Comparison of Different Standards in Designing Signalized Mid-Way Crossings for Maharagama, Sri Lanka.

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Study Area

- Maharagama city in Sri Lanka

Introduction

- In Maharagama, present condition of pedestrian crossings
  - un-signalized
  - under the control of traffic policemen
  - high traffic volume → if policemen service is not there pedestrian face high risk to cross the road
- Design Standard
  - Australian standard → which is designed for Australian condition, question is whether that standard is compatible for Sri Lankan condition.
- Key parameter for safe crossing in signalized crosswalks
  - Pedestrian clearance time

Objectives

- Analyze the pedestrian behavior and design signalized mid-way crossings for Maharagama town, Sri Lanka according to the different traffic signal indication systems (Australian standard and Japanese standard).

- Compare two standards and analyze which design method is more appropriate for existing condition for the Maharagama, Sri Lanka.

Literature Review

Iryo-Asano, M., & Alhajyaseen, W. K. (2014).

Pedestrian Phase	Requirement
Clearance Time	Time required by pedestrians who enter the crosswalk at the end of the green indication to complete the crossing before conflicting released vehicle traffic movement
Discharge Time	Time required for all pedestrians to leave the shoulder and start crossing
Pedestrian green/WALK time	Pedestrian can start walking the crossing
Buffer Interval before Green to pedestrian	Time gap provided to be ensure that vehicle flow is stopped and it is safe to allow pedestrians to start walking
Pedestrian yellow time/flashing DON'T WALK/PFG	Pedestrians should not start to cross, those who are on the crosswalk should complete the crossing immediately or give up the crossing and return to the origin shoulder
Buffer Interval before red to pedestrian	Time gap provided to be ensure that even the last pedestrian is finish walking and it's safe to release the vehicular traffic
Pedestrian red time/DON'T WALK	Pedestrians should not start crossing

AUSTROADS Standard

Akc¸elik, R. (1981).

- Minimum Pedestrian Green time

$$(Ga) = minimum\ walk\ period\ (6s) + \frac{shoulder\ to\ shoulder\ distance\ (D)}{Pedestrian\ walking\ speed\ during\ clearence}$$

- Minimum Pedestrian Red time

$$(Ra) = Number\ of\ PCU\ per\ second(number\ of\ vehicles\ passed\ converted\ to\ PCU\ unit) * Cycle\ length$$

PCU Factors

Vehicle Type	Car	Van	Bus	Truck	Bicycle	Motor Bike	Three Wheeler	Heavy truck	Medium Truck
PCU factor	1.00	1.80	2.40	1.50	0.70	0.40	0.80	3.80	2.00

Time taken by PCU (s)	2.00
Length of PCU (m)	6.00

Road Development Authority, Sri Lanka

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- Passenger car unit (PCU): Obtaining number of vehicles (after converting every vehicle to the standard) per hour

$$\text{Buffer Interval before Green to pedestrians} = \frac{Stopping\ Sight\ Distance\ (SSD)}{Maximum\ speed\ limit\ of\ the\ region}$$

Design speed (Km/h)	Calculated SSD (m)	Design SSD (m)
60	83	85

AUSTROADS Geometric Design of Highways and Streets

- Buffer interval before red to pedestrians= within the range of 1-5 seconds;
  - 1 if the pedestrian volume is low
  - 5 if pedestrian volume is high

Japanese Standard

Miho I., Wael K. M. A. (2014)

- Minimum Pedestrian Green time

$$(Gj) = Clearance\ time + Discharge\ time = \frac{Length}{Pedestrian\ Speed(V)} + \frac{P}{s*Crossing\ Width\ (W)}$$

P - Number of queuing pedestrians at the onset of pedestrian green indication

s - Saturation flow of pedestrians per unit width

- Pedestrian green flashing man time $(PFG) = \frac{Length}{2*Pedestrian\ Speed\ (V)}$

- Buffer Interval before green and Buffer Interval before Red to pedestrians= within the range of 1-5 seconds;

  1 if the pedestrian volume is low

  5 if pedestrian volume is high

Methodology

- Study sites → 4 un-signalized crossings located in Maharagama, Sri Lanka
- Pedestrian survey → recording locations, each video has 1.5 hour duration. For vehicle count selecting the best peak and off peak video each out of each 4 videos.

Pedestrian count (Total 64 videos)

Station 1	WD1	WD2	WE1	WE2
Peak	2	2	2	2
Off peak	2	2	2	2

Vehicle count (Total 16 videos)

Station 1	WD	WE
Peak	1	1
Off Peak	1	1

For each station 16 videos

Total videos=16*4=64 videos

For each station 4 videos

Total videos=4*4=16 video

Note: WE- weekday, WD-weekend

Data Collection

- Camera was placed in the top position where the complete crossing including both ends were recorded clearly.
- The number of pedestrians who walked into the pedestrian crossing from both ends were counted separately and noted.
- Time taken to walk the entire crossing was measured by observing total of random 256 pedestrians of different aged for all 4 stations.

  Calculate the average value for pedestrian travel time.

Pedestrian Time measurement

For each station 64 pedestrians

Total videos=64*4=256 pedestrians

Station 1	WD1	WD2	WE1	WE2
Peak	8	8	8	8
Off peak	8	8	8	8

- This procedure was repeated for other trials of every 4 stations

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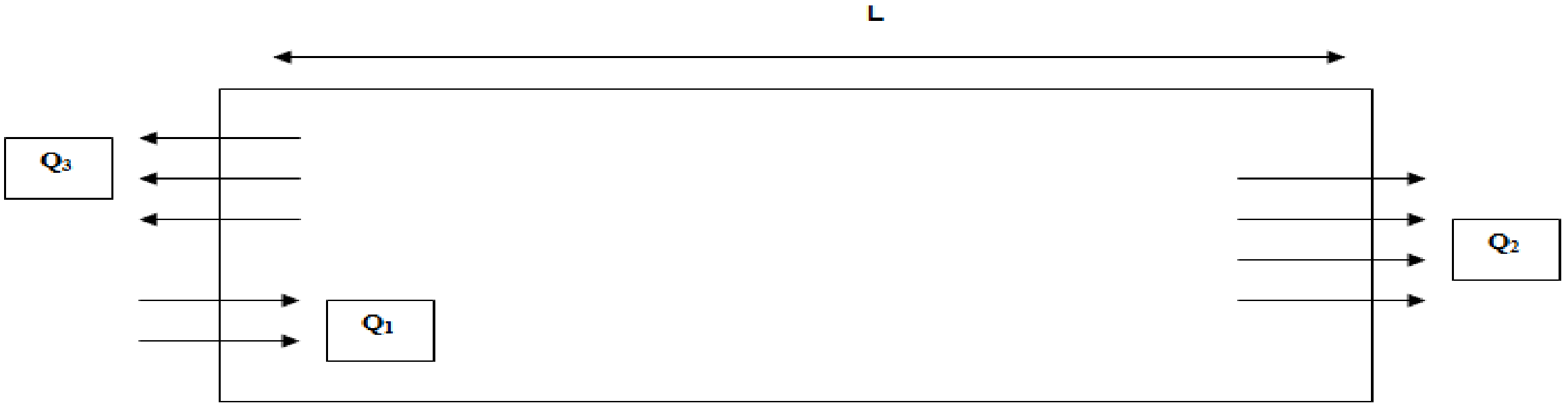
Q1 - Pedestrian entering volume to the pedestrian crossing from one edge

Q2 - Pedestrian exiting volume from the pedestrian crossing from the other edge

Q3 - Pedestrian exiting volume from the pedestrian crossing from the first edge

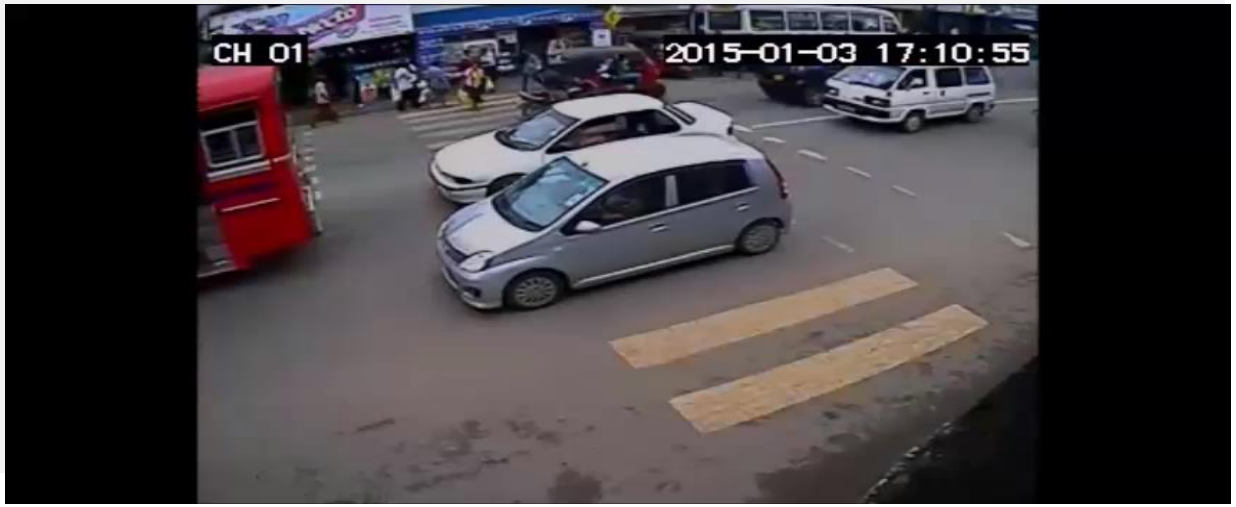
L - Length of the pedestrian crossing

W - Width of the pedestrian crossing



NOTE:

When traffic police service was not functioning, pedestrian travel time is calculated by using a stop watch, so that the obstructed time for walking can be excluded by pausing the stop watch. Time is measured by selecting random pedestrians who walked on the crossing straightly, irrespective of people who diagonally crossed it.



Method of Analysis

- $Pedestrian\ Flow = \sum Pedestrian\ count\ in\ both\ directions$
- $Pedestrian\ Flow\ Rate\ (pedestian\ per\ meter\ per\ minutes)$

$$= \frac{Pedetrian\ Flow\ per\ unit\ crossing\ width\ (\frac{ped}{m})}{Time\ duration\ which\ will\ consider\ in\ counting\ pedestrians\ (min)}$$

- *Saturation Flow Rate = same as above but in saturation condition*
- $Pedestrian\ Speed(meters\ per\ minute)$

$$= \frac{Length\ of\ the\ pedestrian\ crossing\ (m)}{Average\ time\ (of\ 1st\ and\ last\ pedetrian) taken\ to\ walk\ the\ entire\ crossing\ (\mathrm{min})}$$

- *Number of pedestrian at queue on one set (p)*

$$= \frac{Pedestrian\ flow\ rate\ (pedestrian\ per\ meter\ per\ hour)}{Number\ of\ cycles\ per\ hour}$$

- *Total Pedestrian Phase= Pedestrian green time + Pedestrian yellow time*
- *Number of cycles per hour*$= \frac{3600\ seconds}{Time\ of\ one\ phase}$

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Calculating remaining pedestrians time of pedestrian phase

- Cycle Time is measured by observing the crossing in peak hours and non peak hours to obtain the time passed to gather considerable amount of pedestrians at the both edge of the crossing (one phase time)

  Station 1: 3-5 pedestrians , Station 2: 15-20 pedestrians, Station 3 & 4: 8-10 pedestrians

In Japanese standards;

Pedestrian red stable man phase = (one phase time – total pedestrian phase – buffer before pedestrian green time – buffer before pedestrian red time)

- In AUSTROADS standard;

$$Pedestrian\ Yellow\ Time/Flashing\ Red\ man\ phase$$
$$= one\ phase\ time - pedestrian\ green\ time - pedestrian\ red\ tim$$
$$- buffer\ before\ pedestrian\ green\ time - buffer\ before\ pedestrian\ red$$

Analysis

General Measurements

Station 1	Crossing width	3.40 meters
	Left shoulder	3.95 meters
	Right shoulder	3.30 meters
	Length of the crossing	16.75 meters
	Kerb to kerb distance	24.00 meters
Station 2	Crossing width	3.10 meters
	Left shoulder	3.25 meters
	Right shoulder	4.05 meters
	Length of the crossing	19.35 meters
	Kerb to kerb distance	26.65 meters
Station 3	Crossing width	3.05 meters
	Left shoulder	2.10 meters
	Right shoulder	2.65 meters
	Length of the crossing	8.20 meters
	Kerb to kerb distance	12.95 meters
Station 4	Crossing width	3.00 meters
	Left shoulder	1.95 meters
	Right shoulder	1.60 meters
	Length of the crossing	15.20 meters
	Kerb to kerb distance	18.75 meters

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Pedestrian Count

Station 1	Weekday		Average Pedestrian Count	Weekend		Average Pedestrian Count
	1	2		1	2	
Peak	440	393	396.25	293	427	315.00
	364	388		260	280	
Off Peak	322	305	305.50	258	273	231.00
	315	280		168	225	

Station 2	Weekday		Average Pedestrian Count	Weekend		Average Pedestrian Count
	1	2		1	2	
Peak	1739	1503	1603.00	2037	2717	2182.25
	1694	1476		1581	2394	
Off Peak	1132	1376	1131.00	1161	2279	1588.25
	737	1279		681	2232	

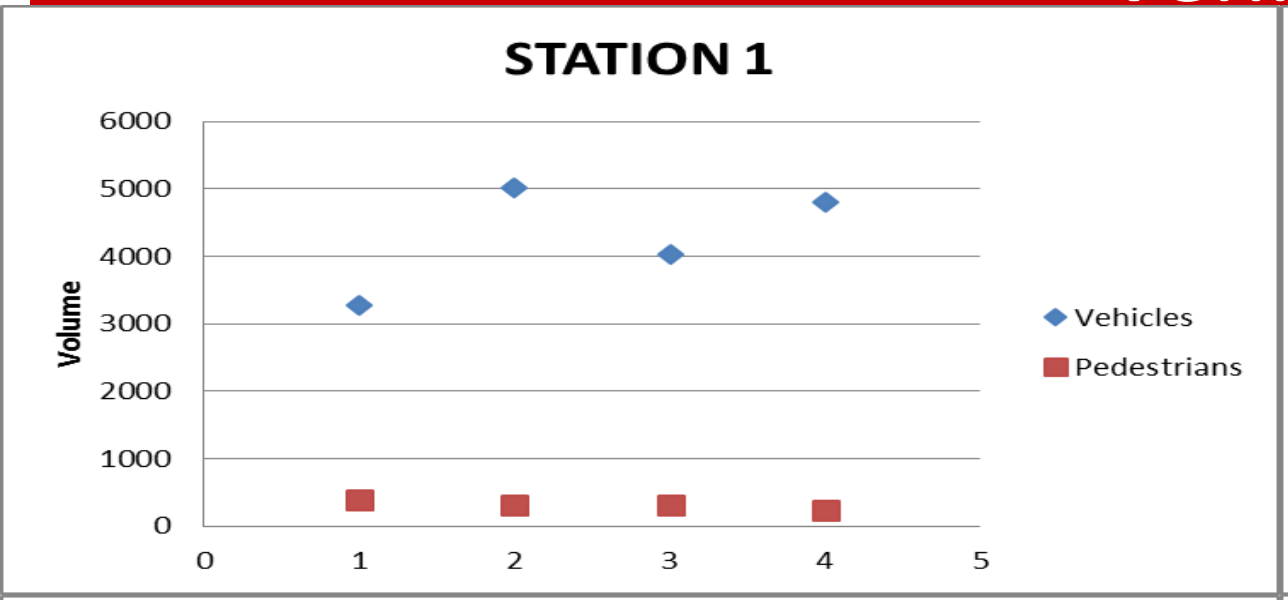
Station 3	Weekday		Average Pedestrian Count	Weekend		Average Pedestrian Count
	1	2		1	2	
Peak	1770	832	1095.25	1045	692	843.75
	1086	693		952	686	
Off Peak	763	659	623.00	795	493	628.75
	566	504		719	508	

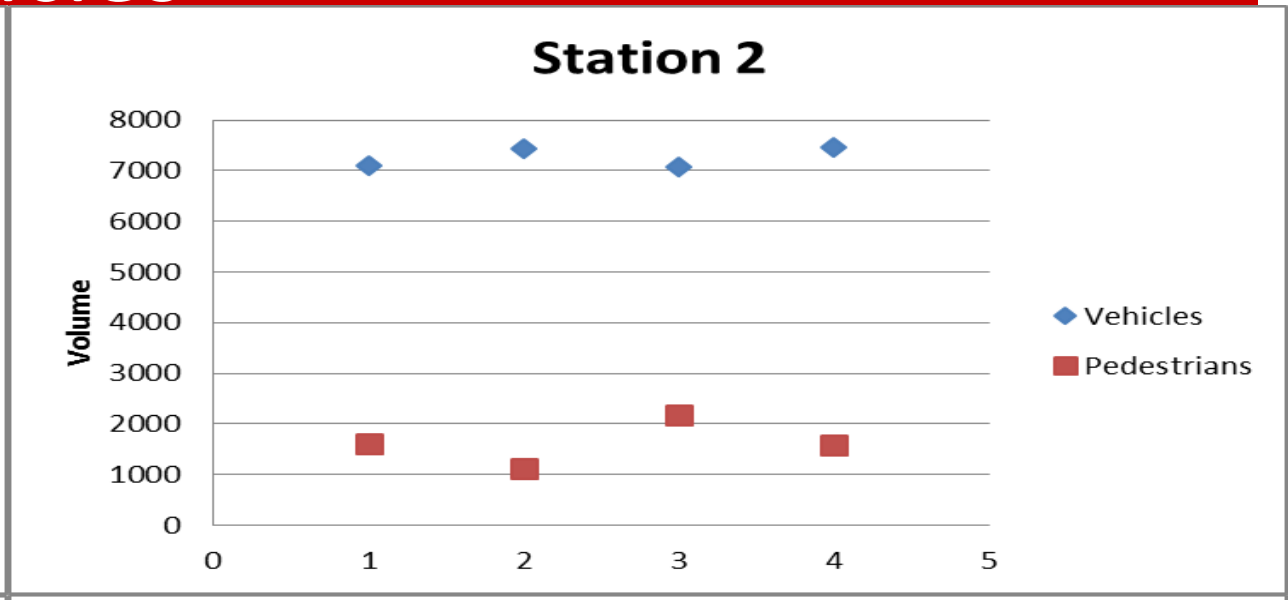
Station 4	Weekday		Average Pedestrian Count	Weekend		Average Pedestrian Count
	1	2		1	2	
Peak	944	939	919.50	789	1081	861.25
	916	879		771	804	
Off Peak	786	855	733.75	752	758	749.00
	629	665		750	736	

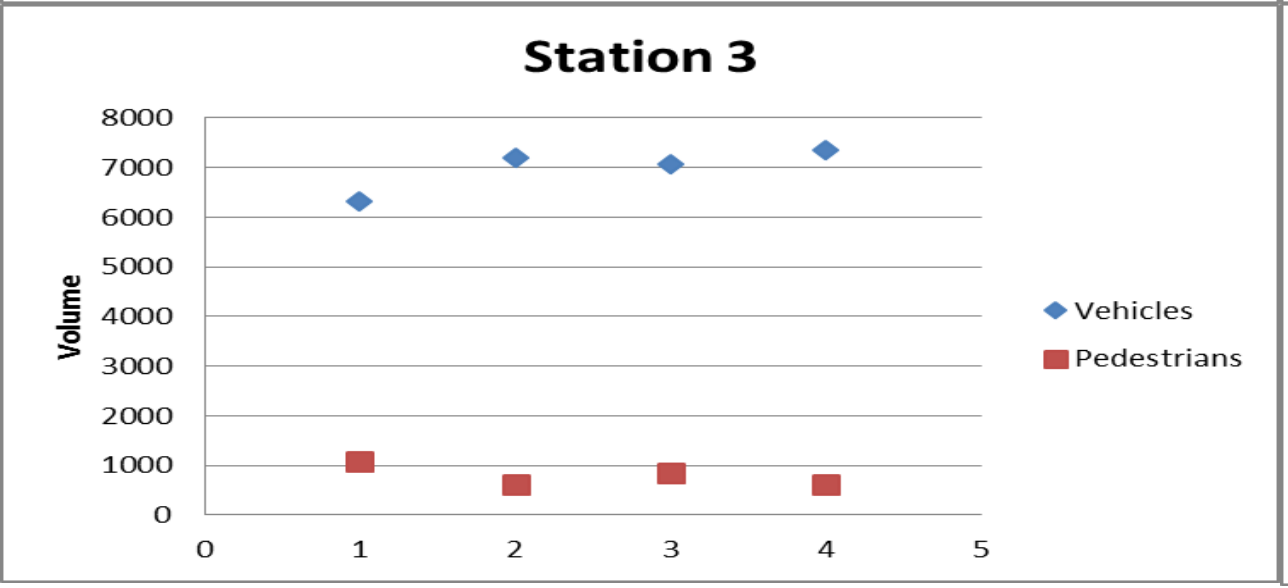
Cont.. Vehicle Count

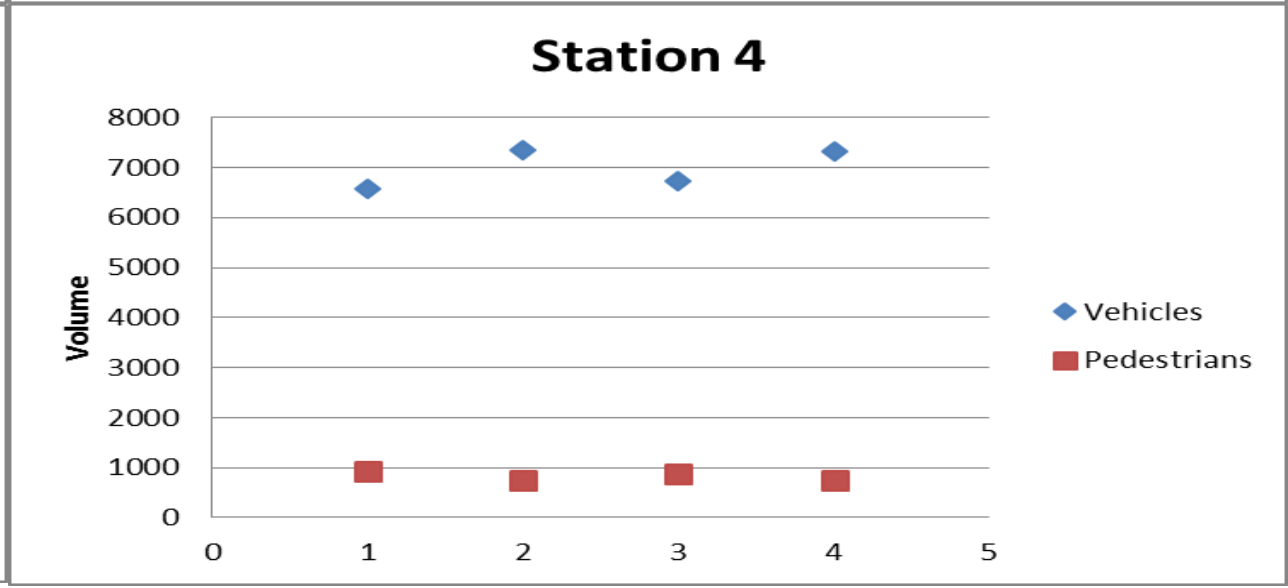
	Station 1	Car	Van	Bus	Truck	Bicycle	Motor cycle	Three wheel	Heavy Truck	Medium Truck-lorry	PCU	Vehicle time for an hour	for 60s cycle length
Week Day	Pedestrian peak	1282	520	396	236	28	808	300	6	60	4248.00	1416.00	23.60
	Pedestrian off peak	920	512	228	312	44	1300	1332	15	238	5006.20	1668.73	27.81
Week end	Pedestrian peak	964	316	200	260	20	1216	1032	12	124	4022.40	1340.80	22.35
	Pedestrian off peak	1294	312	384	264	8	408	880	36	308	4798.80	1599.60	26.66
	Station 2	Car	Van	Bus	Truck	Bicycle	Motor cycle	Three wheel	Heavy Truck	Medium Truck-lorry	PCU	Vehicle time for an hour	for 120s cycle length
Week Day	Pedestrian peak	2040	568	438	409	4	1217	1356	28	346	7099.90	2366.63	78.89
	Pedestrian off peak	2349	514	416	340	28	1714	1478	19	354	7450.40	2483.47	82.78
Week end	Pedestrian peak	2268	549	424	398	4	1060	1404	16	300	7081.60	2360.53	78.68
	Pedestrian off peak	2392	501	421	343	24	1616	1512	13	359	7458.90	2486.30	82.88
	Station 3	Car	Van	Bus	Truck	Bicycle	Motor cycle	Three wheel	Heavy Truck	Medium Truck-lorry	PCU	Vehicle time for an hour	for 90s cycle length
Week Day	Pedestrian peak	1004	688	584	553	16	724	864	24	480	6516.70	2172.23	54.31
	Pedestrian off peak	1384	808	628	664	8	832	732	22	566	7481.20	2493.73	62.34
Week end	Pedestrian peak	1390	692	773	684	10	795	704	21	436	7356.80	2452.27	61.31
	Pedestrian off peak	1484	786	668	700	32	840	944	22	444	7637.20	2545.73	63.64
	Station 4	Car	Van	Bus	Truck	Bicycle	Motor cycle	Three wheel	Heavy Truck	Medium Truck-lorry	PCU	Vehicle time for an hour	for 90s cycle length
Week Day	Pedestrian peak	1364	494	542	400	40	948	1092	16	544	6583.60	2194.53	54.86
	Pedestrian off peak	1676	490	576	568	27	918	1068	12	640	7358.50	2452.83	61.32
Week end	Pedestrian peak	1108	468	536	596	28	960	1096	11	632	6717.00	2239.00	55.98
	Pedestrian off peak	1640	484	572	592	32	960	1028	8	648	7327.20	2442.40	61.06

Relationship of Peak Volume Values of Pedestrians and Vehicles









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Pedestrian travel time during clearance

Pedestrian Travel Time	Weekday		Weekend	
	Peak	Off Peak	Peak	Off Peak
Station 1	12.73	11.68	12.83	11.42
Station 2	15.54	13.63	15.21	13.04
Station 3	12.04	9.08	9.75	8.45
Station 4	12.75	9.88	12.47	10.25

Pedestrian walking speed during clearance

Pedestrian walking speed	Weekday		Weekend	
	Peak	Off Peak	Peak	Off Peak
Station 1	1.32	1.43	1.31	1.47
Station 2	1.24	1.42	1.27	1.48
Station 3	0.68	0.90	0.84	0.97
Station 4	1.19	1.54	1.22	1.48

Average pedestrian walking speed during clearance = 1.235 meters per second

Cont.. Pedestrian Flow Rate

		Weekday		Weekend	
		Peak	Off Peak	Peak	Off Peak
Station 1	Pedestrian flow rate (ped per meter per minutes)	1.29	1.00	1.03	0.75
	Number of cycles per hour	60.00	60.00	60.00	60.00
	No. of queuing pedestrians at the onset of green indication (P)	0.02	0.02	0.02	0.01
	Saturation Flow rate (ped per meter per minutes)	1.44	1.05	1.40	0.89
Station 2	Pedestrian flow rate (ped per meter per minutes)	5.75	4.05	7.82	5.69
	Number of cycles per hour	30.00	30.00	30.00	30.00
	No. of queuing pedestrians at the onset of green indication (P)	0.19	0.14	0.26	0.19
	Saturation Flow rate (ped per meter per minutes)	6.23	4.93	9.74	8.17
Station 3	Pedestrian flow rate (ped per meter per minutes)	3.99	2.27	3.07	2.44
	Number of cycles per hour	40.00	40.00	40.00	40.00
	No. of queuing pedestrians at the onset of green indication (P)	0.10	0.06	0.08	0.06
	Saturation Flow rate (ped per meter per minutes)	6.45	2.78	3.81	2.90
Station 4	Pedestrian flow rate (ped per meter per minutes)	3.41	2.72	3.19	2.79
	Number of cycles per hour	40.00	40.00	40.00	40.00
	No. of queuing pedestrians at the onset of green indication (P)	0.09	0.07	0.08	0.07
	Saturation Flow rate (ped per meter per minutes)	3.50	2.91	4.00	2.81

Station 1	AUSTROADS				JAPANESE			
	Weekday		Weekend		Weekday		Weekend	
	peak	Off peak	peak	Off peak	peak	Off peak	peak	Off peak
Ped Yellow Time	4.38	3.02	4.92	3.78	3.18	2.92	3.21	2.85
Bl before green to ped	1.42	1.42	1.42	1.42	3.00	3.00	3.00	3.00
Ped Green Time	24.23	22.74	24.39	22.36	18.24	16.74	18.39	16.36
Ped Yellow Time	4.38	3.02	4.92	3.78	3.18	2.92	3.21	2.85
Bl before red to ped	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Ped Red Time	23.60	27.81	22.35	26.66	30.40	32.41	30.19	32.93
Total	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

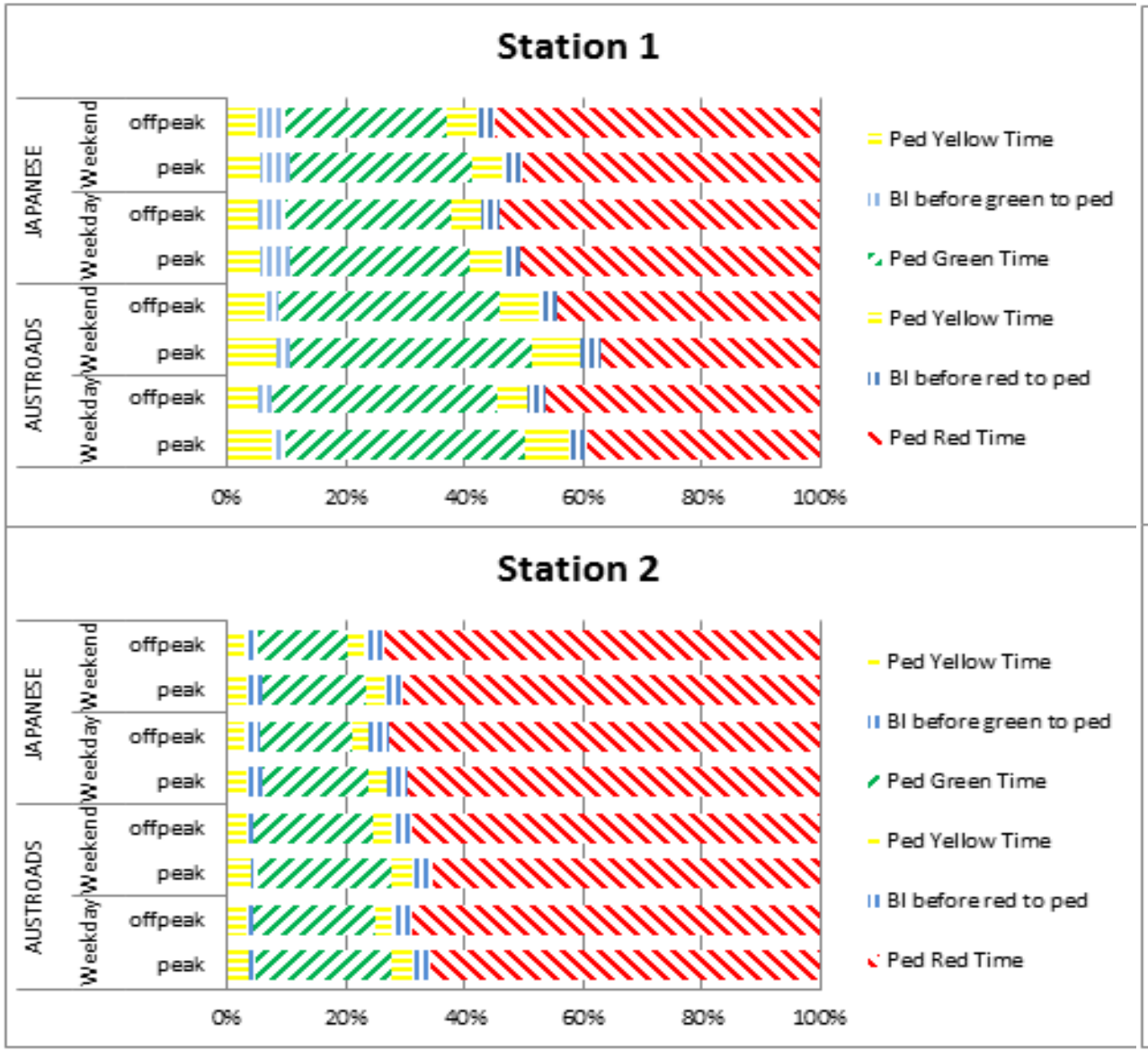
Station 2	AUSTROADS				JAPANESE			
	Weekday		Weekend		Weekday		Weekend	
	peak	Off peak	peak	Off peak	peak	Off peak	peak	Off peak
Ped Yellow Time	4.14	3.52	4.48	3.87	3.89	3.41	3.80	3.26
Bl before green to ped	1.42	1.42	1.42	1.42	3.00	3.00	3.00	3.00
Ped Green Time	27.41	24.77	26.95	23.96	21.42	18.77	20.96	17.97
Ped Yellow Time	4.14	3.52	4.48	3.87	3.89	3.41	3.80	3.26
Bl before red to ped	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Ped Red Time	78.89	82.78	78.68	82.88	83.81	87.41	84.44	88.51
Total	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00

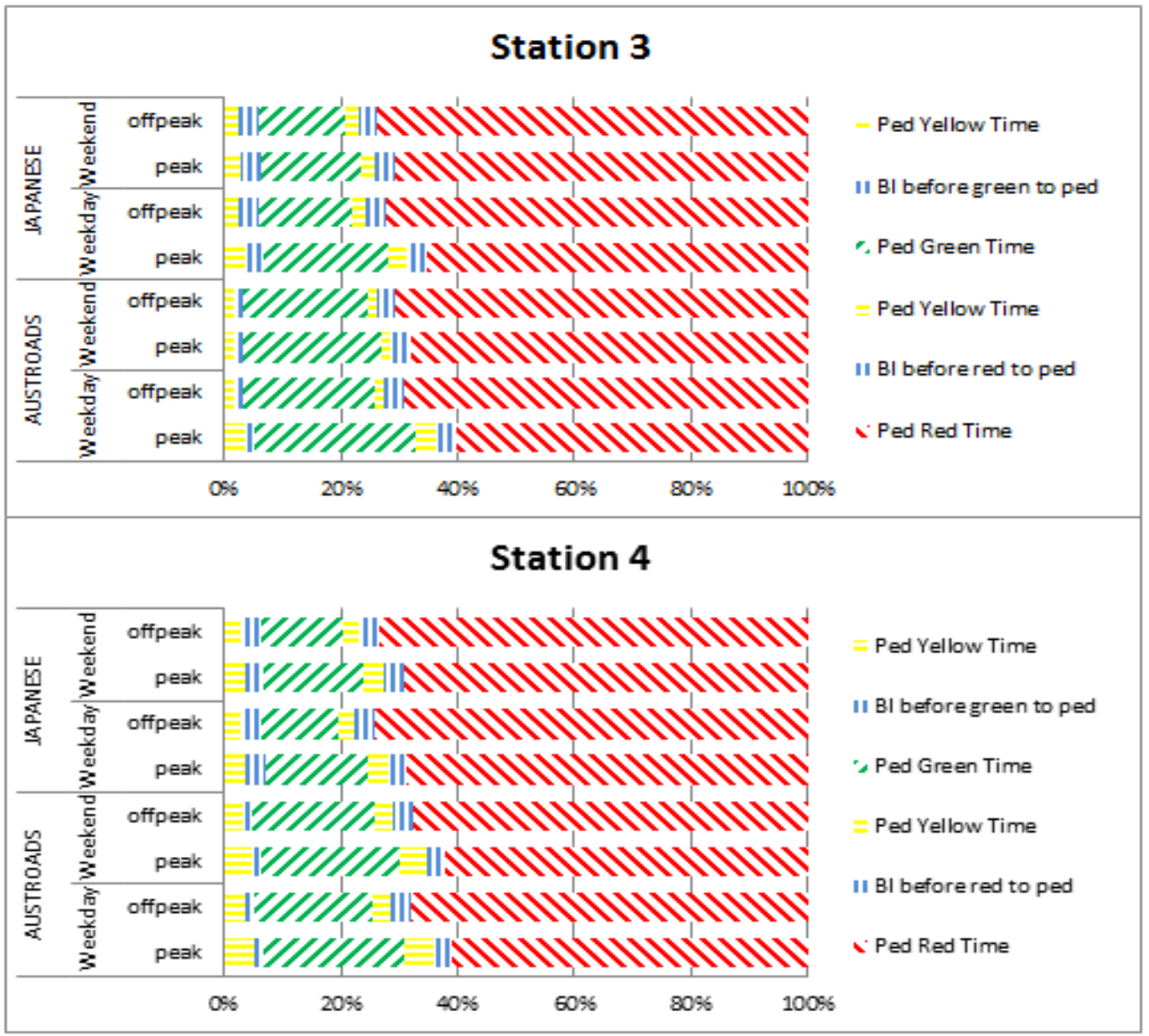
Station 3	AUSTROADS				JAPANESE			
	Weekday		Weekend		Weekday		Weekend	
	peak	Off peak	peak	Off peak	peak	Off peak	peak	Off peak
Ped Yellow Time	3.13	1.45	1.44	1.30	3.01	2.27	2.44	2.11
Bl before green to ped	1.42	1.42	1.42	1.42	3.00	3.00	3.00	3.00
Ped Green Time	25.02	20.33	21.39	19.34	19.02	14.34	15.40	13.35
Ped Yellow Time	3.13	1.45	1.44	1.30	3.01	2.27	2.44	2.11
Bl before red to ped	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Ped Red Time	54.31	62.34	61.31	63.64	58.96	65.12	63.73	66.42
Total	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00

Station 4	AUSTROADS				JAPANESE			
	Weekday		Weekend		Weekday		Weekend	
	peak	Off peak	peak	Off peak	peak	Off peak	peak	Off peak
Ped Yellow Time	4.50	3.04	4.11	2.94	3.19	2.47	3.12	2.56
Bl before green to ped	1.42	1.42	1.42	1.42	3.00	3.00	3.00	3.00
Ped Green Time	21.73	18.18	21.38	18.64	15.74	12.19	15.39	12.65
Ped Yellow Time	4.50	3.04	4.11	2.94	3.19	2.47	3.12	2.56
Bl before red to ped	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Ped Red Time	54.86	61.32	55.98	61.06	61.89	66.87	62.38	66.22
Total	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00

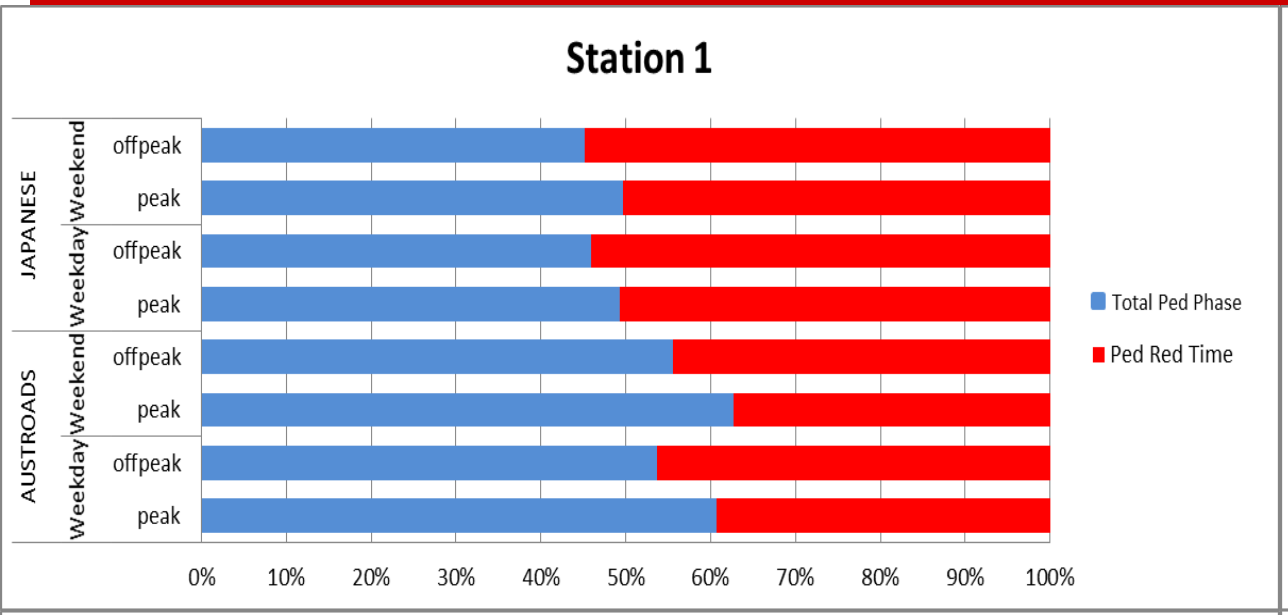
Summary of Calculated Pedestrian Phases of One Cycle for Every Station

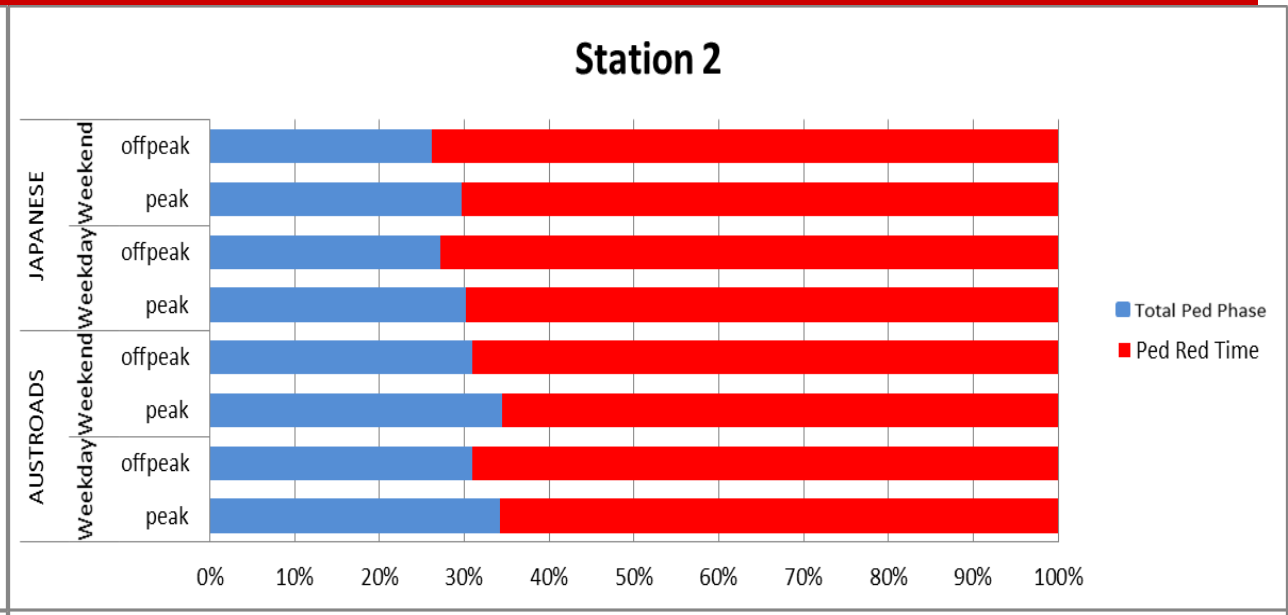
Graphical Representation of Pedestrian Phases of a Cycle

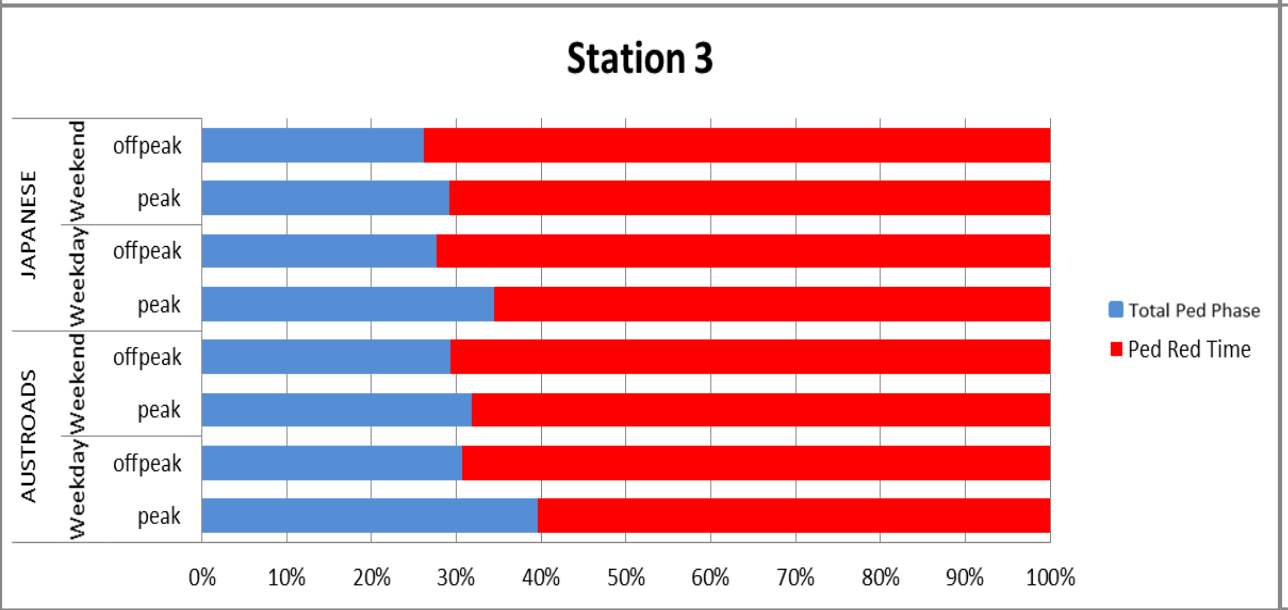


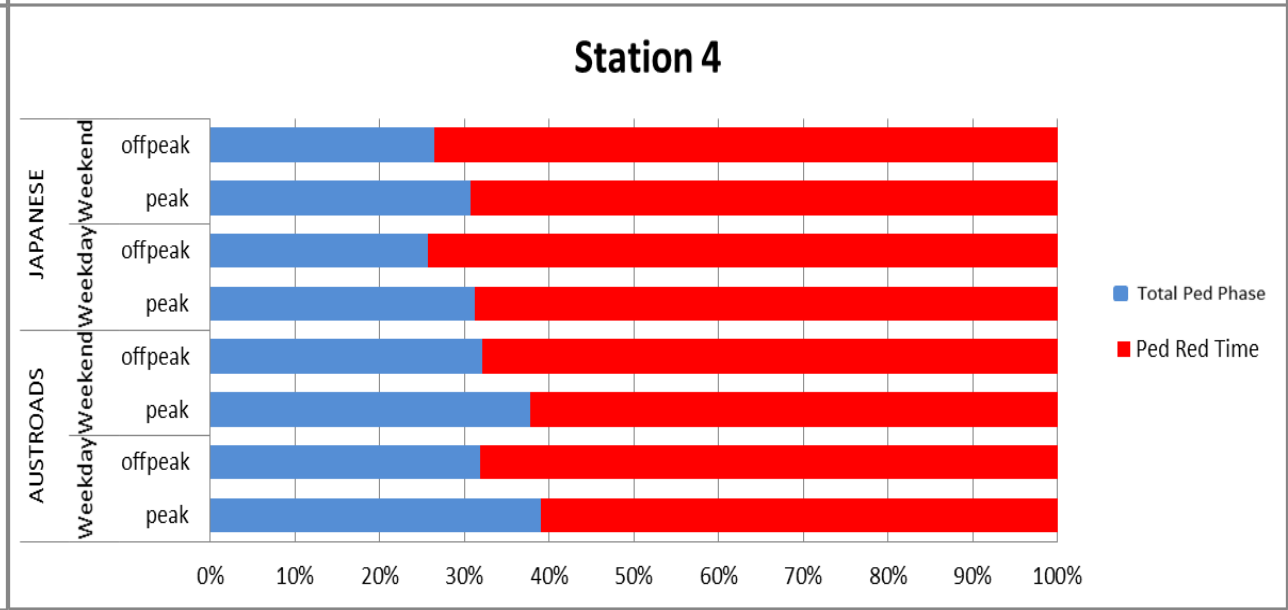


Comparison of Three Standards









Conclusion

- Cycle Length;

  Station 1, Low pedestrian volume station -60 seconds

  Station 2, High pedestrian volume station -120 seconds

  Station 3&4, Medium pedestrian volume stations -90 seconds

- Peak volume values of pedestrians and vehicles shown a vice versa relationship
- First priority → to pedestrian safety, and then drivers comfort.
- Pedestrian crossing for Sri Lankan situation
  - Australian design standard - better pedestrian safety and less risk of pedestrian accidents
  - Japanese design standard - lessen the vehicle queue length and reduce traffic by providing more time for vehicles.

Cont..

- According to the results obtained from Maharagama pedestrian analysis average walking speed of Sri Lankan people during clearance is 1.235 meters per second.

Average walking speed during clearance

Akc¸elik, R. (1981) and Iryo-Asano, M. (2014)

Design Standard	Walking Speed
AUSTROADS	1.2 meters per second
Japanese	1.5 meters per second

- Japanese standard is appropriate for higher walking speed condition.
    - Sri Lankan pedestrian walking speed approximately equal to the Australian pedestrian walking speed

Cont..

- In Maharagama, Sri Lanka roads and crossing usage by pedestrians and vehicles is high,
  - If pedestrians are prioritized: more vehicular traffic and drivers will influence to break the rules and drive without considering pedestrian safety. They will not wait longer in traffic or pause for traffic lights for more than acceptable level of patience.
  - If vehicles are prioritized: will reduce the pedestrian safety, people will influence to cross the road even in their red time and increase the number of pedestrian at queue on one set.
- Comparing to the Japanese standard, the AUSTROADS standard time allocation is more appropriate to Sri Lankan condition because it address the above issues and provides similarity in pedestrian walking speeds.

Thank You!

Sohani Pramoodha Liyanage