Human Factors Considerations in Station Planning & Design

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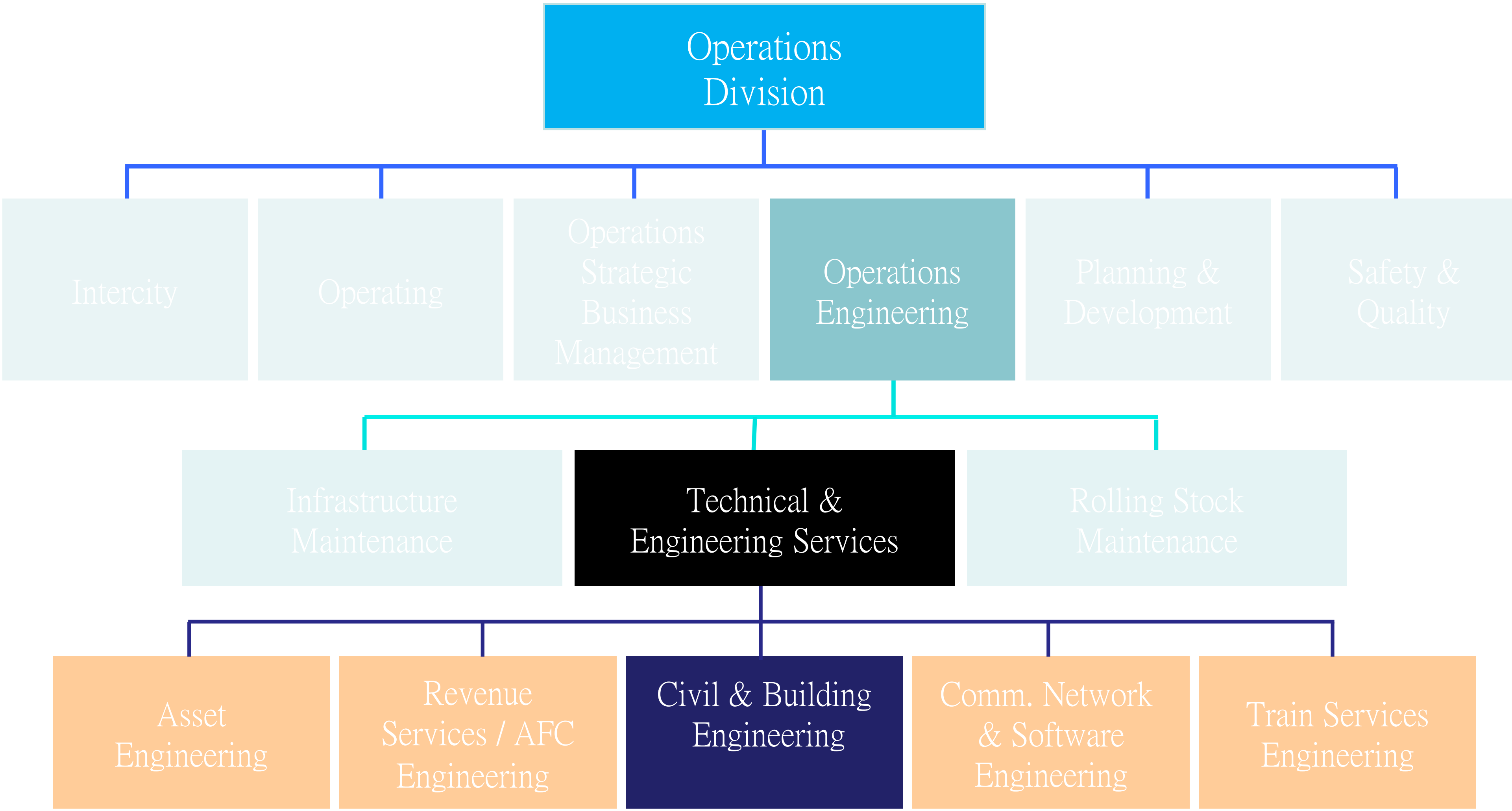
Civil & Building Engineering Manager

Agenda

- Background
- Station Planning
- Station Capacity
- Computational Simulation

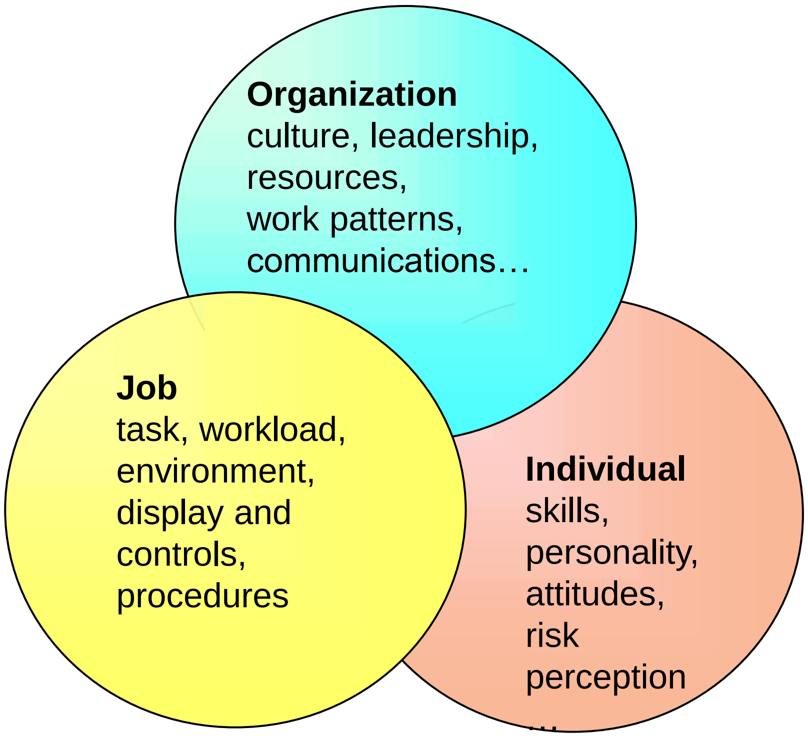
Operations Organization



What is Human factor?

- Focuses on health and safety, the UK Health and Safety Executive (HSE) defines HF as:

  "The environmental, organizational and job factors, and human individual characteristics which **influence behaviour at work** in a way can affect health and safety."
- Three main groups of factors



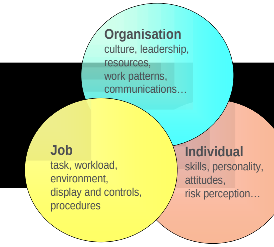
To achieve good performance we need to optimise the influences on behaviour

- **The job** – what are people being asked to do and under what circumstances? (e.g. the task, workload, working environment, procedures, displays and controls).

- **The individual** – who is doing it? (e.g. their competence, skills, personality, attitudes, and risk perception).

- **The organisation** – how is the work organised? (e.g. leadership, resources, work pattern, planning, communication, and culture)

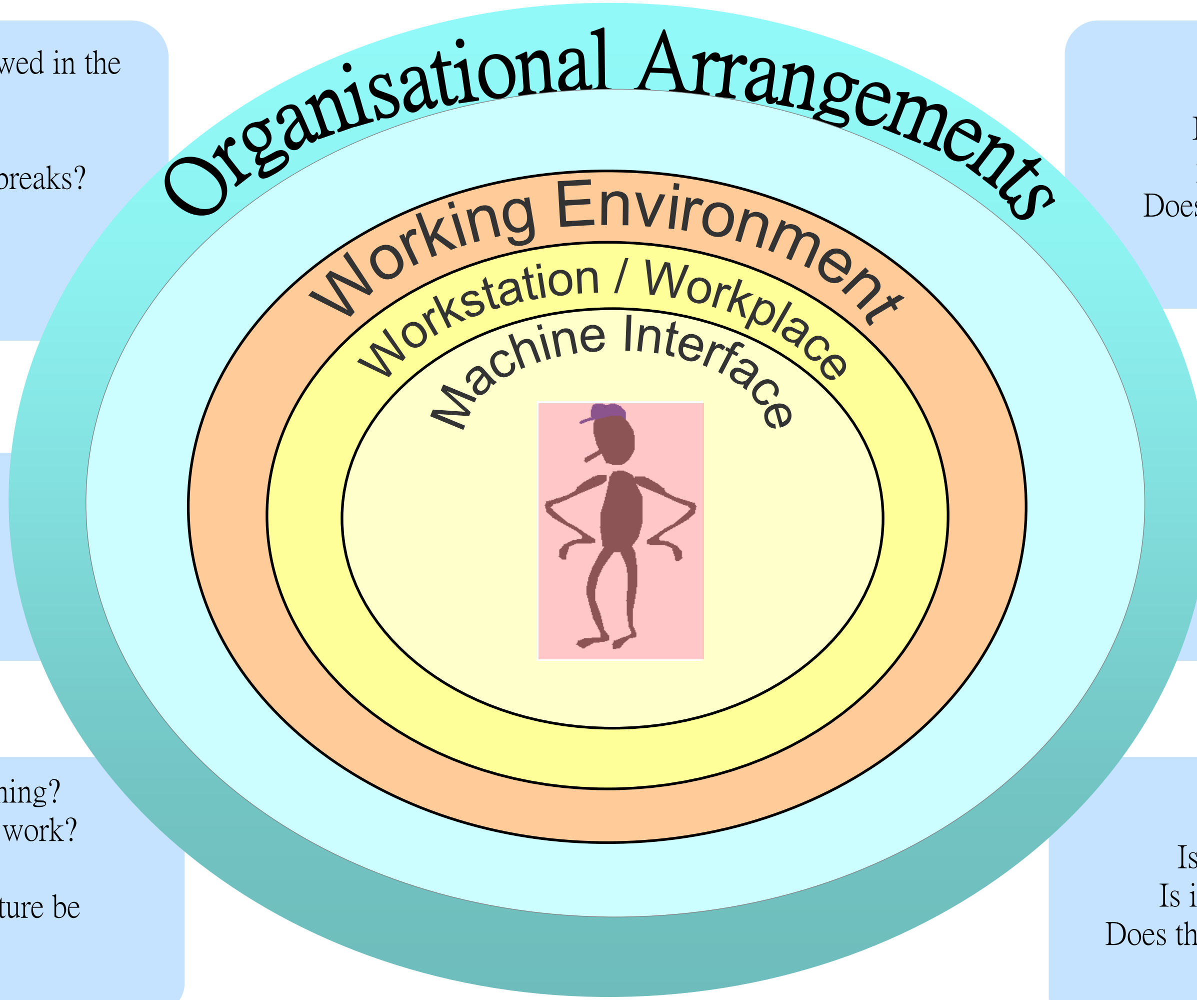
Consider each interface



Can procedures be followed in the workplace?
Is there time pressure?
What working hours or breaks?
What training is given?
What level of supervision is there?

Is there good:
working culture?,
leadership?
motivation?

Can people reach everything?
Is there enough space to work?
Are there obstructions?
Can a good working posture be achieved?



Is the lighting OK?
Is noise a distraction or does it prevent good communication?
Does the temperature make people tired?

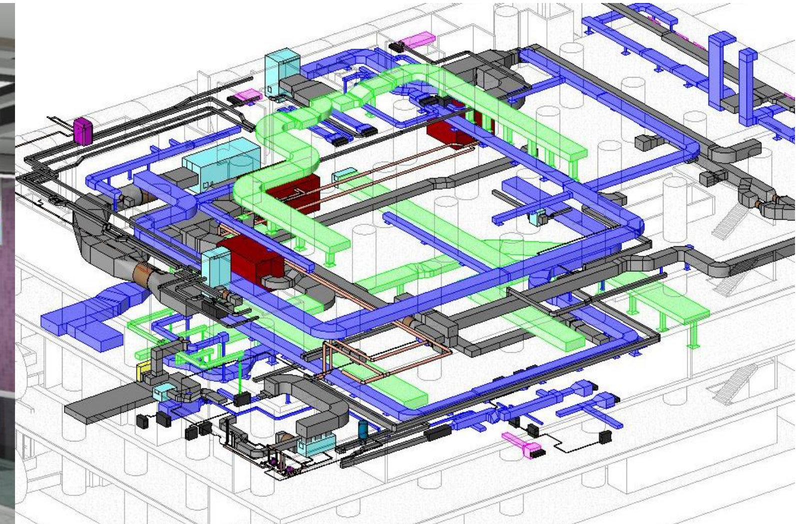
Does a person need:
good vision/hearing,
strength,
particular skills,
personality traits?

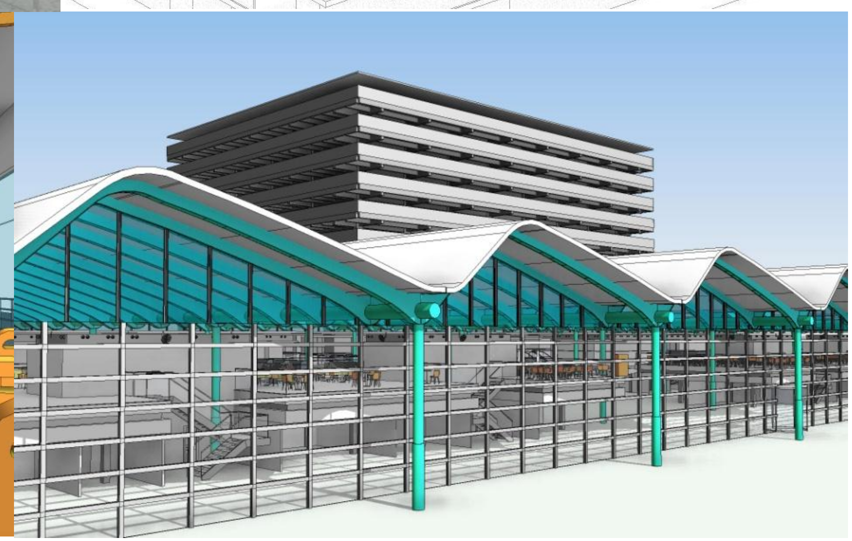
Is the machine/tool easy to use?
Is it available where it is needed?
Does the interface meet expectations?

Human Factors Considerations in Station Planning and Design

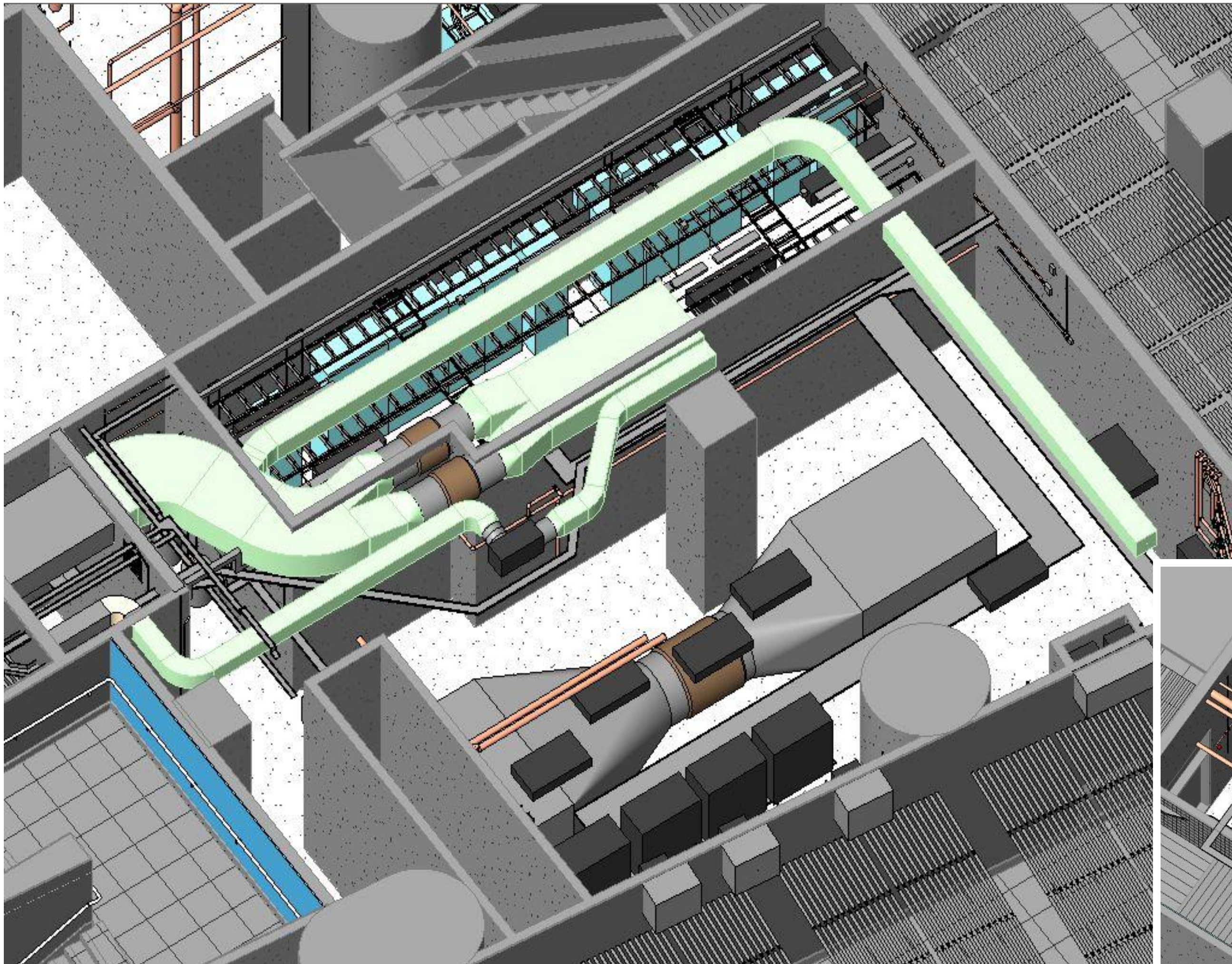
- Increasing Crowdedness
- Station Capacity
- Disabled and Aging Passengers
- Escalators Safety
- Fire Safety and Evacuation

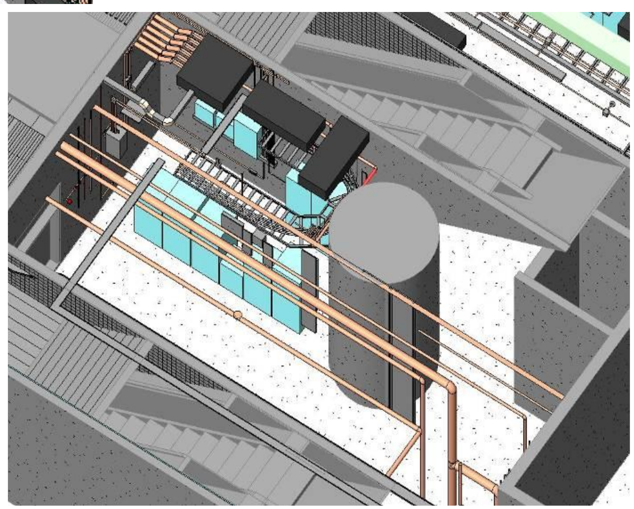
Virtual Design and Construction



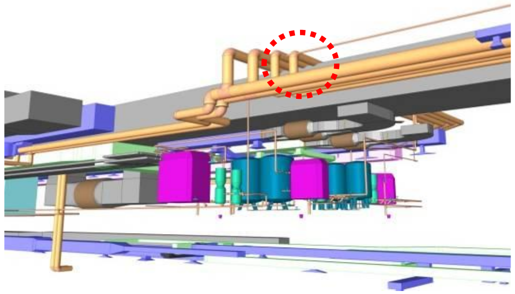


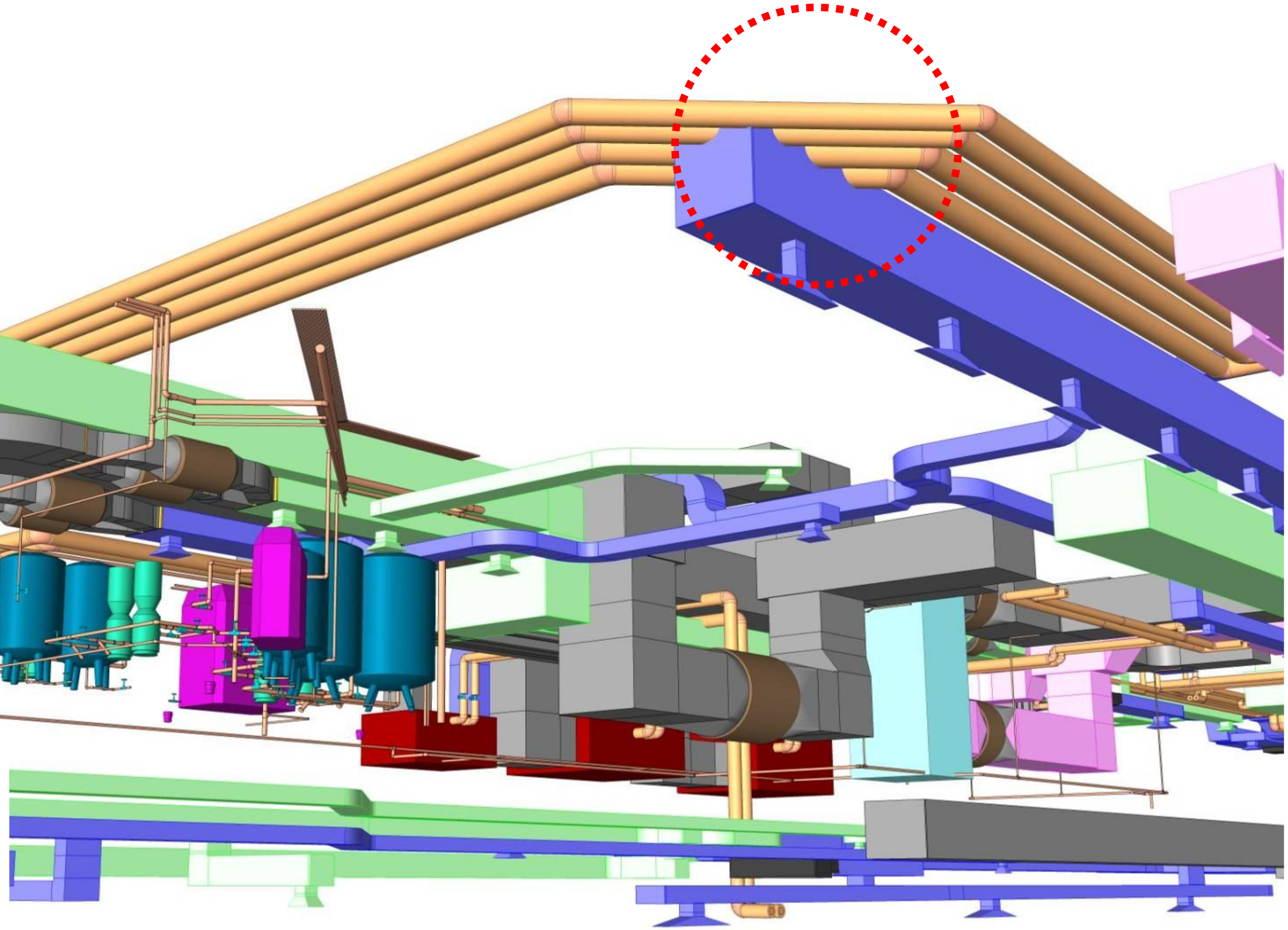
ADM Enabling Works for South Island Line

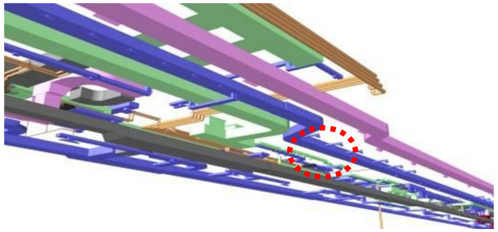




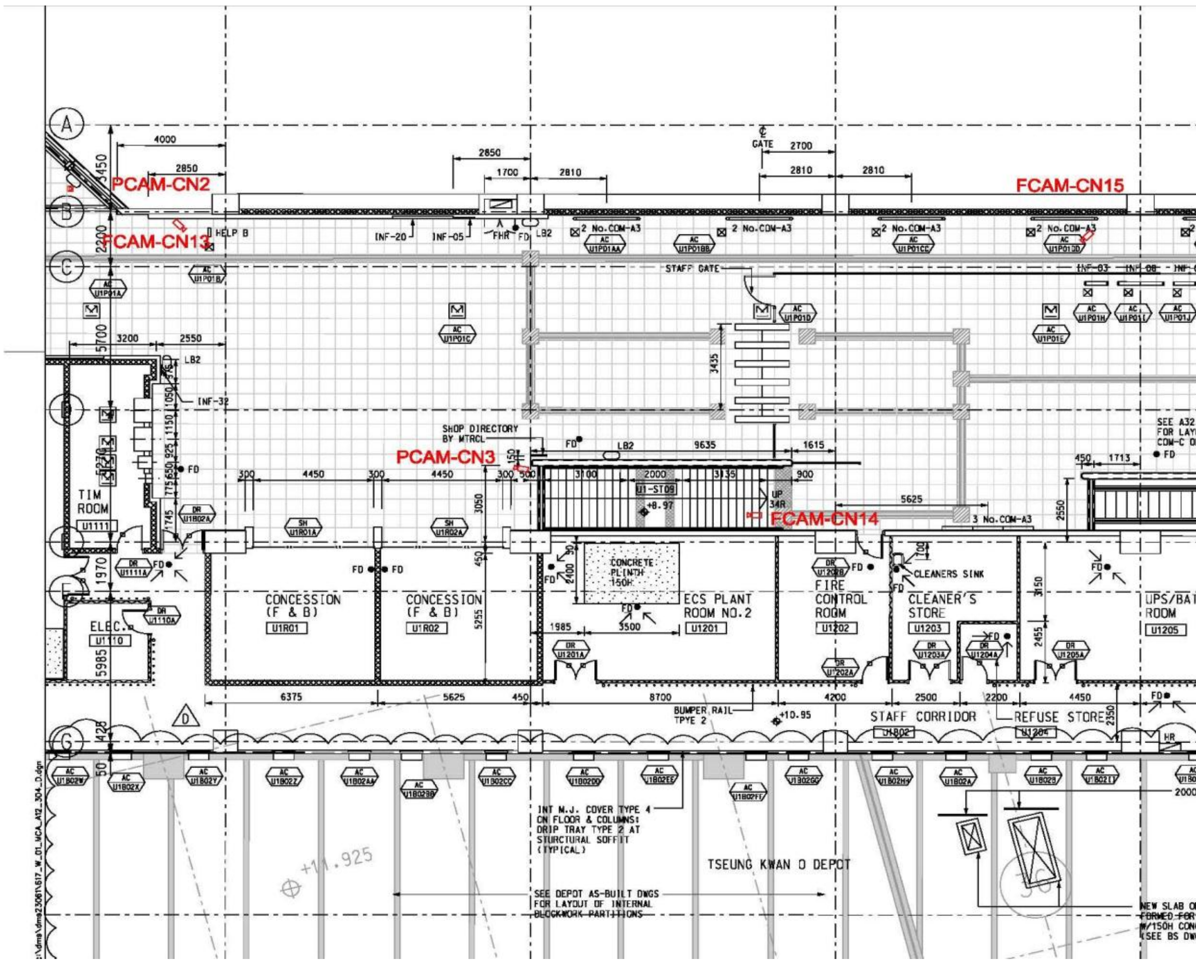
Services Clash Analysis



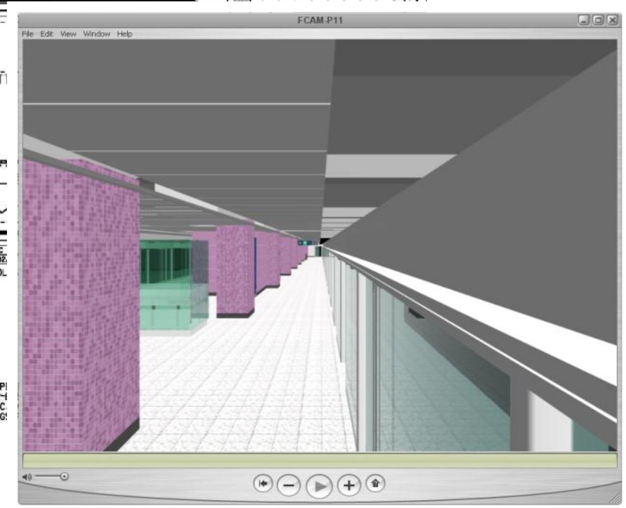




CCTV Coverage Test & Signage Visibility Simulation



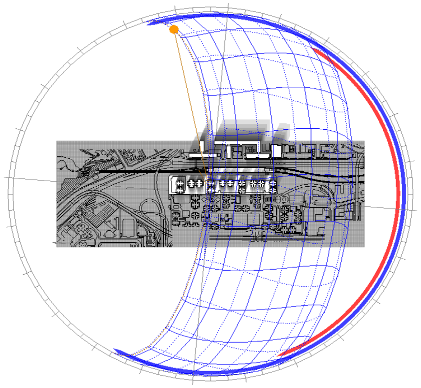
Camera View



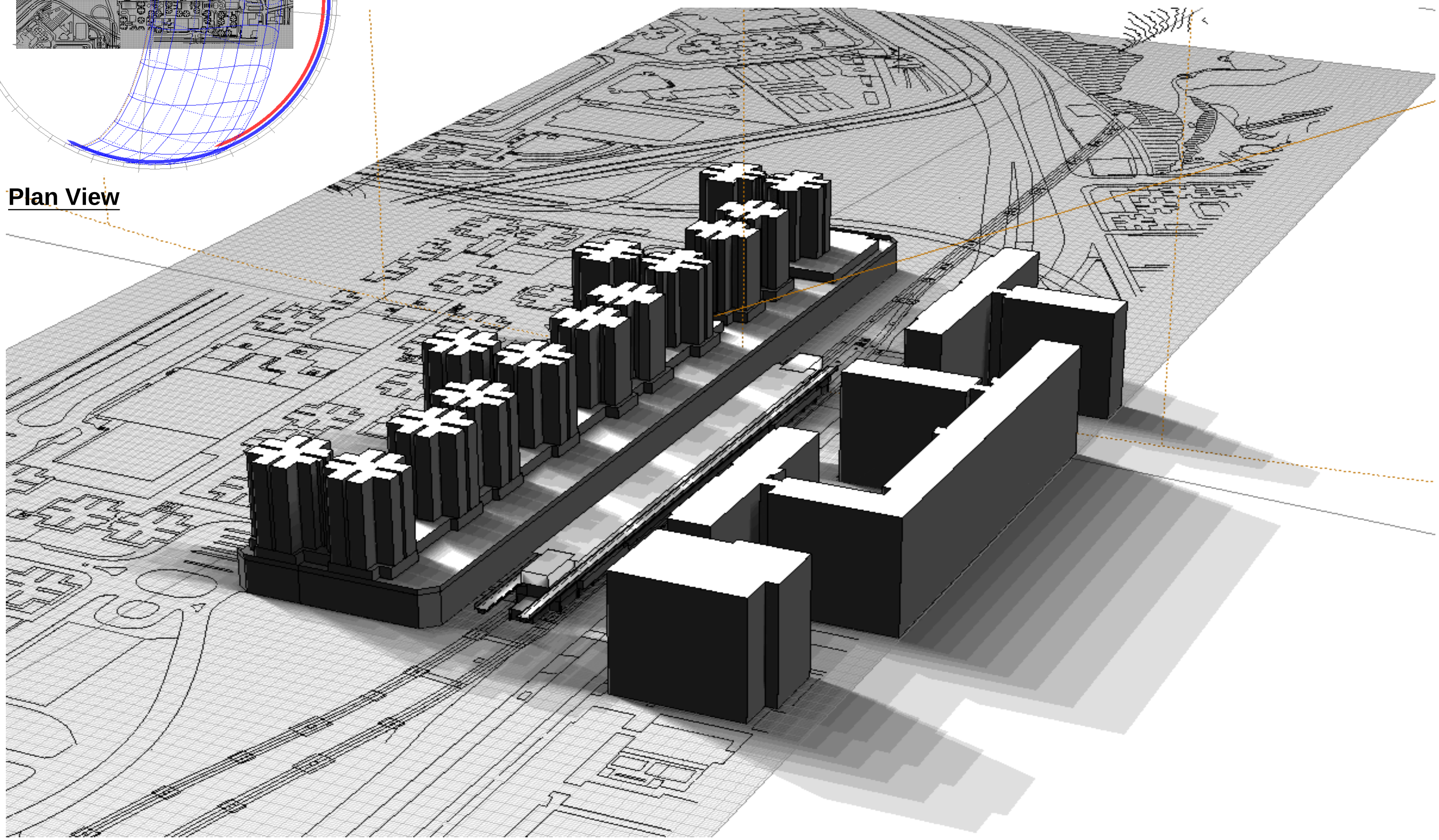
Kowloon Bay Station

Shadow Range Study

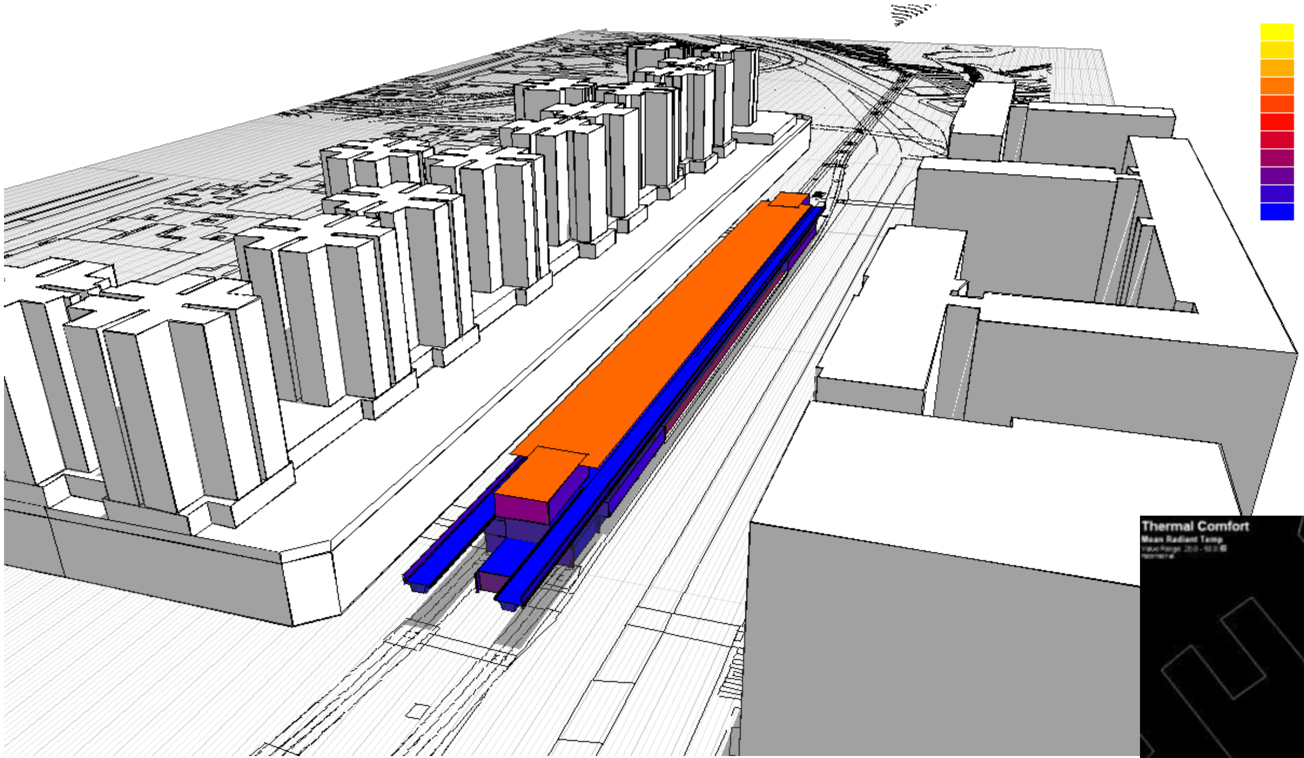
12th day of June 9:00am to 7:30pm

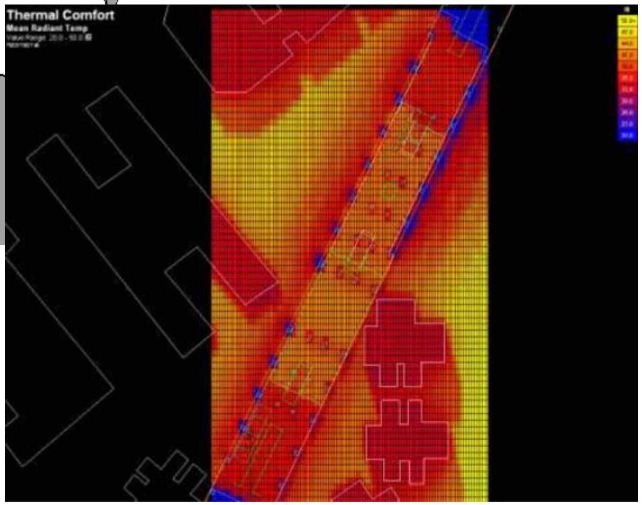


Plan View



Thermal Comfort Analysis – Radiation Analysis



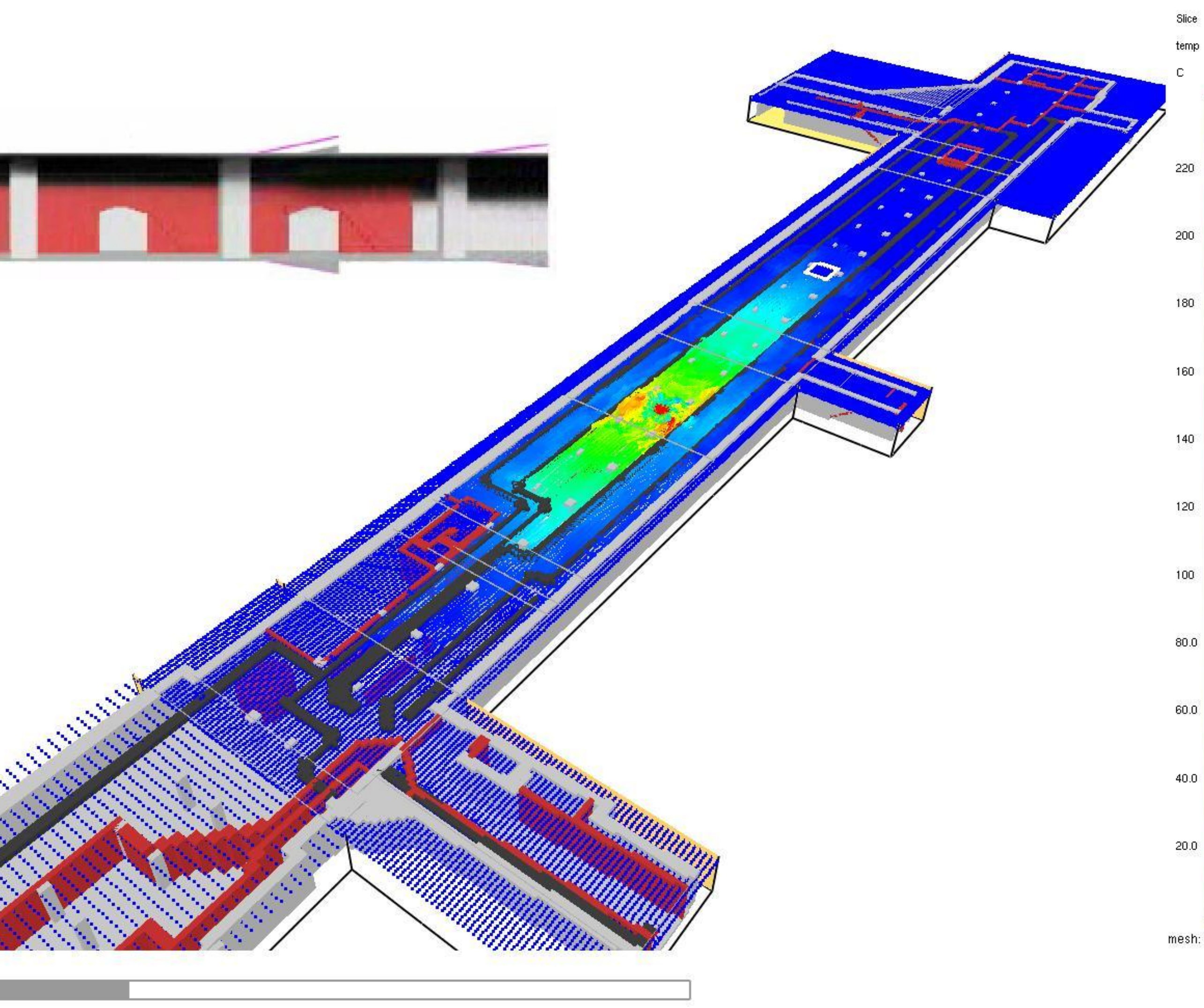


Kowloon Bay Station

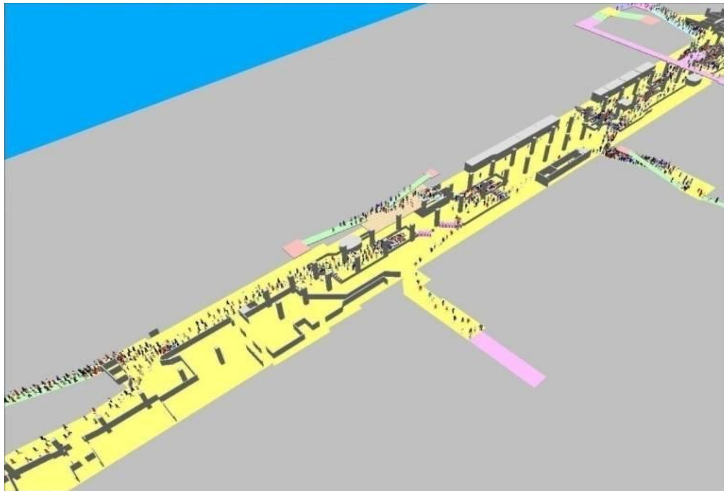
Daily Average Radiation

12th day of June 9:00am to 7:30pm

Fire Simulation



Passenger Flow Simulation



Station Planning and Design

Factors affecting passenger flow in stations

- Walking Speed
- Familiarity with Stations
- Passenger Flow within Stations
  - Counterflow
  - Crossflow
- Waiting passengers and queues
- Trip Purposes
- Luggage

Relationship between Flow, Density and Walking Speed

$$\textit{Passenger Flow Rate } (q) = \textit{Density } (k) * \textit{Walking Speed } (u)$$

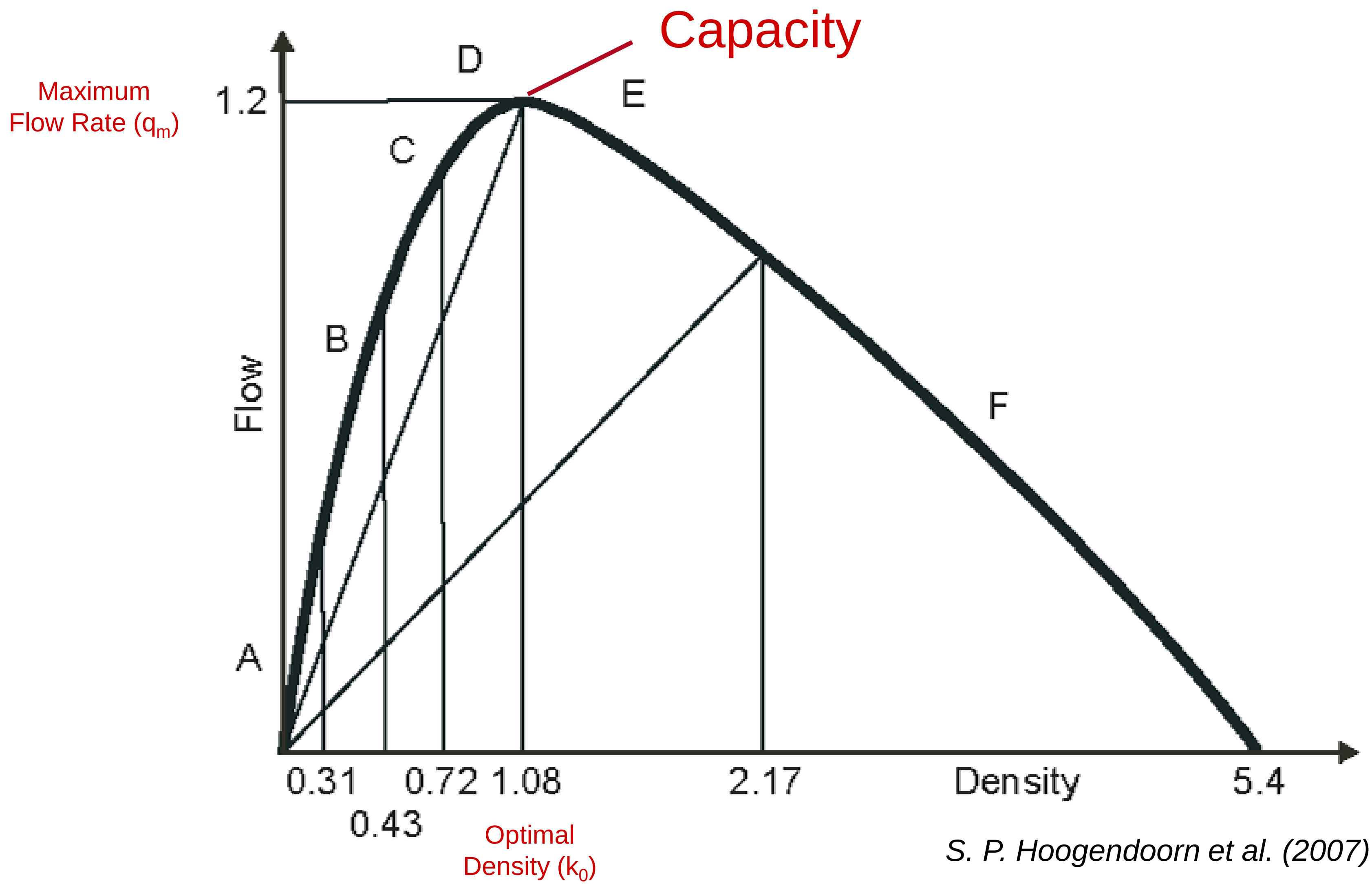
(Pax/min/m) (Pax/m^2) (m/min)

In reality, passengers' walking speed is a function of their density

⇨

$$q = k * F(k)$$

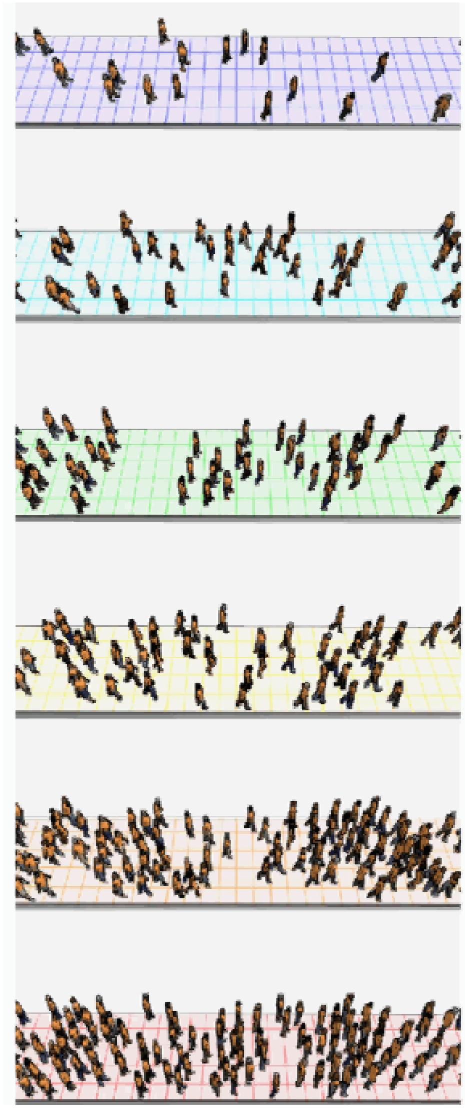
Fundamental Diagram



S. P. Hoogendoorn et al. (2007)

Fruin: Level of Service Standard

A	Normal walking speed can be freely selected & slower pedestrians can be easily overtaken. Crossing conflicts can be easily avoided.
B	Restricted walking speed; overtaking slower pedestrians is difficult. Counter-flows & crossing movements severely restricted. Some probability of reaching critical density causing temporary stoppages.
C	Restricted ability to select normal walking speed & freely pass others. High probability of conflict where crossing movements & counter-flows exist. Conflict avoidance requires frequent adjustment of walking speed & direction. Flow is reasonably fluid, however considerable friction & interaction between pedestrians is likely to occur.
D	Restricted walking speed; overtaking slower pedestrians is difficult. Counter-flows & crossing movements severely restricted. Some probability of reaching critical density causing temporary stoppages.
E	Walking speed & passing ability is restricted for all pedestrians. Forward movement is possible only by shuffling. Counter-flows & crossing movements extremely difficult. Flow volumes approach limit of walking capacity.
F	Severely restricted walking speed; frequent unavoidable contact with others; reverse or cross movements are virtually impossible. Pedestrian flow is sporadic & unstable.



Source: Pedestrian Planning and Design, John J. Fruin, 1987

Design Capacity in NWDSM

		Maximum Practical Capacity (MPC)	Design Factor 0.8 (Normal)	Design Factor 0.6 (New Station)	Design Factor 0.9 (Emergency)
Escalator (speed 0.75 m/s)		150	120	90	135
Stair (Uni-directional)	Up	63	50	37	56
	Down	70	56	42	63
Stair (Bi-directional)	Up	50	40	30	-
	Down	56	44	33	-
Passage	Uni-directional	88	70	52	79
	Bi-directional	70	56	42	-
AFC Gates (Turnstile Gate)		35	28	-	-

MTR's Level of Service Standard

Fruin Level of Service Standard

Design Standard

Person / sq. m.

LOS	A	B	C	D	E	F
Walkway	<0.31	0.31-0.43	0.43-0.72	0.7-1.1	1.1-2.2	>2.2
Queuing	<0.82	0.8-1.1	1.1-1.5	1.5-3.6	3.6-5.6	>5.6
Staircase	<0.54	0.54-0.72	0.7-1.1	1.1-1.5	1.5-2.7	>2.7

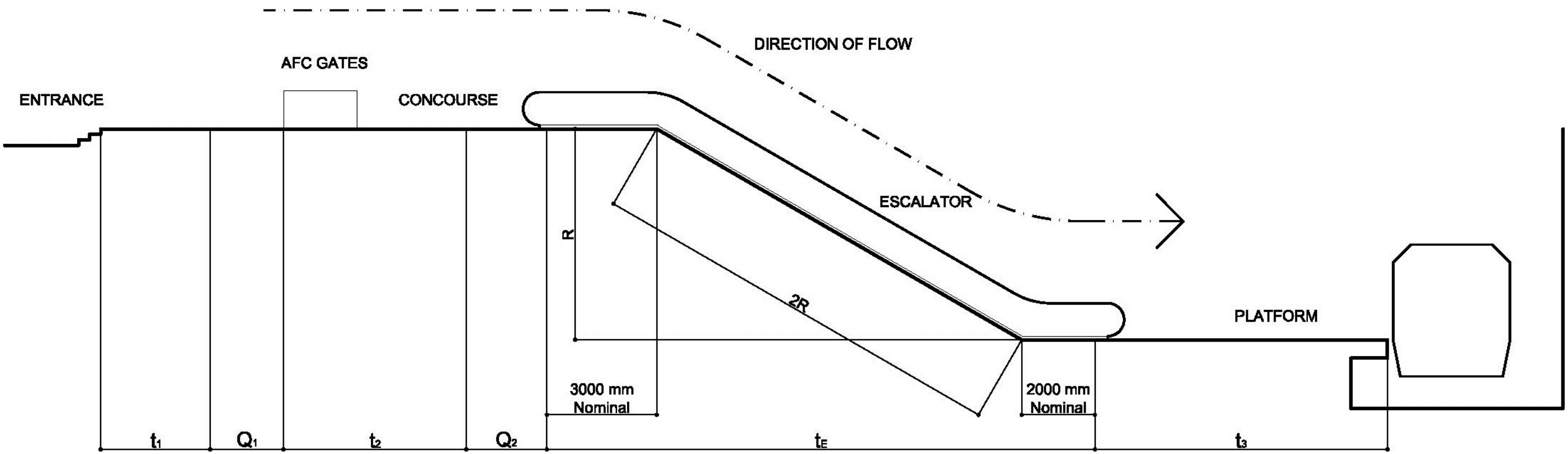
New Works Design Standard

LOS		Good	Acceptable	Undesirable
Escalator	At concourse & entrance levels	No Waiting	0 – 15 sec.	Exceed 15 sec.
	At Platform	No Waiting	0 – 30 sec.	Exceed 30 sec.
TIMs, TMs, AVMs		No Waiting	0 – 30 sec.	Exceed 30 sec.
AFC Gates		No Waiting	0 – 10 sec.	Exceed 10 sec.
Lifts		No Waiting	0 – 30 sec.	Exceed 30 sec.
Journey Time	From Entrance to Platform	0 – 3 minutes	3 – 6 minutes	Exceed 6 min.
	For Interchange	0 – 3 minutes	3 – 6 minutes	Exceed 6 min.

MTR's Classification of Congestion

Classification	Definition	Action Required
CG1 – Safety Compromised Level	Crowding at critical location, duration, and situation that has safety concern	Condition at which service level must be reduced
CG2 – Alert Condition Level	Congestion level that the passenger flow efficiency starts to drop	Permanent crowd control to be put in place by operator. Commission works on congestion work.
CG3 – Sub-standard Customer Service Level	Congestion level that impede passengers' usual walking speed and step length	Intermittent crowd control to be put in place by operator. Commission studies on congestion relief schemes
CG4 – Target Customer Service Level	Congestion level that passengers can move at their unimpeded speed and step length	Maintain through station management action.

MTR's Overall Travelling Time Calculation



OVERALL TRAVELLING TIME CALCULATION FROM ENTRANCE TO PLATFORM:

$T = t_1 + Q_1 + t_2 + Q_2 + t_E + t_3$

where

T = Overall Travelling time

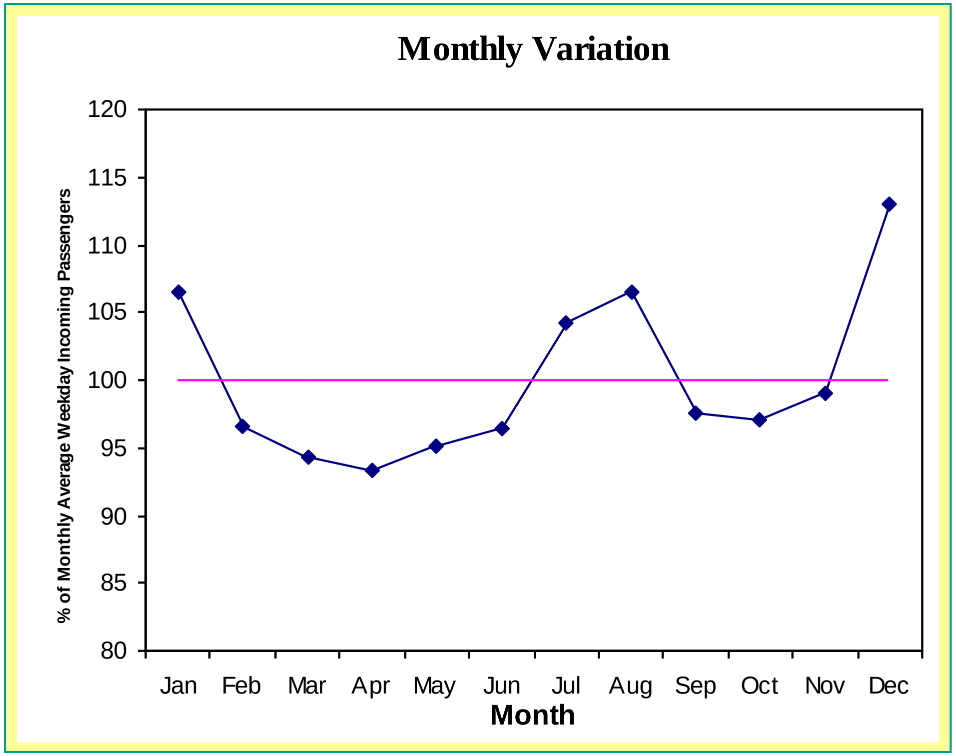
t = Travelling time of a given distance, based on 1.35 m/s, or D / 1.35, where D = distance

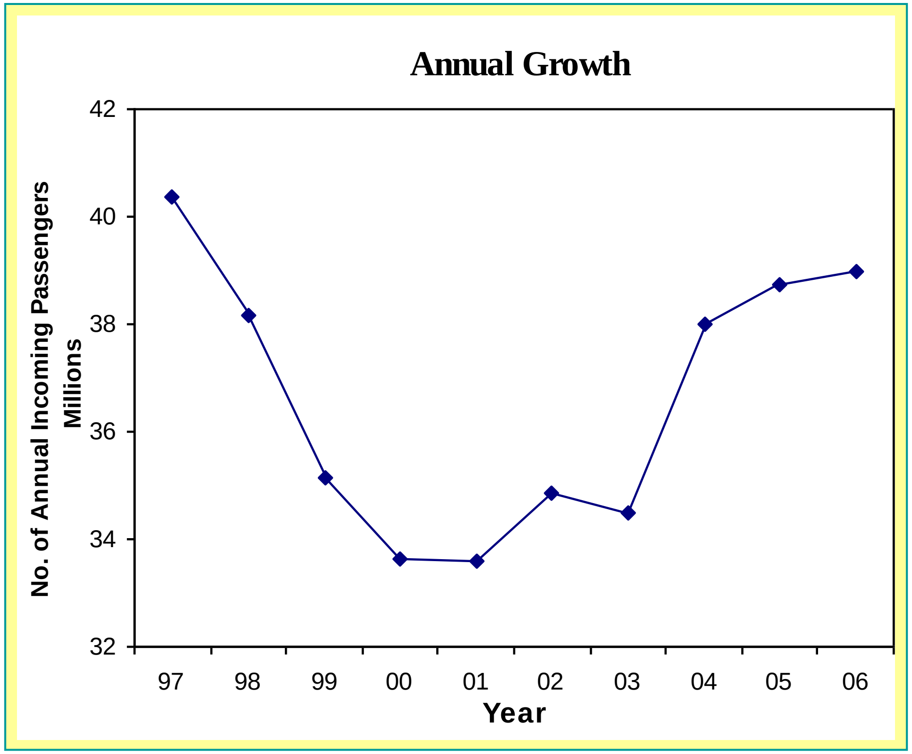
t_E = Travelling time at escalator, based on 0.75 m/s*, or (2R+3+2) / 0.75, where R = floor-to-floor height

Q = Desirable queuing time (max.)
10 seconds for AFC gates*
15 seconds for escalator*

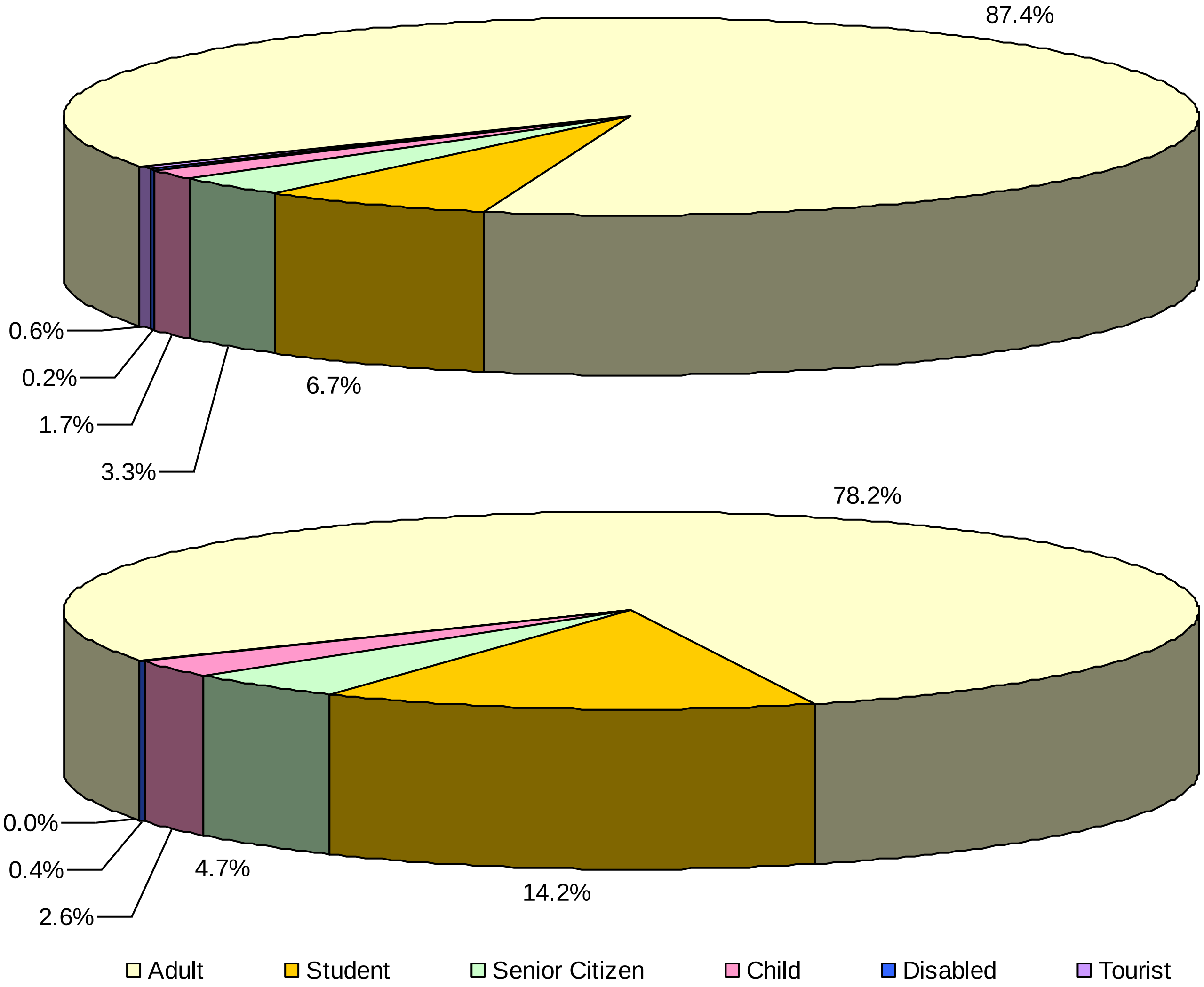
Passenger Flow Data

KOB Demand Variations & Growth





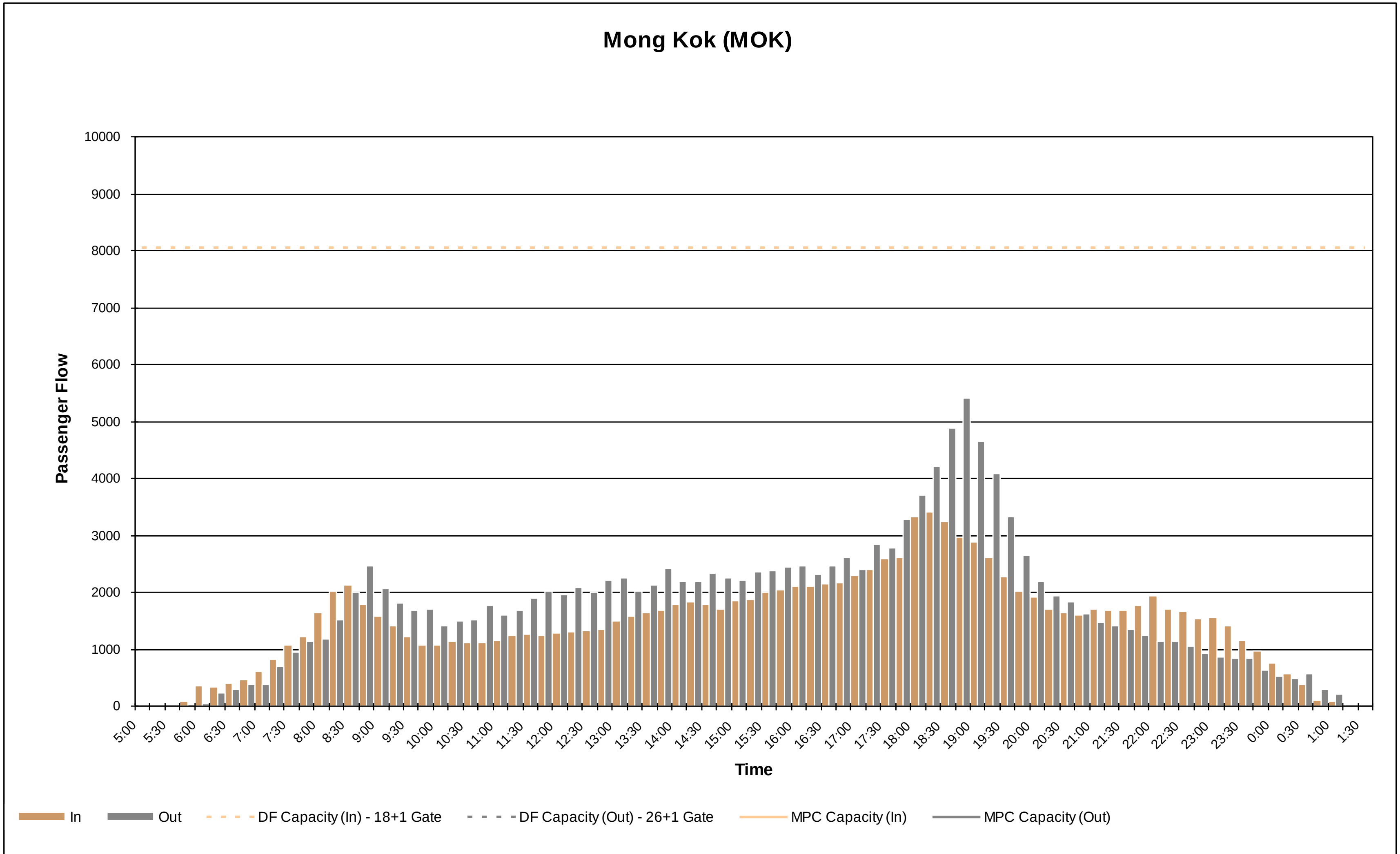
Passenger Profile



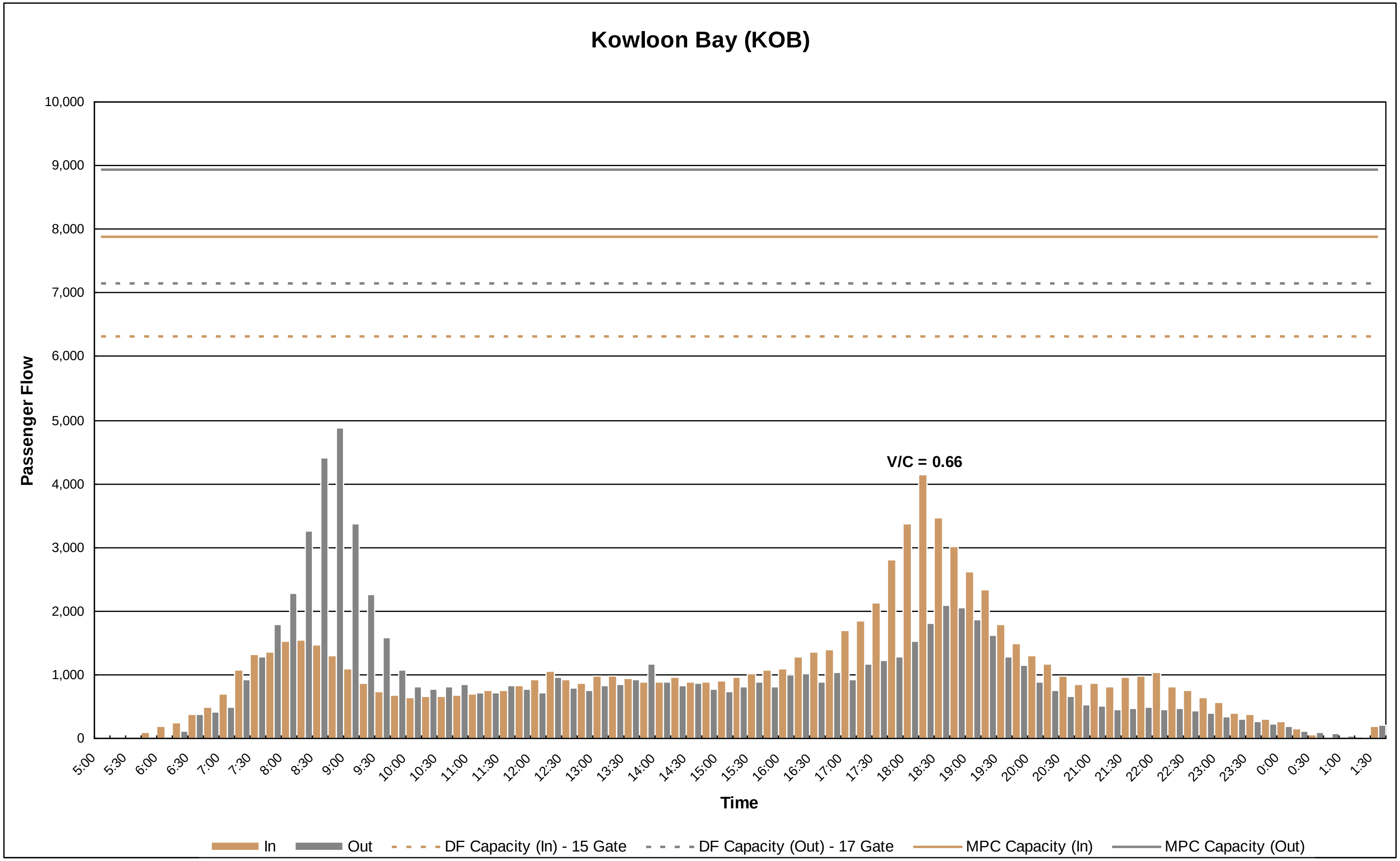
Mong Kok (MOK)

Kowloon Bay (KOB)

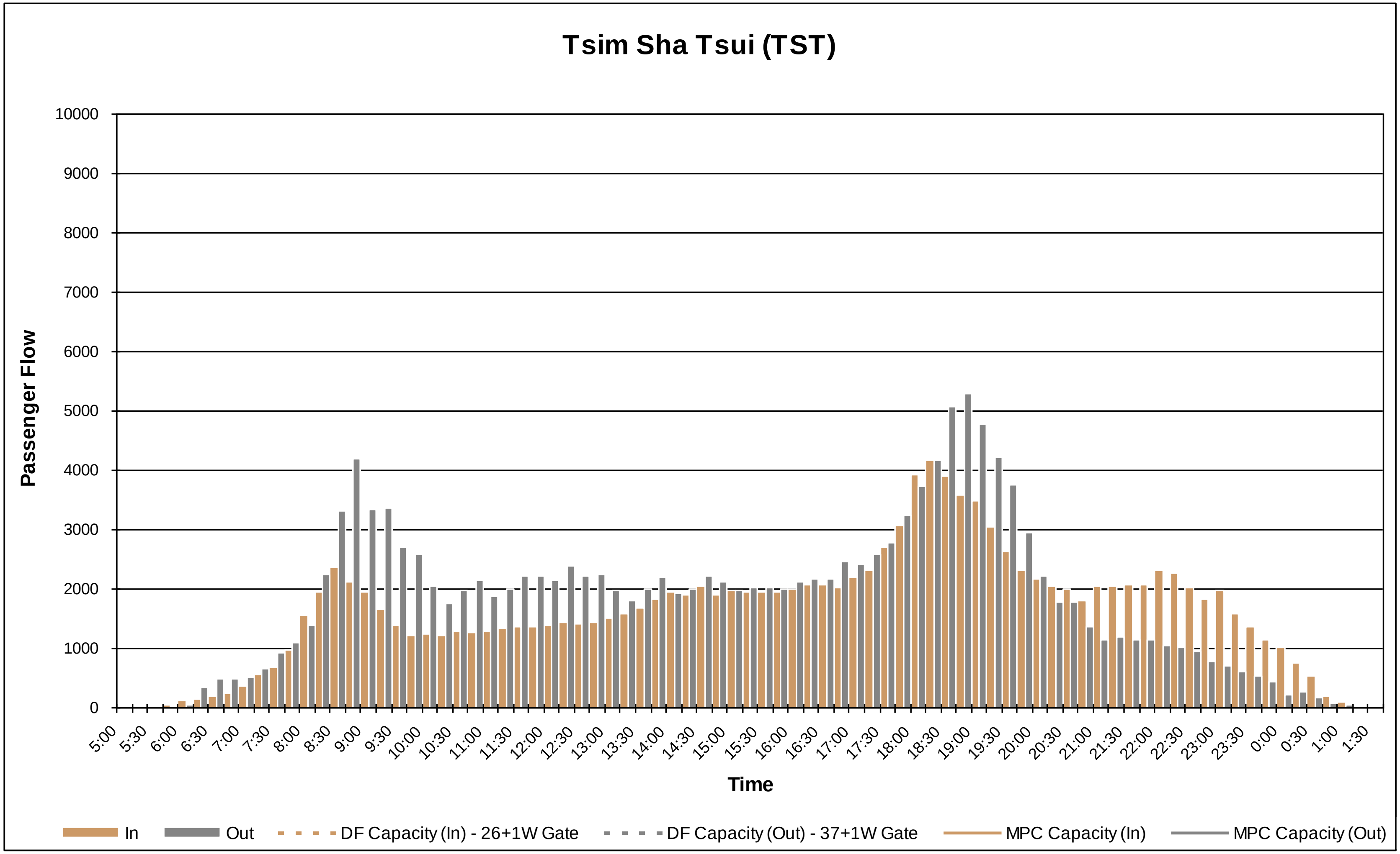
Passenger Flow Characteristics (Weekdays)



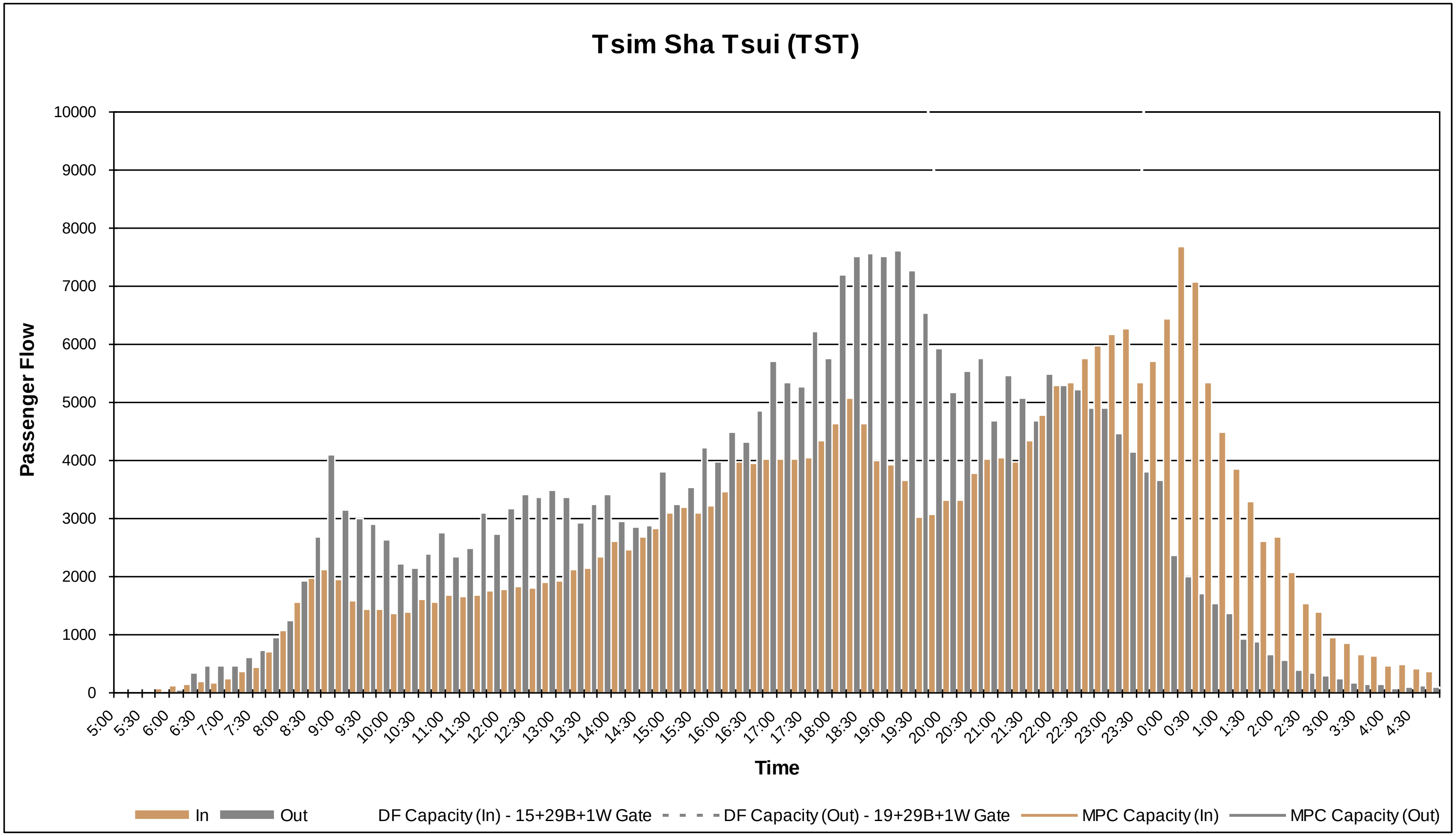
Passenger Flow Characteristics (Weekdays)



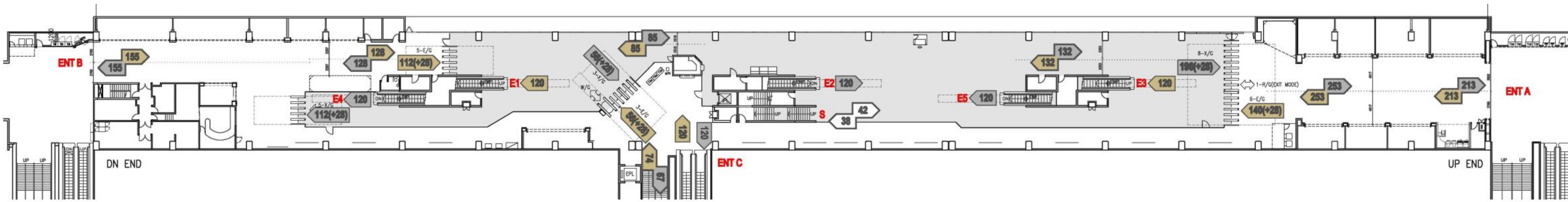
Passenger Flow Characteristics (Weekdays)



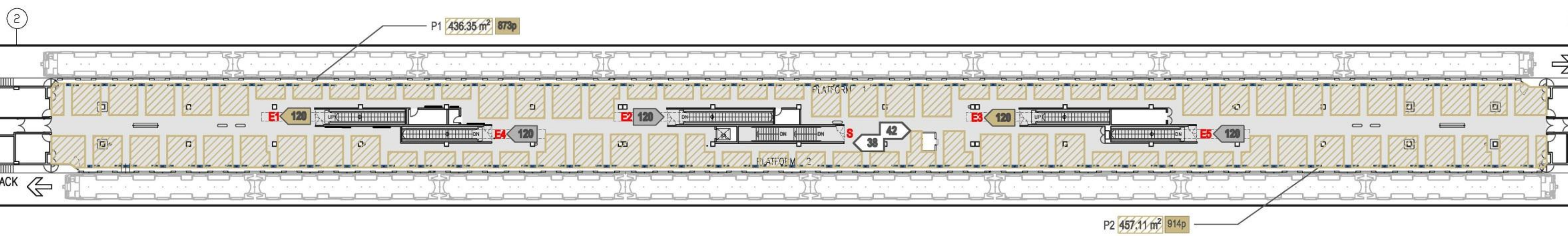
Passenger Flow Characteristics (X'mas Eve)



Station Capacity



Concourse

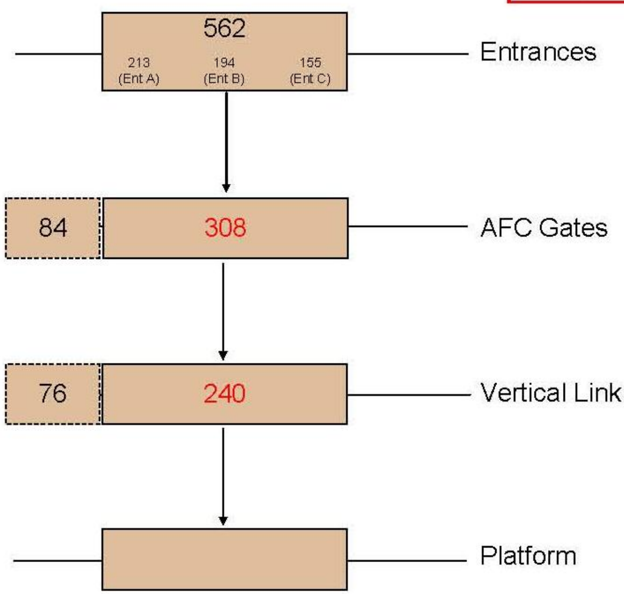


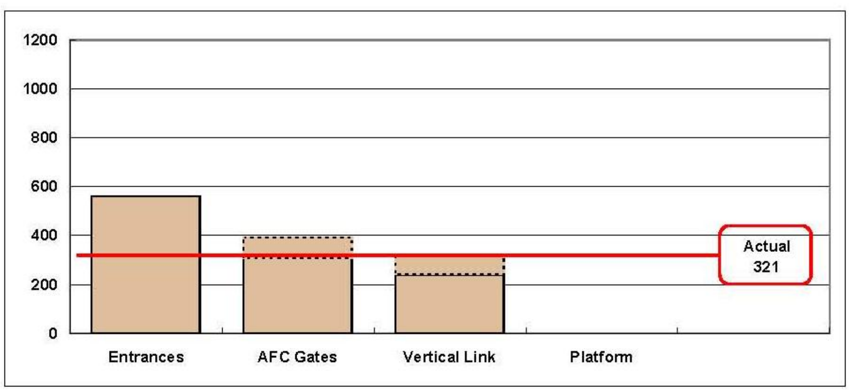
Platform

Station Capacity (KOB)

Entry Capacity (ppm) of Facilities

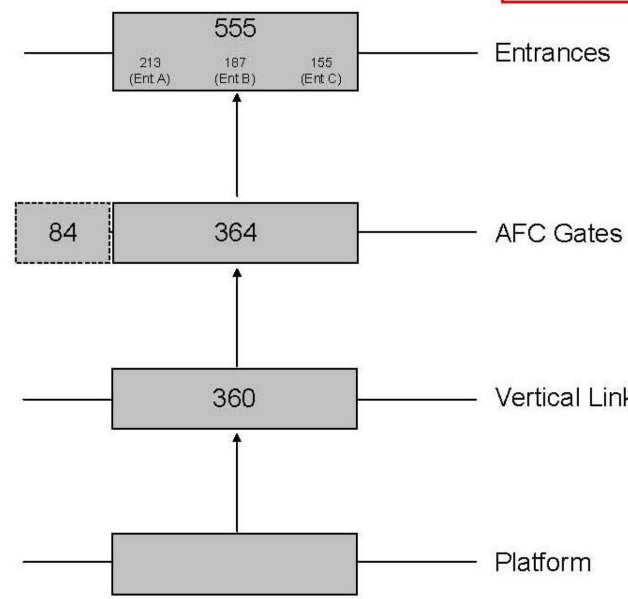
Actual
327 (Max)
321 (Av. 17-21 Oct 2011)

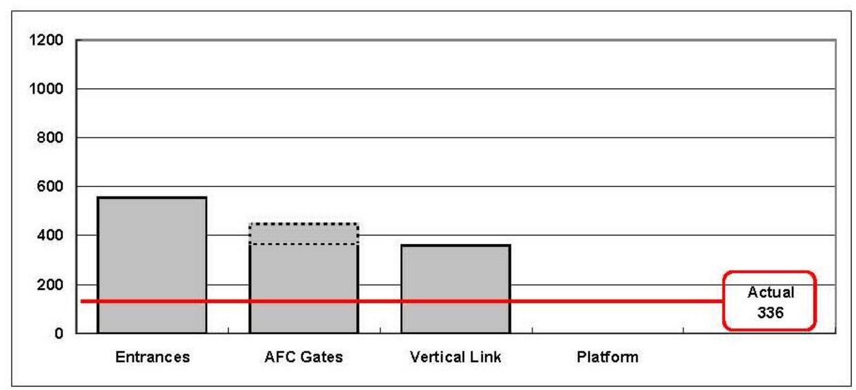




Exit Capacity (ppm) of Facilities

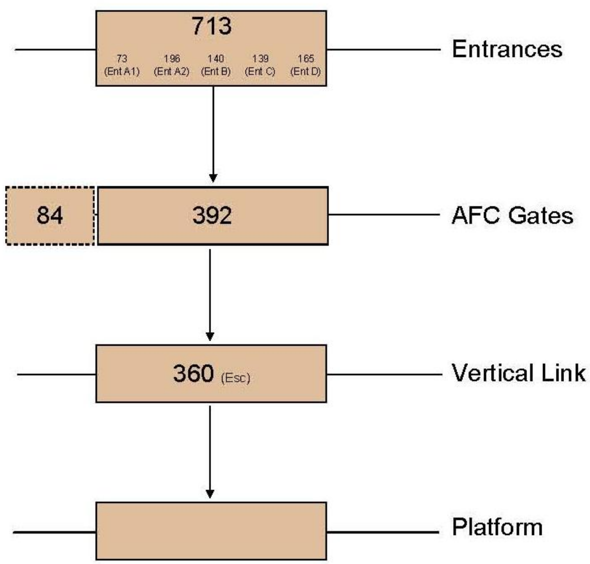
Actual
351 (Max)
336 (Av. 17-21 Oct 2011)



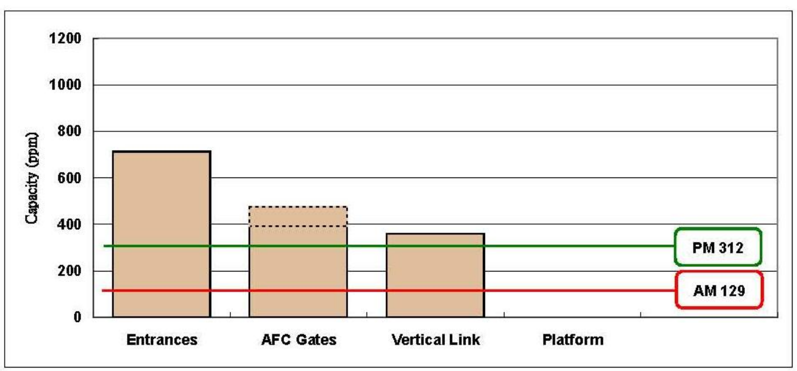


Station Capacity (KWT)

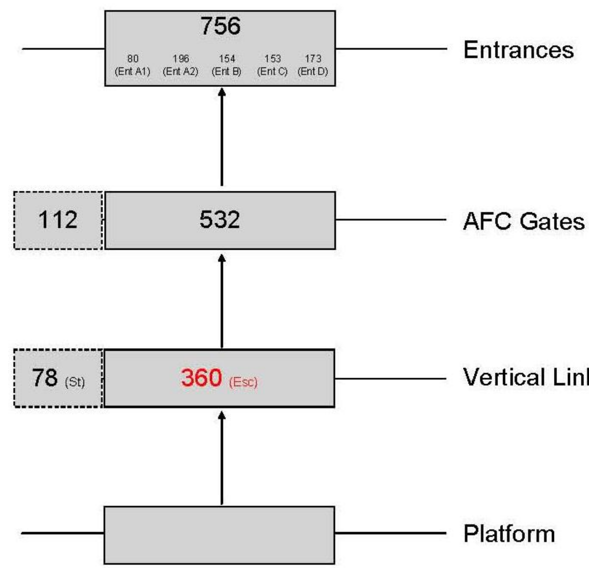
Entry Capacity (ppm) of Facilities



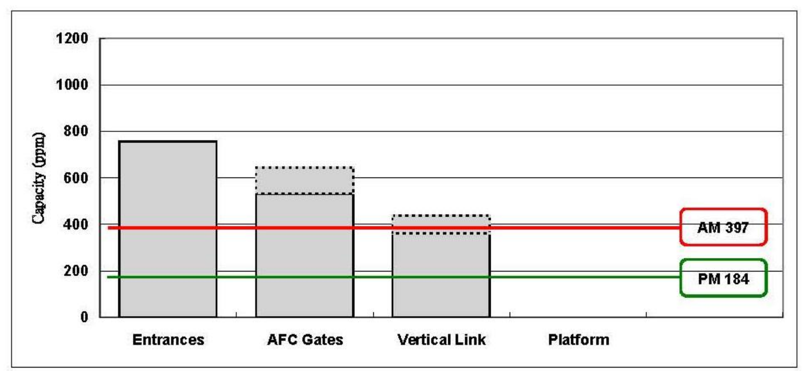
Entrances	713		129	312
AFC Gates	392	84	129	312
Vertical Link	360		129	312
Platform			129	312



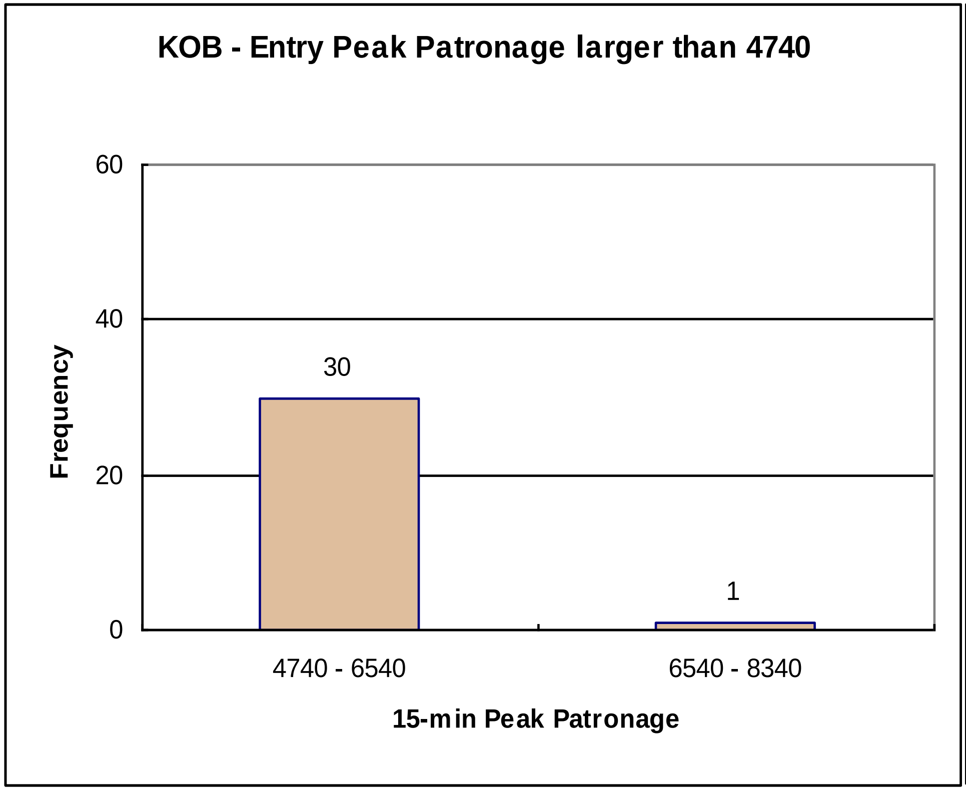
Exit Capacity (ppm) of Facilities

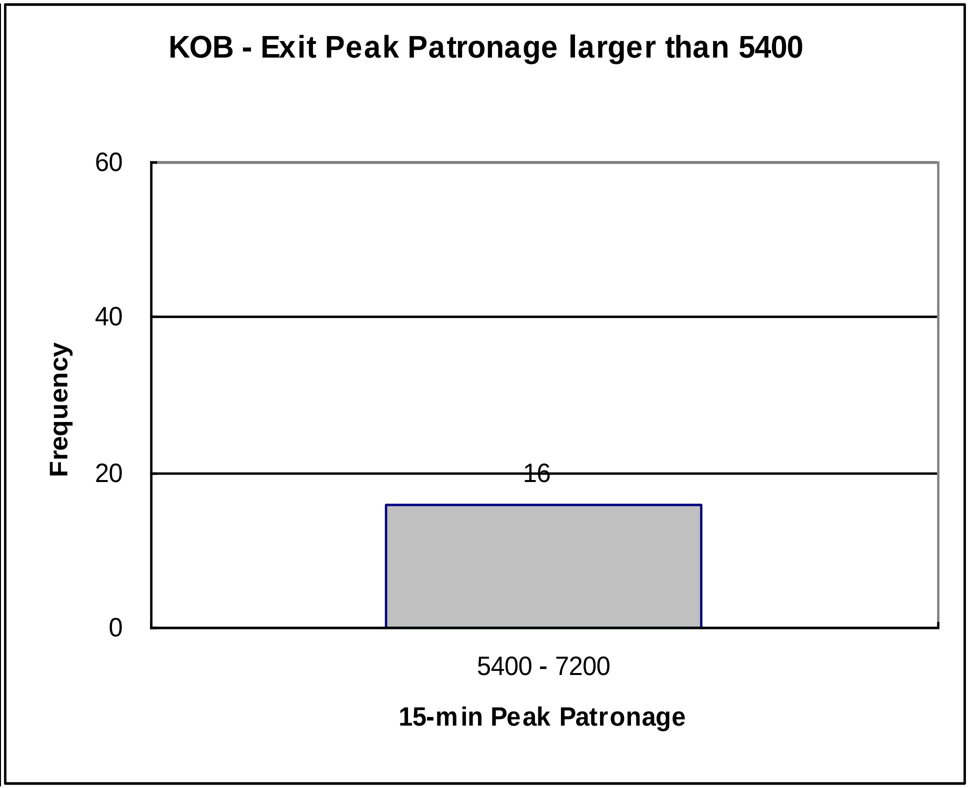


Entrances	756		397	184
AFC Gates	532	112	397	184
Vertical Lir	360	78	397	184
Platform			397	184

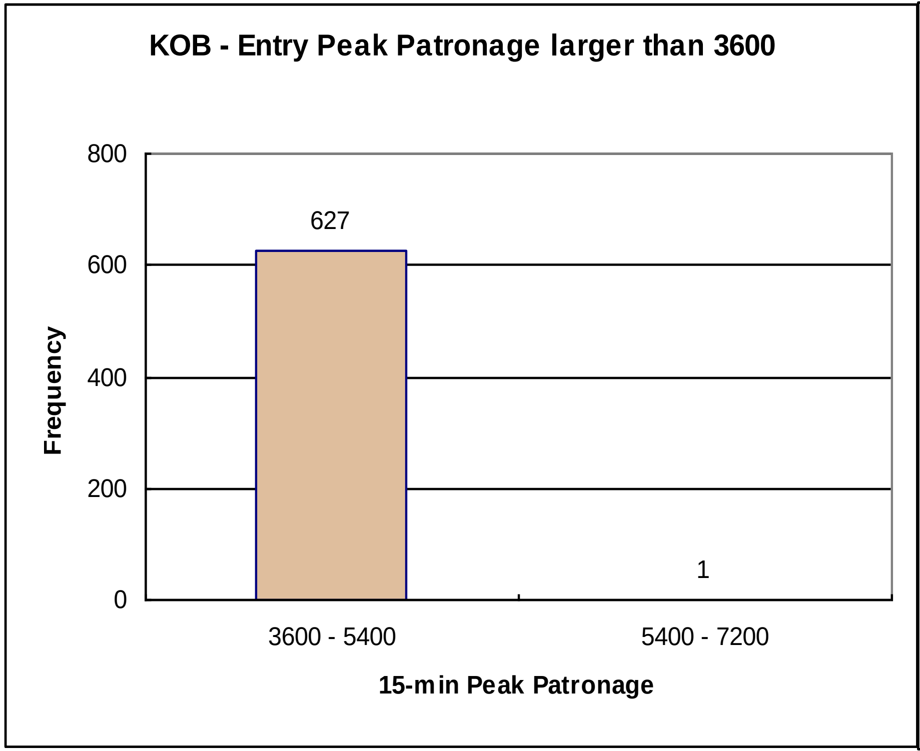


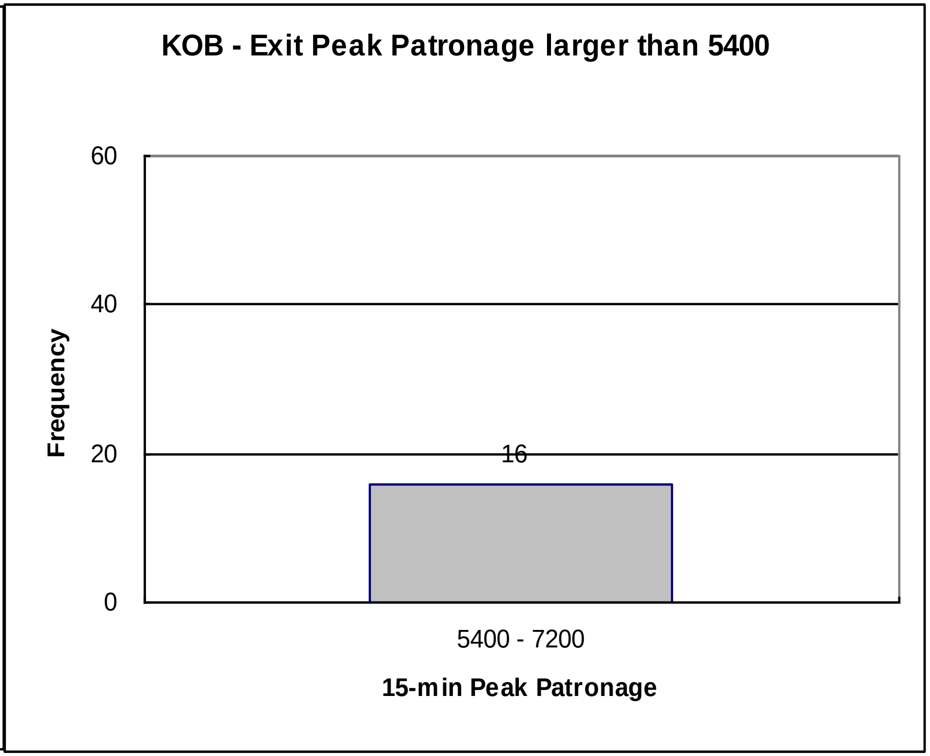
Station Capacity (1)



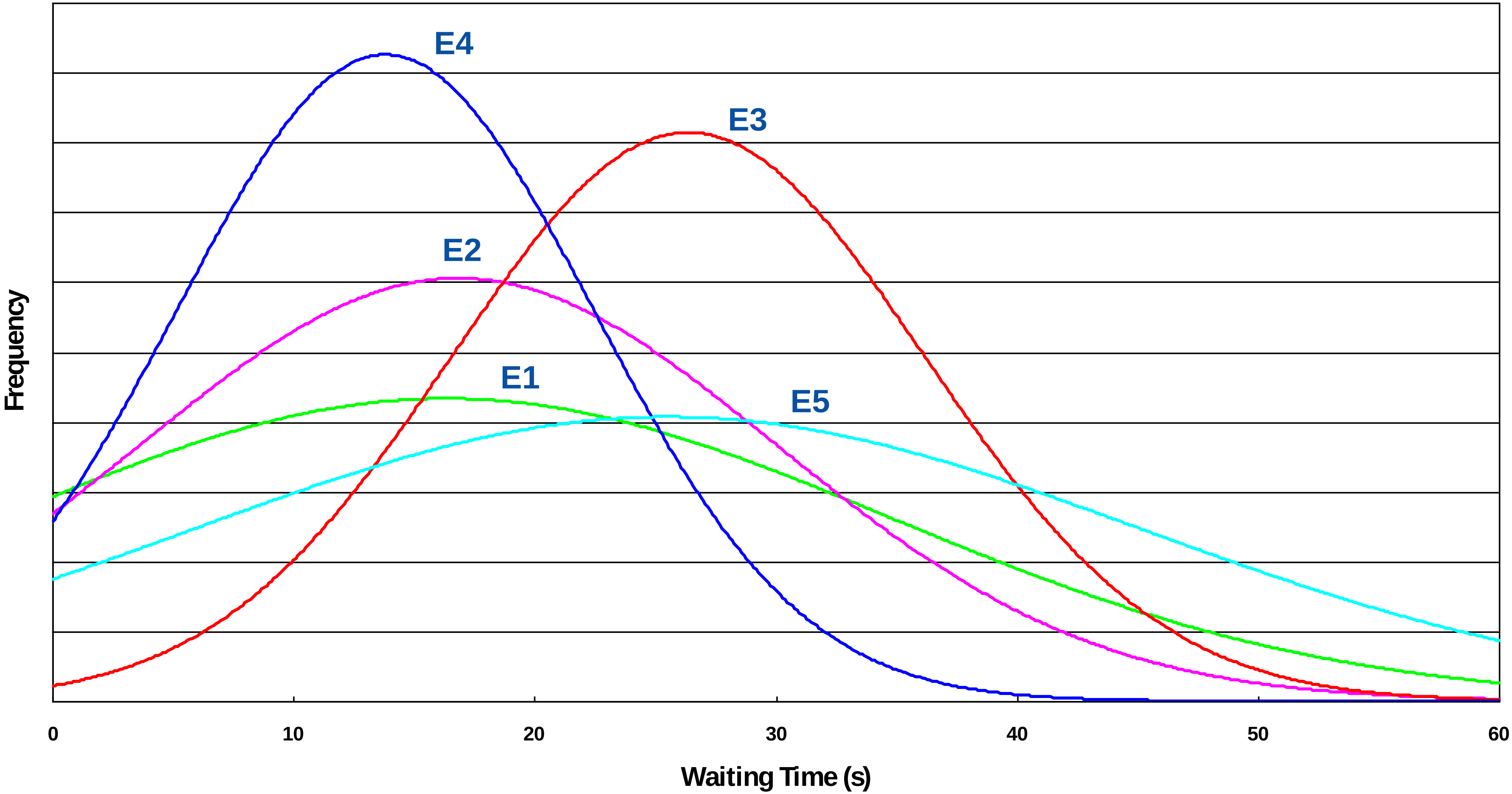


Station Capacity (2)

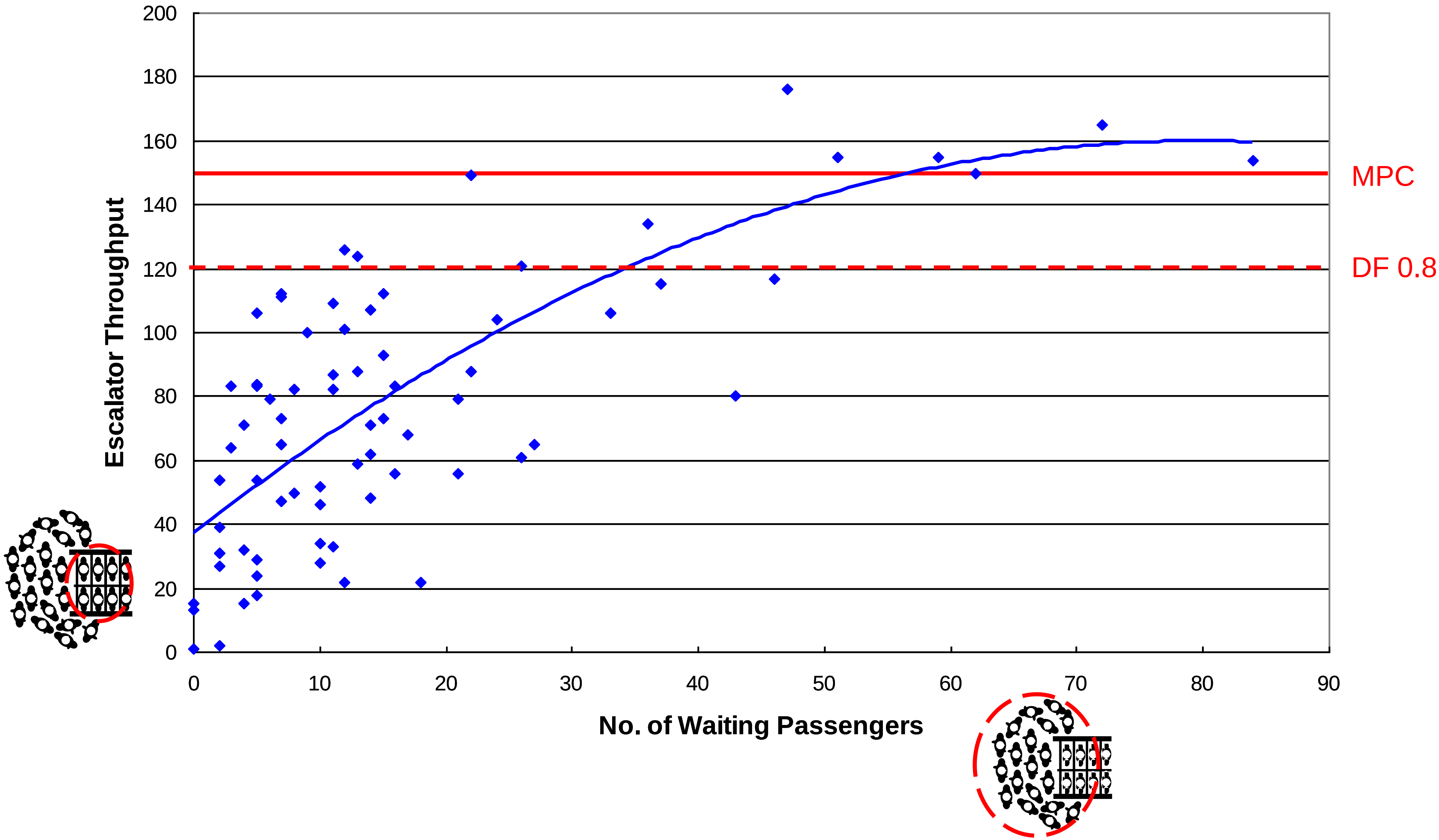




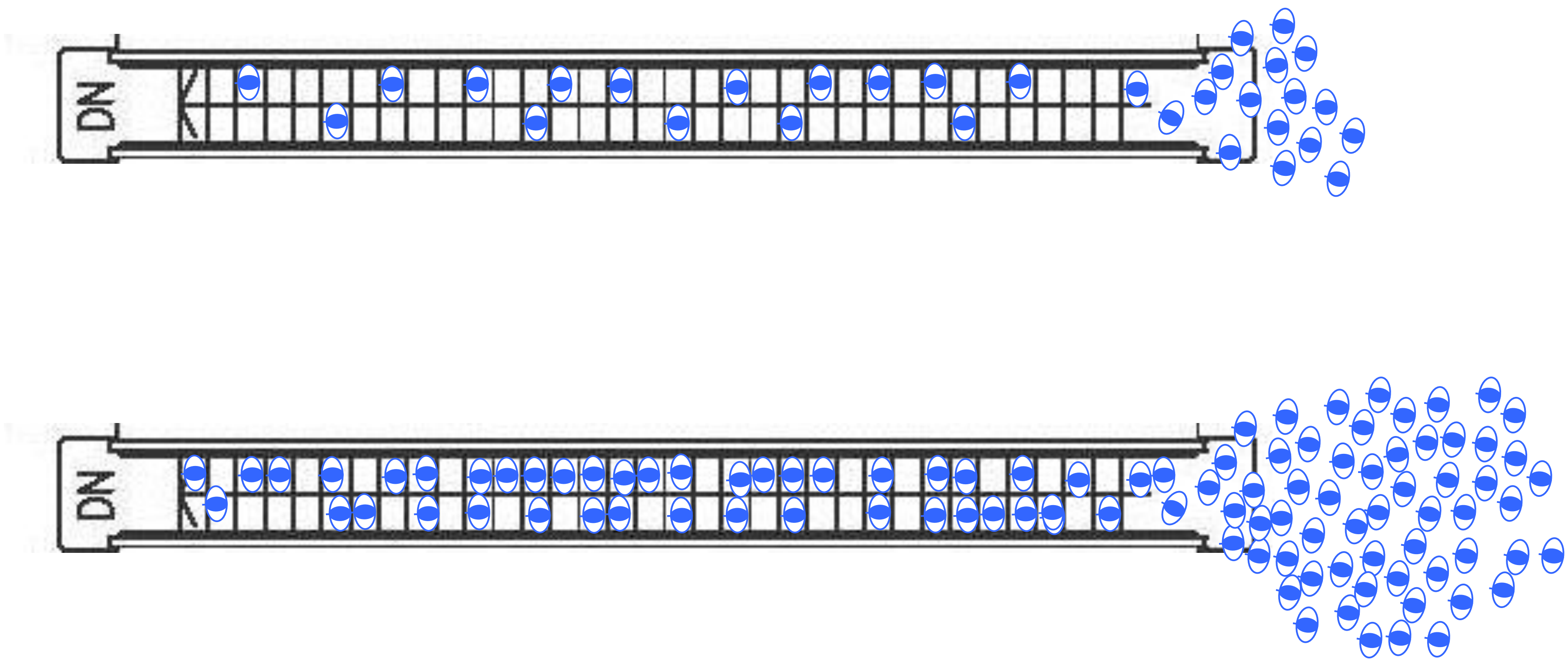
Passenger Waiting Time at Escalator Landings



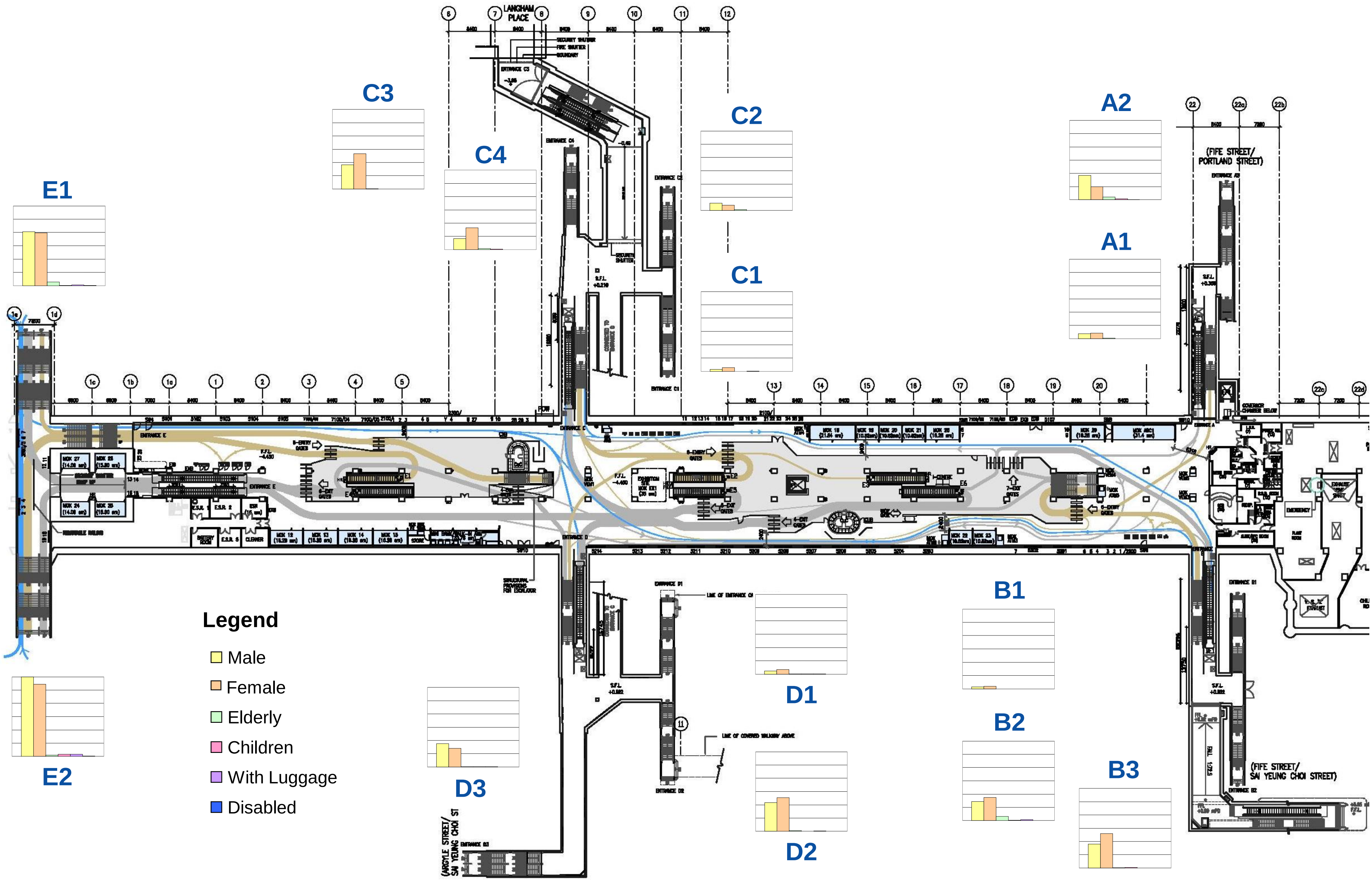
Escalator Throughput



Escalator Throughput

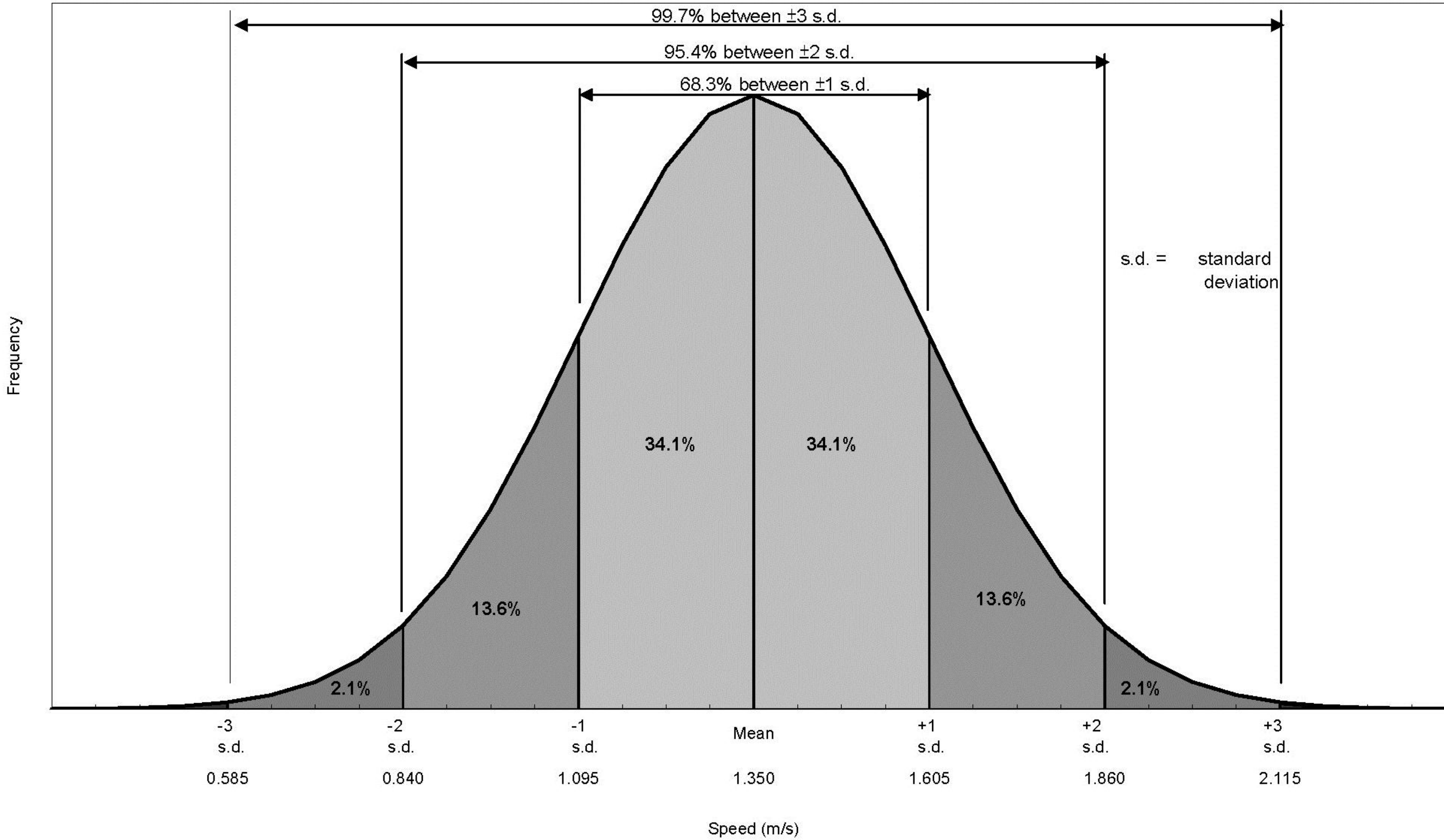


Passenger Flow Characteristics (MOK)



Walking Speed

MTR's Assumed Walking Speed for Station Design



Passenger Walking Speed - Mong Kok (MOK)

Passengers groups	Minimum speed [m/s]	Maximum speed [m/s]	Average speed [m/s]	Standard deviation [m/s]
Male	0.63	4.22	1.28	0.39
Female	0.54	2.03	1.21	0.25
Elderly	0.54	1.65	1.08	0.27
Children	0.75	3.14	1.24	0.41
Disabled	0.54	1.54	0.94	0.29
Passengers with luggage	0.92	1.82	1.26	0.22

Passenger Walking Speed - Mong Kok (MOK)

Passengers groups		Minimum speed [m/s]	Maximum speed [m/s]	Average speed [m/s]	Standard deviation [m/s]
Male	AM	0.63	3.14	1.36	0.39
	PM	0.74	4.22	1.22	0.39
Female	AM	0.70	2.03	1.35	0.30
	PM	0.54	1.70	1.09	0.20
Elderly	AM	0.63	1.65	1.14	0.29
	PM	0.54	1.21	1.00	0.23
Children	AM	0.75	3.14	1.27	0.47
	PM	0.78	1.76	1.19	0.26
Disabled	AM	0.79	1.28	1.01	0.22
	PM	0.54	1.52	0.90	0.33
Passengers with luggage	AM	0.92	1.82	1.26	0.25
	PM	1.09	1.36	1.25	0.10

Passenger Walking Speed - Mong Kok (MOK)

Area	Minimum speed [m/s]	Maximum speed [m/s]	Average speed [m/s]	Standard deviation [m/s]
Walkway	0.54	4.22	1.17	0.25
Ramp	0.29	3.71	0.96	0.25
Stair (Upward)	0.15	1.88	0.52	0.23
Stair (Downward)	0.25	1.67	0.70	0.19

Passenger Walking Speed

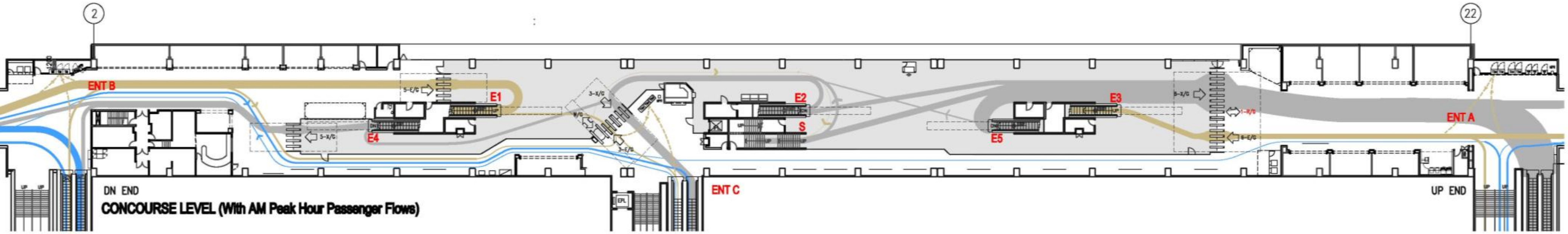
Station	Minimum speed [m/s]	Maximum speed [m/s]	Average speed [m/s]	Standard deviation [m/s]
Mong Kok (MOK)	0.54	4.22	1.17	0.25
Kwun Tong (KWT)	0.43	0.92	1.02	0.26
Kowloon Bay (KOB)	0.42	2.45	1.05	0.21
Kowloon Tong (KOT)	0.58	3.47	1.16	0.25
Wanchai (WAC)	0.41	2.45	1.03	0.24
Admiralty (ADM)	0.54	2.84	1.16	0.21

Passenger Walking Speed

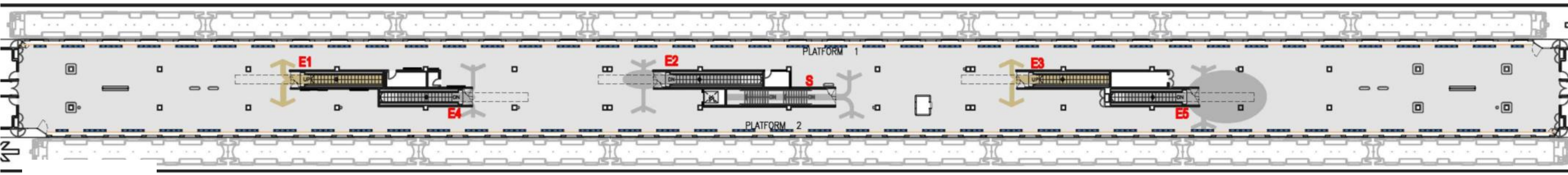
Source	Mean speed (m/s)	Standard deviation (m/s)	Location
CROW (*11*)	1.4		Netherlands
Daamen (*10*)	1.41	0.215	Netherlands
Daly et al. (*12*)	1.47		United Kingdom
FHWA (*13*)	1.2		United States
Fruin (*9*)	1.4	0.15	United States
Hankin and Wright (*14*)	1.6		United Kingdom
Henderson (*15*)	1.44	0.23	Australia
Hoel (*16*)	1.50	0.20	United States
Institute of Transportation Engineers (*17*)	1.2		United States
Knoflacher (*18*)	1.45		Austria
Koushki (*19*)	1.08		Saudi-Arabia
Lam et al. (*20*)	1.19	0.26	Hong Kong
Morrall et al. (*21*)	1.25		Sri Lanka
	1.4		Canada
Navin and Wheeler (*22*)	1.32		United States
O'Flaherty and Parkinson (*23*)	1.32	1.0	United Kingdom
Older (*24*)	1.30	0.3	United Kingdom
Pauls (*25*)	1.25		United States
Roddin (*26*)	1.6		United States
Sarkar and Janardhan (*27*)	1.46	0.63	India
Sleight (*28*)	1.37		United States
Tanariboon et al. (*29*)	1.23		Singapore
Tanariboon and Guyano (*30*)	1.22		Thailand
Tregenza (*31*)	1.31	0.30	United Kingdom
Virkler and Elayadath (*32*)	1.22		United States
Young (*33*)	1.38	0.27	United States
Estimated overall average	1.34	0.37	

Station Simulation

Station Capacity Measurement



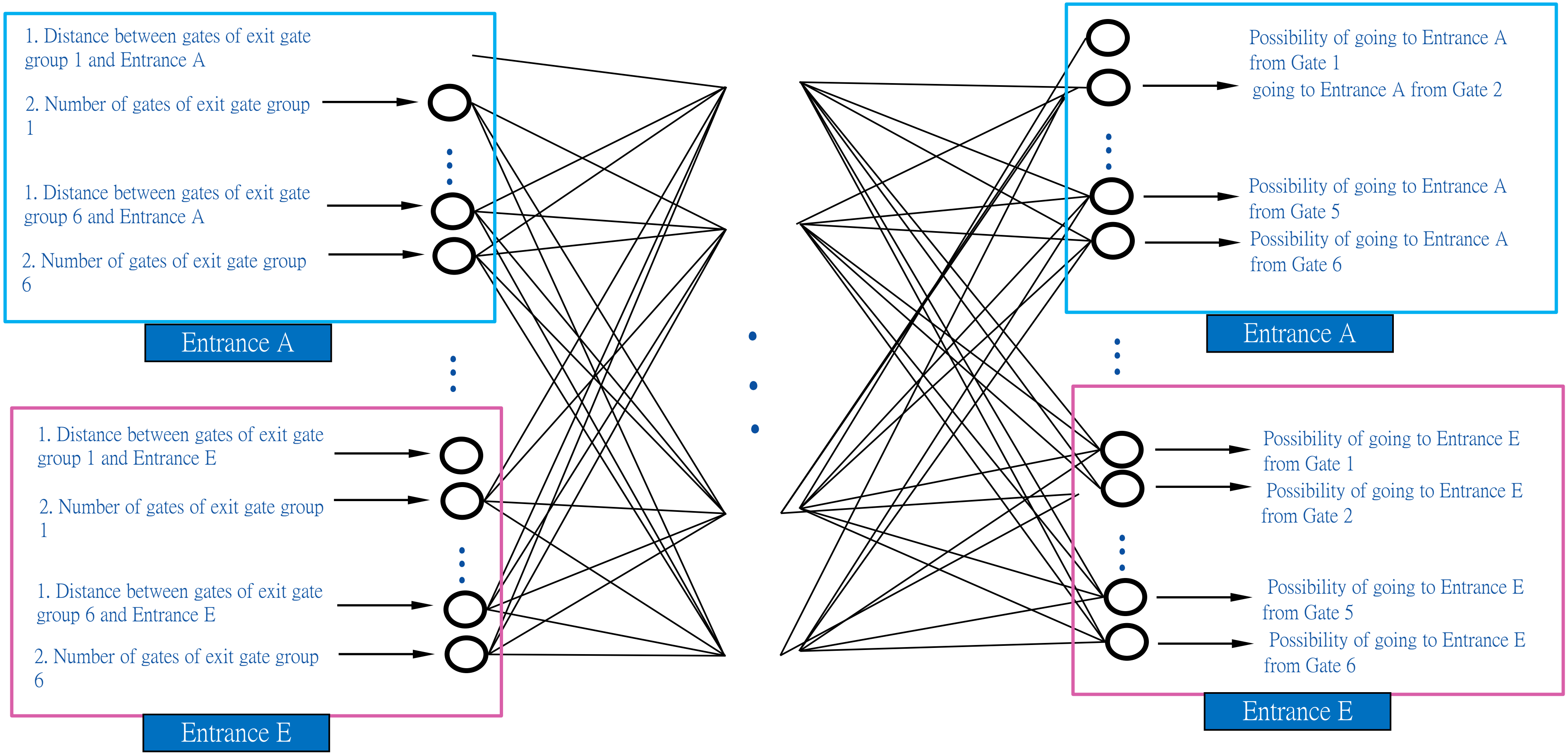
Concourse (AM)



Platform (AM)

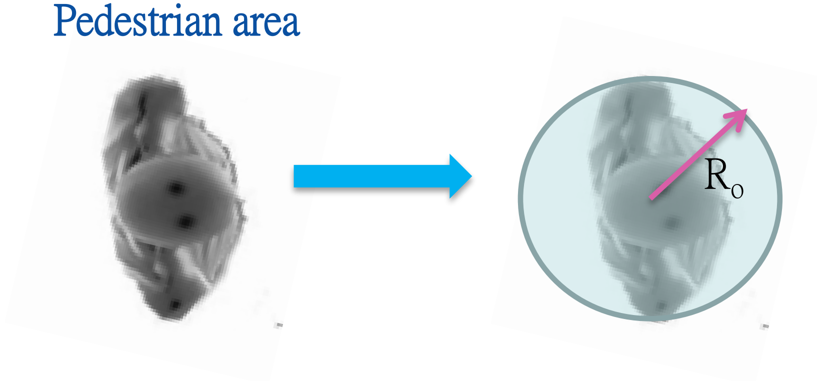
Path Selection Model

Evaluate the weighting (attraction effect) between the gates and the escalators / stairs by using Artificial Neuron Network (ANN) model.

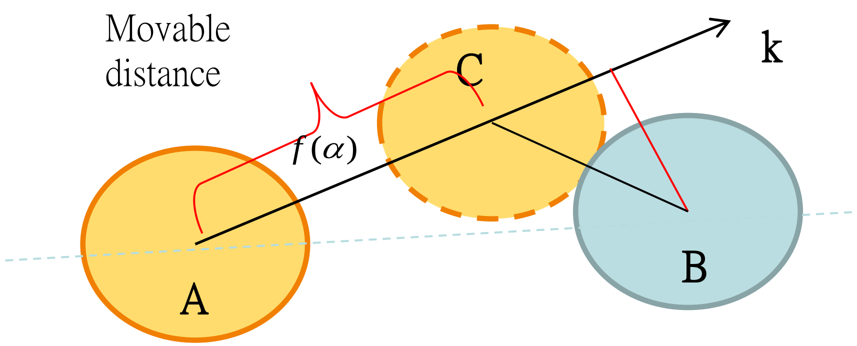


Pedestrian movement rules

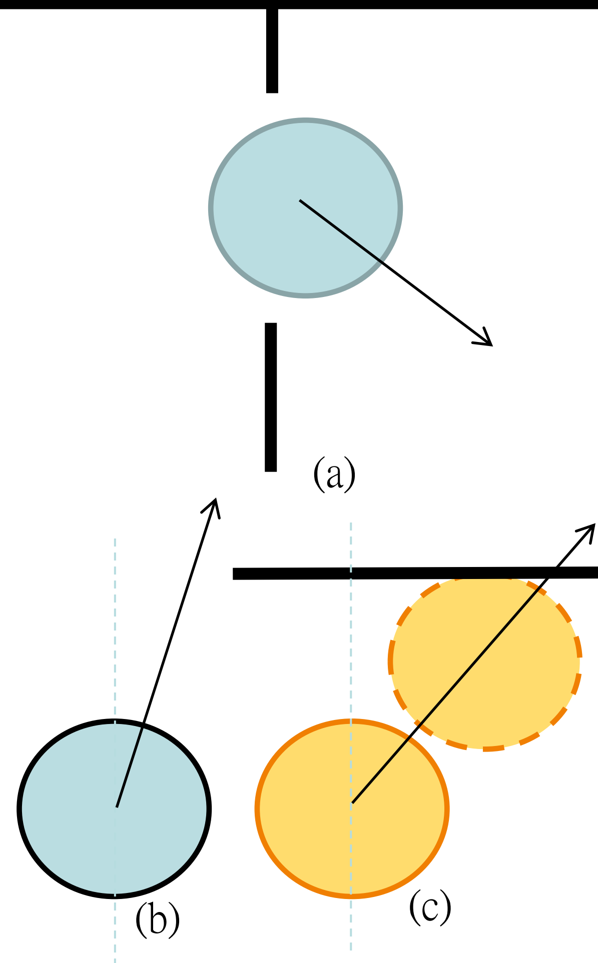
Pedestrian area



Potential collision detection

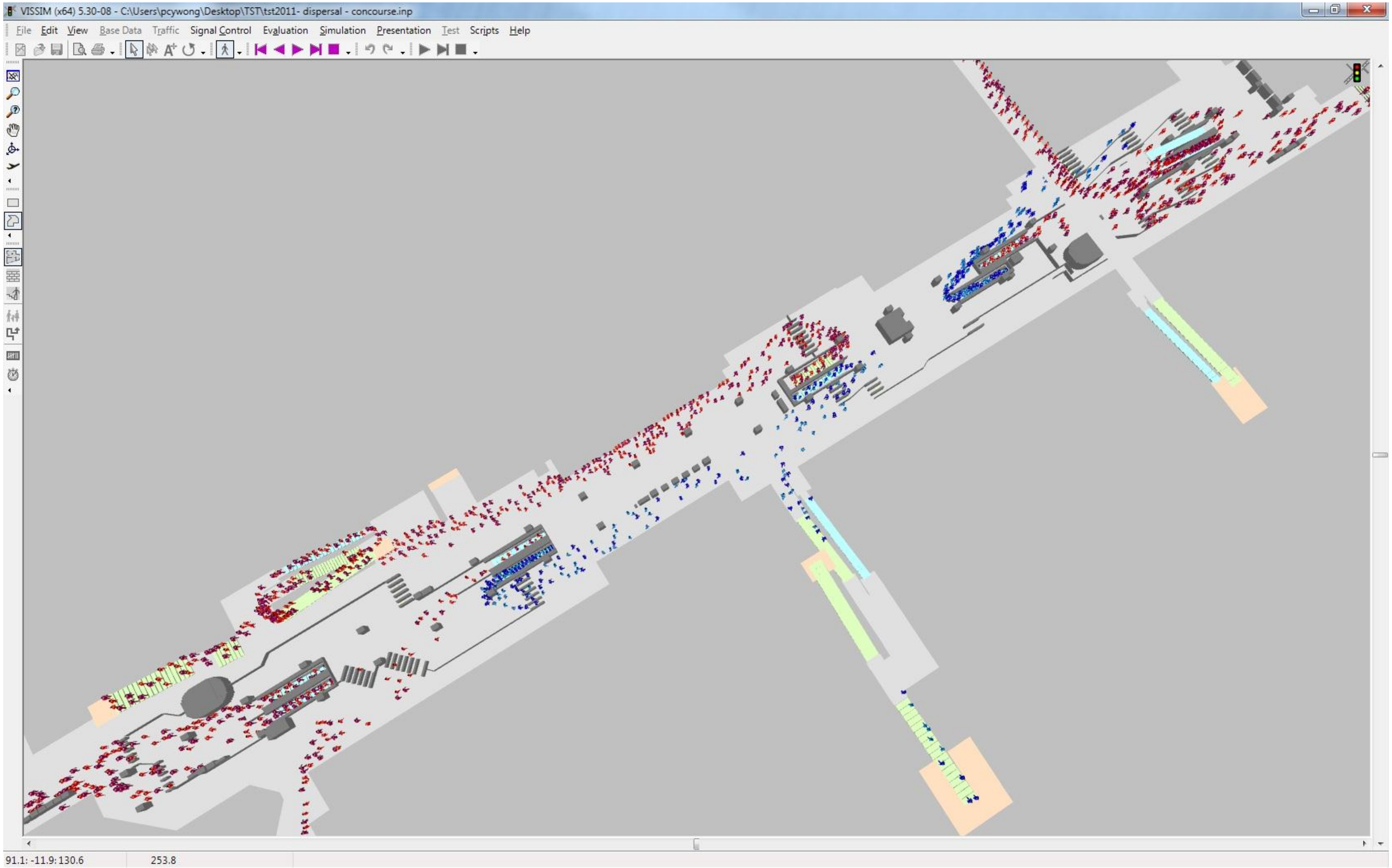


Collision with others

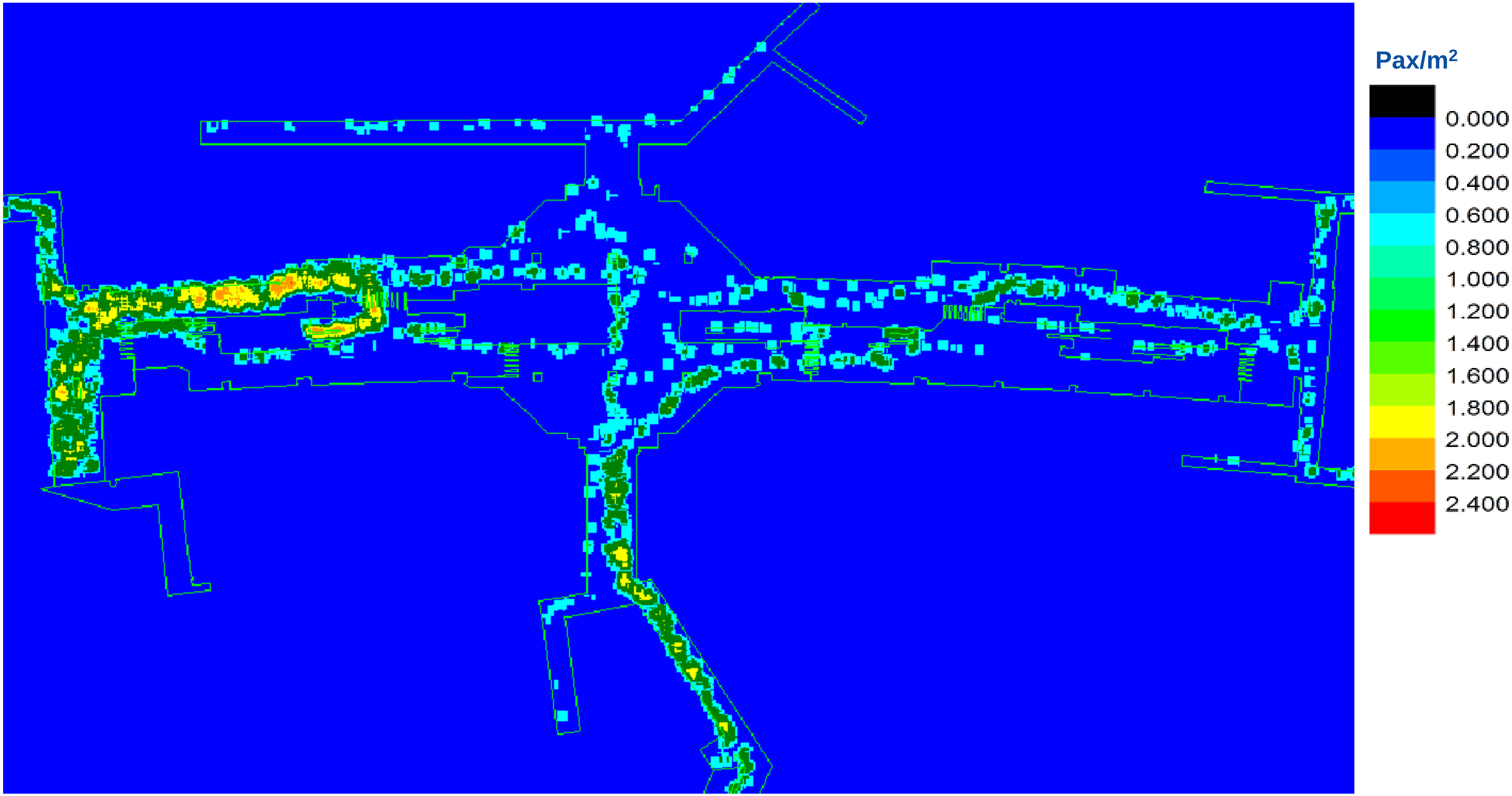


Collision with Walls

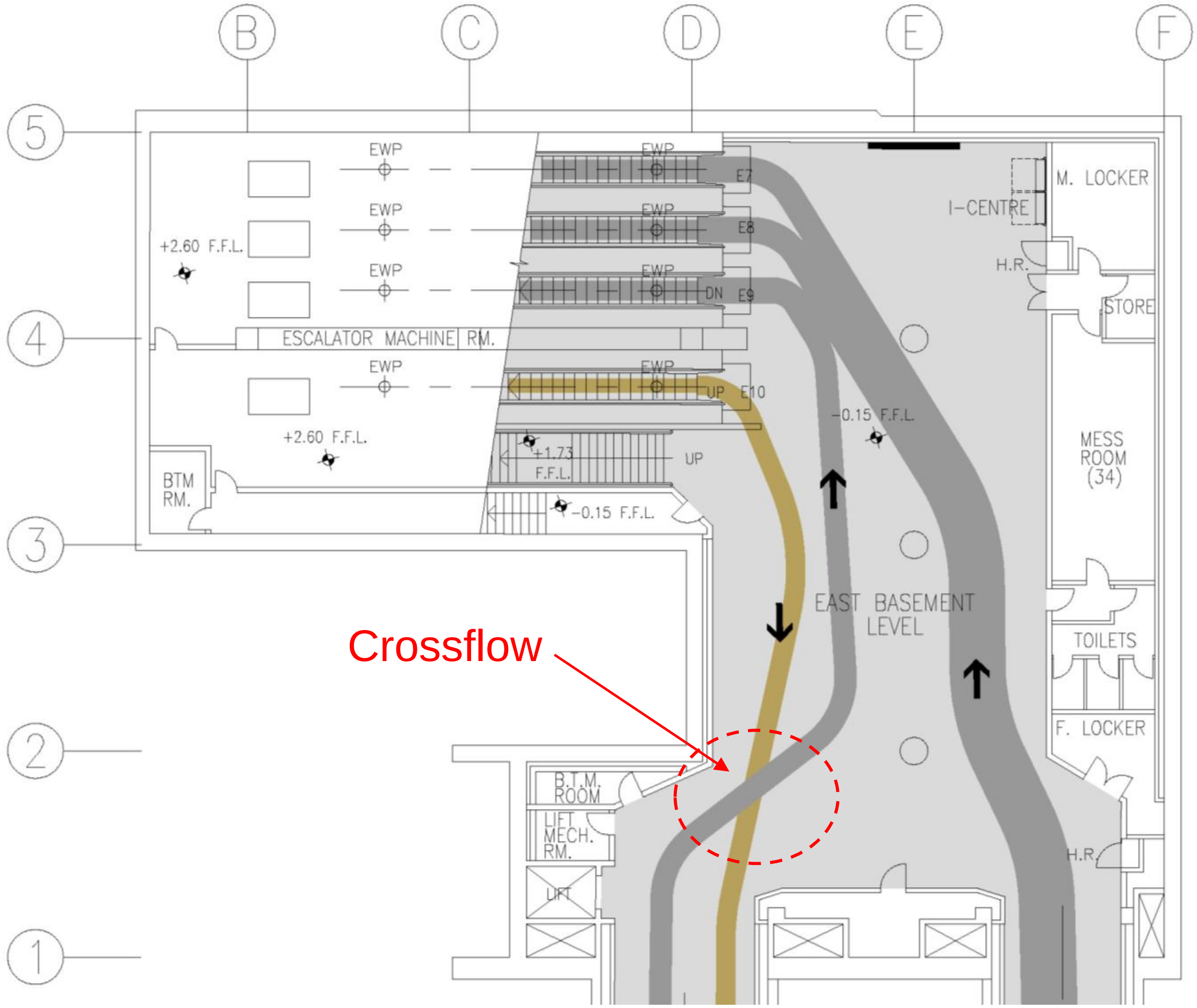
Passenger Flow Simulation



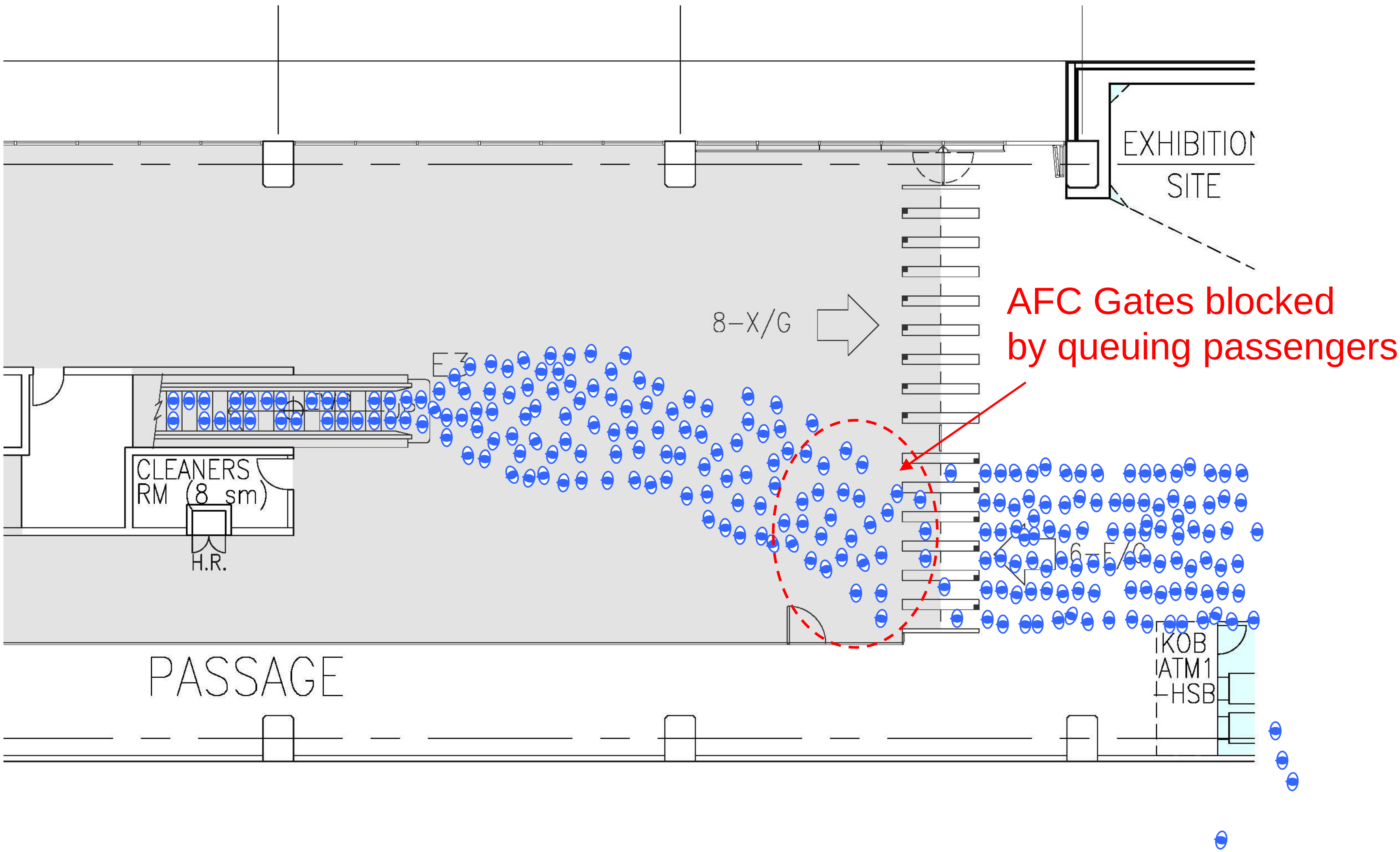
Passenger Flow Simulation



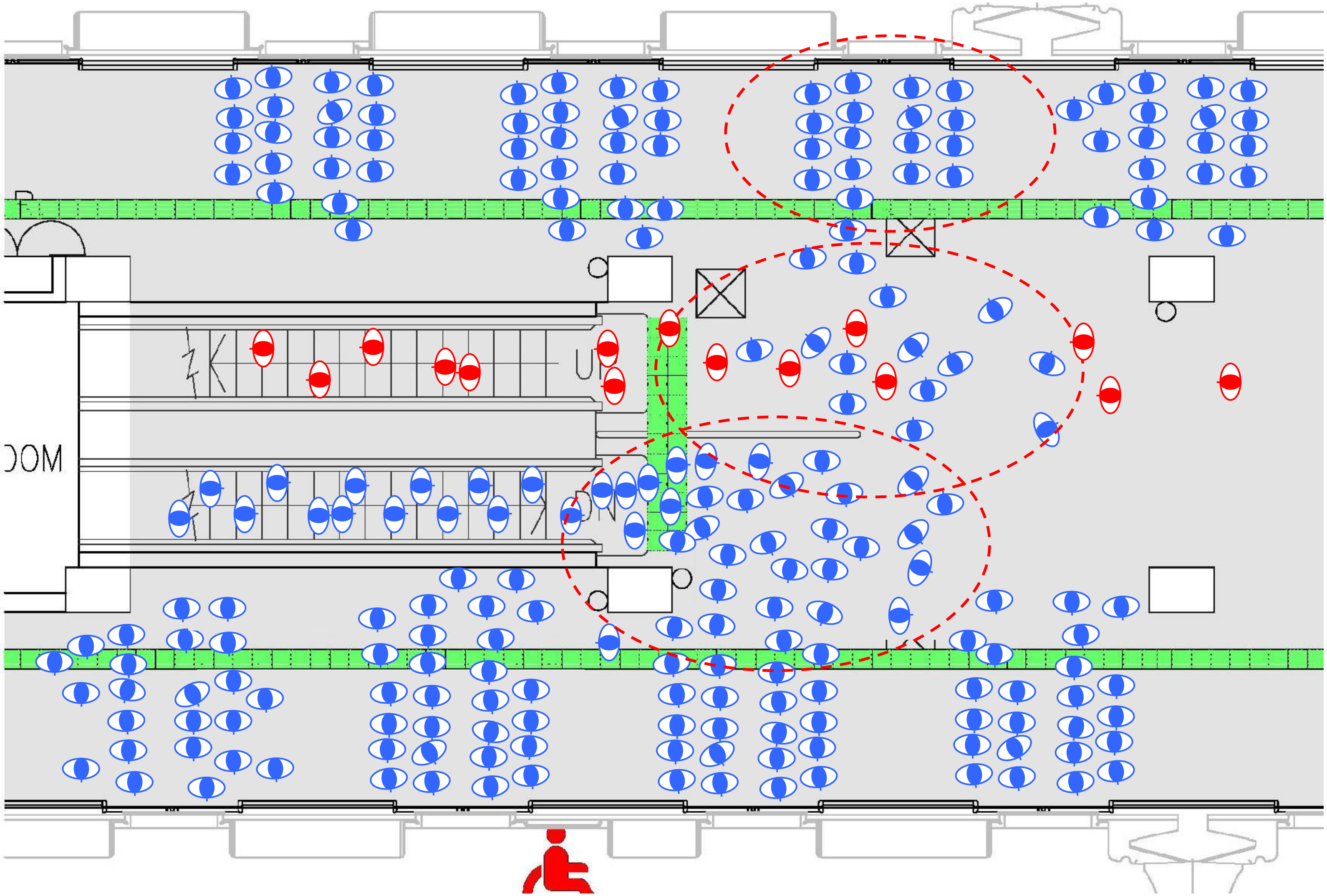
Undesirable Passenger Flow Areas



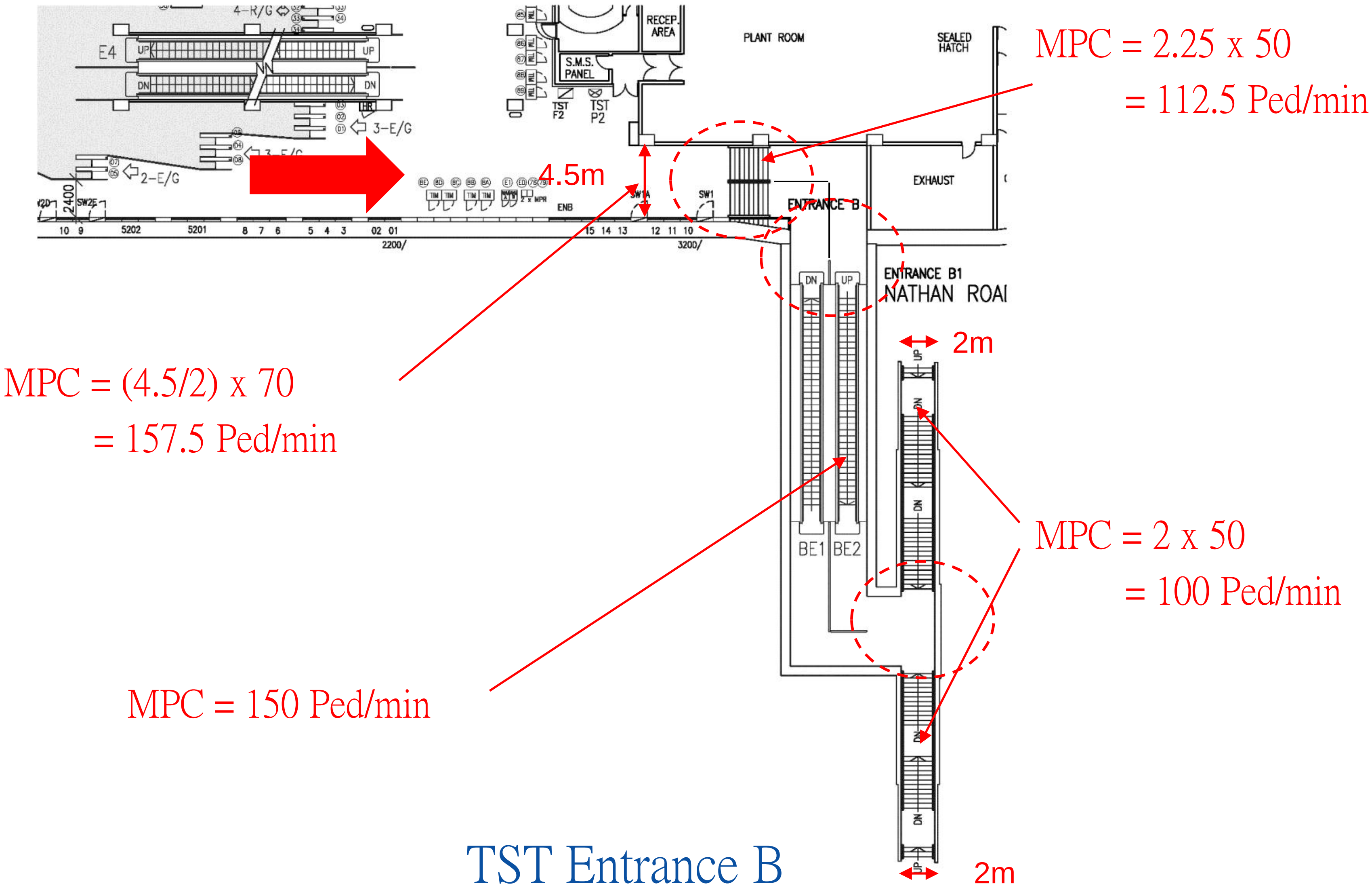
Undesirable Passenger Flow Areas



Undesirable Passenger Flow Areas

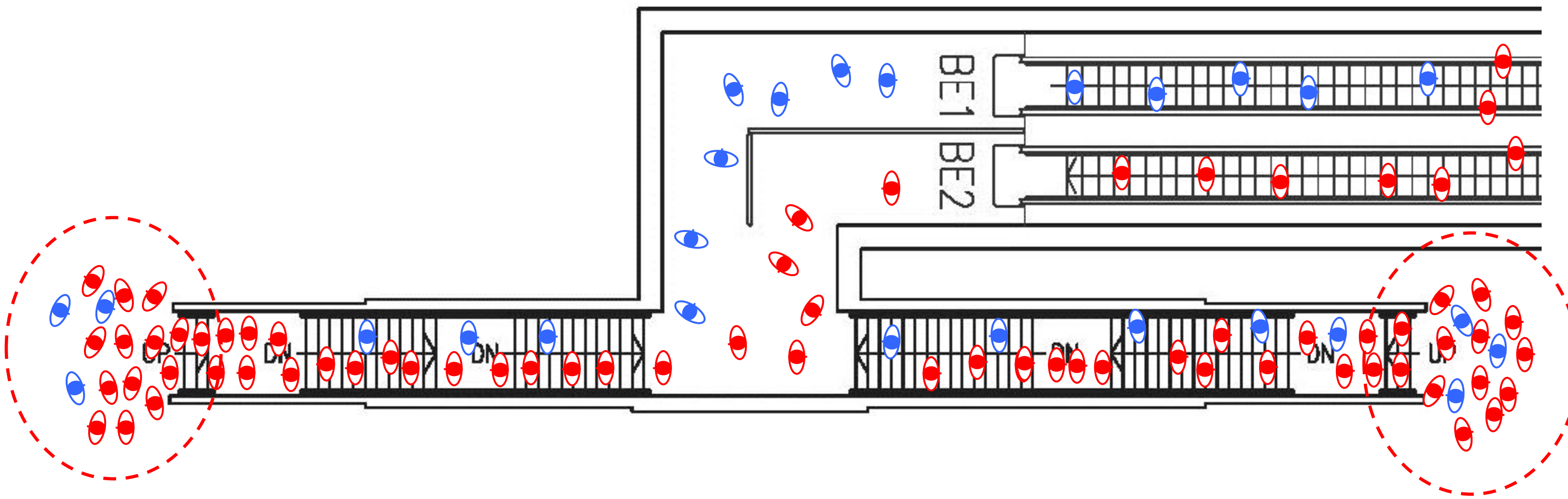


Undesirable Passenger Flow Areas



TST Entrance B

Undesirable Passenger Flow Areas



Entrances may be blocked by pedestrians during rainy days

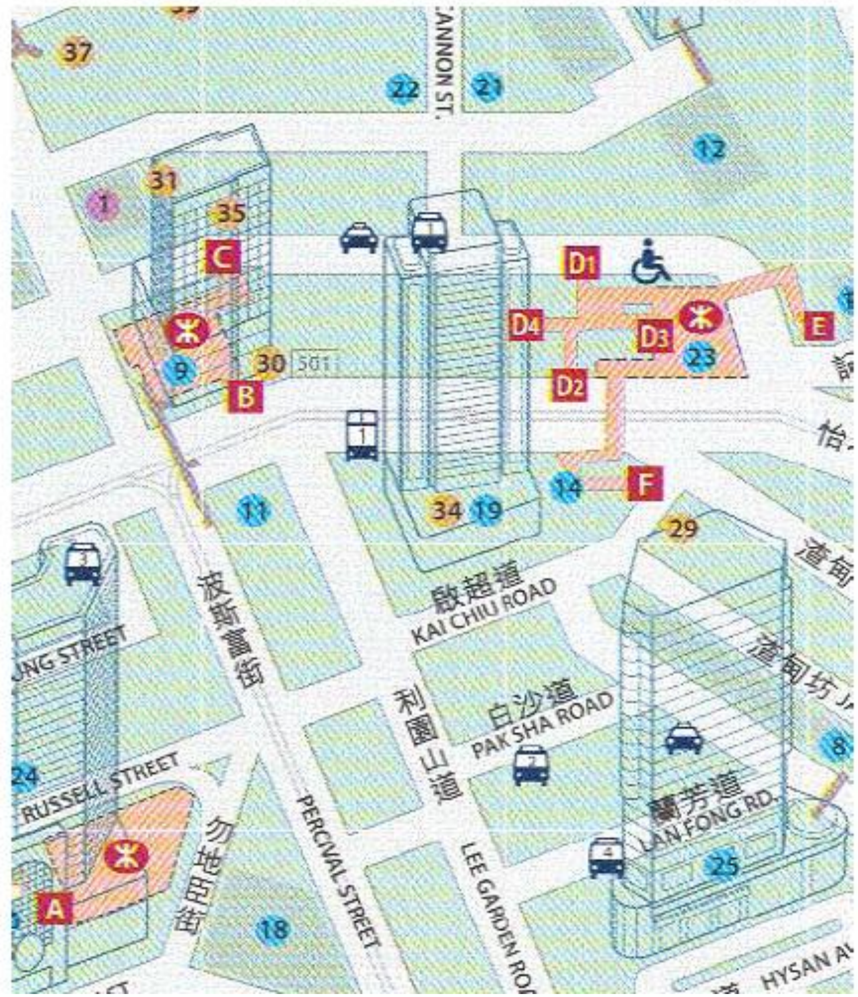
Works in Progress – Transport Modelling

Passenger Flow at Station Entrances

7. Weekday Entrance Pedestrain Flow

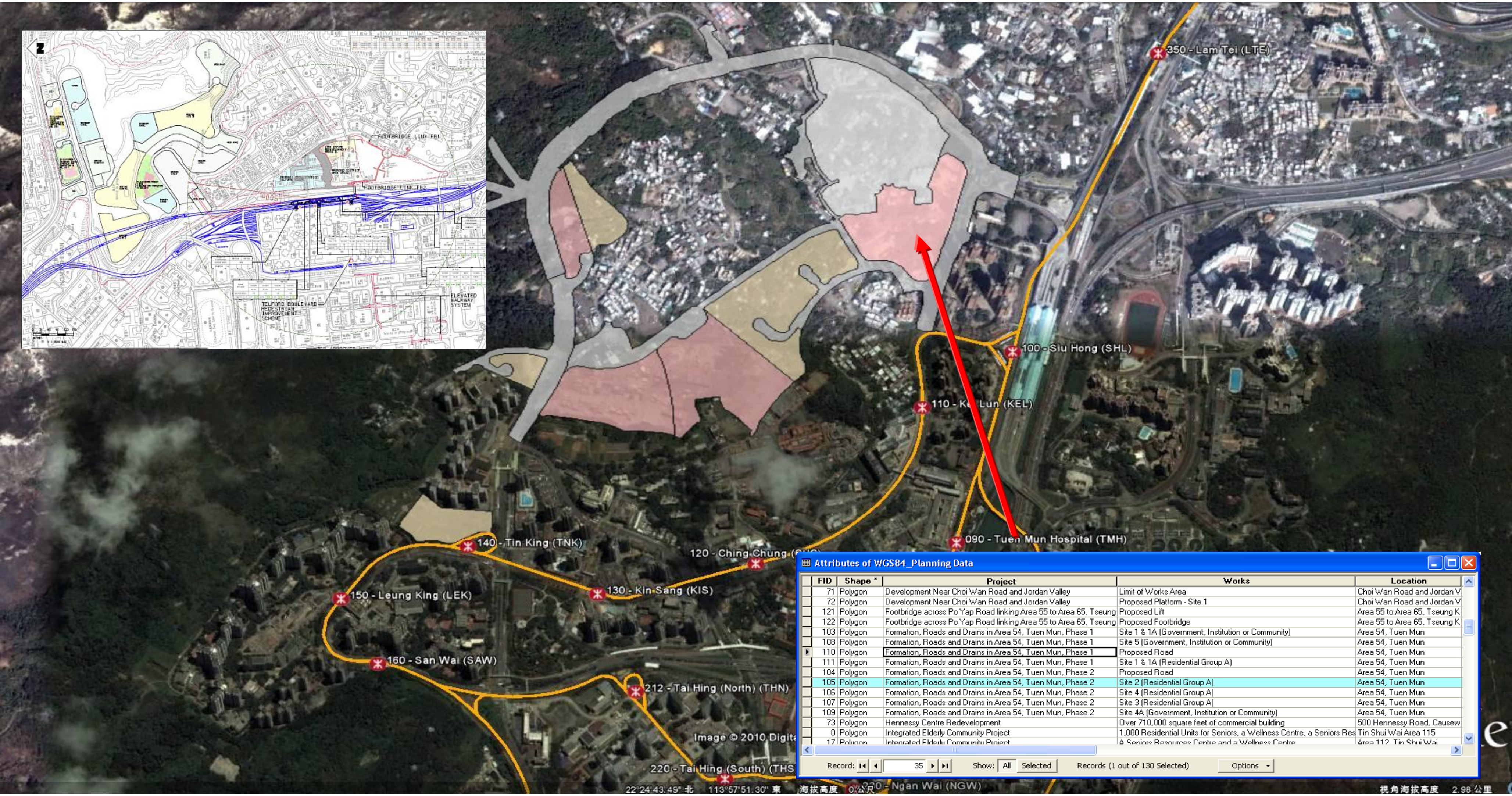
Direction/ Entrance	No. of Pedestrains: Morning Peak Hour	Off Peak Hour	Evening Peak Hour	Estimate Daily: No. of Pede-strains	% Over Station Total
Towards MTR					
A	379	1327	2730	18330	16.2%
B	64	412	588	4557	4.0%
C	735	877	1792	15908	14.1%
D1	268	450	1128	7870	7.0%
D2	698	288	696	9125	8.1%
D3	N.A.	577	1081	9567	8.5%
D4	N.A.	382	568	5728	5.1%
E	1098	1380	2871	24709	21.9%
F	1544	2505	7450	47425	42.0%
DL1	59	129	265	1956	1.7%
From MTR					
A	1800	909	2860	21425	16.2%
B	225	376	755	5526	4.2%
C	1513	607	1610	14858	11.3%
D1	644	523	1325	9818	7.4%
D2	116	276	599	3963	3.0%
D3	N.A.	832	2212	17258	13.1%
D4	N.A.	377	487	5810	4.4%
E	1671	1465	4056	27828	21.1%
F	4255	1824	4245	41859	31.7%
DL1	97	93	134	1407	1.1%

Sketch for Entrance Location of the Station



Development near MTR Stations

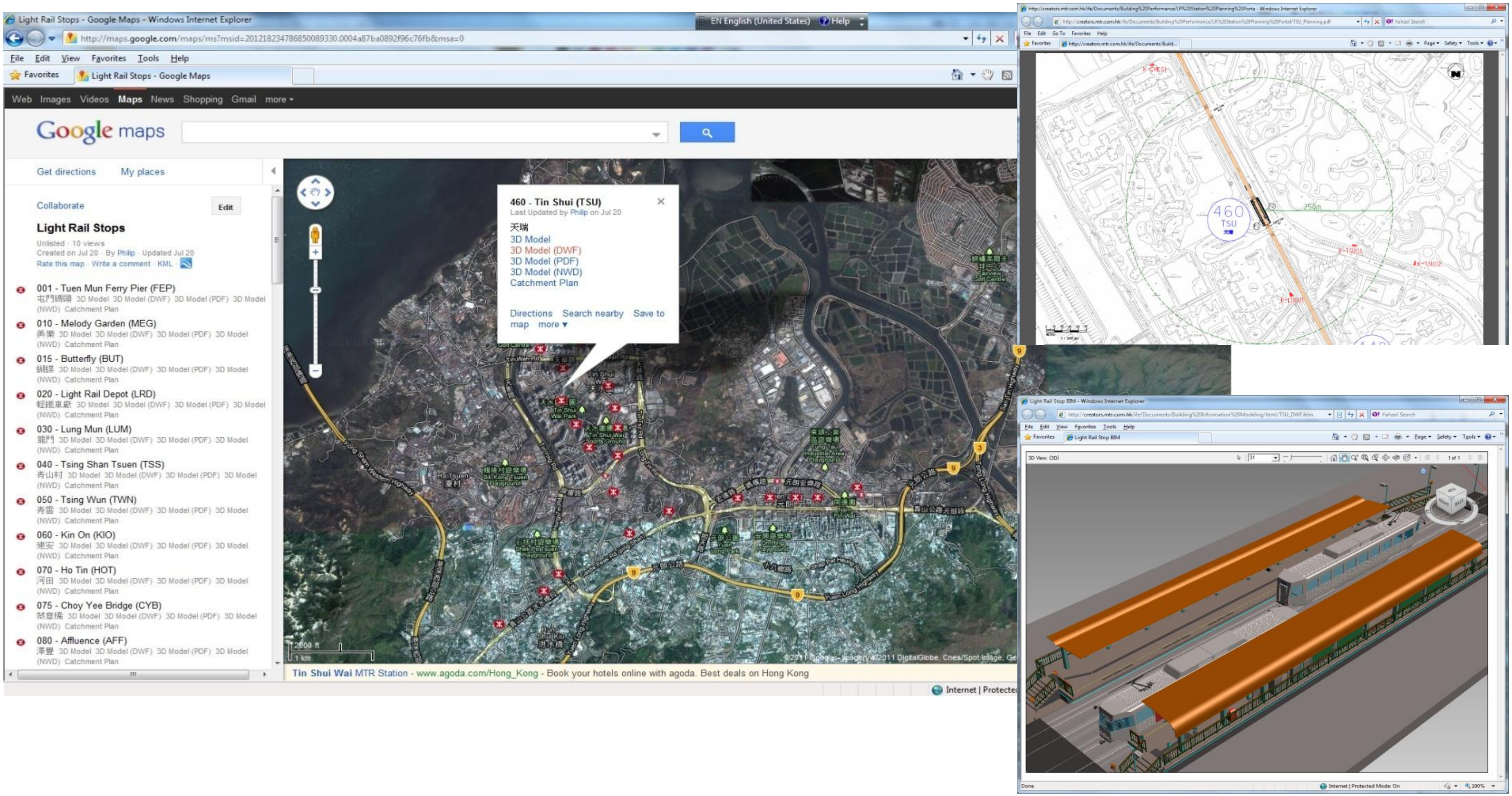
Passenger Flow Simulation



FID	Shape *	Project	Works	Location
71	Polygon	Development Near Choi Wan Road and Jordan Valley	Limit of Works Area	Choi Wan Road and Jordan V
72	Polygon	Development Near Choi Wan Road and Jordan Valley	Proposed Platform - Site 1	Choi Wan Road and Jordan V
121	Polygon	Footbridge across Po Yap Road linking Area 55 to Area 65, Tseung	Proposed Lift	Area 55 to Area 65, Tseung K
122	Polygon	Footbridge across Po Yap Road linking Area 55 to Area 65, Tseung	Proposed Footbridge	Area 55 to Area 65, Tseung K
103	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 1	Site 1 & 1A (Government, Institution or Community)	Area 54, Tuen Mun
108	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 1	Site 5 (Government, Institution or Community)	Area 54, Tuen Mun
110	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 1	Proposed Road	Area 54, Tuen Mun
111	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 1	Site 1 & 1A (Residential Group A)	Area 54, Tuen Mun
104	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 2	Proposed Road	Area 54, Tuen Mun
105	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 2	Site 2 (Residential Group A)	Area 54, Tuen Mun
106	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 2	Site 4 (Residential Group A)	Area 54, Tuen Mun
107	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 2	Site 3 (Residential Group A)	Area 54, Tuen Mun
109	Polygon	Formation, Roads and Drains in Area 54, Tuen Mun, Phase 2	Site 4A (Government, Institution or Community)	Area 54, Tuen Mun
73	Polygon	Hennessy Centre Redevelopment	Over 710,000 square feet of commercial building	500 Hennessy Road, Causew
0	Polygon	Integrated Elderly Community Project	1,000 Residential Units for Seniors, a Wellness Centre, a Seniors Res	Tin Shui Wai Area 115
17	Polygon	Integrated Elderly Community Project	A Seniors Resources Centre and a Wellness Centre	Area 112, Tin Shui Wai

Record: 35 Show: All Selected Records (1 out of 130 Selected) Options

Station Planning Portal



Transport Modelling