3.7)
Body mass (kg)	61.7 (11.5)	65.2 (11.3)	59.4 (7.7)
Height (m)	1.69 (0.10)	1.58 (0.08)	1.56 (0.07)

Data are expressed in mean (SD) unless otherwise stated.

Phase 3: Calculations of pedestrian crossing time

Combining the data obtained in *Phase 1* and *Phase 2*, the percentages of pedestrian failing to cross the road within the given green man time were calculated for each loading condition. Two scenarios were considered: 1) entering the road from stationary when the signal changed from red to green, and 2) entering the road at flashing green (start-up time = 0).

(f) **Results of Research**: A total of 198 pedestrian crossings were measured, among which the total green man time ranged from 21.5 s to 39.0 s (Table 1). When starting from stationary, young and older pedestrians in their sixties would be able to cross more than 99% of the roads in time regardless of loading conditions, except for three crossings in Rochor (Table 3). Those aged 70 yrs and above would struggle at 8.1% of crossings while walking unloaded and up to 14.6% when pulling a shopping cart. Entering at flashing green, however, was more problematic as even young pedestrians would struggle at many crossings especially under loaded conditions. There was a large variation from district to district, with Toa Payoh allowing the longest and Rochor the shortest crossing times. On average, pedestrians at their sixties would fail at 18.7% of the crossings while unloaded and up to 34.8% if loaded. Older pedestrians above 70 yrs would not be able to cross without having to rush in more than 50% of the roads measured. They would have failed at all crossings when pulling a shopping cart in Queenstown.

For young and older pedestrians in their sixties, no additional total green man time was needed for more than 99% of the crossings if they started from the onset of the steady green man (Table 4). Older pedestrians aged 70 yrs and above would benefit from having longer crossing time for up to 6.0 s unloaded and 8.0 s loaded. When entering the road at flashing green, additional time was needed for pedestrians across all age groups to cross without having to rush (Table 5). The majority of crossings can be improved by having up to 10 s of extra time, though certain crossings would need up to 29.9 s more. There was also a large variation among districts, with Queenstown being the most and Outram the least accommodating.

Table 3 Percentage of crossings that pedestrian would fail to cross in time when starting from stationary and entering at flashing green (in bracket)

	Normal unloaded	Pushing a stroller	Pulling a shopping cart	Carrying shopping bags
		Outram		
Young	0 (7.7)	0 (11.5)	0 (15.4)	0 (7.7)
Elderly 1	0 (7.7)	0 (7.7)	0 (23.1)	0 (7.7)
Elderly 2	0 (42.3)	7.7 (46.2)	19.2 (53.8)	7.7 (46.2)
		Downtown Core		
Young	0 (7.9)	0 (25.4)	0 (34.9)	0 (7.9)
Elderly 1	0 (17.5)	0 (17.5)	0 (39.7)	0 (20.6)
Elderly 2	6.3 (54.0)	6.3 (55.6)	7.9 (66.7)	6.3 (55.6)
		Rochor		
Young	1.3 (15.4)	2.6 (37.2)	2.6 (42.3)	1.3 (21.8)
Elderly 1	1.3 (29.5)	2.6 (29.5)	3.8 (43.6)	2.6 (32.1)
Elderly 2	14.1 (55.7)	15.4 (61.5)	21.8 (69.2)	15.4 (61.5)

Queenstown				
Young	0 (0)	0 (16.7)	0 (16.7)	0 (0)
Elderly 1	0 (0)	0 (0)	0 (7.7)	0 (0)
Elderly 2	0 (50.0)	0 (75.0)	8.3 (100.0)	0 (75.0)
Toa Payoh				
Young	0 (0)	0 (10.5)	0 (10.5)	0 (0)
Elderly 1	0 (5.3)	0 (5.3)	0 (10.5)	0 (5.3)
Elderly 2	5.3 (5.3)	5.3 (5.3)	5.3 (5.3)	5.3 (5.3)

Table 4 Number (%) of Crossings Requiring Additional Total Green Man Time for Entry from the Onset of Steady Green Man (Total = 198 Crossings)

Group	Additional Time (s)	Unloaded	Stroller	Shopping cart	Shopping bags
Young	0	197 (99.5)	196 (99.0)	196 (99.0)	197 (99.5)
	0.1-2.0	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)
	2.1-4.0	0 (0)	0 (0)	1 (0.5)	0 (0)
	4.1-6.0	0 (0)	0 (0)	0 (0)	0 (0)
	6.1-8.0	0 (0)	0 (0)	0 (0)	0 (0)
Older 1	0	197 (99.5)	196 (99.0)	195 (98.5)	196 (99.0)
	0.1-2.0	0 (0)	1 (0.5)	2 (1.0)	1 (0.5)
	2.1-4.0	1 (0.5)	1 (0.5)	0 (0)	1 (0.5)
	4.1-6.0	0 (0)	0 (0)	1 (0.5)	0 (0)
	6.1-8.0	0 (0)	0 (0)	0 (0)	0 (0)
Older 2	0	182 (91.9)	179 (90.4)	169 (85.4)	179 (90.4)
	0.1-2.0	13 (6.6)	14 (6.6)	9 (4.5)	14 (7.1)
	2.1-4.0	2 (1.0)	3 (1.5)	15 (7.6)	3 (1.5)
	4.1-6.0	1 (0.5)	2 (1.0)	2 (1.0)	1 (0.5)
	6.1-8.0	0 (0)	1 (0.5)	3 (1.5)	1 (0.5)

Table 5 Number (%) of Crossings Requiring Additional Flashing Green Man Time for Entry at the Onset of Flashing Green Man (Total = 198 Crossings)

Group	Additional Time (s)	Unloaded	Stroller	Shopping cart	Shopping bags
Young	0	179 (90.4)	146 (73.7)	135 (68.2)	174 (87.9)
	0.1 – 5.0	17 (8.6)	48 (24.2)	57 (28.8)	22 (11.1)
	5.1- 10.0	1 (0.5)	3 (1.5)	5 (2.5)	1 (0.5)
	10.1 – 20.0	1 (0.5)	0 (0)	0 (0)	0 (0)
	20.1 – 30.0	0 (0)	1 (0.5)	1 (0.5)	1 (0.5)
Older 1	0	161 (81.3)	161 (81.3)	129 (65.2)	157 (79.3)
	0.1 – 5.0	34 (17.2)	34 (17.2)	63 (31.8)	38 (19.2)
	5.1- 10.0	2 (1.0)	2 (1.0)	5 (2.5)	2 (1.0)
	10.1 – 20.0	0 (0)	0 (0)	0 (0)	0 (0)
	20.1 – 30.0	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)
Older 2	0	98 (49.5)	90 (42.5)	71 (35.9)	90 (45.5)
	0.1 – 5.0	84 (42.4)	85 (42.9)	92 (46.5)	86 (43.4)
	5.1- 10.0	14 (7.1)	21 (10.6)	32 (16.2)	20 (10.1)
	10.1 – 20.0	1 (0.5)	1 (0.5)	2 (1.0)	1 (0.5)
	20.1 – 30.0	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)

(g) **Future Area to Take Note of, and Going Forward**: First, our participants were healthy individuals who were able to ambulate independently. Their gait characteristics are likely to be superior to those requiring walking sticks and other forms of aids. Second, the gait characteristics were assessed in a laboratory setting with minimal distraction, no curbs, non-slippery surface and stable weather conditions. All these would also favor faster start-up times and walking speeds. Thus, we may have under-estimated the number of crossings that are currently too fast as well as the additional green man time required. Finally, our sample was not random and the sample size was relatively small. Future studies could capture the gait characteristics of a wider population to allow the calculation of green man time based on more individual subject characteristics (e.g. sex, 5-year age range, disability level). With the advancement of technology, we may soon be able to store personalized gait data on a sensor which can activate the pedestrian crossing system to cater for individual needs.

(h) **Means of Official Announcement of Research Results**: Preliminary results on start-up time were presented at an international conference (Appendix A). A manuscript will be prepared for peer-reviewed journal publication. In 2013, we may present the final results at a local conference.