DISCRETE EVENT SIMULATION

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Outline

- What is DES?
- How to do DES modelling?
  - Demonstration of Simul8 modelling
- Case study sharing
  - Outpatient: SOC appointment scheduling and waiting time
  - Inpatient: bed crunch and elective admission
  - Polyclinic: resource planning for new polyclinic

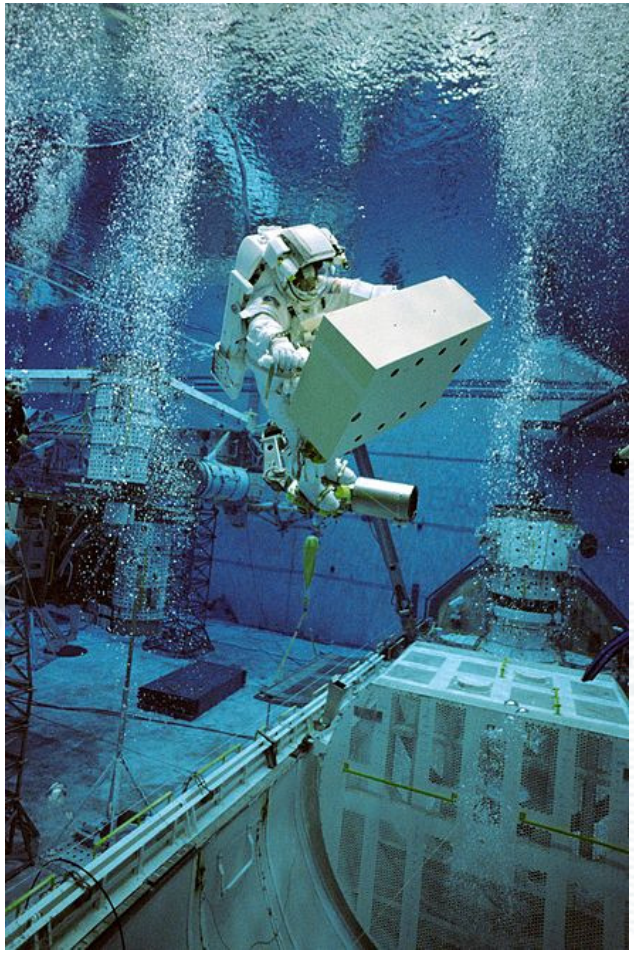
What is simulation?

"Simulation is the process of **designing a model** of a real system and conducting experiments with this model for the purpose either of **understanding the behavior of the system** or of **evaluating various strategies** (within the limits imposed by a criterion or set of criteria) for the operation of a system."

- Robert E. Shannon

Systems Simulation: The Art and Science,1975

What is simulation?



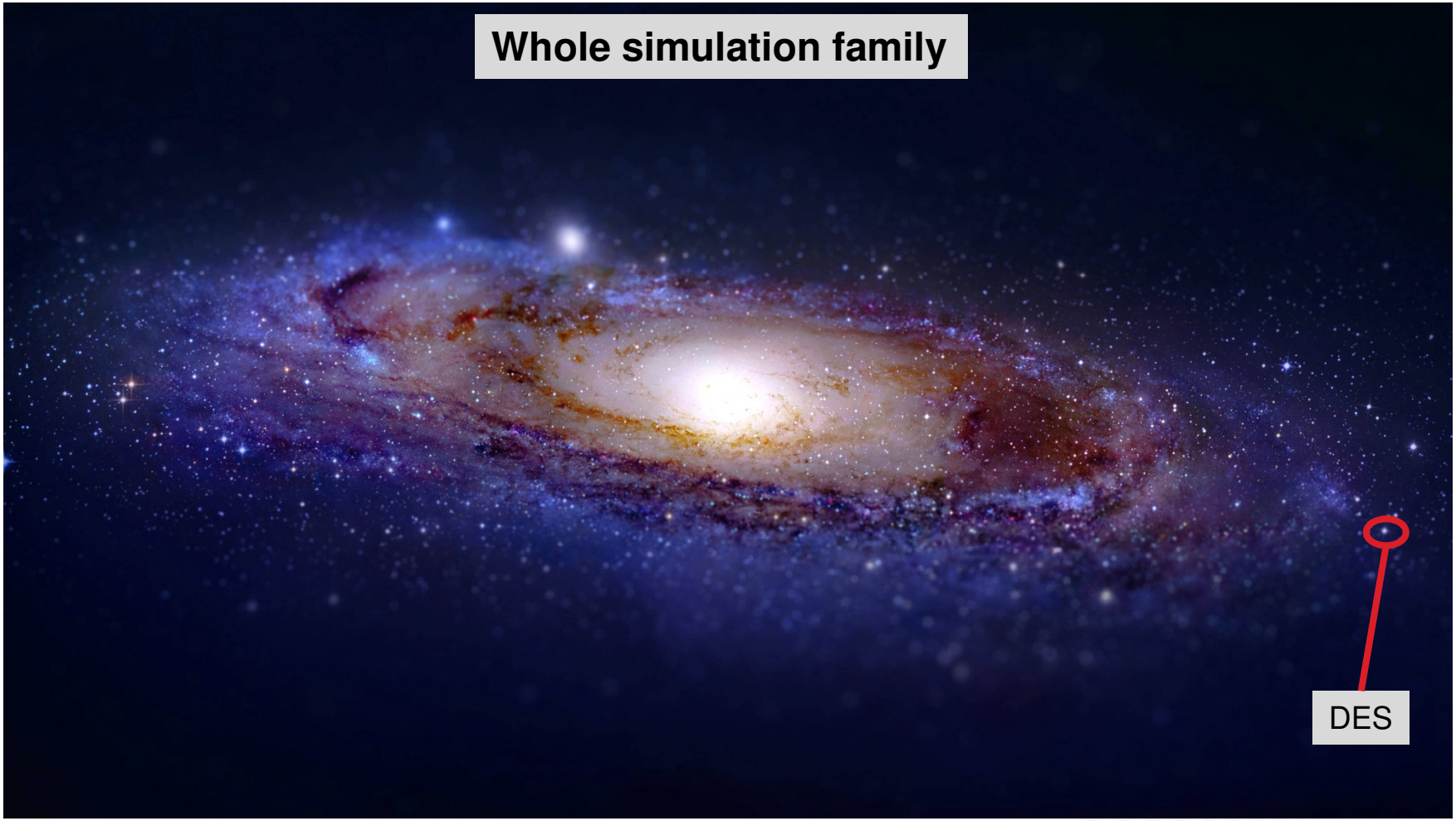
What is simulation?

Computer simulation

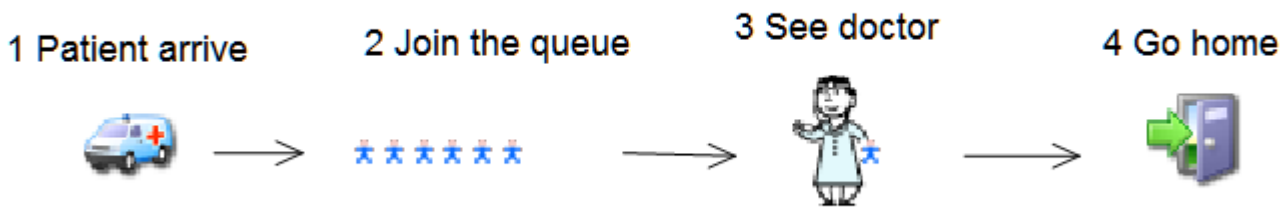
"A computer simulation is an attempt to model a real-life or hypothetical situation on a computer."

-Wikipedia

What do we cover?



What DES looks like?



Definition of DES

"A discrete-event simulation (DES) models the operation of a system as a **discrete sequence of events in time**. Each event occurs at a particular instant in time and marks a change of state in the system."

- Stewart Robinson

Simulation – The practice of model development and use, 2004

Definition of DES

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Simulation – The practice of model development and use, 2004

Real system → **Events in time sequence**

Definition of DES

Real system → **Events in time sequence**

Event	Time
Patient 1 arrives	7:00 AM
Clinic open	8:00 AM
Patient 1 register	8:01 AM
Patient 2 arrives	8:02 AM
Patient 1 consult start	8:05 AM
Patient 2 register	8:06 AM
Patient 1 consult end	8:20 AM
…	…
…	…

DES building blocks

Entity

e.g., patients, staff, machines, kiosk, etc.

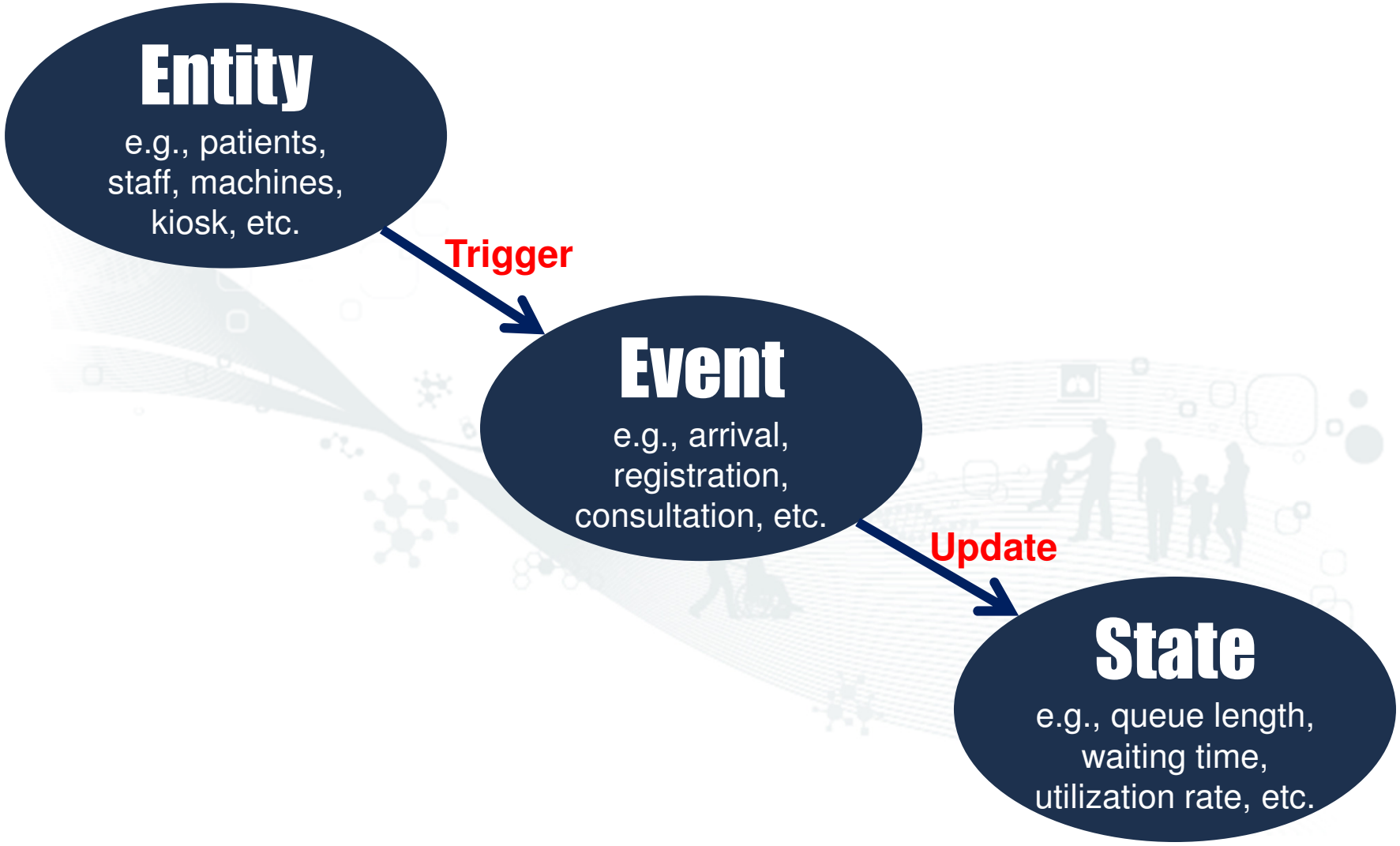
Event

e.g., arrival, registration, consultation, etc.

State

e.g., queue length, waiting time, utilization rate, etc.

DES building blocks



Characteristics of DES

Deterministic e.g., time of news broadcasting	**Stochastic** e.g., time of the next bus
Static e.g., location of a bus stop	**Dynamic** e.g., location of a driving bus
Continuous e.g., gas consumption of driving car	**Discrete** e.g., Queue at an ATM machine

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How to do DES modelling?

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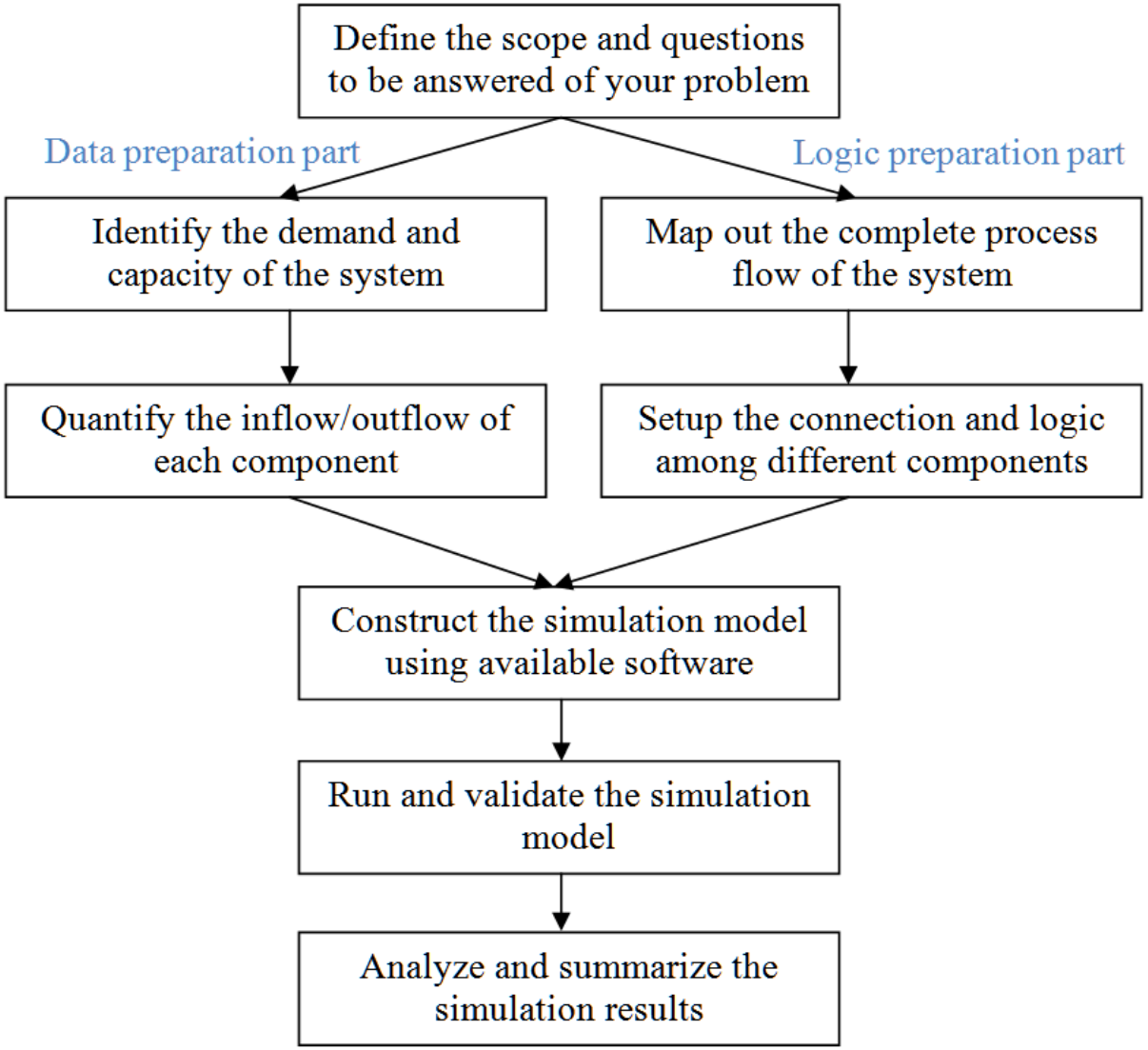
Generic guideline of DES modelling



Choose the suitable tool

Simul 8 Subscription plan starting US$395/user/month	Arena
Anylogic	Flexsim
SimEvents	ProModel

Case study 1
Outpatient: SOC appointment scheduling

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Background

Prevalent problems in SOC

- Long patient waiting time
- Long clinic overtime

DES could be used to identify some possible causes of long waiting time and overtime.

How many appointment slots?

- Suppose an outpatient clinic has one consultation room. It opens from 9am to 11:30am. The average consultation duration per patient is 5 minutes.
- Questions:
  - How many appointment slot will you arrange per day?
  - How do you arrange these appointment slot?

Simulation model

Scenario demonstration

Click here

Scenario comparison

	Waiting time (min)		Over time (min)
	50th%tile	95th%tile	
Scenario 1 (coca cola factory)	0	0	0
Scenario 2 (add patient arrival and consultation variation)	4	16	13
Scenario 3 (compress slots schedule)	28	50	0
Scenario 4 (add clinic lateness)	58	80	30
Scenario 5 (add idle time in between consultations)	93	143	98

Case study 2
Inpatient: bed crunch and elective admission

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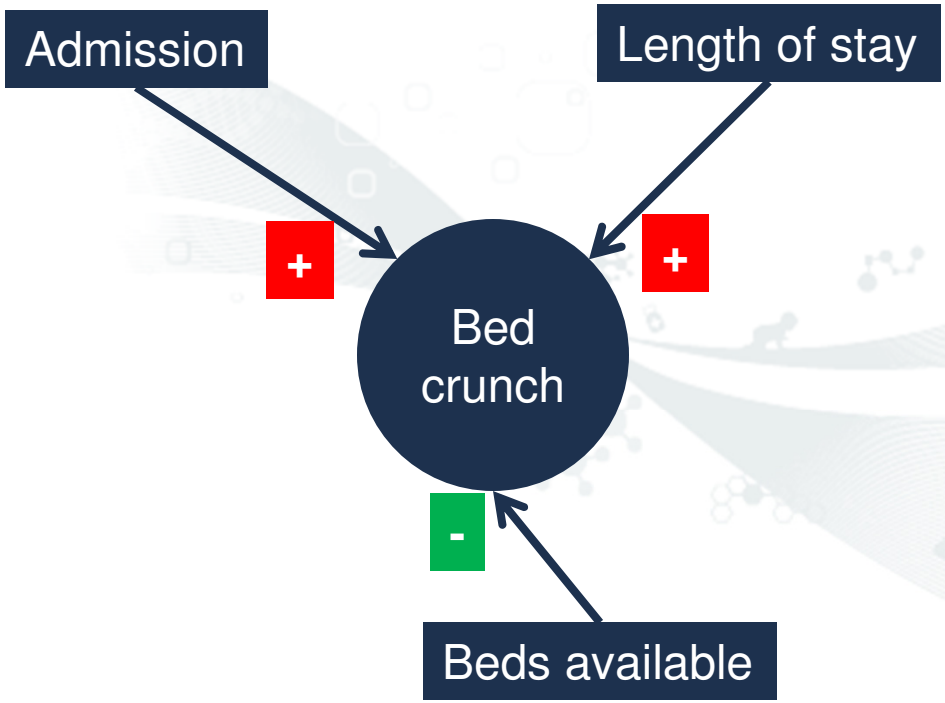
Background



THE STRAITS TIMES

WEDNESDAY, JANUARY 8, 2014

Changi General Hospital started housing patients waiting for beds in this large air-conditioned tent this week. The 800-bed CGH, along with Tan Tock Seng and Khoo Teck Puat hospitals, has resorted to sending patients to Alexandra, one of the few public hospitals here with spare beds. Health Minister Gan Kim Yong said last night that he was aware of the problem – hence, the push to add 1,900 more acute hospital beds and 2,600 community hospital beds by 2020.

ST PHOTO: DESMOND FOO

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over chart

Hospitals facing severe bed crunch take unusual steps

Patients being housed in tent and corridors, or sent to other hospitals

By SALMA KHALIK
SENIOR HEALTH CORRESPONDENT

A SEVERE bed crunch at Singa-

Together with Khoo Teck Puat Hospital (KTPH), they have also resorted to sending patients to Alexandra Hospital, one of the few public hospitals here with spare beds.

waited more than 24 hours for an inpatient bed."

This is despite CGH already renting a ward from Parkway East Hospital and the next-door St Andrew's Community Hospital.

Mr Liak Teng Lit, head of Alexandra Health which runs KTPH, said: "Every day, we have to make decisions regarding our 500 patients. Those who are not so sick are discharged to make way for

beds and 2,600 community hospital beds by 2020.

He added: "The hospitals have also implemented various measures to alleviate the bed crunch.

"CGH has set up a nine-bed Short Stay Unit and expanded its observation ward from 12 to 20 beds at the Emergency Department and also set up an Admission Transit Area for patients who are waiting for a bed in the ward.

Madam Fatimah Beevi, 60,

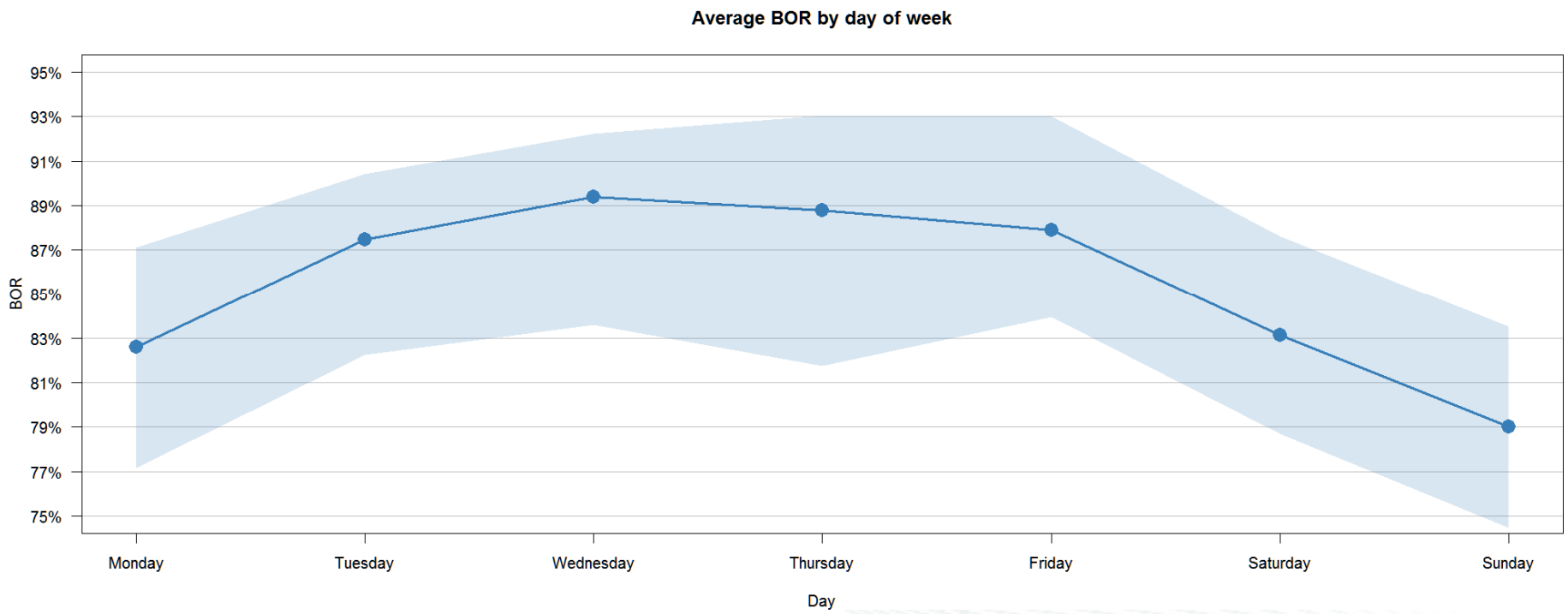
Measuring bed crunch

$$Bed\ occupancy\ rate\ (BOR) = \frac{Occupied\ beds}{Beds\ in\ service}$$

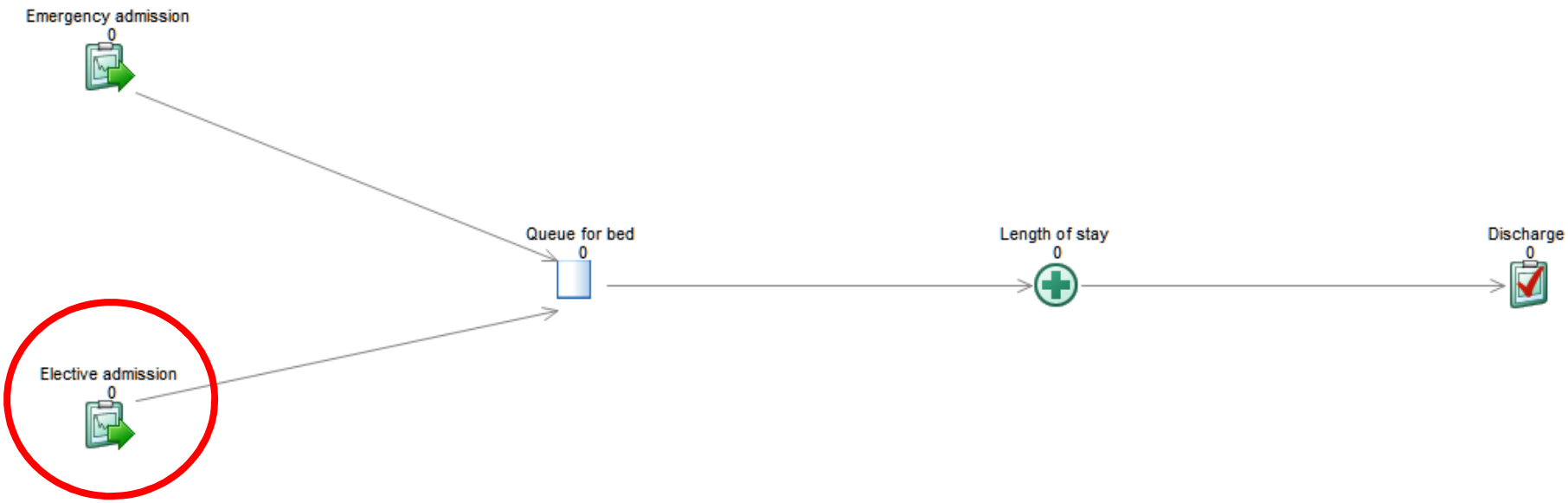
How to bring down BOR?

Possible solution	Limitation
More beds	Cost, space constraints
Early discharge	May cause readmission
Smooth admission	Schedule feasibility

BOR fluctuation by day of week



Simulation model



Scenarios considered

- Baseline: existing elective admission pattern
- Scenario 1a: evenly spread elective admission
- Scenario 1b: evenly spread elective admission except Saturday
- Scenario 2: matching elective admission with emergency admission

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Weekly
Baseline	38	42	35	36	21	2	20	194
Scenario 1a	28	27	27	28	28	28	28	194
Scenario 1b	32	32	32	32	33	0	33	194
Scenario 2	19	15	20	24	25	41	50	194

Simulation result

	Baseline	Scenario 1a	Scenario 1b	Scenario 2
BIS	908	908	908	908
Weekly admission	898	898	898	898
% of EM	22%	22%	22%	22%
% of EL	78%	78%	78%	78%
BOR (Mean)	85.5%	85.4%	85.4%	85.4%
BOR (sd)	4.8%	3.5%	3.9%	3.6%
BOR (95th%tile)	92.1%	90.7%	91.3%	90.6%
% of days BOR over 90%	19.6%	8.4%	10.9%	8.4%

Case study 3
Polyclinic: resource planning for new polyclinic

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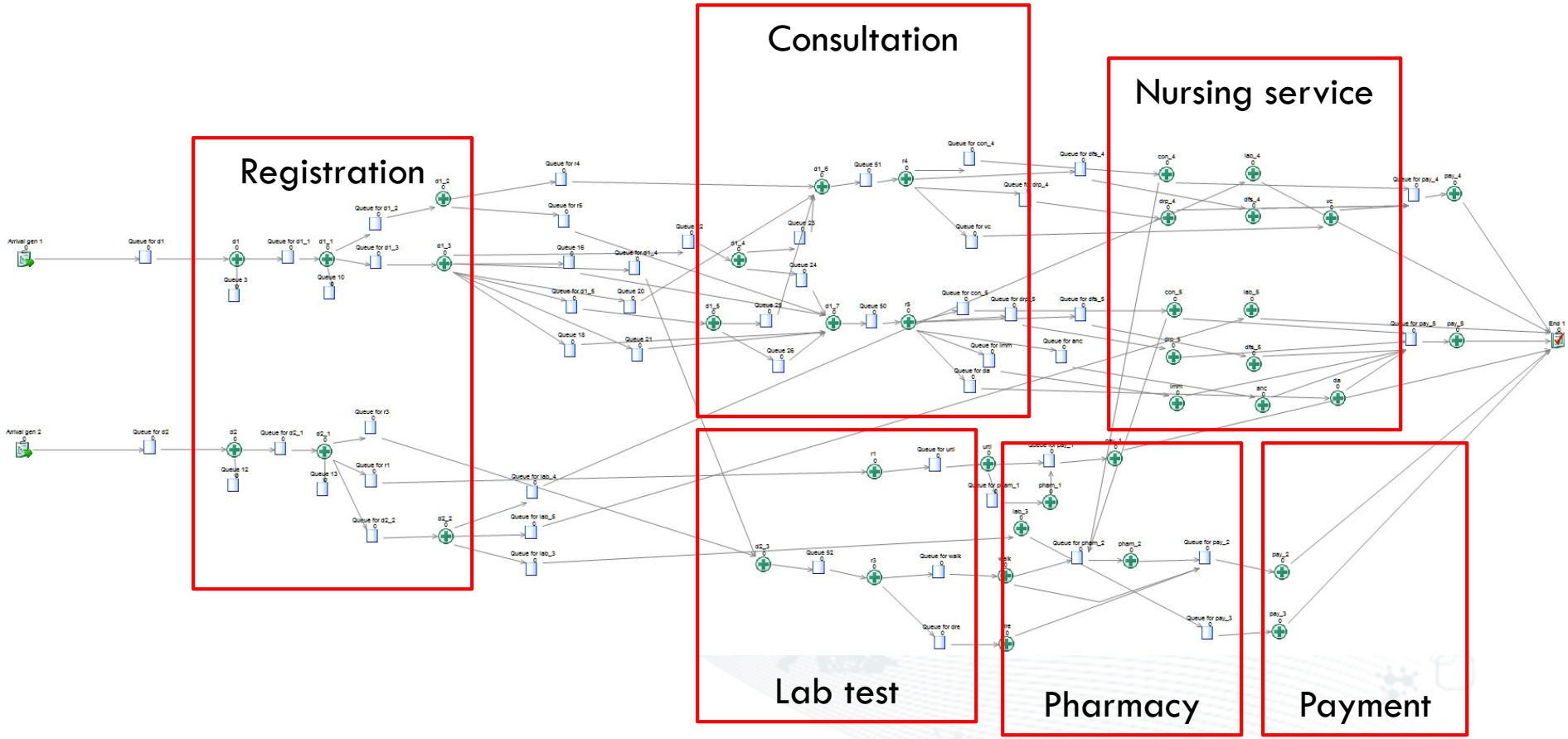
Background

When planning new polyclinic, DES may help in

- Validate workflow
- Estimate resources needed
- Estimate waiting time

Logic workflow/simulation model



Stations considered

Station	%
Registration	100.0%
Consultation	72.4%
Nursing service	15.1%
Lab test	31.7%
Pharmacy	56.8%
Payment	100.0%

Visit sequence

Top 10 sequence	%
REG-CON-PHM-PAY	31.4%
REG-LAB-PAY	11.8%
REG-LAB-CON-PHM-PAY	9.3%
REG-CON-PAY	6.9%
REG-NUR-PAY	5.3%
REG-NUR	4.4%
REG-PHM-PAY	4.1%
REG-PAY	2.6%
REG-CON-LAB-CON-PHM-PAY	1.7%
REG	1.6%
The remaining 1841 patterns	21.0%
Total	100%

Daily workload breakdown by stations

	2018		2023		2030	
Station	Mon-Fri	Sat	Mon-Fri	Sat	Mon-Fri	Sat
Registration	1350	937	1509	1047	1090	756
Consultation	977	678	1093	758	789	547
clinical module	707	490	790	548	571	396
Walk-in	195	135	217	151	157	109
URTI	76	53	85	59	62	43
Nursing service	204	141	228	158	165	114
IMM	54	37	60	42	43	30
Dressing	47	32	52	36	38	26
DRP	27	19	30	21	22	15
DFS	27	18	30	21	21	15
VC	24	17	27	19	19	13
ANC, PAP Smear,FPC, FPP	14	10	16	11	12	8
DA,NNJ	11	8	13	9	9	6
Lab test	433	302	483	337	351	245
Pharmacy	827	592	957	695	719	529
Payment	1350	937	1509	1047	1090	756

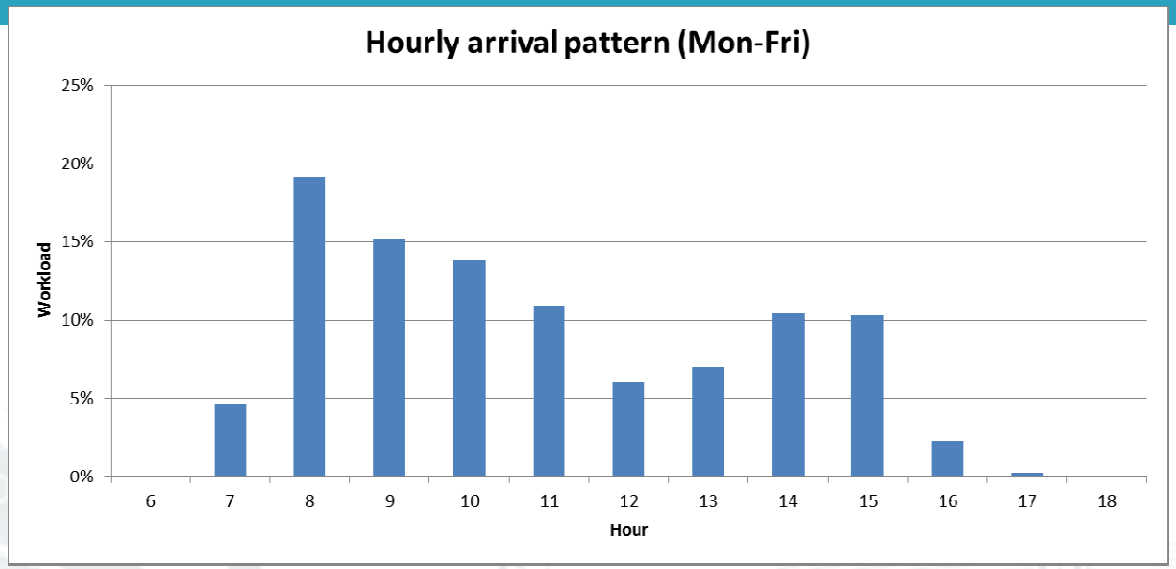
Station location

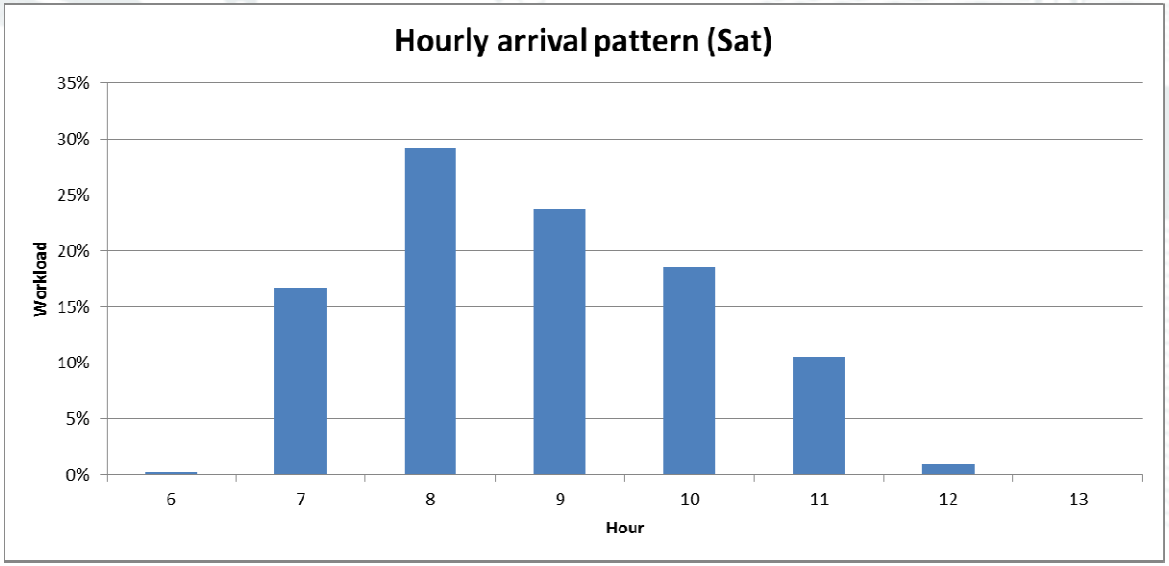
Floor	Registration	Payment	Services
1	Yes	Yes	URTI clinic, Satellite pharmacy
2	Yes	Yes	Walk-in clinic, Dressing, Main pharmacy
3	No	No	Lab
4	Yes	Yes	Clinical modules at level 4, Lab, IMM/DA/NNJ/ANC, DPR/DFS
5	Yes	Yes	Clinical modules at level 5, Lab, DRP/DFS, VC

Service timing of each station

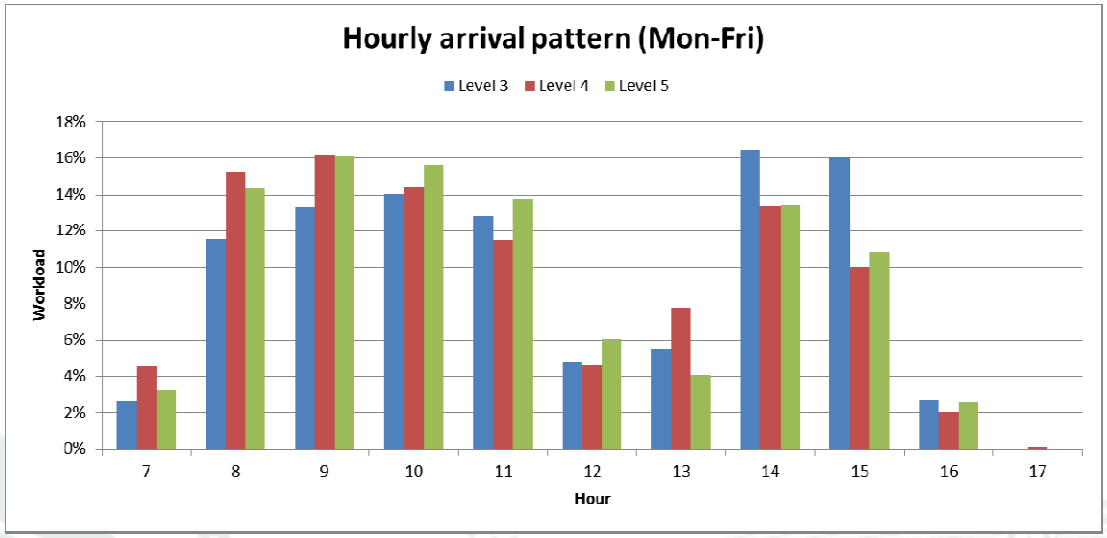
Station	Service timing (mins)
Registration	3
Consultation	
clinical module	13
Walk-in	9
URTI	9
Nursing service	20
Lab test	5
Pharmacy	5
Payment	3

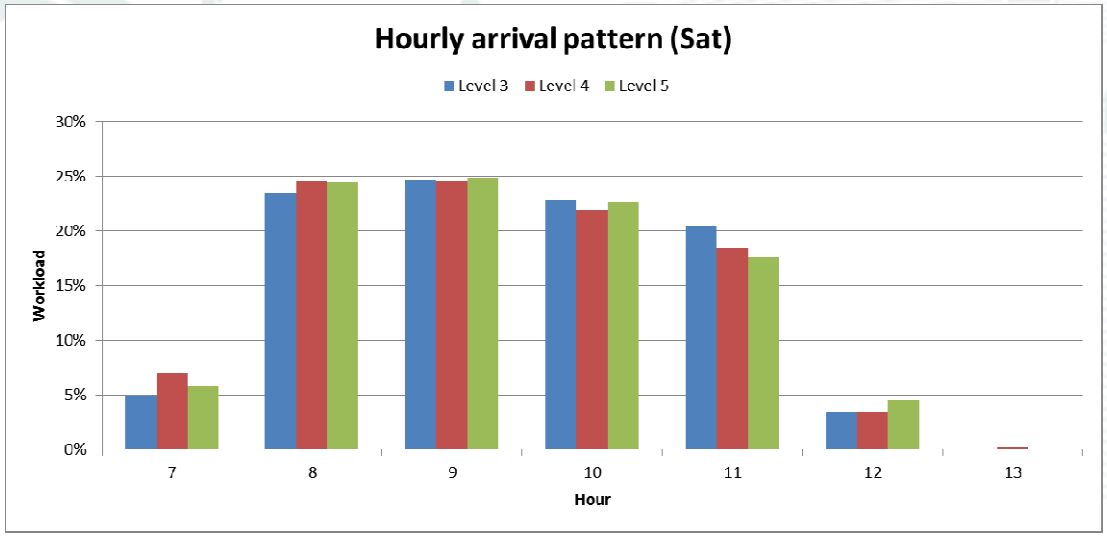
Hourly arrival pattern - consultation





Hourly arrival pattern - nursing service





Simulation result - 2018 Mon-Fri

Floor	Station	Resource	50th%tile WT	95th%tile WT	95th%tile Q
1	Registration	2	0	3	2
	URTI clinic	3	2	12	4
	Satellite pharmacy	3	5	11	7
	Payment	2	0	1	1
2	Registration	4	0	4	5
	Walk-in clinic	4	27	58	26
	Dressing	4	3	13	3
	Main pharmacy	12	10	22	54
	Payment	7	1	6	15
3	Lab	2	1	5	2
4	Registration	5	2	8	14
	clinical module	12	12	33	31
	Lab	4	2	8	7
	DRP	1	16	48	3
	DFS	2	2	7	1
	IMM	4	6	22	5
	ANC, etc.	2	3	11	2
	DA/NNJ	2	2	8	1
	Payment	2	2	8	4
5	Registration	5	1	6	10
	clinical module	16	12	33	41
	Lab	4	2	8	7
	DRP	1	16	48	3
	DFS	2	2	7	1
	VC	2	10	33	4
	Payment	2	0	3	3