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BRT Station Design

Optimizing BRT Design using a Macroscopic Spatial Parameters (SP) Model

Tonkin+Taylor

Presentation Content

- Reasoning (or objective) why the model was put together in the first place
- some definitions and assessment techniques (built into the model)
- some model examples / applications
- Finishing off with some conclusions and recommendations

Introduction

South Africa (pre-2010 World Cup) – Rail Station upgrade programme

SATC, 2009 (South Africa)

Macro Assessment (Rail) - SP-matrix

WCTR, 2010 (Lisbon)

Microsim techniques (LOS Threshold suggestions, dealing with micro-peaks etc)

Introduction

PTV, 2011 (New York)

Microsimulation techniques (rail)

WCTR, 2013 (Brazil)

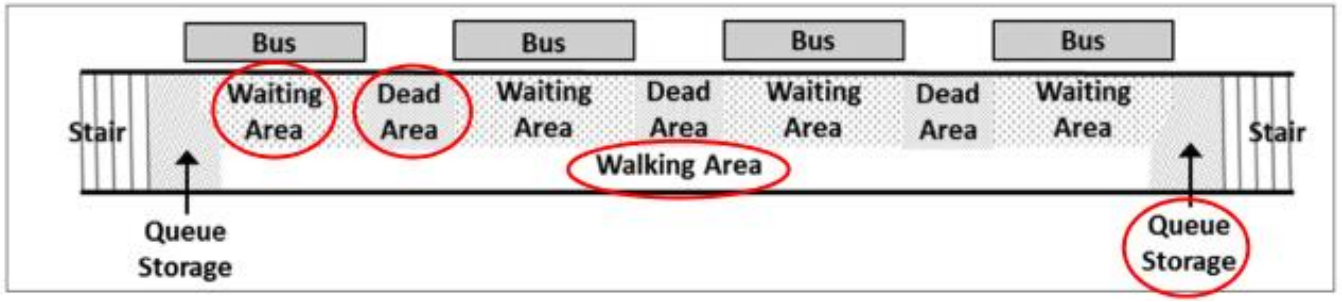
Microsimulation techniques Fare Gate Level-of-Service (LOS)

AITPM, 2014 (Australia)

Microsimulation techniques (Demand Side Assessment only)

Problem Statement

1. Microsimulation requires **considerable detail**.
2. During the Phase 2 BRT conceptual design, there **was a need to evaluate station design typology faster** as operational criteria changed continuously….
3. This led to the **development of a macroscopic model** specifically developed to asses BRT station typologies from
4. both a demand side (pax) and supply side(bus schedule).



BRT Definition

Assessment Components

- Alighting / boarding bus (multiple doors); *or can the pax be accommodated by the bus frequency – ie not left stranded*
- Walking onto or off the platform / waiting on platform; *density LOS on platform*
- Passing through the fare gates / turnstiles;
- Walking on the sidewalk outside the station;
- Evacuation (Emergency) scenario (**NFPA 130**) – *Evac compliancy ?*

Assessment Definitions: Level-of-Service (LOS)

LOS A	LOS B	LOS C	LOS D	LOS E
				

LOS	Platform corridor *Flow* (pax/m/min)	Platform *Queuing* Area Density (m^2/pax)	Platform *Walking* Area Density (m^2/pax)
A	< 23	> 1.2	> 3.3
B	23 – 33	0.9 – 1.2	2.3 – 3.3
C	33 – 49	0.7 – 0.9	1.4 – 2.3
D	49 – 66	0.3 – 0.7	0.9 -1.4
E	66 – 82	0.2 – 0.3	0.5 - 0.9
F	> 82	< 0.2	< 0.5

*defined by the **TCQSM** (Transit Capacity and Quality of Service Manual) (as published by the TRB)*

Model Fundamentals

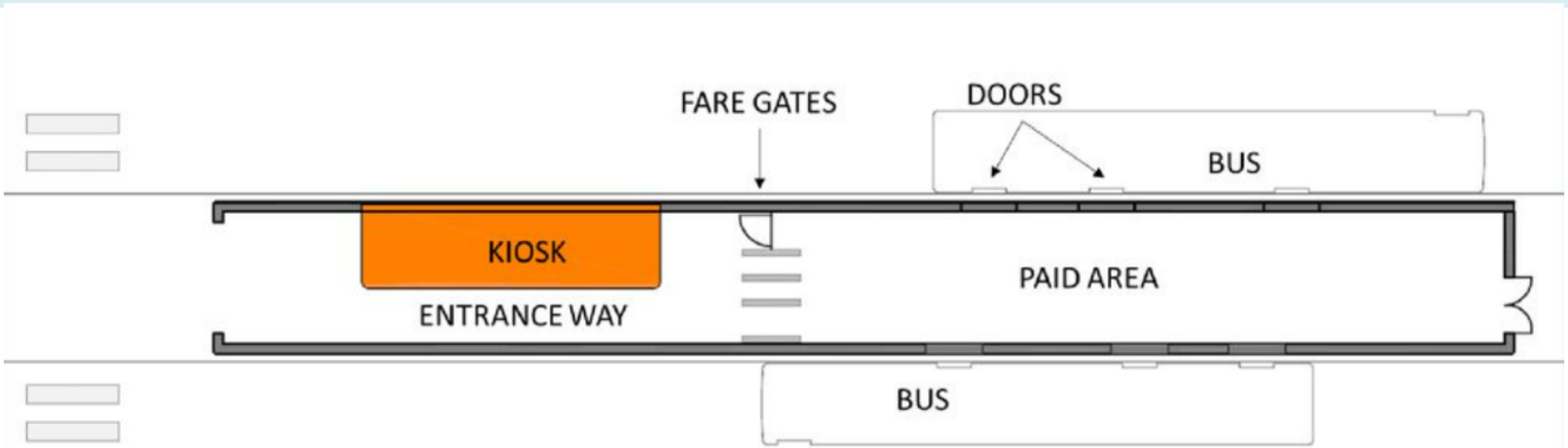
- Basic Excel spreadsheet model
- Tests Demand and Supply Side Metrics (of BRT Station Elements)
- Tests Evacuation Compliancy
- Multiple Station Typologies

Kerbside Stop

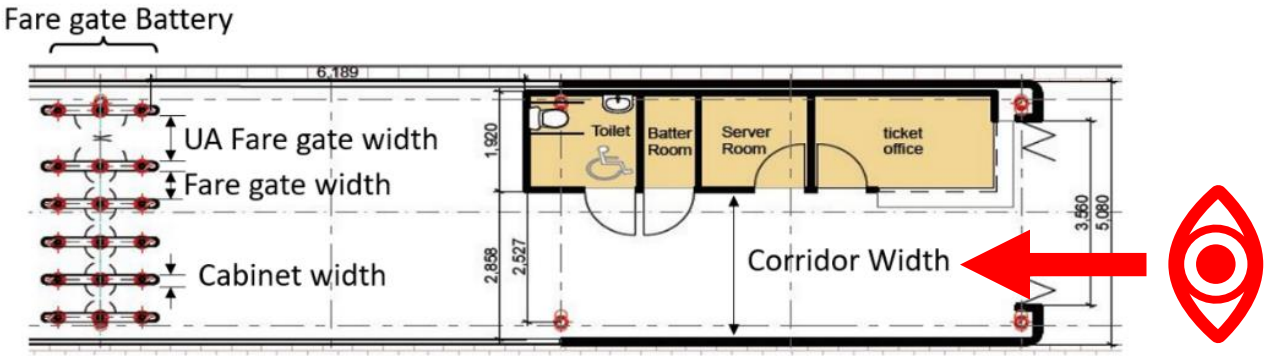
Open LAM Stop

Closed RAM Station

Major Elements of a BRT Station

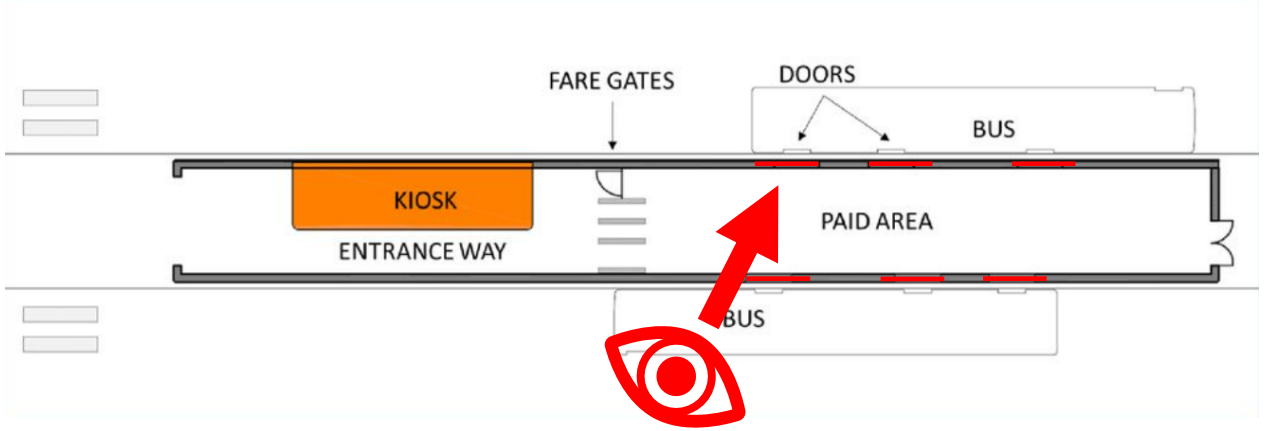


Elements of a BRT Station: *Corridor*



Input Variable: *Width*
Output Metric: *Pax/m/min (Flow)*

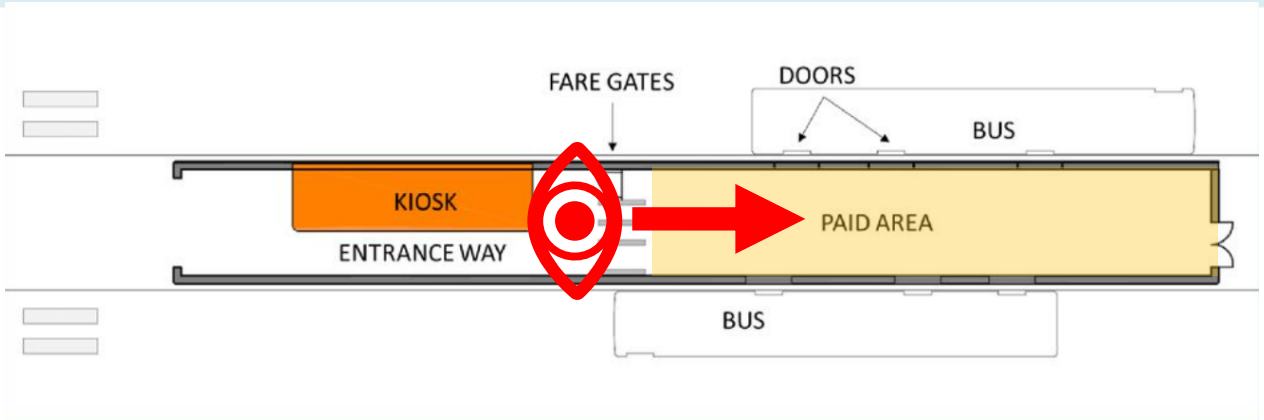
Elements of a BRT Station: *Bus doors*



Input Variable: *no. Doors, Door open/ close time, B&A Rates*

Input Metric: *sec/pax*

Elements of a BRT Station: *Paid Area*



Input Variable: *Area*

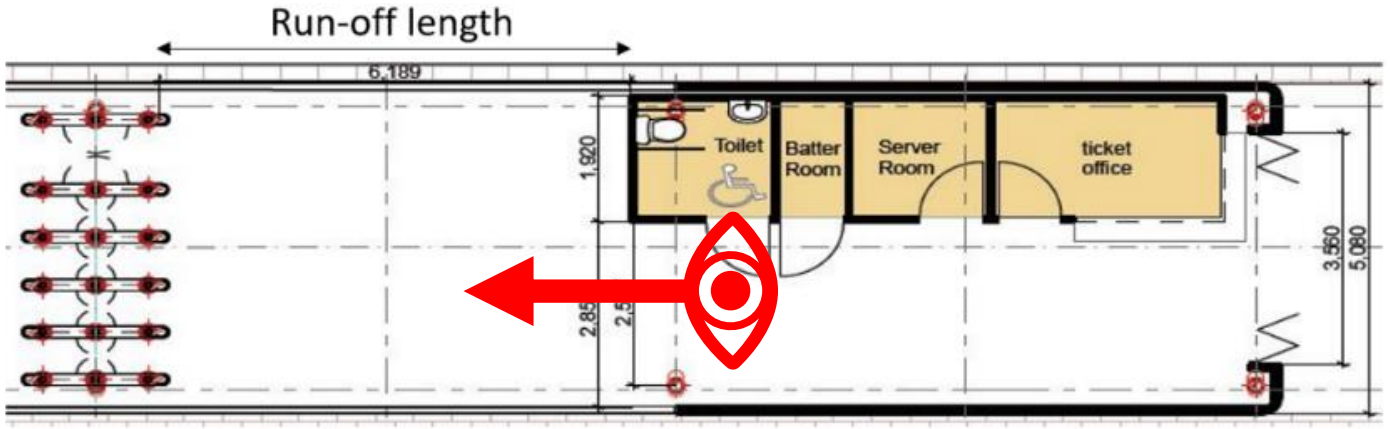
Output Metric: *Density (m^2/pax)*

Elements of a BRT Station: *Fare Gates*

Variable: *no. Fare Gates & Service Flow Rate*

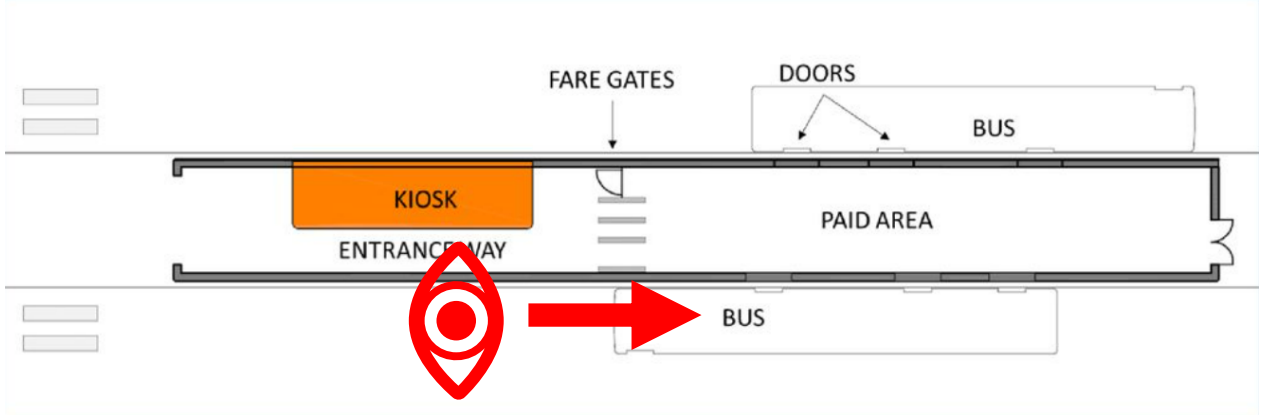
Input Metric: *Pax/min/gate*
Output Metric: *q/c ratio*

Elements of a BRT Station: *Run-off Length*

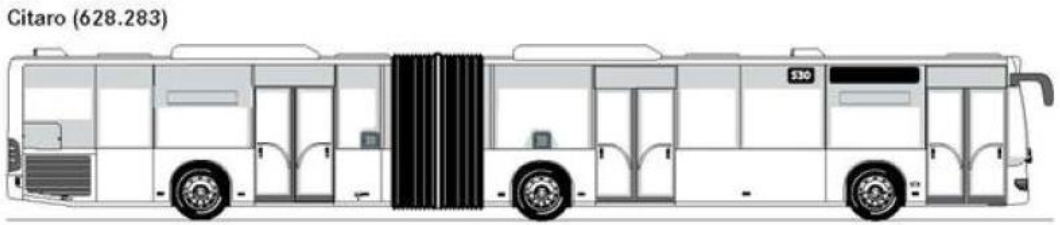


Input Variable: *Length*
Output Metric: *Confined q/c*

Elements of a BRT Station: *Bus*



Variable: *no. Doors, Door open /close time, Ramp Deployment time, Frequency / Headway*

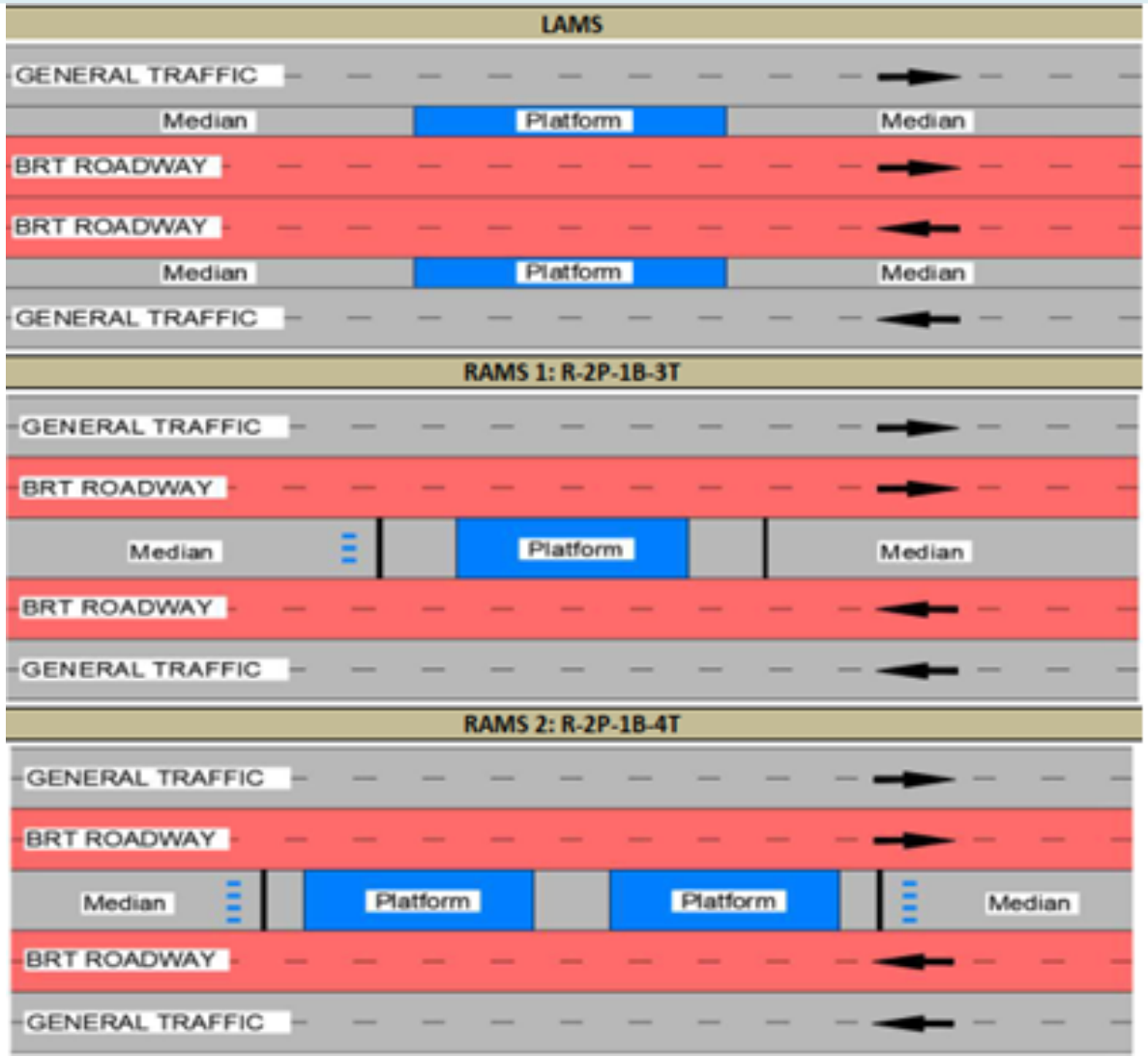


MyCiti Volvo B9LA (18m artic: 131 pax cap)

Model Inputs (Defaults)

Input	Input Description	Default Values			Unit
		Kerbside	LAM	RAM	
Station Infrastructure Inputs	Station Type[*1]	Refer to Legend			-
	Effective Platform length[*2]	20	20	20	m
	Effective Platform width[*2]	3	3	4.3	m
	"Run-off" Length[*3]	-	-	3.0	m
	Kiosk corridor width[*4]	-	-	1.5	m
	Server corridor width[*4]	-	-	1.5	m
	Fare Gate (FG) aisle width[*4]	-	-	0.6	m
	Universally Accessible (UA) Fare Gate (FG) aisle width[*4]	-	-	0.95	m
	Fare Gate (FG) Cabinet width[*4]	-	-	0.2	m
	Fare Gate (FG) Service Capacity[*5]	-	-	24	Pax/min
	Fare Gate (FG) Evacuation Capacity[*6]	-	-	50	Pax/min
	Corridor Evacuation Capacity[*6]	-	-	81.9	Pax/m/min
	Emergency Door Evacuation Capacity[*6]	-	-	89.3	Pax/m/min
	Emergency Door width[*2]	-	-	1.8	m
	Evacuation surge load factor[*7]	-	-	1.5	factor
	Max Saturation Level (X)[*8]	60%	60%	60%	%
Bus Inputs	No. Bus Doors[*9]	1	1	3	no.
	Practical Bus Capacity[*9]	111	111	111	Pax/bus
	Sum of dead time t_m (excluding boarding and alighting time) [*10]	8	8	10	sec/bus
	Bus boarding/alighting rate[*11]	3	3	1.5	sec/pax
	Min Pax threshold warning at platforms[*12]	10	10	10	Pax/plat

Model Typologies



Typology Code	Platform 1	Platform 2	Platform 3	Platform 4	Platform 5
KS1	Kerbside 1				
KS2	Kerbside 2				
L1	Lam 1				
L2	Lam 2				
R-1P-1B-3T	k 3t s E				
R-1P-1B-4T	k 4t s E				
R-2P-1B-3T	k 3t	s E			
R-2P-1B-4T	k 4t	s E			
R-2P-2B-6T	k 3t	s 3t			
R-2P-2B-8T	k 4t	s 4t			
R-3P-1B-3T	k 3t	s	E		
R-3P-1B-4T	k 4t	s	E		
R-3P-2B-6T	k 3t	s	3t		
R-3P-2B-8T	k 4t	s	4t		
R-4P-1B-3T	k 3t	s		E	
R-4P-1B-4T	k 4t	s		E	
R-4P-2B-6T	k 3t	s		3t	
R-4P-2B-8T	k 4t	s		4t	
R-5P-1B-3T	k 3t	s			E
R-5P-1B-4T	k 4t	s			E
R-5P-2B-6T	k 3t	s			3t
R-5P-2B-8T	k 4t	s			4t

Legend:
s: server room
k: ticket kiosk
t: turnstiles / fare gates
E: Evacuation gate

Model Output Criteria (1/2)

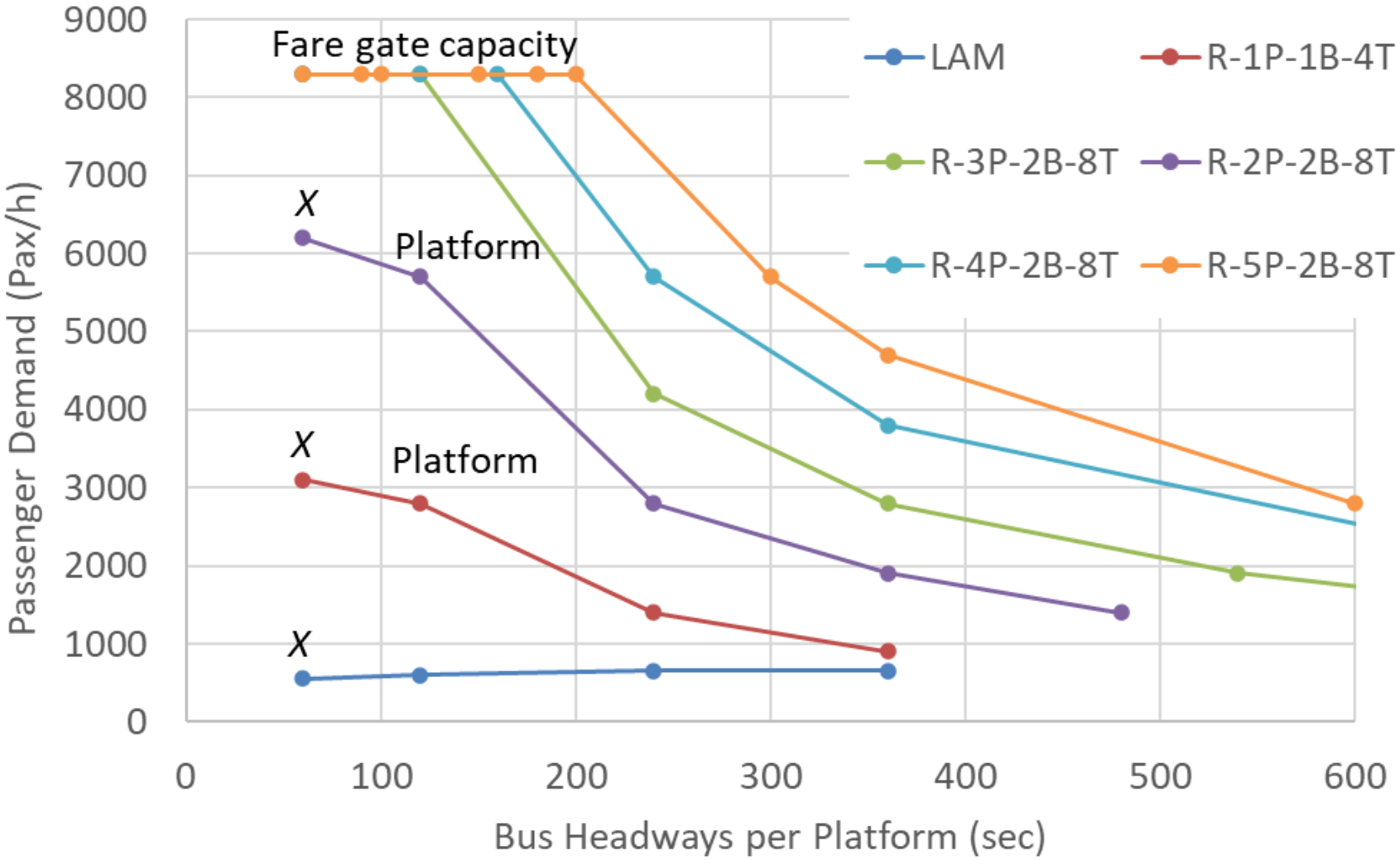
Output	Unit	Output Description
Bus headways per platform (H_w)	Sec/bus	Cells output values are highlighted red if H_w < 80 sec and highlighted amber for the 80 < H_w < 120 condition.
Low Boarding Pax alert	Pax	Cell output values are identified as "Low" if the calculated boarding pax is less than the threshold defined under the "Inputs" tab (Row 37) Default at 10 pax
Boarding Pax	% of Bus Capacity	Cells output values are highlighted red if Boarding values exceed the bus passenger capacity defined in the "Inputs" tab (Row 25).
Alighting Pax	% of Bus Capacity	Cells output values are highlighted red if Alighting values exceed the bus passenger capacity defined in the "Inputs" tab (Row 25).
Platform Saturation (X)	%	Percentage of time (of the peak 1 hour) that a platform is occupied by a bus. Cell output values are highlighted red if Saturation levels > 60% (60% is the default X value).
Fare Gate (FG) Volume (q) to Capacity (c) ratio	q/c	If cells values q/c < 0.8 then this indicates stable queue; If cell values q/c < 0.9 then unstable queues are expected and cells are highlighted amber; If cell values q/c > 0.9 then infinite queueing can be expected and cells are highlighted red.
Average Fare Gate (FG) Queue length	Pax	Based on a M/M/1 single server queuing system (p177, Van As and Joubert, 1993) where Average queue length = $(q/c)/(1-q/c)$
Run-off Length Adequate?	OK/Not OK	The run-off length is considered acceptable if the q/c (at LOS C/D queue density threshold) > FG q/c.
Kiosk Corridor LOS*	LOS*1	LOS A < 23 Pax/m/min, LOS B < 33 Pax/m/min, LOS C < 49 Pax/m/min, LOS D < 66 Pax/m/min, LOS E < 82 Pax/m/min, LOS F > 82 Pax/m/min
Server Corridor LOS*		
Worst Platform LOS*3	LOS*2	LOS A < 0.5 m^2/pax, LOS B < 0.9 m^2/pax, LOS C < 1.4 m^2/pax, LOS D < 2.3 m^2/pax, LOS E < 3.3 m^2/pax, LOS F > 3.3 m^2/pax
Average Platform LOS*4		
Evacuation via Fare Gate (FG)	OK/Not OK	If NFPA 130 "Test 1" Evac time < 4 min, then "OK". If Evac time > 4 min, then "Not OK".
Evacuation via Emergency Gate		
Kiosk Corridor Evacuation		

Model Outputs (2/2)

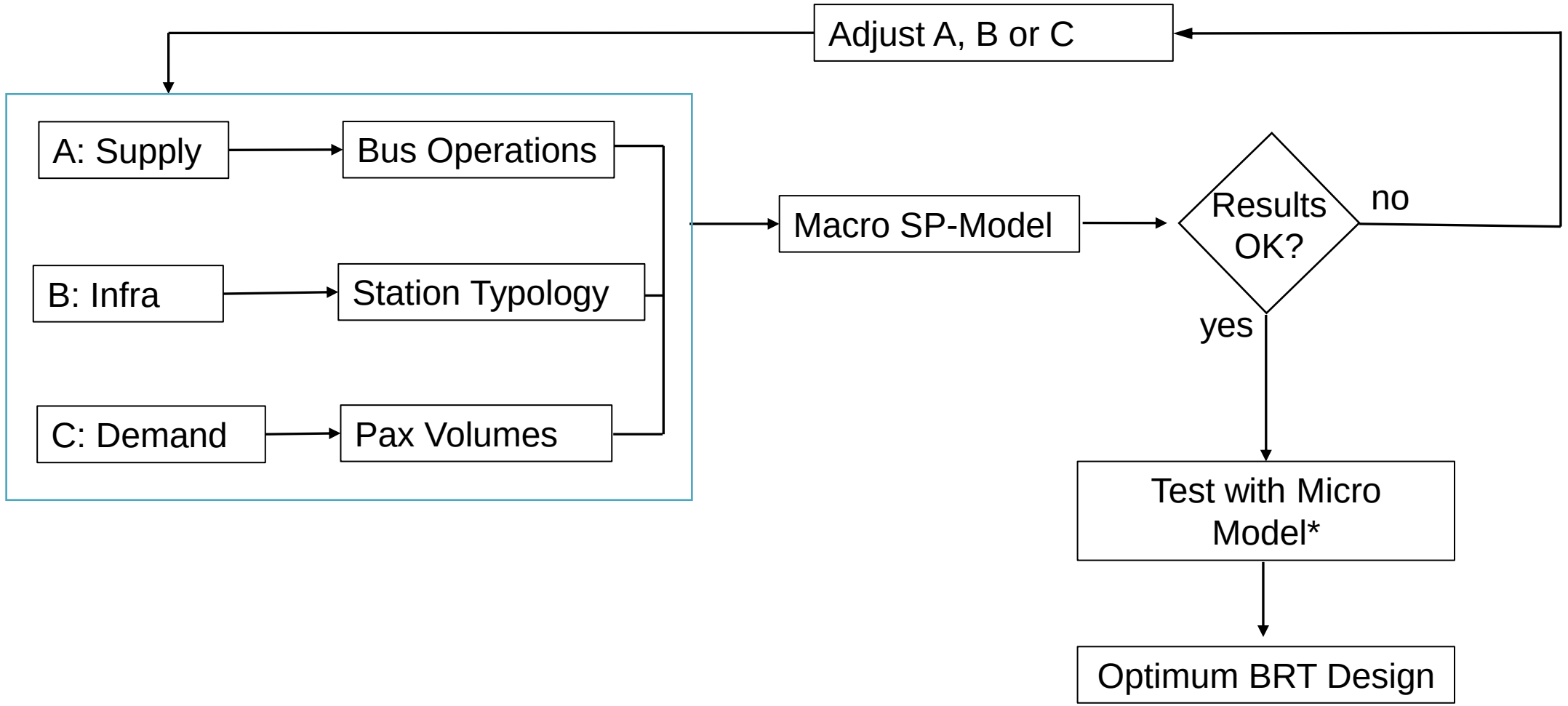
STATION PARAMETER ASSESSSMENT

No.	Station	Pax Vol (Pax/hr)	Typology	Bus Freq (Bus/hr)	Combined Station *Hw* (Sec/bus)	*Hw* per Platform (sec/bus)[1]	Required Dwell Time in peak dir (sec/bus)	Low Boarding Pax Alert (< 10 pax)	Boarding Pax (% of bus cap)[2]	Alighting Pax (% of bus cap)[2]	Platform Saturation (*X*) (%)[3]	Platform width wide enough for Fare Gates ?	Fare Gate (q/c)[4]	Ave Fare Gate Queue length (pax)	Run-off Length Adequate ?	Platform Saturation (incl Surge factor + Fare Gate limit) (%)[3]	Kiosk Corridor LOS	Server Corridor LOS	Worst (Max) Platform LOS	Average Platform LOS	Evac via Fare Gates	Evacuation via Emergency gate	Kiosk Corridor Evacuation
1	Test 1	2000	R-2P-1B-4T	38	96	192	37		24.0%	24.0%	19.1%	OK	0.38	0.6	OK	24.3%	A		C	C	OK	OK	OK
2	Test 2	2100	R-2P-1B-4T	38	96	192	38		25.2%	25.2%	19.8%	OK	0.40	0.7	OK	25.3%	A		D	C	OK	OK	OK
3	Test 3	2200	R-2P-1B-4T	38	96	192	39		26.4%	26.4%	20.5%	OK	0.42	0.7	OK	26.2%	A		D	C	OK	OK	OK
4	Test 4	2300	R-2P-1B-4T	38	96	192	41		27.6%	27.6%	21.2%	OK	0.44	0.8	OK	27.2%	A		D	C	OK	OK	OK
5	Test 5	2400	R-2P-1B-4T	38	96	192	42		28.8%	28.8%	21.9%	OK	0.46	0.8	OK	28.1%	A		D	D	OK	OK	OK
6	Test 6	2500	R-2P-1B-4T	38	96	192	43		30.0%	30.0%	22.6%	OK	0.48	0.9	OK	29.1%	A		D	D	OK	OK	OK
7	Test 7	2600	R-2P-1B-4T	38	96	192	45		31.2%	31.2%	23.3%	OK	0.50	1.0	OK	30.0%	A		D	D	OK	OK	OK
8	Test 8	2700	R-2P-1B-4T	38	96	192	46		32.4%	32.4%	24.0%	OK	0.52	1.1	OK	31.0%	B		D	D	OK	OK	OK
9	Test 9	2800	R-2P-1B-4T	38	96	192	47		33.6%	33.6%	24.7%	OK	0.53	1.1	OK	31.9%	B		D	D	OK	OK	OK
10	Test 10	2900	R-2P-1B-4T	38	96	192	49		34.8%	34.8%	25.3%	OK	0.55	1.2	OK	32.9%	B		D	D	OK	OK	OK
11	Test 11	3000	R-2P-1B-4T	38	96	192	50		36.0%	36.0%	26.0%	OK	0.57	1.3	OK	33.9%	B		D	D	OK	OK	OK
12	Test 12	3100	R-2P-1B-4T	38	96	192	51		37.2%	37.2%	26.7%	OK	0.59	1.5	OK	34.8%	B		D	D	OK	OK	OK
13	Test 13	3200	R-2P-1B-4T	38	96	192	53		38.4%	38.4%	27.4%	OK	0.61	1.6	OK	35.8%	B		D	D	OK	OK	OK
14	Test 14	3300	R-2P-1B-4T	38	96	192	54		39.6%	39.6%	28.1%	OK	0.63	1.7	OK	36.7%	B		E	D	OK	OK	OK
15	Test 15	3400	R-2P-1B-4T	38	96	192	55		40.8%	40.8%	28.8%	OK	0.65	1.9	OK	37.7%	B		E	D	OK	OK	OK
16	Test 16	3500	R-2P-1B-4T	38	96	192	57		42.0%	42.0%	29.5%	OK	0.67	2.0	OK	38.6%	B		E	D	OK	OK	OK
17	Test 17	3600	R-2P-1B-4T	38	96	192	58		43.2%	43.2%	30.2%	OK	0.69	2.2	Not OK	39.6%	B		E	E	OK	OK	OK
18	Test 18	3700	R-2P-1B-4T	38	96	192	59		44.4%	44.4%	30.9%	OK	0.71	2.4	Not OK	40.5%	B		E	E	OK	OK	OK
19	Test 19	3800	R-2P-1B-4T	38	96	192	61		45.6%	45.6%	31.6%	OK	0.73	2.6	Not OK	41.5%	B		E	E	OK	OK	OK
20	Test 20	3900	R-2P-1B-4T	38	96	192	62		46.8%	46.8%	32.3%	OK	0.74	2.9	Not OK	42.4%	C		E	E	OK	OK	OK
21	Test 21	4000	R-2P-1B-4T	38	96	192	63		48.0%	48.0%	33.0%	OK	0.76	3.2	Not OK	43.4%	C		E	E	OK	OK	OK
22	Test 22	4100	R-2P-1B-4T	38	96	192	65		49.3%	49.3%	33.7%	OK	0.78	3.6	Not OK	44.4%	C		E	E	OK	OK	OK
23	Test 23	4200	R-2P-1B-4T	38	96	192	66		50.5%	50.5%	34.4%	OK	0.80	4.1	Not OK	45.3%	C		E	E	OK	OK	OK
24	Test 24	4300	R-2P-1B-4T	38	96	192	67		51.7%	51.7%	35.1%	OK	0.82	4.6	Not OK	46.3%	C		E	E	OK	OK	OK
25	Test 25	4400	R-2P-1B-4T	38	96	192	69		52.9%	52.9%	35.8%	OK	0.84	5.3	Not OK	47.2%	C		E	E	OK	OK	OK
26	Test 26	4500	R-2P-1B-4T	38	96	192	70		54.1%	54.1%	36.5%	OK	0.86	6.1	Not OK	48.2%	C		E	E	OK	OK	OK
27	Test 27	4600	R-2P-1B-4T	38	96	192	71		55.3%	55.3%	37.2%	OK	0.88	7.2	Not OK	49.1%	C		E	E	OK	OK	OK
28	Test 28	4700	R-2P-1B-4T	38	96	192	73		56.5%	56.5%	37.8%	OK	0.90	8.8	Not OK	50.1%	C		E	E	OK	OK	OK
29	Test 29	4800	R-2P-1B-4T	38	96	192	74		57.7%	57.7%	38.5%	OK	0.92	11.0	Not OK	51.0%	C		E	E	OK	OK	OK
30	Test 30	4900	R-2P-1B-4T	38	96	192	75		58.9%	58.9%	39.2%	OK	0.94	14.6	Not OK	52.0%	C		E	E	OK	OK	OK
31	Test 31	5000	R-2P-1B-4T	38	96	192	77		60.1%	60.1%	39.9%	OK	0.95	21.2	Not OK	53.0%	C		E	E	OK	OK	OK
32	Test 32	5100	R-2P-1B-4T	38	96	192	78		61.3%	61.3%	40.6%	OK	0.97	37.4	Not OK	53.9%	C		E	E	OK	OK	OK
33	Test 33	5200	R-2P-1B-4T	38	96	192	79		62.5%	62.5%	41.3%	OK	0.99	143.0	Not OK	54.9%	C		E	E	OK	OK	OK
34	Test 34	5300	R-2P-1B-4T	38	96	192	81		63.7%	63.7%	42.0%	OK	1.01	infinite	Not OK	55.8%	C		E	E	OK	OK	OK
35	Test 35	5400	R-2P-1B-4T	38	96	192	82		64.9%	64.9%	42.7%	OK	1.03	infinite	Not OK	56.8%	C		E	E	OK	OK	OK
36	Test 36	5500	R-2P-1B-4T	38	96	192	83		66.1%	66.1%	43.4%	OK	1.05	infinite	Not OK	57.7%	C		E	E	OK	OK	OK
37	Test 37	5600	R-2P-1B-4T	38	96	192	85		67.3%	67.3%	44.1%	OK	1.07	infinite	Not OK	58.7%	C		E	E	OK	OK	OK
38	Test 38	5700	R-2P-1B-4T	38	96	192	86		68.5%	68.5%	44.8%	OK	1.09	infinite	Not OK	59.6%	D		E	E	OK	OK	OK

SP-Model Application: Station Capacity



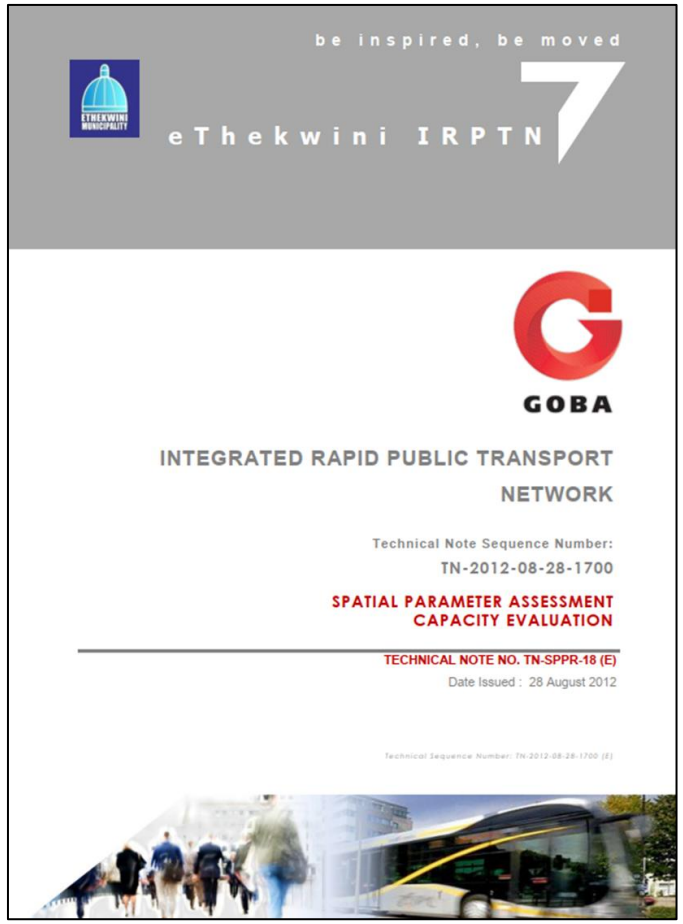
Application of SP-Model



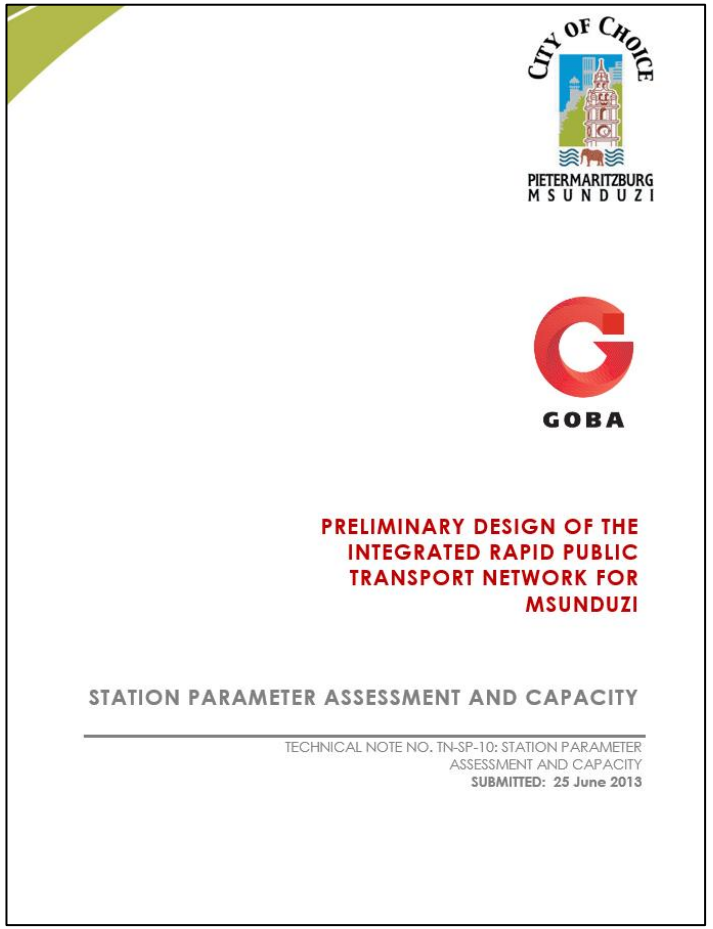
**macro results always more optimistic than micro results*

Application: Projects

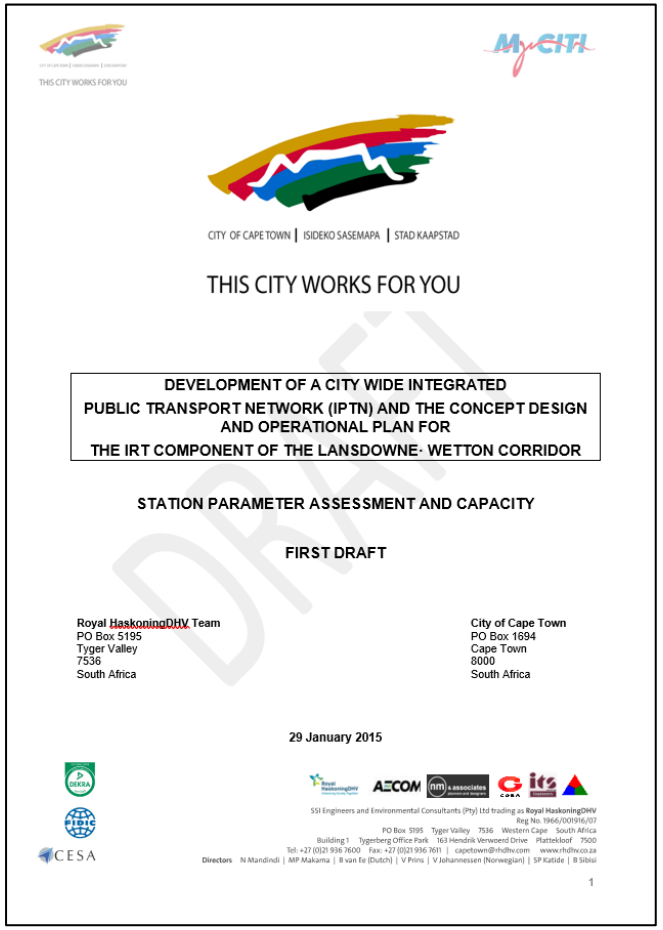
Durban, 2012



Pietermaritzburg, 2013



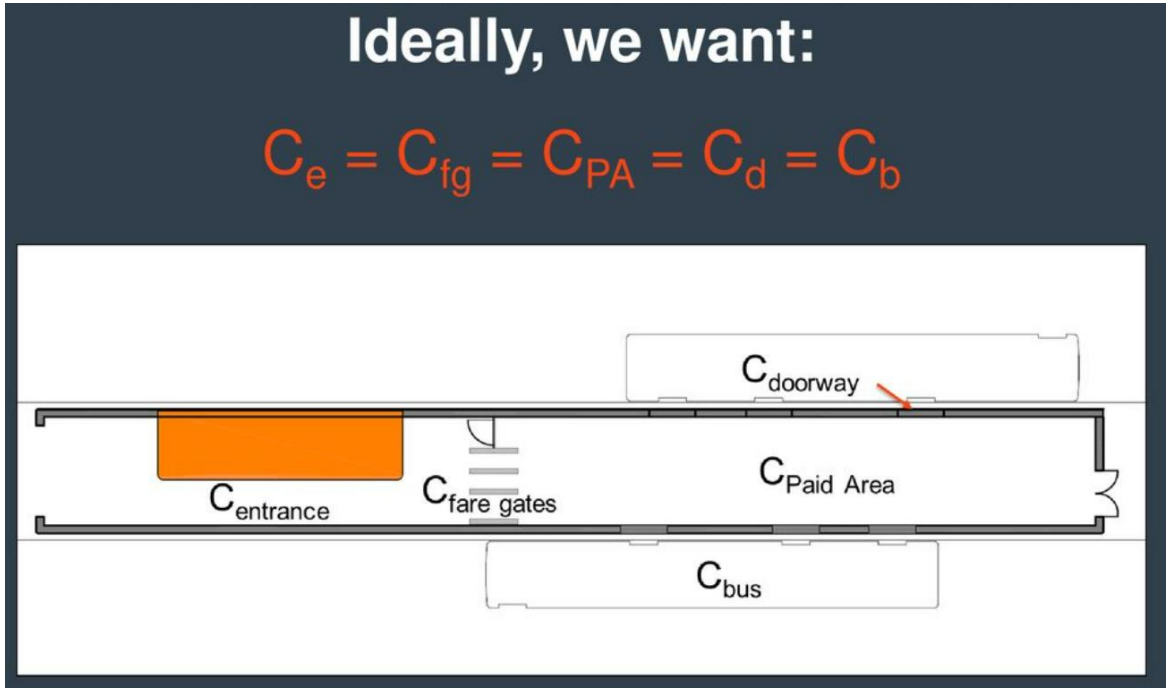
Cape Town, 2015



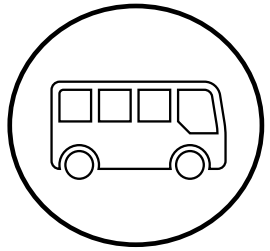
Concluding Remarks

Overall BRT Station Operation restricted to capacity of *critical limiting* component ;

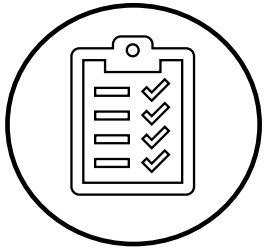
Limiting BRT component *<u>can change</u>* dependant on conditions;



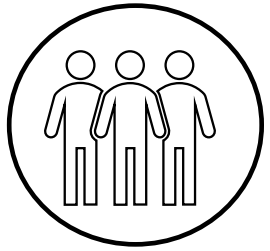
Recommendations



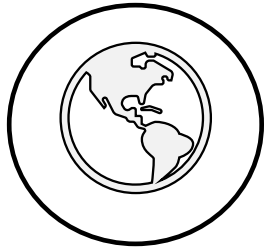
BRT Station Specific



Evaluation & Optimisation Tool (*High-level assessment*)



Accessible to all people working with design, planning and implementing BRT
(*Don't need to be a modeller - just familiar with Excel*)



Promote Sustainable Design Practice

Tonkin+Taylor