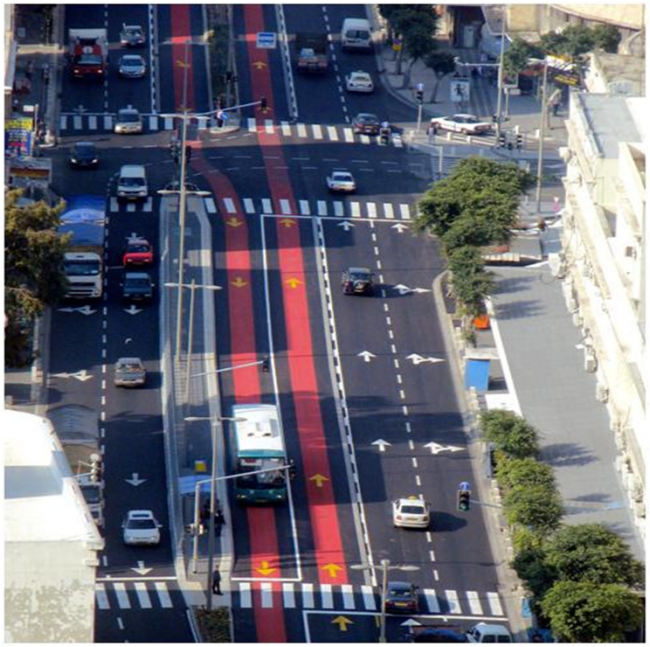
Advancements in planning and operation of public transport
Workshop 4.7.16, TRI, Technion

Safety impacts of pedestrian crossing configurations and other features of signalized junctions on public transport routes



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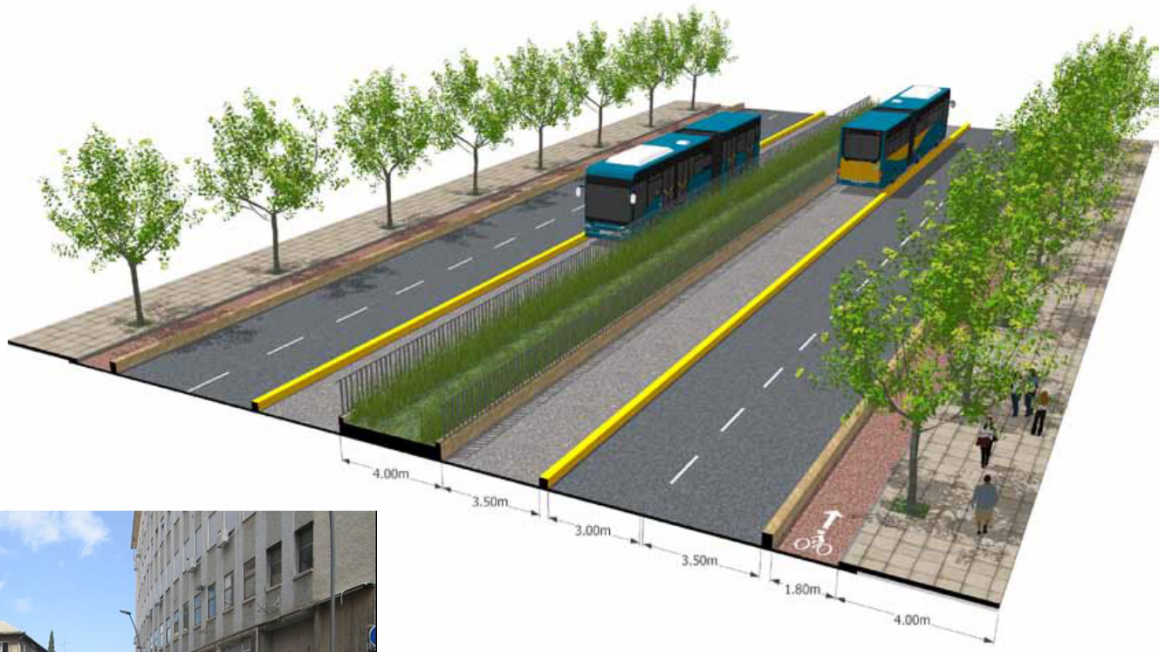
Background

- Public transport priority systems (BRT/LRT) are becoming an attractive solution for improving mobility and promoting PT in big cities, throughout the world

- In Israel, the development of public transport routes for buses is one of the main subjects promoted today by the Ministry of Transport

Definition

- **A public transport route (PTR) or bus corridor** is a special route designed for PT only, where it is separated, usually physically, from the general traffic lanes, so that it is maintained **exclusivity** for public transport vehicles enabling them to run **at undisturbed travel speeds** (ITDP, 2007).

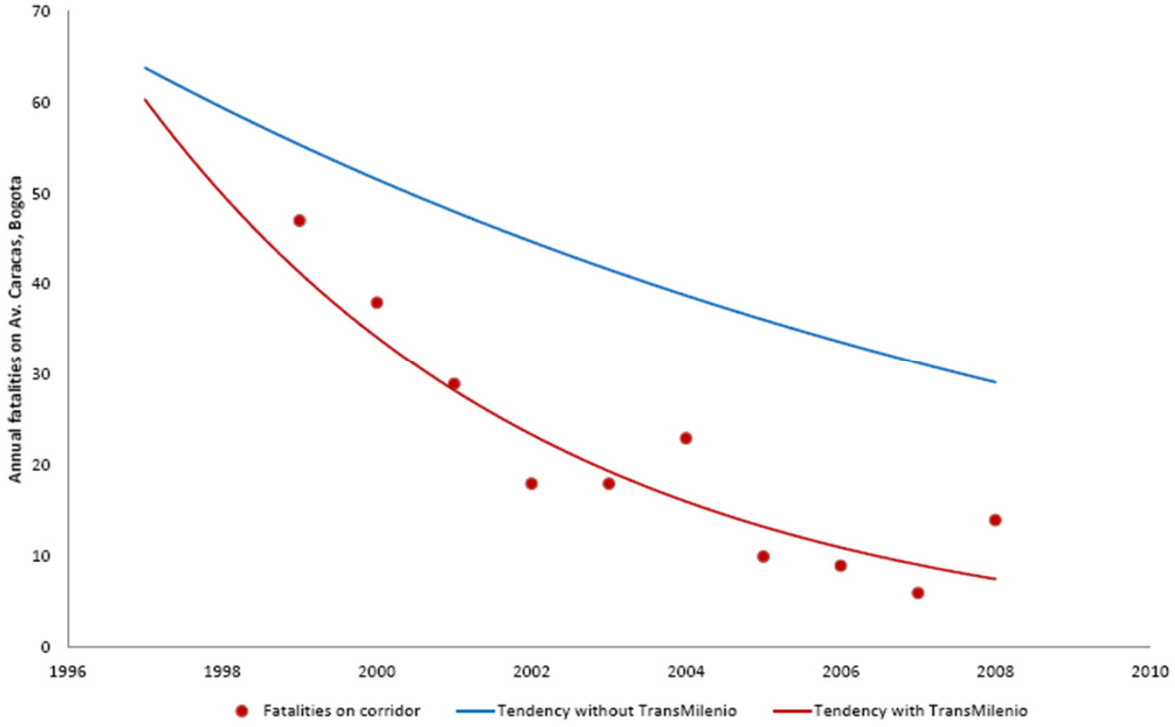


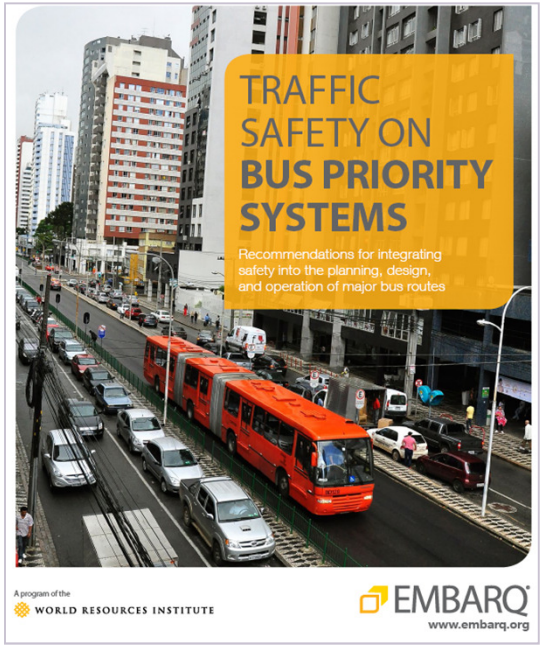
Duduta et al, 2012

Safety level of BRT - International findings*

- In general, BRT had a **positive impact** on the safety level of the urban roads involved,

  e.g. Av. Caracas, Bogota, TransMilenio





- **Exceptions**: Belo Horizonte in Brazil and Delhi in India

* Duduta et al, 2012; 2015

Safety impacts of bus priority systems - International findings*

- Main forms of the bus system configurations:
  - centre-lane bus-way → **safer**
  - curb-side bus lane
  - counter-flow bus lane

	Crash type	% change in crashes	95% confidence interval
Introducing a counterflow bus lane	Severe	+83%	(+23%, +171%)
	Vehicle collisions	+35%	(+0.02%, +86%)
	Pedestrian crashes	+146%	(+59%, +296%)

* Duduta et al, 2012; 2015

Safety-related recommendations - internationally *

- Focus on pedestrian safety
- Design solutions:

  - pedestrian access to bus stops through grade-separated or signalized intersections

  - fencing PTR street segments

  - highlighting PTR through a different aggregate colour

  - avoiding mid-block crosswalks

	Crash type	% change in crashes	95% confidence interval
Shortening crosswalks (each additional meter removed)	Severe	-2%	(-0.04%, -4%)
	Pedestrian crashes	-6%	(-2%, -8%)

* ITDP, 2007; TCRP, 2007; Duduta et al, 2015

Common PTR features on urban roads, in Israel

- Bus-lane/corridor **in the center** of a dual-carriageway urban arterial, with motor vehicle lanes on both sides
- High traffic volumes and pedestrian activities
- PTR is **physically separated** from other vehicle lanes and, typically, **fenced**
- Bus stops are **adjacent to junctions**, mid-block pedestrian crossings are avoided
- All intersections and pedestrian crossings are **signalized**

However: severe pedestrian accidents occurred on a bus route situated on an arterial road (Jabotinsky road) of the city of Petah Tiqwa
(Ministry of Transport, 2013)

The problem

Central PTR, left-side bus lane with stops on median*:

- The majority of pedestrian accidents concentrated **at signalized intersections**
- Two phenomena suggested as contributing to high-risk situations:
  - pedestrians crossing on red light **10%-20%** (int. findings)
  - **"three-route effect"**

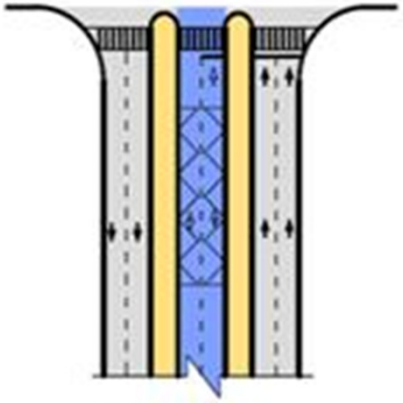
Pedestrians are expected **to change the traditional rules of checking the direction of approaching traffic**: to look *left* on the first route of general traffic, to look ***left again*** while crossing the bus route and then look *right* and *right again*

* Ministerial Commission (Ministry of Transport, 2013)

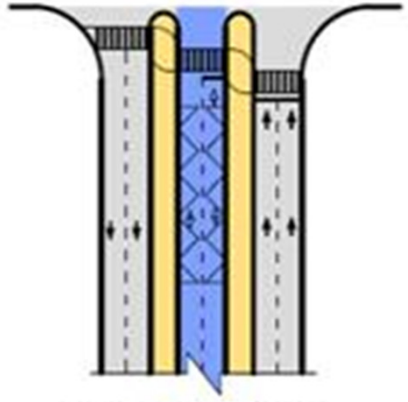
The study's topic

- To explore the impact of pedestrian crossing configurations and other design features of **signalized junctions with bus corridors** on accident occurrences
- **PTR**: bi-directional central bus corridors, situated on urban arterial streets of metropolitan areas
- Crossing configurations: a **gradated** or z-crossing vs **direct** crossing

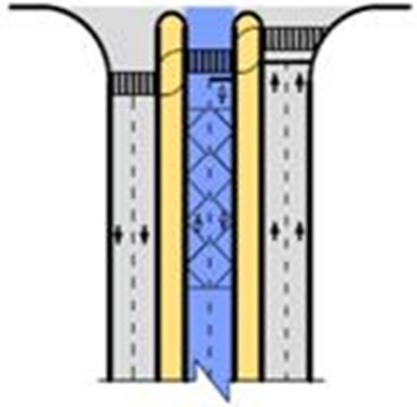
Pedestrian crossing configurations at signalized intersections with central PTR



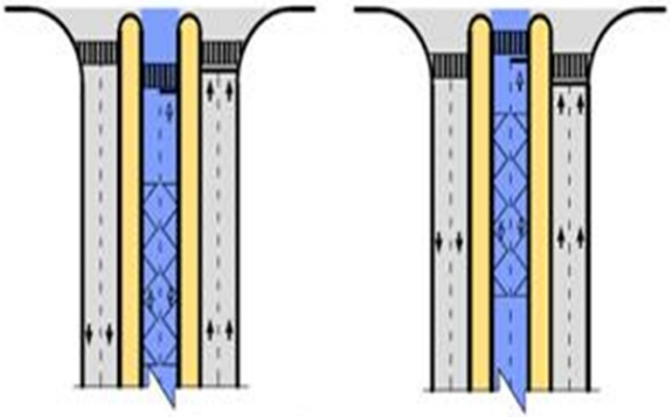
Type 1 – a direct three-routes crossing



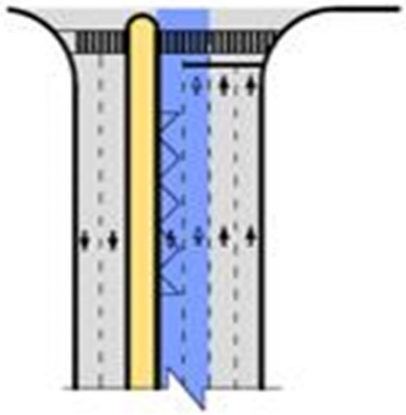
Type 2 – a gradated right-right crossing



Type 3 – a gradated left-left crossing



Type 4 – a gradated-crossing with mixed-shifting: right-left or left-right



Type 5 – a direct two-routes crossing

Evaluation framework

- **Accident analysis** to compare the safety performance of:

  - PTR sites, according to design characteristics

  - PTR junctions (treatment) vs comparison-group sites

- **Design features**: junction configuration (# of legs); # of pedestrian crossings at junction; # of lanes for vehicles, per each general traffic direction; pedestrian crossing configuration

- **Exposure**: traffic volumes n/a, high at all sites (assumption); categories of pedestrian activities assigned

- **Dataset:** 34 treatment and 38 comparison-group junctions. **Comparison-group:** signalized junctions situated on similar urban arterials, but not including a PTR

- **CBS accident files 2010-2012, five types**: total injury accidents; severe accident; pedestrian accidents; bus accidents; accidents involving both pedestrians and buses

Analysis methods

❖ **Comparison of accident indices by groups of sites*:**

$T = \ln(\theta)/\sqrt{(1/N1+1/N2)}$

where: $\theta = R1/R2$

N1 - total number of accidents in group 1
N2 - total number of accidents in group 2
R1 - accident index in group 1
R2 - accident index in group 2

Ho :θ =1, rejected when $p<0.05$

❖ **Fitting a regression model to predict the number of accidents on the sites, using available characteristics**

Multivariate regression, stepwise method, in SPSS v.20

** Griffith, M. S. (1999) Statistical Analysis Techniques*

Characteristics of PTR junctions included in the study

Characteristic	Distribution acc. to categories
Junction configuration	3-legged (53%), 4-legged (47%)
Pedestrian crossing configuration	**type 1 direct (32%), type 3 gradated (18%), type 4 mixed shifting (44%), type 5 direct two-routes (6%)**
Speed limits	70 km/h (18%), 50 km/h (82%)
# of pedestrian crossings on main street	with 1 (44%), with 2 (56%)
# of lanes of general traffic going straight, per direction	2 lanes (74%), 3 lanes (24%), 1 lane (2%)

Accident indices, per junction, in 2010-2012

	All injury accidents	Severe accidents	Pedestrian accidents	Accidents involving buses	Accidents involving a bus and a pedestrian
Average	**6.9**	**1.1**	**1.7**	**1.5**	**0.7**
s.d.	±5.0	±1.4	±2.3	±2.0	±1.4

Regression models for accident numbers at the PTR junctions

Total injury accidents

Variables	B	Std. Error	t	Sig.
(Constant)	5.16	1.06	4.87	0.000
type 4	**3.91**	1.59	2.45	**0.020**

Model statistics: p-value = 0.020; Adjusted R Square = 0.132.

Pedestrian accidents

(Constant)	0.58	0.46	1.25	0.219
type 4	**2.49**	0.69	3.58	**0.001**

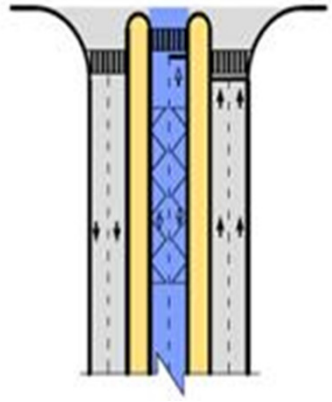
p-value <0.001; Adjusted R Square = 0.264.

Bus accidents

(Constant)	0.63	0.40	1.59	0.122
type 4	**1.97**	0.60	3.29	**0.002**

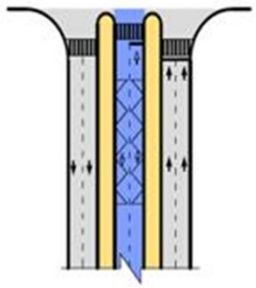
p-value = 0.002; Adjusted R Square = 0.229

❑ **For all accident types, crossing type 4 (gradated with a mixed shifting) is associated with an increase in accident numbers**



Comparing accident indices at the PTR sites, by pedestrian crossing configuration

	All accidents			Pedestrian accidents			Bus accidents		
Sites groups	Total	Serious	Fatal	Total	Serious	Fatal	Total	Serious	Fatal
Average accident indices:									
Type 1	6	0.6	0.2	0.8	0.3	0.1	0.9	0.1	0.1
Type 3	3.3	0	0	0.2	0	0	0.3	0	0
Type 4	**9.1**	**1.3**	**0.5**	**3.1**	**0.8**	**0.3**	**2.6**	**0.5**	**0.5**
Type 5	6	0	0.5	0.5	0	0.5	0	0	0
Differences between the site groups, estimated by means of T-statistics (p-values):									
Type 1 vs 3	0.02*			0.13			0.20		
Type 1 vs 4	0.01*	0.12	0.24		0.09#	0.24	0.00*	0.09#	0.13
Type 1 vs 5	1.0		0.41	0.64		0.23			
Type 3 vs 4	0.00*			0.00*			0.00*		
Type 3 vs 5	0.12			0.44					
Type 4 vs 5	0.17		0.95	0.07#		0.71			



Significant differences: *p<0.05, #p<0.10

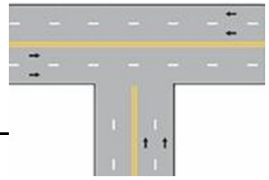
Comparing accident indices at the PTR sites, by junction configuration

Sites groups	All accidents			Pedestrian accidents			Accidents involving buses		
	Total	Serious	Fatal	Total	Serious	Fatal	Total	Serious	Fatal
Average accident indices:									
3-legged	5.7	0.6	0.2	1.5	0.4	0.1	1.3	0.2	0.1
4-legged	**8.2**	**0.9**	**0.4**	**1.9**	**0.5**	**0.3**	**1.8**	**0.4**	**0.4**
Differences between the site groups, estimated by means of T-statistics (p-values):									
3-legged vs 4-legged	0.01*	0.281	0.162	0.400	0.627	0.216	0.264	0.251	0.054*

* Significant difference

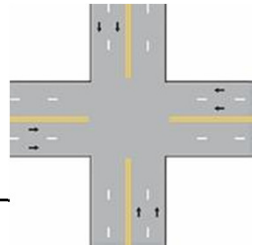
Comparing accident indices at the PTR and comparison-group (CG) sites, by junction configuration

3-legged junctions



	All accidents			Pedestrian accidents			Bus accidents		
Sites	Total	Serious	Fatal	Total	Serious	Fatal	Total	Serious	Fatal
PTR	5.7*	0.6	0.2	1.5	0.4	0.1	1.3	0.2	0.1
CG	2.3	0.3	0	0	0	0	0.9	0.2	0

4-legged junctions



	All accidents			Pedestrian accidents			Bus accidents		
Sites	Total	Serious	Fatal	Total	Serious	Fatal	Total	Serious	Fatal
PTR	8.2*	0.9*	0.4*	1.9*	0.5	0.3	1.8	0.4	0.4*
CG	5.0	0.3	0.1	0.4	0	0	1.2	0.1	0.1

* Significant difference at $p<0.05$

Regression models for accident numbers at the PTR and CG sites

Total injury accidents

Variables	B	Std. Error	t	Sig.
(Constant)	8.29	0.86	9.60	0.000
CG vs PTR	-3.42	0.97	-3.54	0.001
3-legged vs 4-legged	-2.50	0.96	-2.60	0.012

Model statistics: p-value<0.001; Adjusted R Square = 0.191

Pedestrian accidents

(Constant)	1.56	0.31	5.11	0.000
CG vs PTR	-1.43	0.39	-3.69	0.000
High pedestrian volume vs others	2.03	0.61	3.36	0.001
70 km/h speed limit vs 50 km/h	-2.18	0.75	-2.91	0.005

p-value<0.001; Adjusted R Square = 0.304

- **Signalized junctions with PTR are characterized by higher accident numbers than similar junctions without PTR**

Discussion

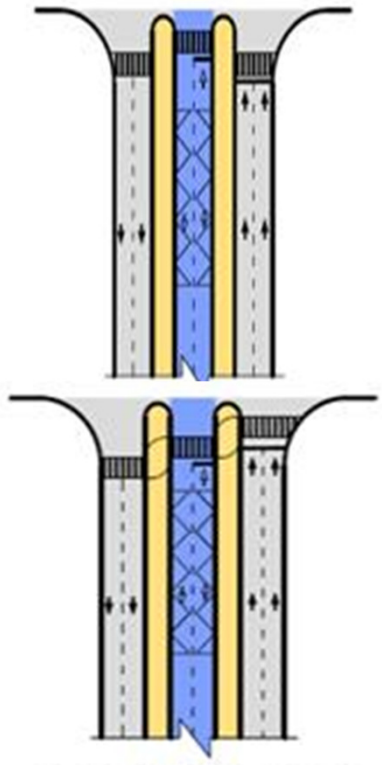
For signalized junctions on central PTR situated on urban arterials:

- Pedestrian crossing configurations have a more consistent impact on accident occurrences compared to other design features

- Sites with a **mixed-shifting gradated-crossing (type 4)** were associated with higher accident frequencies, for various accident types, related to other configurations.

- Some results pointed towards safety benefits associated with a **gradated left-left configuration of pedestrian crossings (type 3)**

- An indication that **a direct crossing** (type 1 and type 5) is safer than a mixed-shifting (type 4)



Discussion (2)

❖ Among signalized junctions on central PTR, **4-legged junctions tend to higher accident numbers** related to the 3-legged junctions – higher complexity of traffic movements, longer cycles

- But a preference of the 3-legged junctions over the 4-legged should be **practical**.

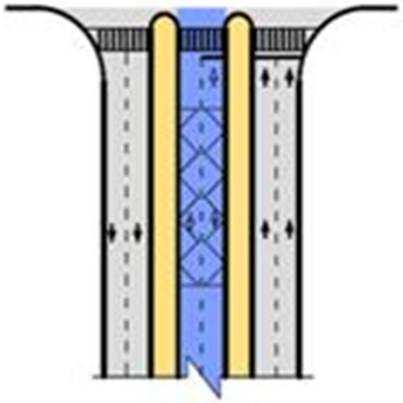
❖ Signalized junctions on PTR are characterized by **higher numbers** of total injury, severe and pedestrian accidents, related to comparison-sites without PTR, when controlling for other design features

- Can be counterbalanced by a reduction in accidents **on the PTR street segments**.

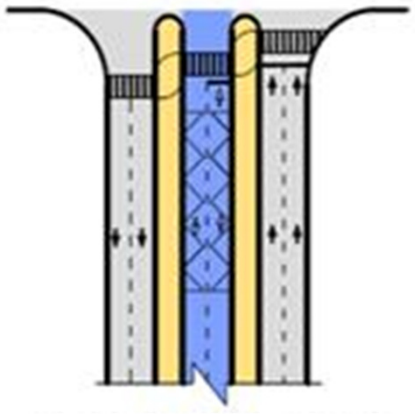
❖ Study limitations: small samples, lack of traffic volume estimates

Conclusions

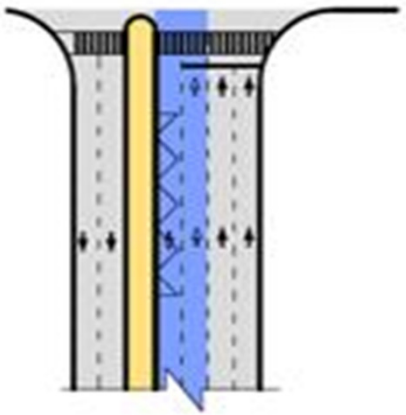
- A gradated-crossing with mixed-shifting is not recommended for future application.
- **A gradated left-left crossing** (type 3) and **a direct crossing** (types 1,5) should be considered as safer arrangements for the PTR junctions.
- Accounting for the rapid development of PT priority systems, more research studies are required to ascertain the safety impacts of various road design solutions



Type 1



Type 3



Type 5