Optimizing Nurse Workforce Scheduling in a Healthcare Call Centre

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1. Executive Summary

This report focuses on using integer linear programming and simulation to model a workforce planning problem in a health call centre and solving the model using Excel Solver and Simul8. The findings and results demonstrate an optimum schedule that reduces the number of required workforce while efficiently managing the task in response to changing demand for services, thus minimizing the total workforce cost. The report is structured into the following sections: Executive Summary, ILP Model and Formulation, Simulation Model, Simulation Results and Analysis, Discussion, and References.

2. ILP Model and Formulation

Problem Definition

The nurses answering telephones in a healthcare call centre are expected to speak to 5 patients each per hour. The service operates between 9am and 5pm. As many patients call in their lunch breaks the service is busiest in the middle of the day.

Time Period	No. of Patients	Needs of Nurses to Cover Patients
9a.m. – 10a.m.	45	9
10a.m. – 11a.m.	55	11
11a.m. – noon	70	14
noon – 1p.m.	85	17
1p.m. – 2p.m.	88	18
2p.m. – 3p.m.	84	17
3p.m. – 4p.m.	70	14
4p.m. – 5p.m.	60	12

TABLE 1: Average number of patients will call in by time period.

The call centre can employ up to 20 full-time nurses and up to 20 part-time nurses at most. Part-time nurses work 4 consecutive hours a day if they are requested to work at all, and can start anytime from 9am to 1pm. They earn £16 per hour.

Full-time nurses work 8 hours from 9am to 5pm and are entitled to one hour break where half the full-

time nurses start their break at noon and the other half at 1pm (if there are an odd number of full-time nurses then the higher number of nurses have an earlier break), they earn £80 per day. For consistency there must be at least 4 full time nurses working each day.

As a result, a solution to this model is created with the goal to accomplish its effectiveness and optimality.

Model Formulation

Decision Variable:

Let:

F	= Full-time Nurses
P1	= Part-Time Nurses Starting at 9am
(Leaving at 1pm) P2	= Part-Time Nurses Starting at 10am
(Leaving at 2pm) P3	= Part-Time Nurses Starting at 11am
(Leaving at 3pm) P4	= Part-Time Nurses Starting at 12am
(Leaving at 4pm) P5	= Part-Time Nurses Starting at 1pm
(Leaving at 5pm)	

Objective function:

Minimize total workforce cost = 80F + 64(P1+P2+P3+P4+P5)

Subject to:

No													**Needs of Nurses**	Time Period
1	F	+	P1									>=	**9**	(9am – 10am)
2	F	+	P1	+	P2							>=	**11**	(10am – 11am)
3	F	+	P1	+	P2	+	P3					>=	**14**	(11am – noon)
4	0.5F	+	P1	+	P2	+	P3	+	P4			>=	**17**	(noon – 1pm)
5	0.5F			+	P2	+	P3	+	P4	+	P5	>=	**18**	(1pm – 2pm)
6	F					+	P3	+	P4	+	P5	>=	**17**	(2pm – 3pm)
7	F							+	P4	+	P5	>=	**14**	(3pm – 4pm)
8	F									+	P5	>=	**12**	(4pm – 5pm)
9	F											>=	**4**	Per Days

10	F											<=	**20**	Per Days
11			**P1**	+	**P2**	+	**P3**	+	**P4**	+	**P5**	<=	**20**	Per Days

Restriction:

$F, P1, P2, P3, P4, P5 \geq 0$, integer

Results and Analysis

Nurses Schedulling Model									
Decision Variables: Various Type of Nurses Starting Their Work On Difference Time Periods									
Variables	F	P 1	P 2	P 3	P 4	P 5	Objective is to Minimize Total Workforce Cost		
Coefficient	80	64	64	64	64	64	1696		
Value	10	1	0	9	2	2			
Constraints on Nurses Availability									
Shift	F	P1	P2	P3	P4	P5	Number of Nurses Available		Number of Nurses Needed
9 a.m. - 10 a.m.	1	1	0	0	0	0	11	>=	9
10 a.m. - 11 a.m.	1	1	1	0	0	0	11	>=	11
11 a.m. - noon	1	1	1	1	0	0	20	>=	14
noon - 1 p.m.	0.5	1	1	1	1	0	17	>=	17
1 p.m. - 2 p.m.	0.5	0	1	1	1	1	18	>=	18
2 p.m. - 3 p.m.	1	0	0	1	1	1	23	>=	17
3 p.m. - 4 p.m.	1	0	0	0	1	1	14	>=	14
4 p.m. - 5 p.m.	1	0	0	0	0	1	12	>=	12
Full Time Nurse Needed Per Day	1	0	0	0	0	0	10	>=	4
Total Full Time Nurse	1	0	0	0	0	0	10	<=	20
Total Part Time Nurse	0	1	1	1	1	1	14	<=	20

TABLE 2: The Solution Obtained After Running Excel Solver

A value of 1 indicates that the nurse is required to work, while a value of 0 indicates that the nurse is not needed for work during that time period.

Table 2 presents the results showing that 10 full-time nurses start working for the entire day. Additionally, 1 part-time nurse starts working at 9 a.m., and there are no staff starting at 10 a.m. However, 9 part-time nurses start their shifts at 11 a.m. In addition, 2 part-time nurses start their shifts at noon, while 2 others start their shifts at 1 p.m.

Using Excel Solver, we were able to determine that 24 nurses (10 full-time and 14 part-time) were more than enough to cover every shift. Additionally, every constraint condition is met.

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$I$4	Coefficient Objective is to Minimize Total Workforce Cost	1696	1696

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$5	Value F	10	10	Integer
$C$5	Value P 1	1	1	Integer
$D$5	Value P 2	0	0	Integer
$E$5	Value P 3	9	9	Integer
$F$5	Value P 4	2	2	Integer
$G$5	Value P 5	2	2	Integer

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$H$10	9 a.m. - 10 a.m. Number of Nurses Available	11	$H$10>=$J$10	Not Binding	2
$H$11	10 a.m. - 11 a.m. Number of Nurses Available	11	$H$11>=$J$11	Binding	0
$H$12	11 a.m. - noon Number of Nurses Available	20	$H$12>=$J$12	Not Binding	6
$H$13	noon - 1 p.m. Number of Nurses Available	17	$H$13>=$J$13	Binding	0
$H$14	1 p.m. - 2 p.m. Number of Nurses Available	18	$H$14>=$J$14	Binding	0
$H$15	2 p.m. - 3 p.m. Number of Nurses Available	23	$H$15>=$J$15	Not Binding	6
$H$16	3 p.m. - 4 p.m. Number of Nurses Available	14	$H$16>=$J$16	Binding	0
$H$17	4 p.m. - 5 p.m. Number of Nurses Available	12	$H$17>=$J$17	Binding	0
$H$18	Full Time Nurse Needed Per Day Number of Nurses Available	10	$H$18>=$J$18	Not Binding	6
$H$19	Total Full Time Nurse Number of Nurses Available	10	$H$19<=$J$19	Not Binding	10
$H$20	Total Part Time Nurse Number of Nurses Available	14	$H$20<=$J$20	Not Binding	6
$B$5:$G$5=Integer					

TABLE 3: Answer Report

As shown in TABLE 3, the Excel Solver's Answer Report can be used to prove that all constraints and optimality conditions are satisfied. The status of the constraint can be found in the report, indicating whether it is binding or not.

The summary of the results can be seen in the objective cell and variable cells, where it shows the original and final values. The final values of objective cells show that our smallest value of workforce cost will be 1696. The final values of variable cells show we need to hire 24 nurses(10 full-time and 14 part-time) to minimize our workforce cost.

The constraints for 9 am to 10 am, noon to 3 pm, 2 pm to 3 pm, full-time nurse needed per day, total full-time nurses, and total part-time nurses show the amount of slack of 2, 6, 6, 6, 10, and 6 respectively indicated for Not Binding constraints, which means we have an excess of nurses in these time periods and are able to make an adjustment.

The constraints on 10 a.m. to 11 a.m., noon to 1 p.m., 1 p.m. to 2 p.m., 3 p.m. to 4 p.m., and 4 p.m. to 5 p.m. show binding restrictions, the slack is 0, and the constraints are at their maximums with no excess, meaning we are unable to make any modifications during these times.

Therefore, the goals of reducing the number of nurses as well as the cost of the workforce have both been accomplished through this process of producing an effective work shift for the nurse.

3. Simulation Model

After determining the optimal roster from the ILP model, the actual roster model was created using the simulation tool SIMUL8 which uses discrete-event simulation. Based on the data collected from Excel Solver, this model attempts to represent the average reality.

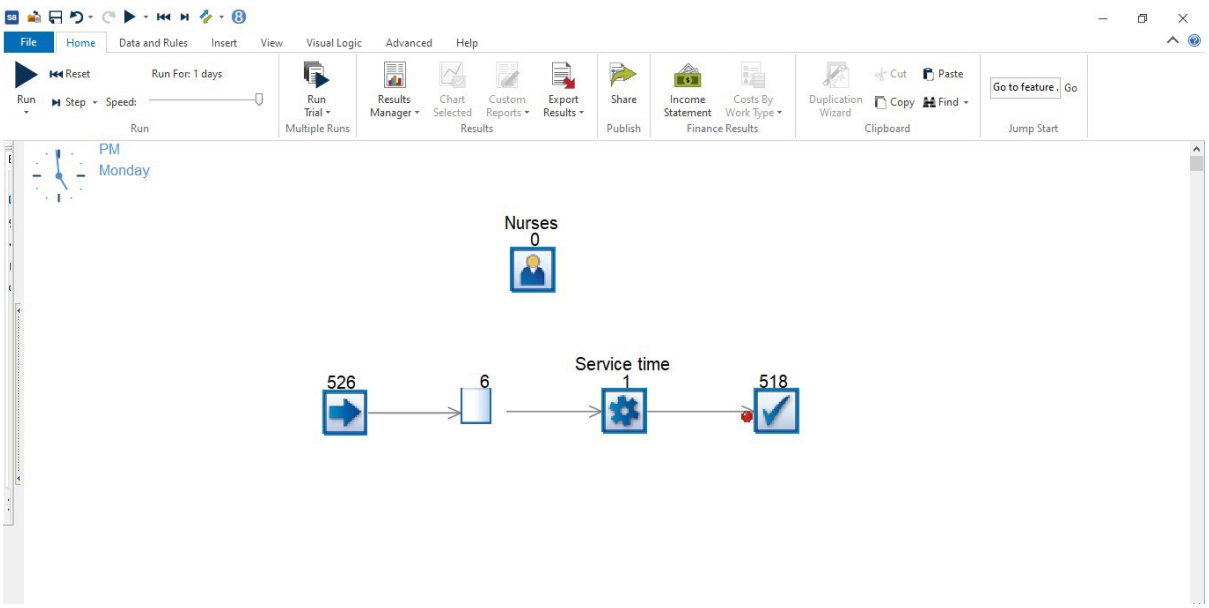

TABLE 4: Screenshot from Simul8 Showing Scenario

The variables of this model will be:

1. *Patient arrival rates:* In this model, we will assume that the arrival rate of patients is exponentially distributed, with the mean number of arrivals in each time period given in Table 1 above.
2. *Number of nurses:* fill in the number of nurses available by shift generated by TABLE 2.
3. *Queuing Time*
4. *Service Time:* assume that service time is normally distributed with a mean of 12 minutes and a standard deviation of 4 minutes.

By inputting the mentioned variables into the simulation model, the outcomes which will be analysed are:

1. Nurses Utilization
2. Average Queuing Time
3. Maximum Queuing Time
4. Average Queue Size

All these cases identify the main path through the system as follows:

The arrival of Patients ---> Patients Queue ---> Nurses Serve Patients ---> End.

Simulations Results and Analysis

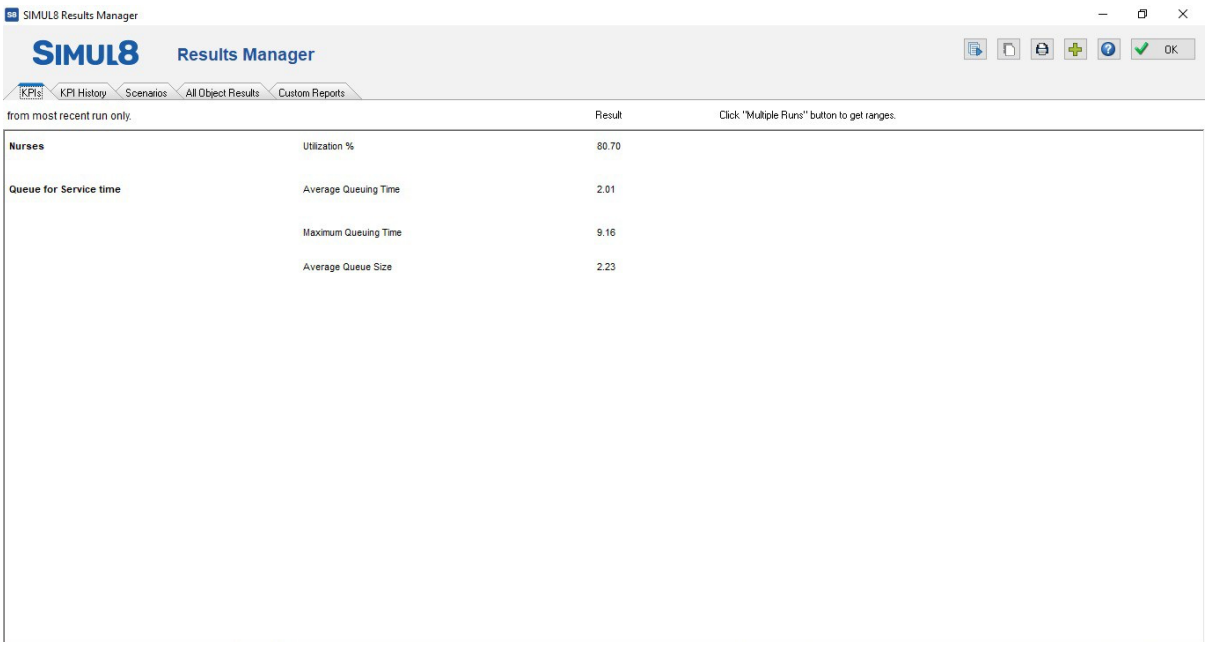

TABLE 5: Screenshot from Simul8 Showing Result of the Scenario

80.70% nurse resource utilisation: This shows a high percentage nurse utilisation in the system, which is a positive indicator.

Indicating that people wait an average of 2.01 time units before receiving service from a nurse, the average queue time was 2.01. Although this level of waiting time may be acceptable, it could also be a sign that the system is experiencing bottlenecks that could be fixed to shorten wait times.

Maximum wait time of 9.16: This shows that some patients are waiting a lot longer than usual.

The average queue length was 2.23: This shows that there were average 2.23 patients in queue at any given time. This level of queue size might be considered acceptable, but it might also be a sign that there are inefficiencies in the system that should be fixed to decrease the amount of customers or patients that need to wait.

4. Discussion

Considering the objective of effectively utilising time and effort and balancing the workload to deliver more fulfilling and effective results, the results were acquired to reduce the workforce cost while taking into account all of the constraints.

With the aid of Excel Solver, it has been established that 24 nurses (10 full-time and 14 part-time) are more than enough to cover all shifts and manage daily operations. We must thus hire 10 full-time nurses who start working throughout the day, 1 part-time nurse who starts at 9 am, 9 part-time nurses who start at 11 am, 2 part-time nurses who start at noon, and 2 part-time nurses who start at 1 pm.

The only aspect of suggested future work that needs to be improved is the shift equality during the break time shift. Alternate shifts are one suggestion made to address this need: make sure there are enough nurses to cover every shift.