9th Urban Mobility India Conference & Expo 2016
Planning Mobility for City's Sustainability

GUIDELINES FOR SELECTION OF APPROPRIATE PEDESTRIAN CROSSING FACILITY AT MID-BLOCK SECTIONS

Udit Jain
Research Scholar
Indian Institute of Technology Roorkee

Need of the Study

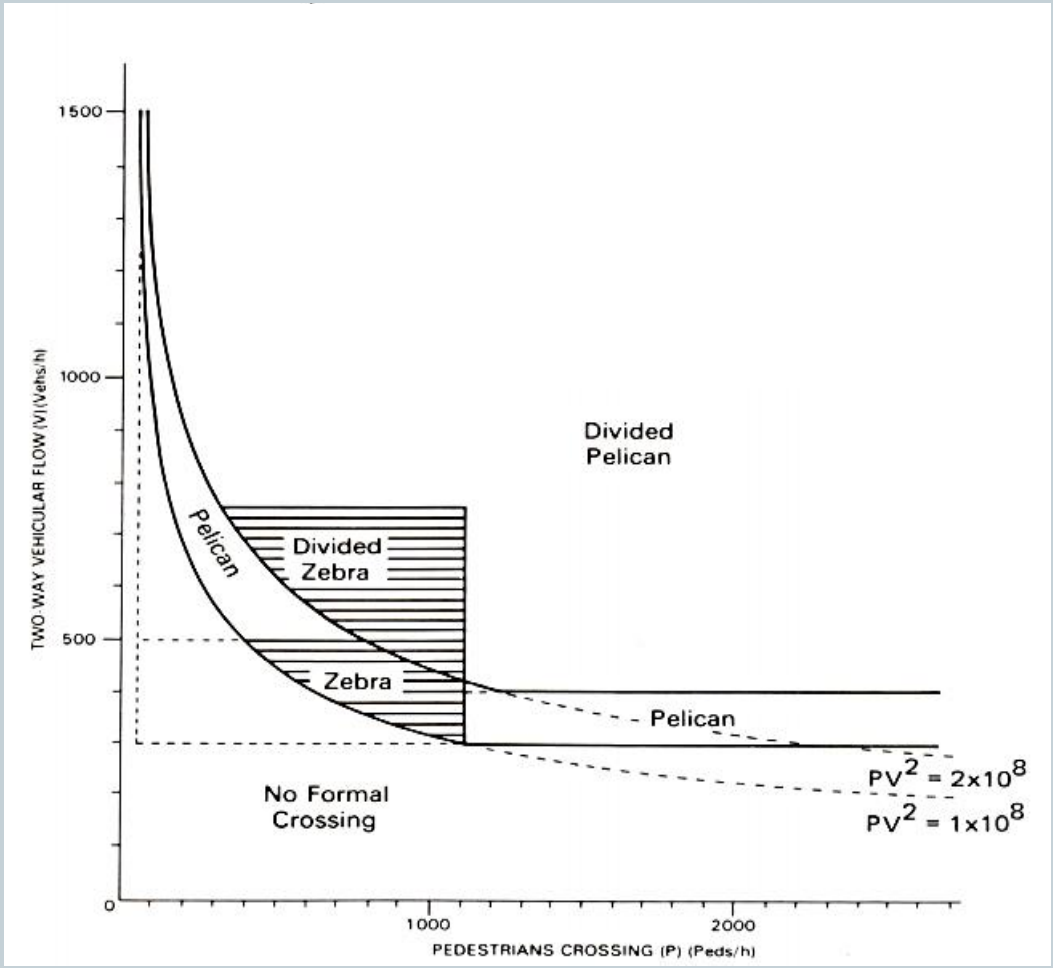
- Pedestrian fatalities highest in road users
- 90% fatalities in Kota & Mumbai at Mid-Block
- 75% pedestrian crashes due to no facility (UK)
- Remaining 25% due to improper facility
- In India, IRC 103: 2012 does not recommend the type of crossing facility to be provided
- Solution: Develop Pedestrian Crossing Warrant Guidelines for Indian Conditions

PV^2 Based Warrants

- P – Peak Hour Pedestrian Volume (ped/hr)
- V – Peak Hour Vehicular Volume (veh/hr)
- PV^2 based crossing warrants first introduced in UK in 1987
- Also used in other countries like India and Iran

PV^2 Based Warrants in UK

- Graphical Form
- PV2 thresholds –
  - $PV^2 = 1 \times 10^8$
  - $PV^2 = 2 \times 10^8$
- Recommends crossing facilities
- Based on peak traffic flows of 1980s



Adaptations of PV^2 Based Warrants

- Several counties in UK modified this criteria after LTN-1/95
- Maintains balance between PV^2 & pedestrian characteristics
- Uses factors like Age, Waiting Time, Gap Size to suggest facilities based on Adjusted PV^2 values

PV^2 Based Warrants in India

- Indian Roads Congress Code, IRC-103 introduced in 1988
- Revised in 2012 – No change in Pedestrian Crossing Warrants
- Warranting is recommended when either of the following is true:

1. $PV^2 > 10^8$ for undivided roads or $PV^2 > 2 \times 10^8$ for divided roads
2. Vehicle Speed > 65 kmph; or
3. Waiting time for pedestrian/vehicle too long; or
4. Pedestrian injuries > 5 per year

PV^2 Based Warrants in India

- Limitations –
  - Threshold values same as UK
  - No warrant chart or graph
  - No recommendation of facility type
  - Ambiguity in parameters used
  - Based on traffic flows of 1980s
- Need of revision of pedestrian crossing warrants

Objectives

- Develop warrants based on existing traffic flow conditions
- Re-examine the existing threshold values of PV^2
- Identify the type of crossing facilities to be installed

Methodology

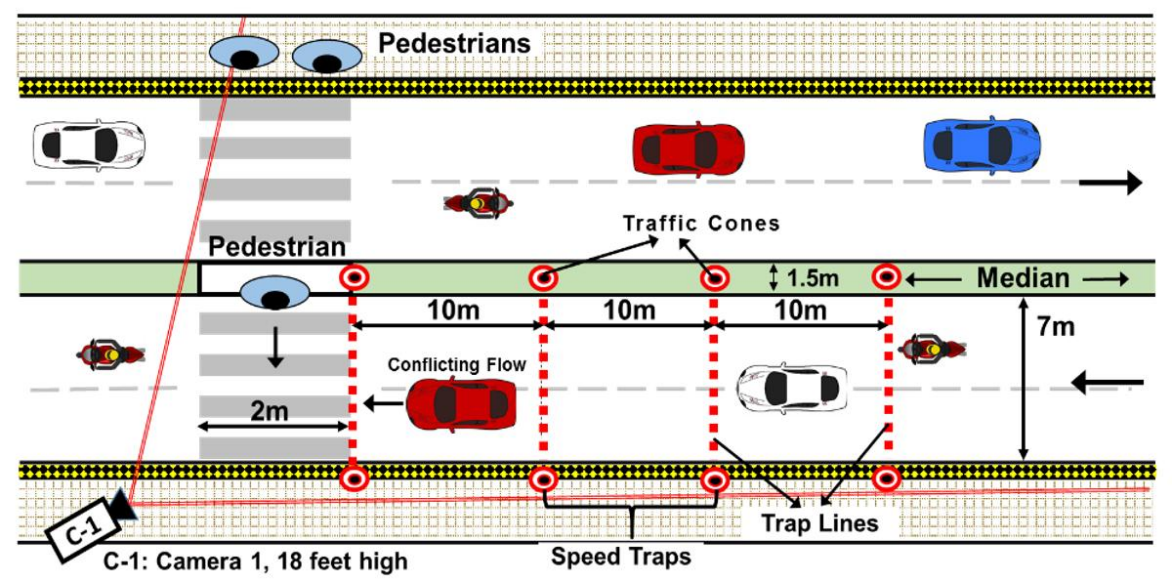
- Maximum Hourly Vehicle Flow (V)
- Maximum Hourly Pedestrian Flow (P)
  - Critical Gap
  - Follow Up Time
- PV^2 Matrices - Upper Limits ‘P’ and ‘V’
- PV^2 Values Data Set
- New PV^2 Threshold Values
  - Cluster Analysis
- Pedestrian Crossing Warrants

Data Requirements

1. Maximum Hourly Vehicle Flow (V)
   - Vehicle Flow
   - Vehicle Speed
2. Maximum Hourly Pedestrian Flow (P)
   - Pedestrian Flow
   - Critical Gap
   - Follow up Time

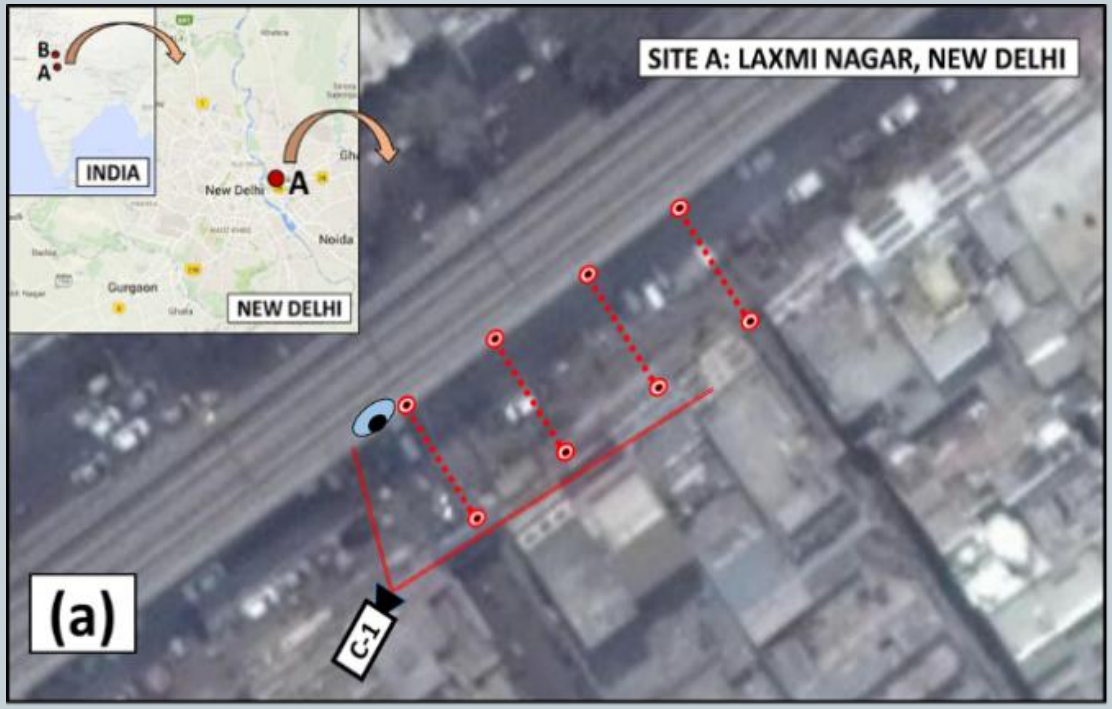
Data Collection & Extraction

S.No	Site Code	City	Location	Road Configuration
1	Site A	Chandigarh	Sec 17 ISBT	2 Lane Undivided
2	Site B	Chandigarh	Sukhna Lake	3 Lane Undivided
3	Site C	Delhi	Laxmi Nagar	4 Lane Divided
4	Site D	Delhi	Dwarka sec 6	6 Lane Divided



Data Collection & Extraction

- Videography with Trap markings



Aerial View of the Site

Data Collection & Extraction

- Frame by frame data extraction

Camera View of the Site

Max Hourly Vehicle Flow (V)

- Max Hourly Vehicle Flow using Greenshields model

Site Code	Roadway Configuration	Max Hourly Vehicle Flow (PCU/hr)
Site A	2 Lane 2 Way Undivided	3,018
Site B	3 Lane 2 Way Undivided	4,672
Site C	4 Lane 2 Way Divided	8,172
Site D	6 Lane 2 Way Divided	12,630

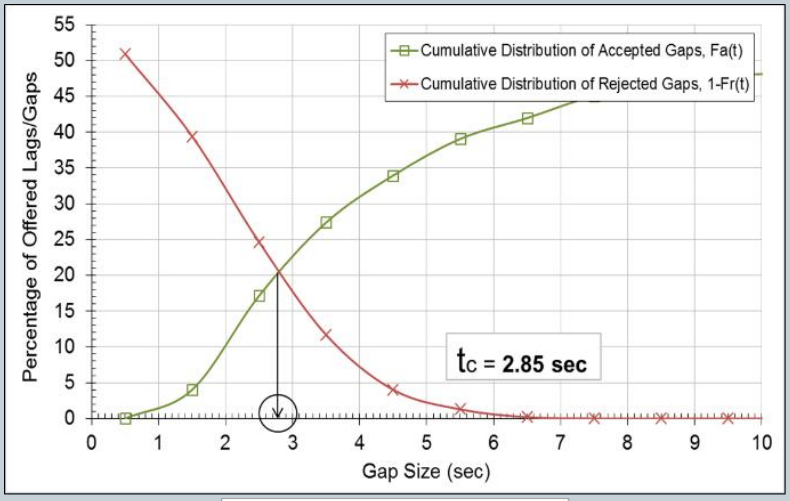
Max Hourly Pedestrian Flow (P)

- Maximum Hourly Pedestrian Flow by maximization of the HCM 2010 model

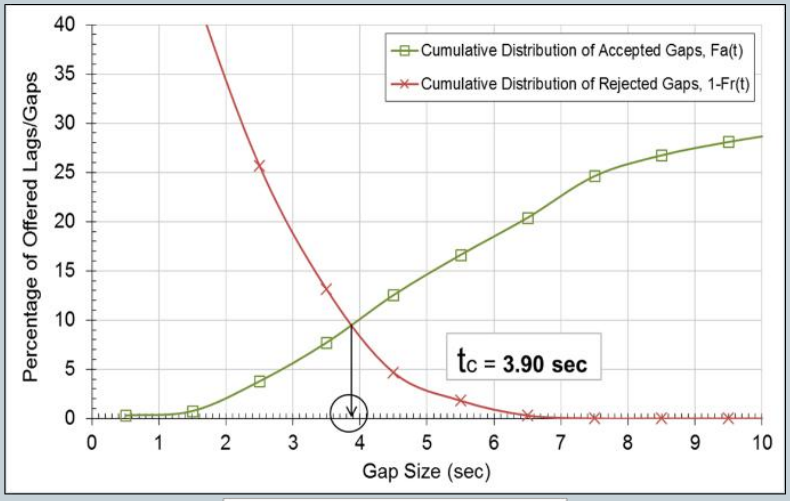
$$\max\left(c_{px} = v_{cx} \frac{e^{-v_{cx} t_{cx} / 3600}}{1 - e^{-v_{cx} t_{fx} / 3600}} \right) \quad \textit{subject to: } v_{cx},\ t_{cx},\ t_{fx} > 0$$

Where,
c_{px} – Potential capacity of pedestrians;
v_{cx} – Conflicting major stream vehicle flow rate;
t_{cx} – Critical gap for pedestrians;
t_{fx} – Follow-up time for pedestrians (0.80 sec)

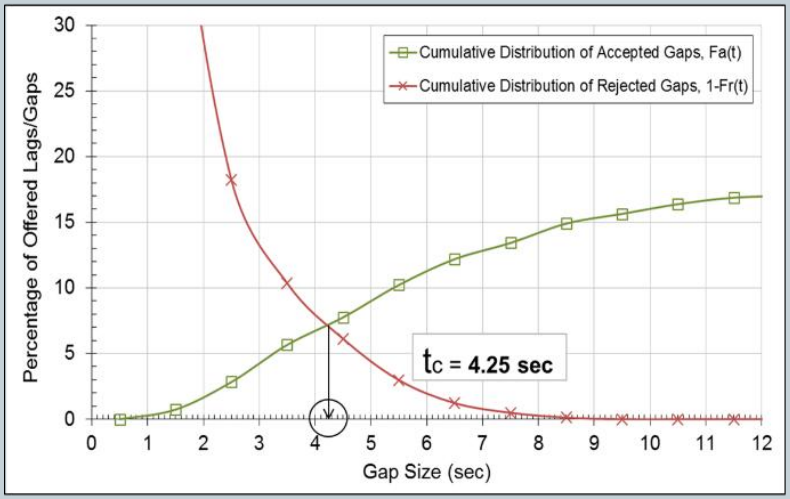
Critical Gap Analysis – Raff's Method



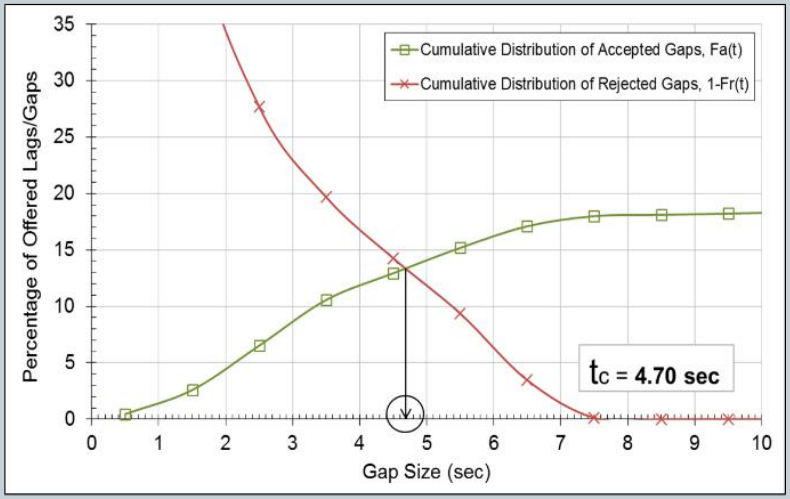
(a) 2-Lane 2-Way-Undivided Roads



(b) 4-Lane 2-Way-Dvided Roads



(c) 6-Lane 2-Way-Divided Roads



(d) 8-Lane 2-Way-Divided Road

Max Hourly Pedestrian Flow (P)

$$\max\left(c_{px} = v_{cx} \frac{e^{-v_{cx}t_{cx}/3600}}{1-e^{-v_{cx}t_{fx}/3600}} \right) \quad \textit{subject to: } v_{cx},\ t_{cx},\ t_{fx} > 0$$

- Maximum hourly pedestrian flow ~ 4,500 ped/hr for all four road configurations
- Verification based on IRC:103 (2012)
  - Pedestrian flow rate for high densities (LOS E) = 36 ped/min/meter
  - For crosswalk width of 2 meters
  - Maximum Hourly Flow similar to HCM estimates

PV^2 Analysis – Matrices

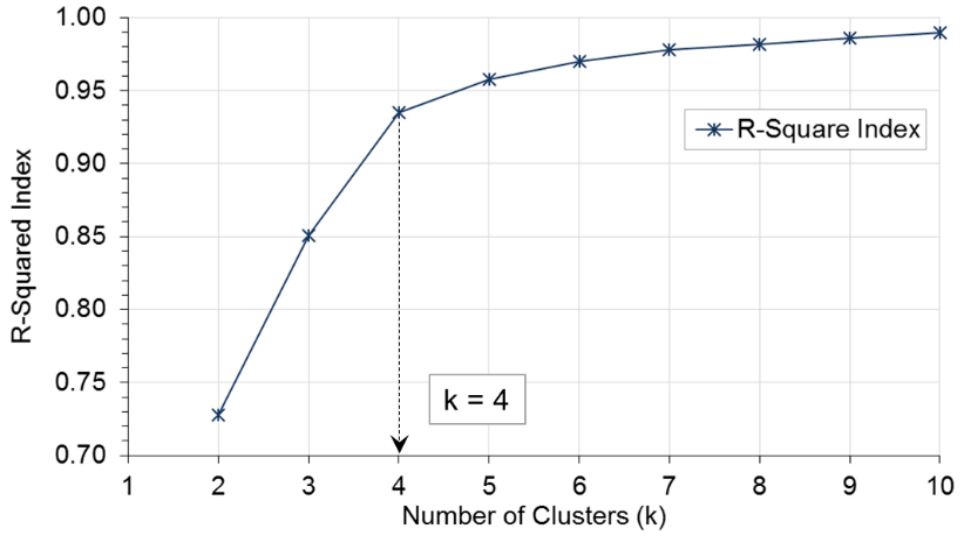
P\V	100	200	300	..	..	..	..	..	'V'
100	1.0.E+06	4.0.E+06	9.0.E+06	..	..	..	..	..	..
200	2.0.E+06	8.0.E+06	1.8.E+07	..	..	..	..	..	..
300	3.0.E+06	1.2.E+07	2.7.E+07	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
'P'	..	..	..	..	..	..	..	..	PV^2

PV^2 Analysis – Clustering

- K-means clustering technique suitable for dense data sets (Wu et al., 2009)
- Number of clusters (k) identified using cluster validation indices
  - Davies-Bouldin Index
  - Silhouette Index
  - Calinski-Harabasz Index
  - Dunn Index
  - R Squared Index

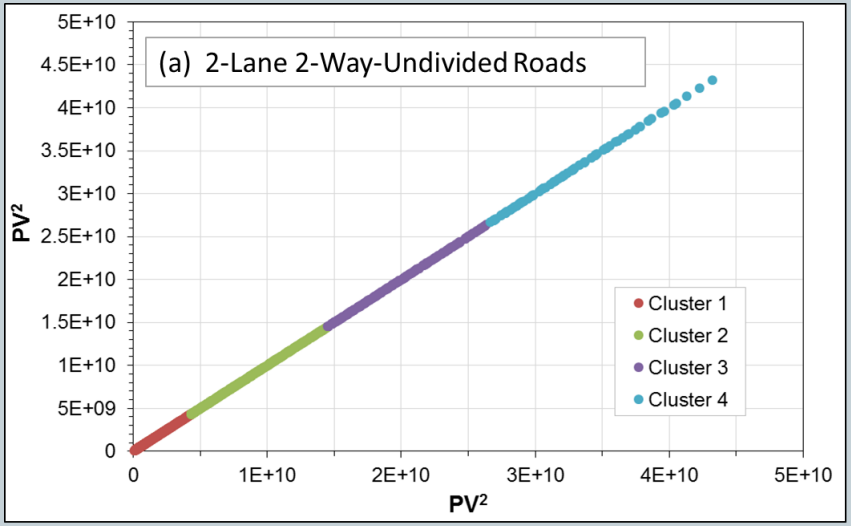
PV^2 Analysis – Clustering

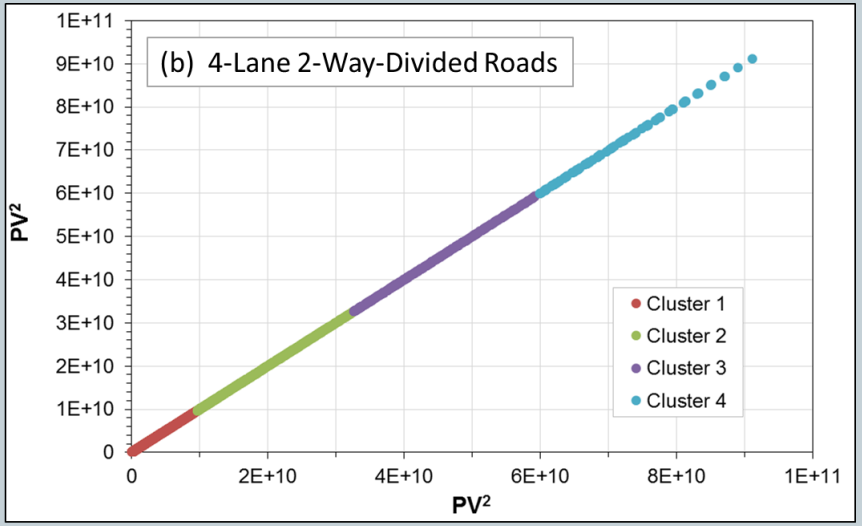
- Four Indices were found to be inconclusive due to indistinct minima and maxima values
- Using the elbow of the R-squared index, k = 4

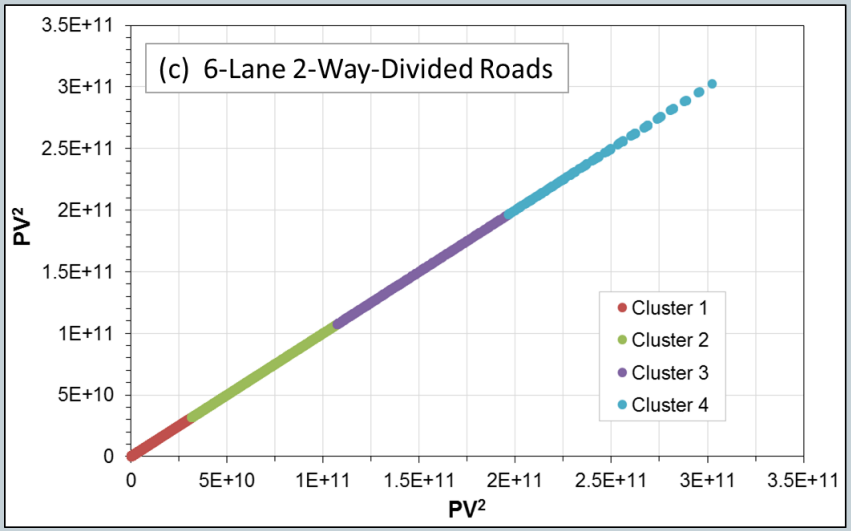


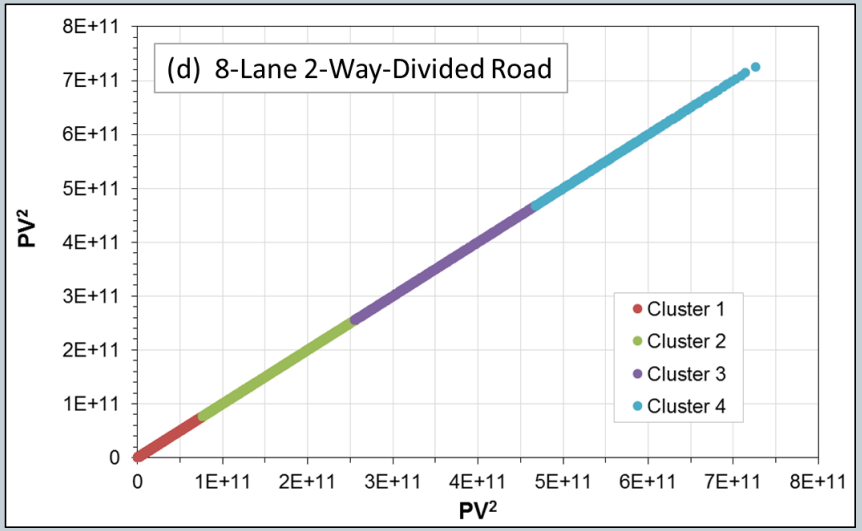
- K-means clustering algorithm with squared Euclidean distance implemented in MATLAB™ with k = 4

PV^2 Analysis – Clustering









PV^2 Analysis – Clustering

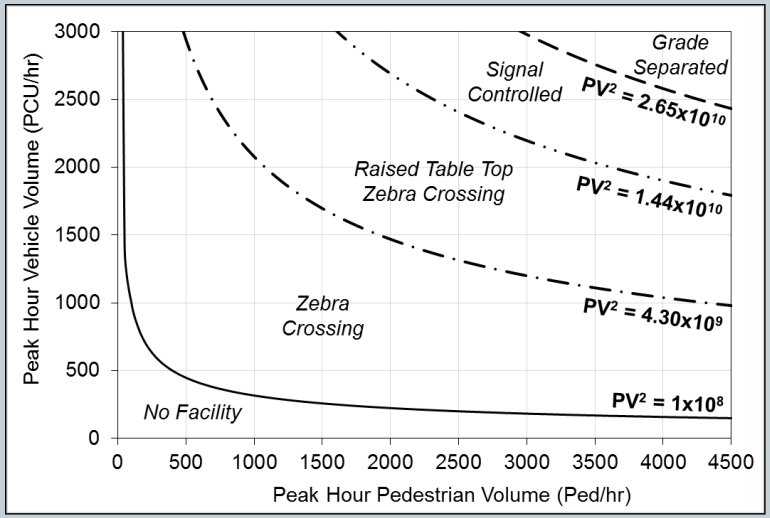
Cluster	2-Lane 2-Way	4-Lane 2-Way	6-Lane 2-Way	8-Lane 2-Way
1	4.30×10^9	9.63×10^9	3.16×10^{10}	7.61×10^{10}
2	1.44×10^{10}	3.24×10^{10}	1.07×10^{11}	2.55×10^{11}
3	2.65×10^{10}	5.95×10^{10}	1.96×10^{11}	4.68×10^{11}
4	4.09×10^{10}	9.09×10^{10}	3.00×10^{11}	7.17×10^{11}

Crossing Facility**	PV^2 Value Ranges*			
	2-Lane 2-Way	4-Lane 2-Way	6-Lane 2-Way	8-Lane 2-Way
No Facility	**$< 1.00 \times 10^8$**	**$< 1.00 \times 10^8$**	**$< 2.00 \times 10^8$**	**$< 2.00 \times 10^8$**
Zebra Crossing	**$1.00 \times 10^8 – 4.30 \times 10^9$**	**$1.00 \times 10^8 – 9.63 \times 10^9$**	**$2.00 \times 10^8 – 3.16 \times 10^{10}$**	**$2.00 \times 10^8 – 7.61 \times 10^{10}$**
Zebra with Speed Table	**$4.30 \times 10^9 – 1.44 \times 10^{10}$**	**$9.63 \times 10^9 – 3.24 \times 10^{10}$**	**$3.16 \times 10^{10} – 1.07 \times 10^{11}$**	**$7.61 \times 10^{10} – 2.55 \times 10^{11}$**
Signal Controlled	**$1.44 \times 10^{10} – 2.65 \times 10^{10}$**	**$3.24 \times 10^{10} – 5.95 \times 10^{10}$**	**$1.07 \times 10^{11} - 1.96 \times 10^{11}$**	**$2.55 \times 10^{11} – 4.68 \times 10^{11}$**
Grade Separated	**$> 2.65 \times 10^{10}$**	**$> 5.95 \times 10^{10}$**	**$> 1.96 \times 10^{11}$**	**$> 4.68 \times 10^{11}$**

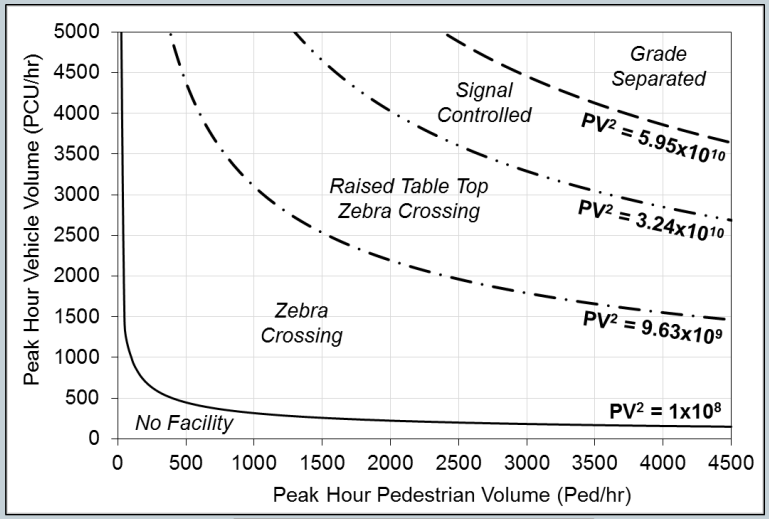
*Where ‘P’ is the Peak Hour Pedestrian Flow & ‘V’ is the Peak Hour Vehicle Flow of both directions

**It is recommended that the design specifications of these facilities should be as per IRC-103:2012

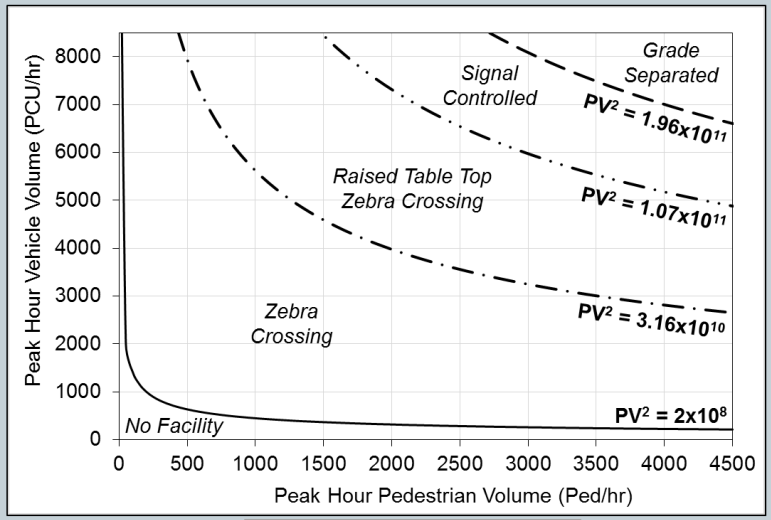
Warrant Charts



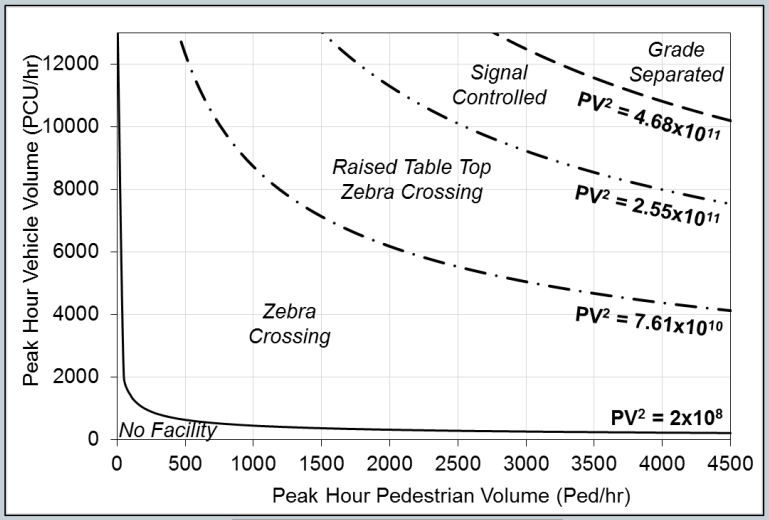
(a) 2-Lane 2-Way-Undivided Roads



(b) 4-Lane 2-Way-Divided Roads



(c) 6-Lane 2-Way-Divided Roads



(d) 8-Lane 2-Way-Divided Road

Application & Validation

Site	Location	Lanes	P (Ped/hr)	V (PCU/hr)	PV^2	Existing Facility	Recommended Facility
A	Sector-17 ISBT	2 Lane	4,080	1,276	6.55E+09	Unprotected	Zebra w/ speed table
B	Sukhna Lake Road	3 Lane	3,780	3,266	4.03E+10	Zebra Crossing	Zebra w/ speed table
C	Laxmi Nagar	4 Lane	2,760	7,248	1.45E+11	Zebra Crossing	Signal Controlled
D	Dwarka Sector-6	6 Lane	3,360	4,604	7.12E+10	Unprotected	Zebra Crossing
E	Prithviraj Road	4 Lane	1,760	4,286	3.23E+10	Signal Controlled	Zebra w/ speed table
F	Aurobindo Marg	6 Lane	3,960	8,061	2.57E+11	Signal Controlled	Signal Controlled
G	Old Fort	6 Lane	1,880	7,885	1.17E+11	Signal Controlled	Zebra w/ speed table
H	ITO PWD Headquarter	6 Lane	1,840	8,624	1.37E+11	Grade Separated	Zebra w/ speed table
I	Kotla Mubarakpur	6 Lane	1,260	7,422	6.94E+10	Grade Separated	Zebra Crossing
J	Anand Vihar ISBT	6 Lane	4,398	10,755	5.09E+11	Grade Separated	Grade Separated

Limitations

- Warrants based on peak flows observed in India
- Factors like delay and gap size can also be explored as a part of the warrant criteria

Thank You

Provide appropriate crossing facilities to ensure pedestrian safety at crossing locations

Udit Jain

Research Scholar, IIT Roorkee

udit.iitr@gmail.com