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1. Introduction

The project describes a walk-in health centre where a nurse prioritises patients into 3 different priorities. Moreover, 4 doctors provide medical treatment based on priority, and the duration of therapy varies according to priority. However, resulting from the available number of doctors and the proportion of patients in different precedence, low-priority patients might leave the queue due to the enduring waiting time or the over-occupied waiting room. As a result, the management team proposes to hire a nurse practitioner who is responsible for only patients in low priority in order to reduce the low-priority patients who leave earlier.

To analyse the performance of the proposed scenario, the project is deconstructed into topics as Problem Statement and Objectives, Scenarios and Justifications, Configuration and Output Analysis, Results Interpretation, and, finally, Recommendations.

2. Problem Statement & Objectives

The goal of the new layout is to improve the efficiency of handling patients in low priority. Hence, the objective of the model is to reduce the average waiting time for low-priority patients receiving the treatment and the number of patients leaving earlier so that low-priority patients wait for less than before and the number of low-priority patients leaving earlier decreases with the limit of 1 nurse, 4 doctors, and 1 nurse practitioner who will be responsible for only patients in low-priority. Also, the management wants to know the sensitivity of the performance to the prediction that 80% of low priority patients will be handled by only the nurse practitioner.

3. Scenarios & Justifications

To simulate the description of the walk-in health centre and control the experiments of the proposed model, the process of seeking medical advice is analysed and split, and experimental factors are identified in order to assure the statistically meaningful output.

3.1 Scenarios Description

Two simulation models for different scenarios were built in order to conduct the experiment of adding a nurse practitioner and examine the change of efficiency of low-priority patients. Also, the different scenarios of routing out probability distribution (70%, 75%, 80%, 85%, 90%) in the proposed model are built for the sensitivity analysis.

3.1.1 Current Scenario

To easier obtain the results of each priority, Appendix 1 demonstrates the current simulation model that patients will be triaged by the nurse at the activity “Triage” and split into 3 routes according to their priority (high priority accounts for 25%, medium priority takes 60%, and low priority is the rest (15%)). Furthermore, all 4 doctors have the same capability of treating patients in any priorities and move between each treatment room without travelling time. Finally, low-precedence patients will leave before entering the queue if more than 10 people are waiting in the queue. Moreover, patients in low precedence will quit the queue if they wait for more than 10±5 minutes.

3.1.2 Proposed Scenario

Comparing to the current model, the management team introduces a nurse practitioner who will take over the treatment of low-precedence patients first as Appendix 2; then, 20% of the patients after cured by a nurse practitioner will need further treatment from doctors and increase the priority to the highest level.

3.2 Experimental Factors

Experimental factors are the elements designed to examine the influence on the results in different scenarios; thus, other factors should remain the same as the control group. In this project, experimental factors are classified into quantitative and qualitative factors.

3.2.1 Quantitative Experimental Factors

In order to investigate the effect of the new layout, the number of nurse practitioner is set to 1; after the treatment of the nurse practitioner, 80% of patients in low priority finish their therapy and 20% will need to receive further treatment.

3.2.2 Qualitative Experimental Factors

In the experiment, the priority of low-priority patients after receiving the treatment from the nurse practitioner changes to the most urgent level to see a doctor.

4. Configuration & Output Analysis

By inspecting the time-series graph of treatments activities, system type and output type could be confirmed. Moreover, calculating the warm-up period and MSER-5 verifies the judgement of the time series plot. Finally, initialization bias and sensitivity analysis would be discussed to reflect the possibilities of optimisation.

4.1 Type of System

To begin with, the walk-in health centre opens at 8am and stops accepting new patients at 6pm from Monday to Friday, which represents a terminating system.

Moreover, Figure 1 demonstrates the de-aggregated number of low-priority patients leaving the health centre after receiving treatment in the current model. Furthermore, to confirm the type of system, both Appendix 3 and Appendix 4 validate the inference that number of patients in low priority leaving after the treatment in proposed model shifts based on the change of input.

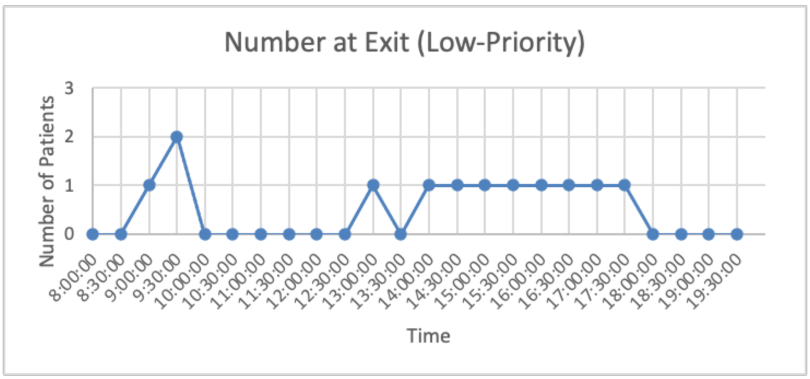


Figure 1: Number of Low-Priority Patients Leaving after Treatment (Current Model)

Finally, Figure 2 represents the decumulated mean number of patients in low precedence at the exit with data collected every 10 mins and 6 replications, which shows the pattern that the number of patients always starts from zero and ends at zero.

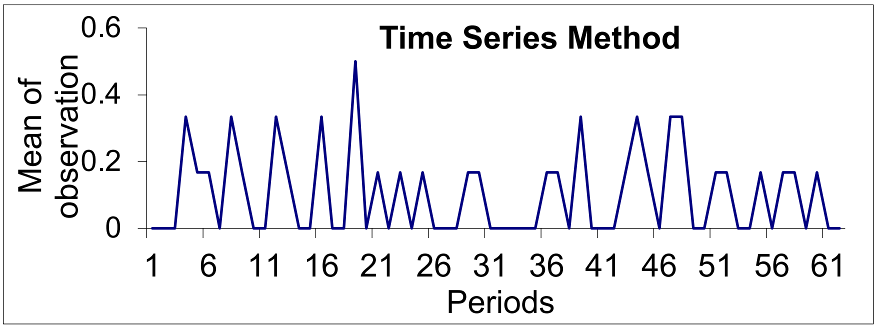


Figure 2: Mean Count of Exit for Low-Priority Patients (Current Model)

To conclude, as the input varies, the output changes consequently. Moreover, the data starts and ends at zero. Hence, the output type could be considered as the transient output.

4.2 Initialization Bias

Schruben (1982) stated that the initialization bias seemed to not appear to transient output. Moreover, the walk-in health centre is an empty-to-empty type model with transient output. Therefore, there is no initialization bias in this case, and it seems unnecessary to set the initial conditions or warm-up period as this model starts in a typical state as Figure 2 above.

4.3 Warm-up Period

Besides the reason stated by Schruben (1982), MSER-5 as Figure 3 shows an unregular pattern that recommends a truncation point of zero and identifies that there is no need to set the warm-up period.

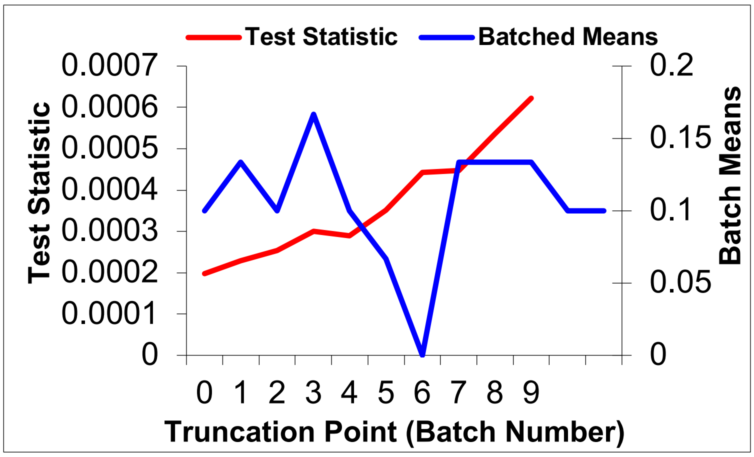


Figure 3: MSER-5 of Mean Count at Exit for Low-Priority Patients (Current Model)

4.4 Number of Replication

To secure a 95% confidence interval output of average time for low-priority patients leaving after the treatment in the current model, Figure 4 implicates even 20 replications are insufficient to acquire stable results.

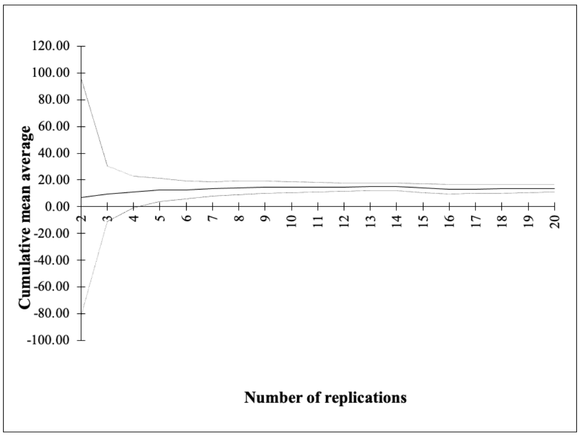


Figure 4: Number of Replications – Avg Time of Low-Priority Patients at Exit (Current Model)

Moreover, Appendix 5 demonstrates the number of low-priority patients leaving after treatment in the current model with 95% confident interval, which provides a similar result that 20 replications seem to be inadequate to obtain the convincing output.

Also, Appendix 6 to 9 show the graphs that the patterns seem to be unsuitable within 20 replications (with 18% precision). Hence, the trial calculator in Simul8 is introduced in Figure 5, which seems to be obvious that at least 635 replications are required to ensure 5% precision for the number of low-priority patients leaving after treatment. However, both the number and mean time of patients in low priority leaving due to more than 10 people waiting in the queue require more than 4000 replications, which become unrealistic.

KPI	Recommended Runs
(Recommended runs for 5% precision)	
exit (low priority): Number Completed	635
exit (low priority): Average Time in System	171
Exit (wait for 10 to 20 min): Number Completed	430
Exit (wait for 10 to 20 min): Average Time in System	18

KPI	Recommended Runs
(Recommended runs for 5% precision)	
exit (low priority): Number Completed	71
exit (low priority): Average Time in System	6
Exit (10 ppl in queue): Number Completed	4
Exit (10 ppl in queue): Average Time in System	4
exit (after nurse n doctor): Number Completed	479
exit (after nurse n doctor): Average Time in System	108

Figure 5: Trial Calculator (Left: Current Model; Right: Proposed Model)

As a result, 635 replications are adapted in both current and proposed models in order to obtain a statistically meaningful output with 95% confidence interval.

4.5 Sensitivity Analysis

To examine the sensitivity of the percentage change of routing out rule (80% of low-priority patients handled only by nurse), sensitivity analysis is conducted in the proposed model.

Figure 6 represents the sensitivity tests for different exits. The orange line shows the number completed, the blue line demonstrates the average time, and the light lines indicate the confidence interval. Obviously, both number and average time in most exits is inelastic, which means the output remains similar no matter how the routing out rules changes.

However, the number completed in the exit for patients in low priority leaving after receiving treatment from only nurse practitioner seems to be sensitive that every 5% the rule enhances, 0.72 people in average increases. Moreover, the number completed for the patients who received treatment from both nurse and doctor seems to be sensitive as well that 0.72 people decreases by every 5% increase; also, the average time in the same exit seems to be more sensitive (from -0.45 to -2.19) as percentage increases.

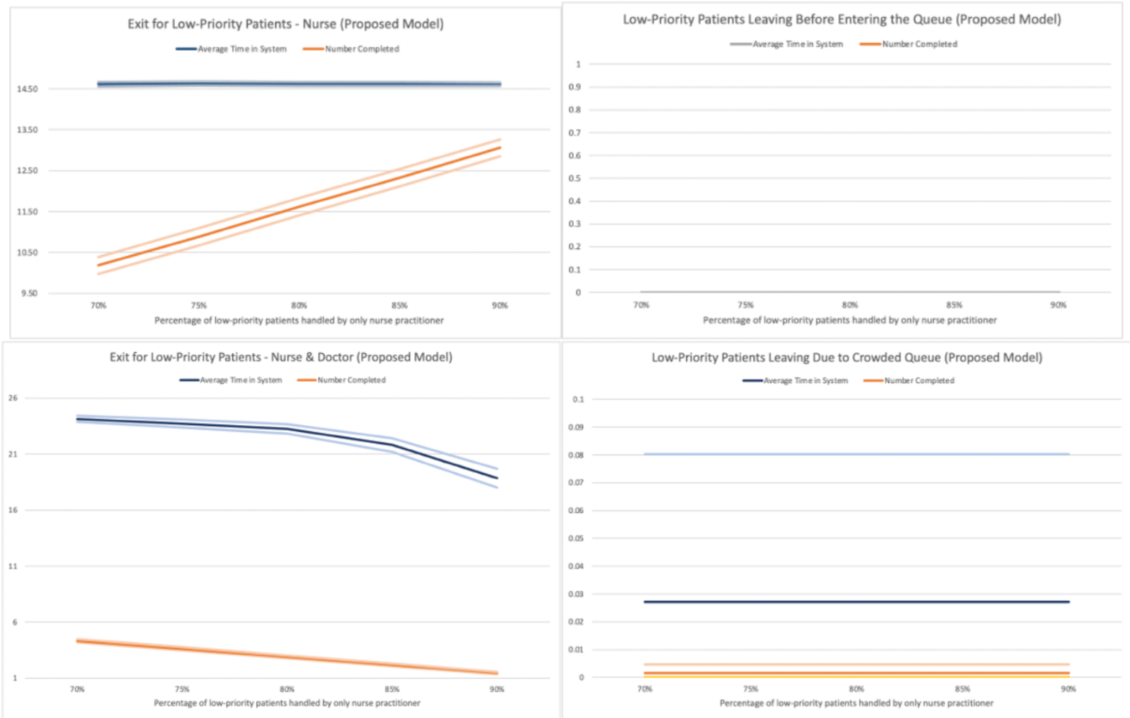


Figure 6: Sensitivity Tests (Proposed Model)

Interestingly, owing to the insensitivity of low-priority patients leaving earlier the sum of the number and the sum of the average time of patients receiving treatment from either nurse or both remain nearly the same, which represents the insensitive sign.

5. Results Interpretation

By applying the variance reduction technique, common random numbers (CRNs) in this case, all the differences except for experimental factors would be eliminated. Hence, the difference of results between the 2 scenarios could be interpreted as the effect of experimental factors.

5.1 Common Random Numbers (CRNs) & Statistical Test

The random number is set to 1 and the replications conducts 635 times in both scenarios to eliminate any differences except for experimental factors.

To begin with, in order to compare the results of low-priority patients leaving after the treatment between two scenarios, the number of those receiving treatment from only the nurse practitioner is added to the number from both nurse and doctor in the proposed scenario. Moreover, in order to compare the slight difference of average time between different percentage distribution scenarios, the average time is calculated as a weighted average of the number above in the models with routing out probability 75%, 80%, and 85%.

For the number of low-priority patients leaving earlier because of either long waiting time or crowded queue, although Figure 7 demonstrates the results that the change of number is not significant to reduce the variance, the standard t-test shows the mean differences with (5.63, 6.12) and (1.41, 1.84) respectively, which imply that under 95% confidence interval the mean number of patients leaving earlier for the current model is significantly greater than the proposed model (S2<S1). As a result, hiring a nurse practitioner significantly decreases the number of patients in low priority leaving the health centre without treatment.

Number - Leave (wait 15+-5 mins)					
Variance Reduction Conclusion		*Sum of Variances*		*Confidence Intervals for Mean Differences*	
Scenarios	Proposed	Scenarios	Proposed	Scenarios	Proposed
Current	Not Reduced	Current	9.7621004	Current	(5.63, 6.12)
Variance of Differences		*Mean Differences*		*Significance Conclusions*	
Scenarios	Proposed	Scenarios	Proposed	Scenarios	Proposed
Current	9.762100401	Current	5.875590551	Current	S1> S2

Number - Leave (10ppl in queue)					
Variance Reduction Conclusion		*Sum of Variances*		*Confidence Intervals for Mean Differences*	
Scenarios	Proposed	Scenarios	Proposed	Scenarios	Proposed
Current	Not Reduced	Current	7.565925632	Current	(1.41, 1.84)
Variance of Differences		*Mean Differences*		*Significance Conclusions*	
Scenarios	Proposed	Scenarios	Proposed	Scenarios	Proposed
Current	7.565925637	Current	1.625196849	Current	S1> S2

Number - Receive Treatment					
Variance Reduction Conclusion		*Sum of Variances*		*Paired-t Confidence Intervals for Mean Differences*	
Scenarios	Proposed	Scenarios	Proposed	Scenarios	Proposed
Current	Reduced	Current	27.38587645	Current	(-7.83, -7.17)
Variance of Differences		*Mean Differences*		*Paired-t Significance Conclusions*	
Scenarios	Proposed	Scenarios	Proposed	Scenarios	Proposed
Current	18.01064607	Current	-7.499212598	Current	S1< S2

Avg Time - Receive Treatment							
Variance Reduction Conclusion				*Paired-t Confidence Intervals for Mean Differences (Bonferroni Correction)*			
Scenarios	Proposed-75%	Proposed-80%	Proposed-85%	Scenarios	Proposed-75%	Proposed-80%	Proposed-85%
Current	Reduced	Reduced	Reduced	Current	(-2.59, -1.66)	(-2.09, -1.17)	(-1.62, -0.7)
Proposed-75%		Reduced	Reduced	Proposed-75%		(0.43, 0.56)	(0.88, 1.06)
Proposed-80%			Reduced	Proposed-80%			(0.41, 0.54)
Sum of Variances				*Paired-t Significance Conclusions (Bonferroni Correction)*			
Scenarios	Proposed-75%	Proposed-80%	Proposed-85%	Scenarios	Proposed-75%	Proposed-80%	Proposed-85%
Current	20.15233586	19.9504731	19.61979266	Current	S1< S2	S1< S3	S1< S4
Proposed-75%		3.956997054	3.626316614	Proposed-75%		S2> S3	S2> S4
Proposed-80%			3.424453852	Proposed-80%			S3> S4
Variance of Differences							
Scenarios	Proposed-75%	Proposed-80%	Proposed-85%				
Current	19.49111424	19.25911646	19.23501765				
Proposed-75%		0.385552715	0.735570396				
Proposed-80%			0.398436841				
Mean Differences							
Scenarios	Proposed-75%	Proposed-80%	Proposed-85%				
Current	-2.124286625	-1.632921842	-1.156903621				
Proposed-75%		0.491364783	0.967383003				
Proposed-80%			0.47601822				

Figure 7: CRNs & Statistical Test

For those who leave after the treatment, the 95% confidence interval around the mean of the differences between the current model and the proposed model is (-7.83, -7.17). Hence, the mean number of low-priority patients for the proposed model is significantly greater than for the current model (S1<S2). Briefly, the proposed scenario increases the number of low-priority patients receiving the treatment.

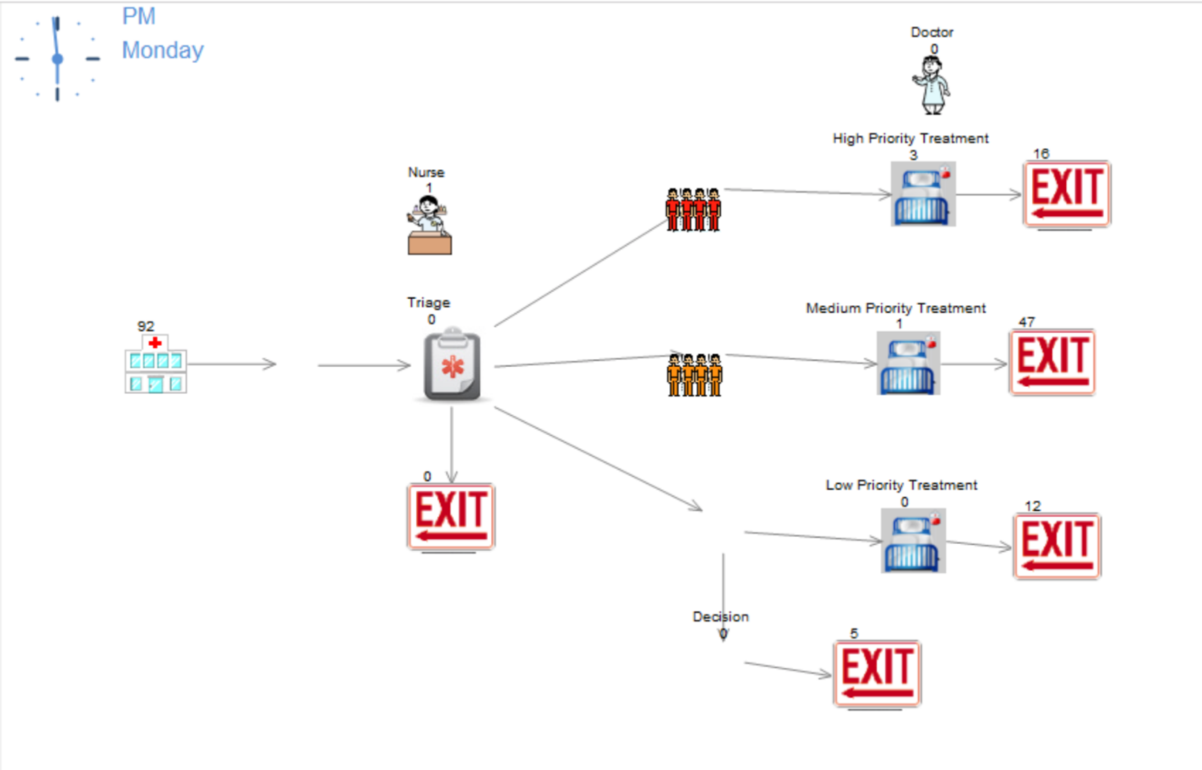
Finally, the paired t-test indicates that all three scenarios with different percentage distributions significantly increase the average time of patients in low priority receiving the treatment comparing to the current scenario. However, the average time in the scenario with 80% probability distribution seems to be the longest among these scenarios with a 95% confidence interval (S3>S2>S4>S1), but the sensitivity analysis has indicated that the difference is slight.

To conclude, although the average time of patients in low priority taking the treatment increases in the proposed model, the number of those increases significantly as well. Also, the number of quitting patients decreases, which is the result that management team expects.

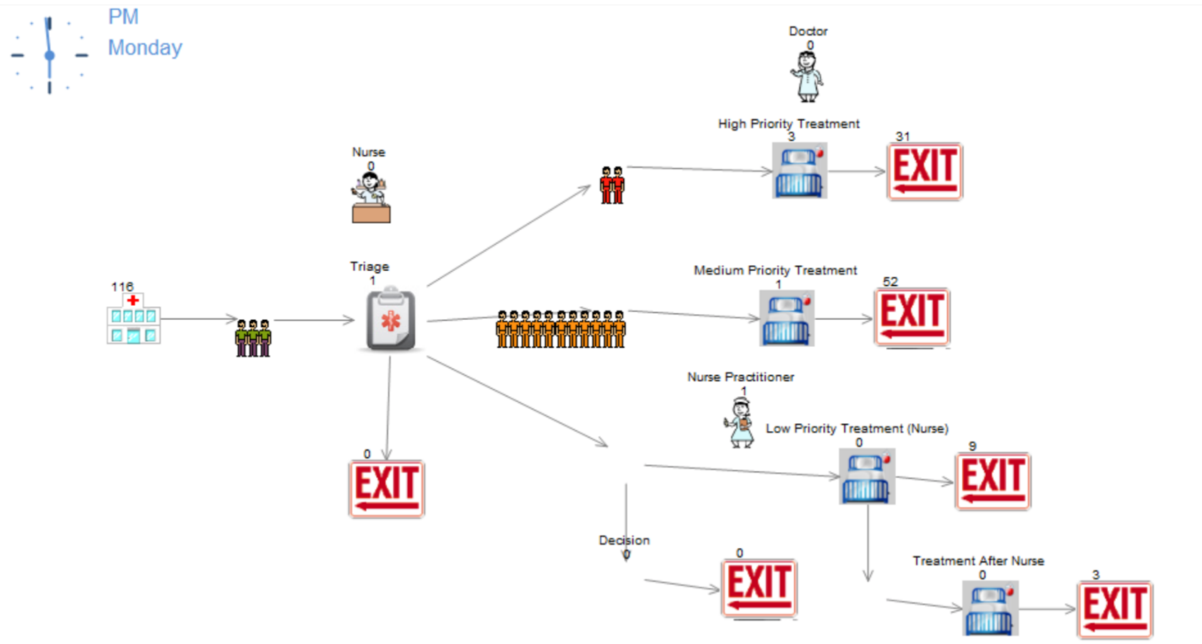
6. Recommendations

The experiment draws a conclusion that hiring a nurse practitioner who handles only low-priority patients successfully reduces the number of patients leaving earlier and increases the number of patients receiving the medical treatment. Moreover, the average time of medium- and high-priority patients receiving the treatment seems to remain the same, which implicates the similar medical quality received by patients. Also, although the 80% distribution is speculation, the tests indicate the insensitivity of the change of percentage. As a result, it seems to be highly recommended to the management team to hire a nurse practitioner to better deal with low-priority patients.

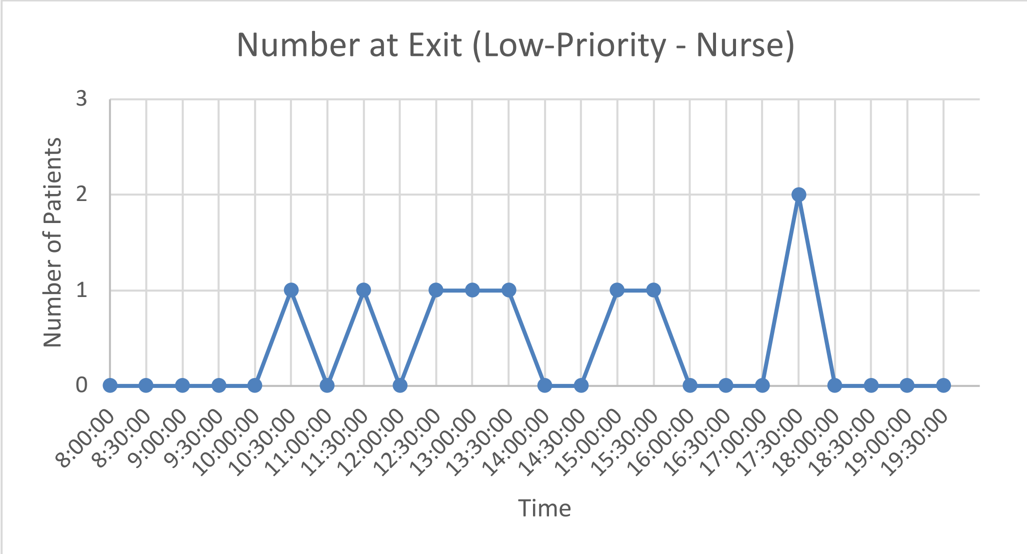
7. Appendices



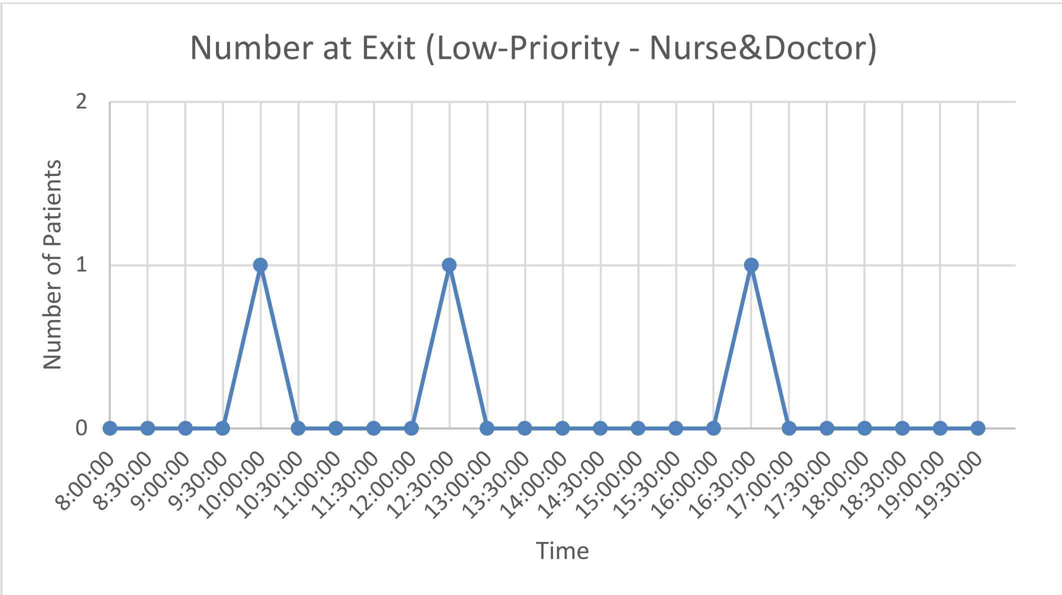
Appendix 1: Current Simulation Model



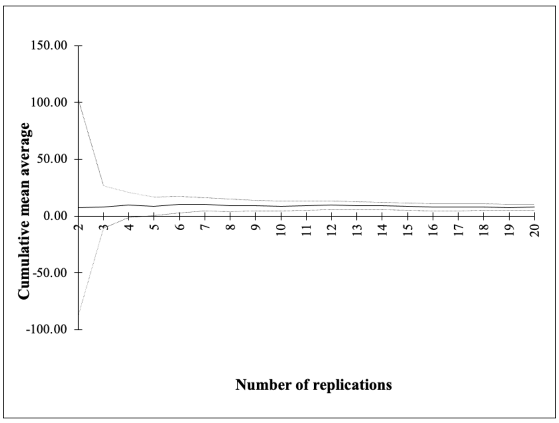
Appendix 2: Proposed Simulation Model



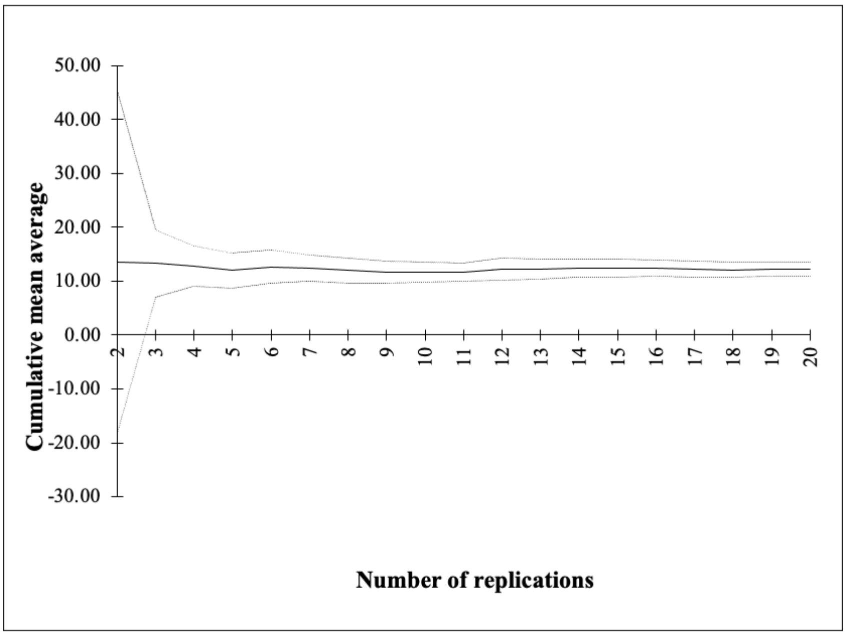
Appendix 3: Number of Low-Priority Patients Leaving after Nurse Treatment (Proposed Model)



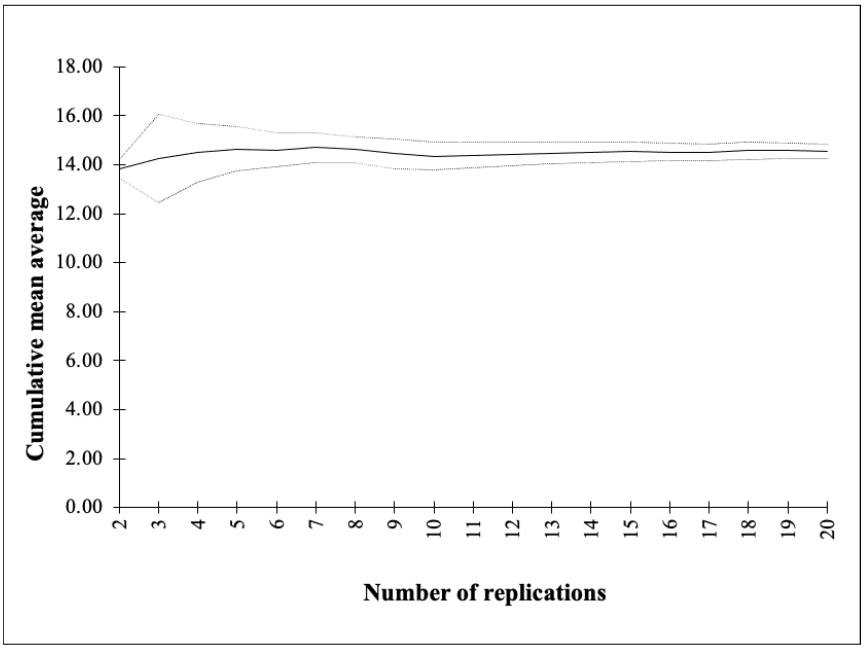
Appendix 4: Number of Low-Priority Patients Leaving after Nurese & Doctor Treatment (Proposed Model)



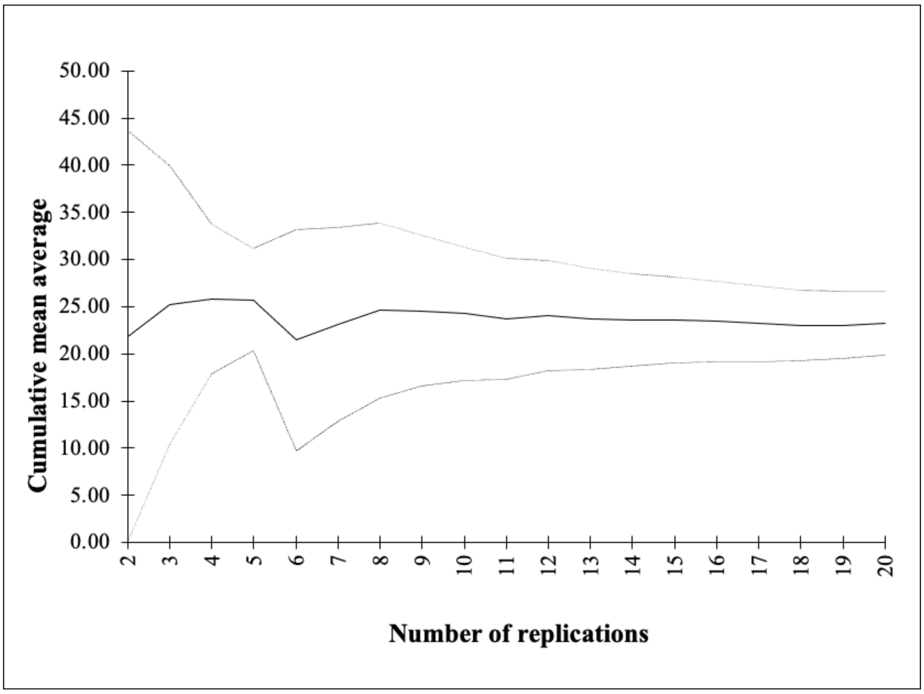
Appendix 5: Number of Replications - Number of Low-Priority Patients at Exit (Current Model)



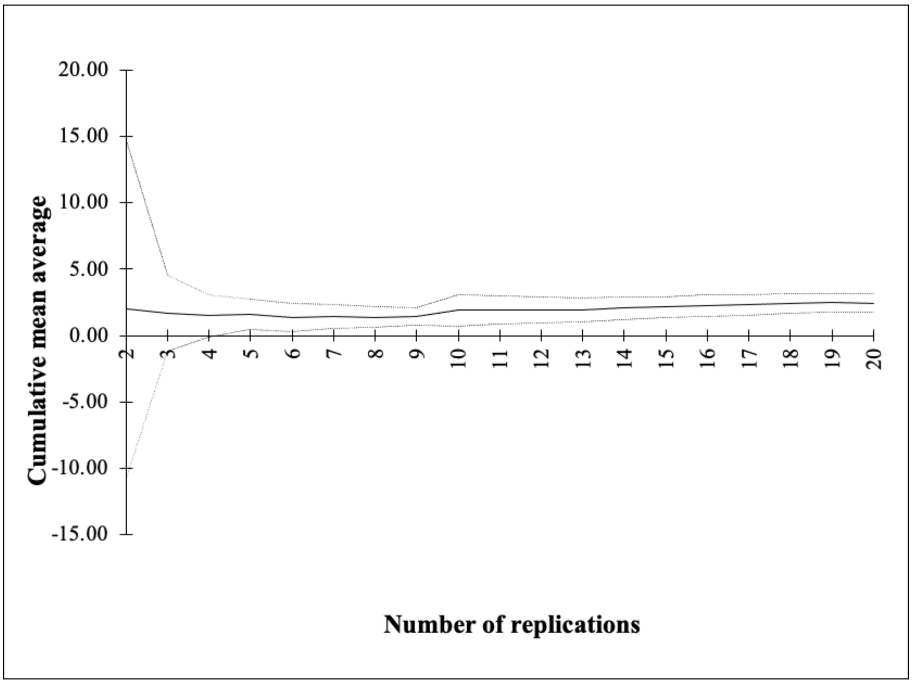
Appendix 6: Number of Replications - Number of Low-Priority Patients at Exit after Treatment from Nurse (Proposed Model)



Appendix 7: Number of Replications – Avg Time of Low-Priority Patients at Exit after Treatment from Nurse (Proposed Model)



Appendix 8: Number of Replications – Avg Time of Low-Priority Patients at Exit after Treatment from Nurse and Doctor (Proposed Model)



Appendix 9: Number of Replications – Number of Low-Priority Patients at Exit after Treatment from Nurse and Doctor (Proposed Model)

8. Reference Lists

Schruben, L. W., 1982. Detecting Initialization Bias in Simulation Output.. *Operations Research*, June, p. 569.