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1. Introduction

The walk-in health centre is a no-appointment facility where nurse triages and prioritises patients who will be treated by doctors based on priority. However, the limited number of doctors and the priority setting might lead to the left of patients in low priority owing to excessive queues or long waiting times. To improve the handling of low-priority patients, introducing a nurse practitioner who can individually handle 80% of the patients in low priority is proposed by the management team. Although the renege of low-priority patients might remain, the introduction of nurse practitioner reduces the departure and the waiting time of low-priority patients. To verify the feasibility of the approach, the software simul8 is utilised to simulate a regular scenario and the proposed condition to identify whether the introduction of a nurse practitioner reduces the baulking and reneging of low-priority patients.

The report starts with the conceptual model of original health centre and the scenario with an additional nurse practitioner. Then the process of the two simulation models built in simul8 is described. Finally, the analysis of results and the verification process of the two simulation models are presented.

2. Conceptual Model

To simulate the current problem and proposed situation of the walk-in health centre, the conceptual model is developed and split into objectives, inputs, and outputs. Afterwards, model scope and level of detail are identified to build activity cycle diagram and logic flow diagram with assumptions and simplification.

2.1 Objectives

The management of the clinic aims to improve the handling of low-priority patients; thus, the objective of model is to reduce the average waiting time for low-priority patients waiting to receive the treatment and the number of patients leaving before receiving the treatment so that low-priority patients wait for less than before and the number of low-priority patients leaving earlier decreases with the use of 1 nurse, 4 doctors, and 1 extra nurse practitioner and different layout of the organisation.

2.2 Inputs

Inputs are identified as resources, work items, and triage rules and classified into quantitative inputs and qualitative inputs shown below:

2.2.1 Quantitative Inputs

i. 1 nurse
ii. 4 doctors
iii. 1 extra nurse practitioner
iv. Patients (the arrival rates follow the exponential distribution with a mean of 6 minutes.)

2.2.2 Qualitative Inputs

i. Patients are split into one of 3 branches after triage according to priority level.
ii. Low-priority patients leave before entering the queue after triage if the number of patients waiting in queues from different priorities exceeds 10.
iii. Patients in low priority quit the queue if the waiting time surpasses 15±5 minutes.
iv. In the new model, 80% of low-priority patients leave after the treatment of the nurse practitioner, 20% flow into the queue to wait for a doctor.

2.3 Outputs

Model objectives are deconstructed to identify the outputs to measure the achievement and the reasons for failure to meet objectives.

2.3.1 Achievement of Objectives

To determine the achievement of the objectives, 3 targets are taken into account:

1. Number of low-priority patients leaving the clinic after triage
2. Number of low-priority patients leaving after waiting for 10 to 20 minutes in the queue
3. Average time of low-priority patients receiving the medical treatment from either a nurse practitioner or a doctor

2.3.2 Reasons for failure

To identify reasons for failure to meet the objectives, 5 results are analysed:

1. Min, max, mean, and variance of waiting times for patients in each priority
2. Bar chart of waiting time for low-priority patients in the queue
3. Utilisation of nurse
4. Utilisation of doctors
5. Utilisation of nurse practitioner

2.4 Model Contents

For the purpose of simulating the configure of the project in Simul8, the models are broken into components, model scope, level of detail, assumptions, and simplifications.

2.4.1 Model Components

The components of the models are classified as entities, activities, queues, and resources:

- Entities: patients in low/medium/high priority
- Activities: service in triage room, treatment by doctor, treatment by nurse practitioner in proposed model
- Queues: queue for triage, queue for doctors in low priority (same as queue for nurse practitioner in proposed model), queue for doctors in medium/high priority/after nurse practitioner
- Resources: 1 nurse, 4 doctors, 1 nurse practitioner in proposed model

2.4.2 Model Scope & Level of Detail

Model scope (Table 2.1) and level of detail (Table 2.2) are introduced to demonstrate the justification, comments, and whether to include the components of scenario into the models.

Based on the current model, “Queue for doctors in low priority” is replaced by “Queues for nurse practitioner”, and “Queues for doctors after nurse practitioner” and “Nurse practitioner” are added into model scope of the proposed model as Table 2.1.

Table 2.1: Model Scope

Component	Include/Exclude	Justification
Patients	Include	Flow through the service processes
Nurse	Include	Experimental factor
Doctor	Include	Experimental factor
Nurse practitioner	Include	Experimental factor
Other staff-clinic activities (i.e., payment)	Exclude	Do not interconnect with the diagnosis services
Queues for triage by nurse	Include	Required for waiting time responses
Queues for doctors after nurse practitioner	Include	Required for waiting time responses
Queues for doctors with medium priority	Include	Required for waiting time responses

Queues for doctors with high priority	Include	Required for waiting time responses
Queues for nurse practitioner	Include	Required for waiting time responses
Queues for other activities (i.e., medicine collection)	Exclude	Not related to the diagnosis services
Parking spaces	Exclude	Not related to waiting for diagnosis

Table 2.2: Level of Detail

Component	Detail	Include/Exclude	Comments
Patients	Inter-arrival time	Include	Exponential Distribution
	Priority	Include	Percentage Distribution
Nurse triage	Service time	Include	Distribution
	Set-up/change-over	Exclude	Assume no time needed
Doctor diagnosis	Service time	Include	Distribution
	Set-up/change-over	Exclude	Assume no time needed
Nurse practitioner	Service time	Include	Distribution
Diagnosis	Set-up/change-over	Exclude	Assume no time needed
Queues	Quantity	Include	5 queues
	Capacity	Exclude	No limit
	Queue discipline	Include	Assume FIFO discipline
	Routing	Include	Percentage route out
Nurse	Quantity	Include	1
	Where required	Include	triage
Doctor	Quantity	Include	4
	Where required	Include	Diagnosis for 3 priorities
Nurse practitioner	Quantity	Include	1
	Where required	Include	Diagnosis for low priority

2.4.3 Assumptions & Simplifications

Owing to the limit and the performance of the model, assumptions and simplifications are taken as the following to reduce the model complexity.

- Assumptions:
  - i. The priority of patients waiting for doctor after receiving the treatment from nurse practitioner is higher than high-priority patients.
  - ii. All doctors can treat all patients in different priorities.
  - iii. No shelf time is required for patients in high or medium priority in the queue.
- Simplifications:
  - i. The priority of incoming patients follows the probability distribution with 25% high

priority, 60% medium priority, and 15% low priority.

ii. Travel time between nurses and triage, doctors and treatment, and nurse practitioner and treatment are set to zero.

iii. Nurses and doctors are always available throughout the day and the simulation days

iv. No need to set up or change over for nurses and doctors

2.4.4 Activity Cycle Diagram

In order to simulate the project, the activity cycle diagram as Appendix 5.1 shows that patients are triaged into 3 queues according to the priority level, and the patients in medium and high priority will leave only after being treated by a doctor. Meanwhile, the low-priority patients decide to leave if the sum of the queues for 3 priorities is more than 10 or the waiting time in the queue exceeds 10 to 20 minutes.

Figure 2.1 demonstrates the proposed introduction that 80% of low-priority patients treated by a nurse practitioner at the activity **"Treatment for Low-priority Patient"** leaves; the rest needs to be cured by a doctor at the activity **"Treatment after a nurse"** with the highest priority. Moreover, patients in low priority decide to not enter the queue if more than 10 people are waiting in the **"Queue for Low Priority"** rather than the sum of 3 queues.

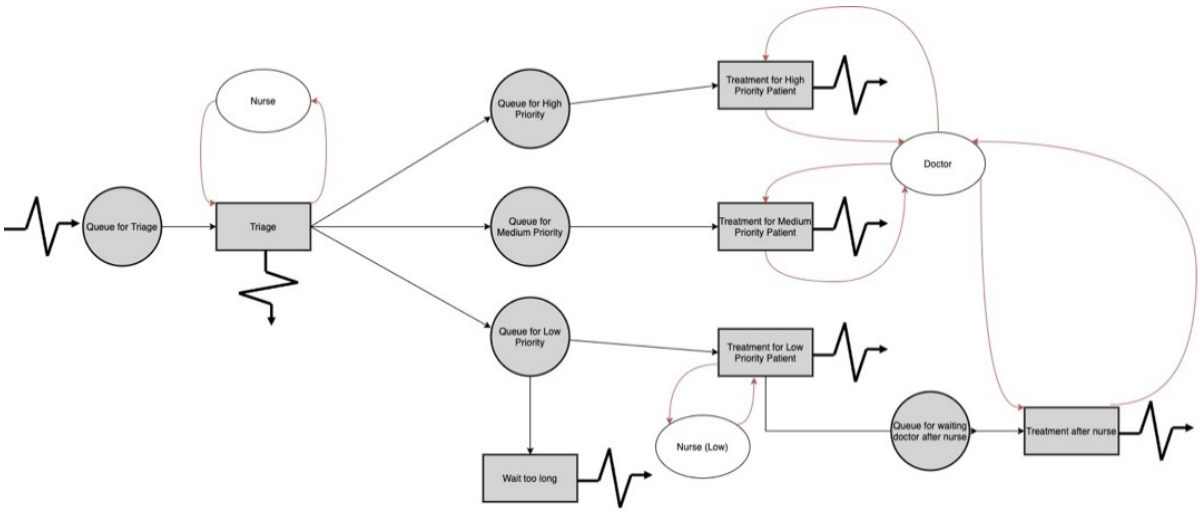


Figure 2.1: Activity Cycle Diagram – Proposed Situation

2.4.5 Logic Flow Diagram

Patients are triaged into 3 different routes as Appendix 5.2. However, only patients in low priority have to make a decision to leave either more than 10 people in the queue or waiting

for more than 15±5 minutes; otherwise, patients in other priorities will stay in the queue until receiving the treatment.

The only difference between the current situation and the proposed project is that patients in low priority might need to go through further treatment by a doctor as Figure 2.2.

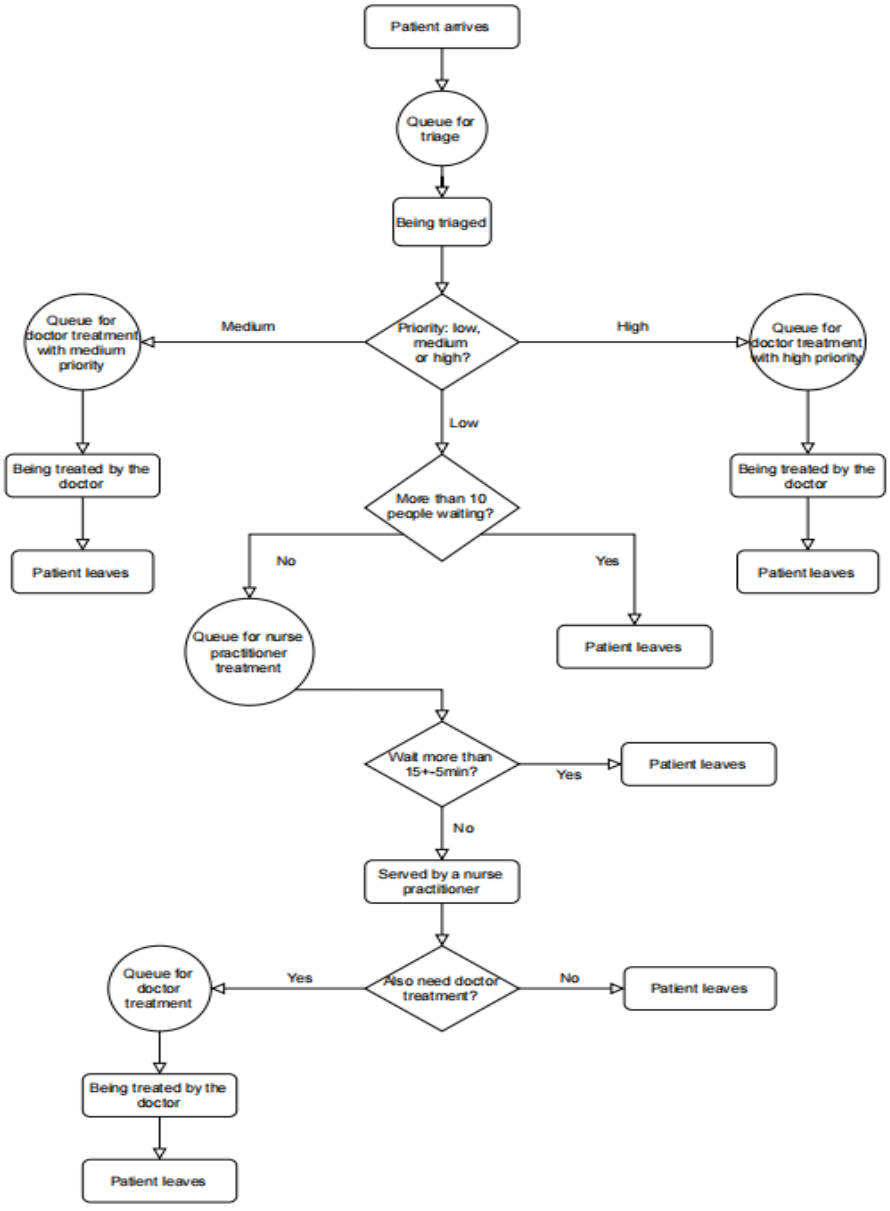


Figure 2.2: Logic Flow Diagram – Proposed Situation

3. Model Construction

The process of scenario is scripted out as the layout of the Simul8 model shown in Appendix 5.3. After being triaged by the nurse, the waiting queue for treatment is separated into 3

different routes according to priority for the purpose of estimating the results and observing the animation simulation. Eventually, the simulation adding nurse practitioner is deployed as Appendix 5.4 that the decision logic of leaving low-priority patients changes so as to adapt to the new deployment.

4. Verification & Validation

To verify the performance of each element and validate the models, both models are tested 100 times on the time scale of 1 day with operation hours from 8 am to 6 pm to measure and compare the statistically justifiable results. The models are inspected in 4 different methods, including structured walkthrough, animation inspection, trace analysis, and test runs.

4.1 Structured Walkthrough

Both of the models are tested in 100 trials after eliminating randomness with fixed input value, right data, and logic. The counts for walk-in patients at start point equal to the counts for patients leaving in each route, which shows the completed and correct flow of patients. The patients are triaged into high, medium and low priority. Most of the high-priority patients are treated, some low-priority patients leave because of long waiting time or crowded queue. However, a number of patients in medium priority stuck in the queue in both of the models due to the high probability distribution for medium priority. Last but not least, both of the models are transformed properly corresponding to the conceptual models.

4.2 Animation Inspection

Models are simulated at a slow speed to inspect whether the logic and the flow follow the construction models. In both of the models, doctors correctly provide medical treatment based on the priorities and first-in-first-out order. Patients in low priority leave according to the right decisions setting either the sum of the queues exceeds 10 or the patients wait for too long. In the proposed model, patients who need to be diagnosed by doctor after nurse have been treated prior to the high-priority patients.

4.3 Trace Analysis

The characteristics of selected objects are in line with model expectations. Under extreme conditions, such as high probability distribution of patients in different priorities, both of the models behave properly.

4.4 Test Runs

The performance of each element is monitored to inspect the model operation. From the resource utilisation perspective, there is no strong evidence to show the difference between the proposed and original models. However, as Table 4.1, the number of low-priority patients who finish the treatment increases from 6.87 to 11.49 and the number of leaving sufferers in low priority without treatment decreases to zero, showing that the changed layout and additional nurse improve the handling of low-priority patients. In addition, the mean and standard deviation for patients in both high and medium priority remain roughly representing the change of the system achieves the goal without obviously sacrificing other performance. To conclude, the new model has improved the handling of low-priority patients.

Table 4.1: Comparison of Models Performance

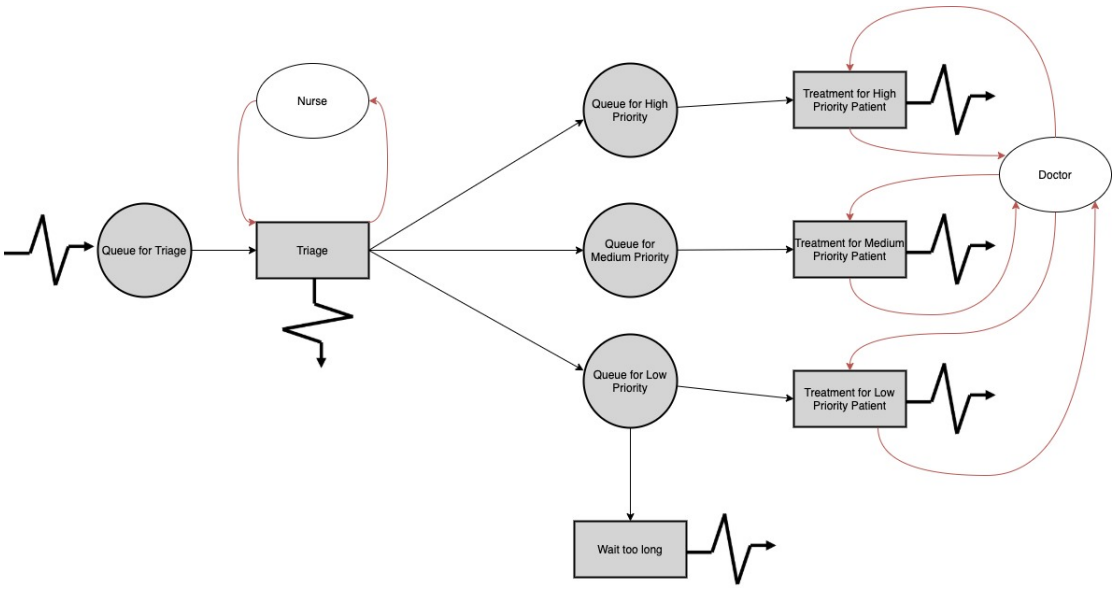
		Before			After		
		Min	Mean	Max	Min	Mean	Max
Exit (high priority)	Number Completed	22.49	23.74	24.99	22.57	23.8	25.03
	Average Time	48.56	49.8	51.03	48.51	49.76	51.01
	St Dev	10.39	11.05	11.72	10.48	11.14	11.79
Exit (medium priority)	Number Completed	48.89	50.49	52.09	48.63	50.24	51.85
	Average Time	59.76	67.62	75.49	59.47	67.48	75.48
	St Dev	28	33.49	38.98	28.24	33.84	39.44
Exit (low priority)	Number Completed	5.95	6.87	7.79	11.01	11.49	11.97
	Average Time	13.28	14.35	15.41	14.47	14.6	14.74
	St Dev	2.41	2.83	3.25	1.86	1.95	2.04
Exit (10 ppl in queue)	Number Completed	1.43	2.07	2.71	0	0	0
	Average Time	0.79	1.04	1.28	0	0	0
	St Dev	0.06	0.09	0.12	0	0	0
Exit (wait for 10 to 20 min)	Number Completed	4.65	5.24	5.83	0	0	0
	Average Time	16.32	16.88	17.44	0	0	0
	St Dev	1.86	2.1	2.34	0	0	0
Exit (after nurse n doctor)	Number Completed				2.34	2.63	2.92
	Average Time				22.58	23.85	25.13
	St Dev				1.6	2.15	2.71

4.5 Validation

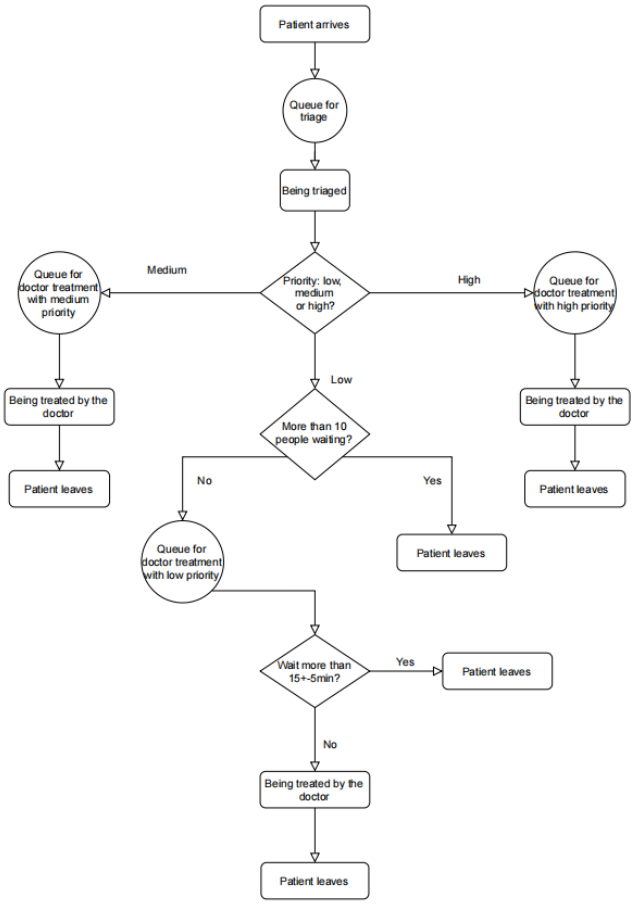
Though the model is verified and performs properly, validation tests for the models are necessary to confirm the simulation is close enough to the real-world scenario. Validation tests include three aspects, conceptual validity, operational validity, and believability. In the health centre case, validation tests are not conducted due to the lack of real-world data.

5. Appendices

5.1 Diagrams & Tables



Appendix 5.1: Activity Cycle Diagram – Current Situation

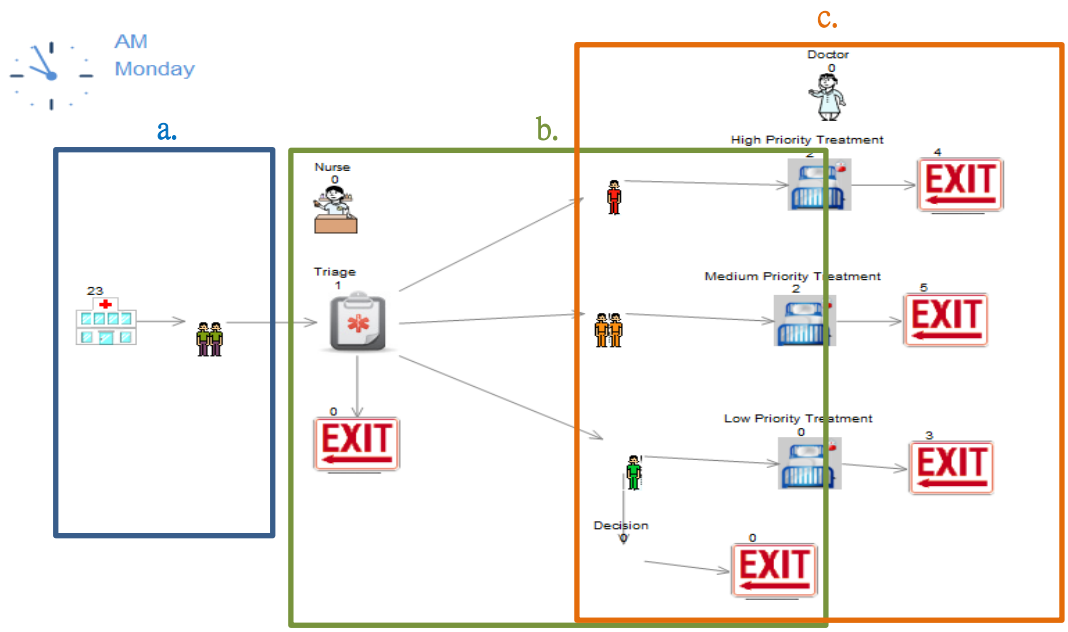


Appendix 5.2: Logic Flow Diagram – Current Situation

5.2 Model Documentation

5.2.1 Original Model

Appendix 5.3 demonstrates the whole picture of the simulation model for the original walk-in health centre. The figure of the model is split into 3 parts to develop the construction process.



Appendix 5.3: Simul8 Model – Original Situation

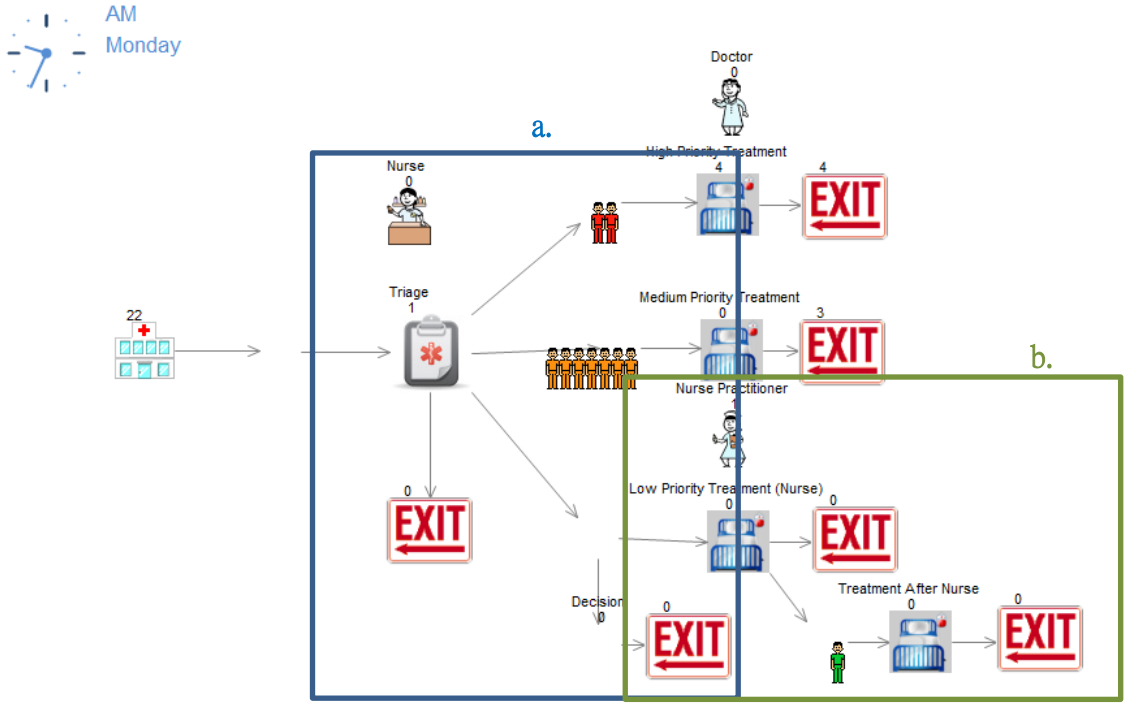
In Appendix 5.3, part a. represents that patient enter the health centre through the start point **"Entry"** sequentially in the arrival rate of 15 people per hour and then join the queue **"Queue for triage"**.

As part b. in Appendix 5.3, patients will then be triaged in 2 to 3 minutes at the activity **"Triage"** by a nurse into high (red colour), medium (orange colour), and low (green colour) priority patients based on the probability distribution of patients in the label **"classification"**, and then enter the doctor's waiting queue. High priority patients will enter the **"Queue for High Priority Treatment"**, medium priority patients will enter the **"Queue for Medium Priority Treatment"** and low-priority patients will enter the **"Queue for Low Priority Treatment"** respectively. At this point, when the total number of patients waiting in these three queues exceeds 10, the low-priority patients who have just been triaged will go to the endpoint **"Exit (10 ppl in the queue)"**. Also, if the waiting time of low-priority patients reaches the uniform distribution of 10 – 20 minutes of label **"Waiting Limit (Low)"** in the **"Queue for Low Priority Treatment"**, those patients will enter the dummy activity **"Decision"** and leave at the endpoint **"Exit (wait for 10 to 20 min)"**

Finally, part c. in Appendix 5.3 demonstrates that patients will enter the Treatment activity based on the availability of doctors. According to the priority of the patient, the 4 doctors are prioritized first to **"High Priority Treatment"** activity, then to **"Medium priority treatment"** and finally to **"Low Priority Treatment"**. After the treatment, patients will exit the health Centre through the end of each treatment activity.

5.2.2 Proposed Model

Appendix 5.4 represents the simulation model of the health centre adding nurse practitioner. Two differences as part a. and b. have been conducted to simulate the proposed situation.



Appendix 5.4: Simul8 Model – Proposed Situation

The first difference as part a. in Appendix 5.4 shows the patients in low priority who have just been triaged will go to the end **"Exit (10 ppl in the queue)"** when the number of patients waiting in the queue for nurse practitioner exceeds 10 rather the sum of the 3 queues.

The other changed configure shown in part b. is that 4 doctors will prioritize serving low-priority patients who require additional treatment by a doctor after the nurse practitioner, then serving at activity **"High Priority Treatment"**, and finally the activity **"Medium priority treatment"**. Low-priority patients are first diagnosed by a nurse practitioner at activity **"Low**

priority treatment”. In this case, after nurse practitioner serves the patients in low priority, 80% of them exit the clinic directly, while the rest of the patients needs to wait in **“Queue for Treatment After Nurse”** for further diagnosis in **“Treat After Nurse”** by a doctor before they can exit the health centre.

5.3 Meeting Minutes

5.3.1 Meeting: 03/06/2021

Group Members & Attendees: Leidan Chen, Parker Wu, Jingxuan Chen, Xinmian Wang
Record: Studied the case for the first time and understood the objectives of the model. We discussed the specific methods of modelling and initially worked on conceptual models.
Decisions Taken: Divided and set the deadlines for each part and briefly splitting the tasks

5.3.2 Meeting: 04/06/2021

Group Members & Attendees: Leidan Chen, Parker Wu, Jingxuan Chen, Xinmian Wang
Record: The preliminary model had been made. We had basically understood the key issues of modelling design and revised the conceptual model.
Decision Taken: Modified the models and tried to solve the label and other problems

5.3.3 Meeting: 05/06/2021

Group Members & Attendees: Leidan Chen, Parker Wu, Jingxuan Chen, Xinmian Wang
Record: According to the conceptual model, used SIMUL8 to build the simulation model, set the parameters and the trial times to do the verification and validation of the model.
Decision Taken: Made clear the structure of the report and the division of team members in writing the report, and made sure that we would not miss the deadline

5.3.4 Meeting: 07/06/2021

Group Members & Attendees: Leidan Chen, Parker Wu, Jingxuan Chen, Xinmian Wang
Record: Completed the first version of the report and detailed check whether the model conforms to the application of real problem together.
Decision Taken: Optimised the models and revised the report

5.3.5 Meeting: 08/06/2021

Group Members & Attendees: Leidan Chen, Parker Wu, Jingxuan Chen, Xinmian Wang
Record: Reviewed and made necessary changes

Decision Taken: Sent the draft to professor

5.4 Percentage of Work Done

Appendix 5.5: Division of Work

Content	**Group member**
Introduction	Leidan Chen
Activity Cycle Diagram	Parker Wu
Logic Flow Diagram	Jingxuan Chen
Simulation model	Parker Wu
Model Construction	Parker Wu
V&V	Xinmian Wang
Working model (documentation)	Leidan Chen
Appendix	Xinmian Wang
Reports Combination & Unification	Parker Wu 80%, Jingxuan Chen 20%

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