
# IE 324
# TERM PROJECT
# STAGE 3

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## A. OptQuest Optimization

### 1. Control Section

For this section, following variables were defined:

- Ambulance Resource
- CCR Nurse
- Other Services Nurse

“Ambulance Resource” for the ambulances which are assigned to patients, “CCR Nurse” is a variable that represents only the nurses who are assigned to CCR patients, and “Other Services Nurse” variable was defined for the nurses who are assigned to triage, registration, injection etc. We used these variables in our objective to minimize inefficiency and find optimal values.

### 2. Responses Section

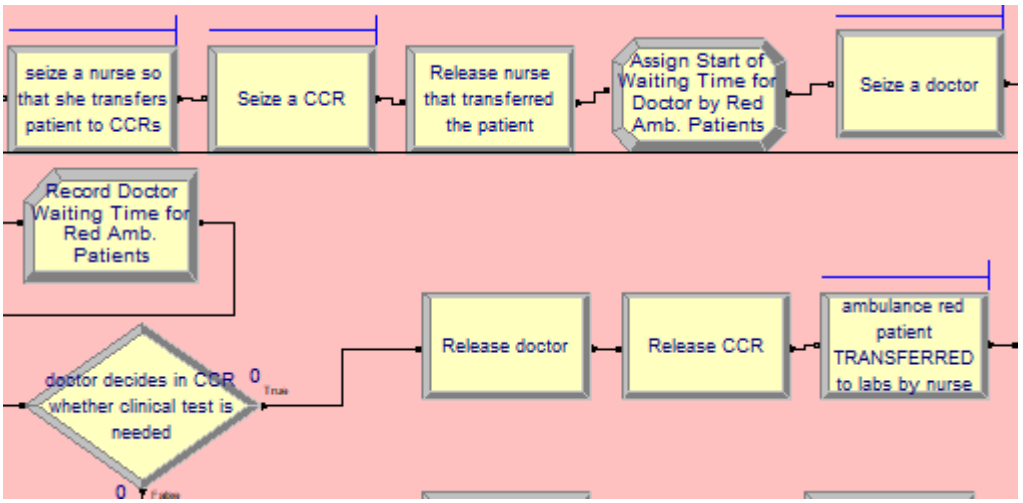
In this section, record blocks were used and following results are obtained:

- The number of accepted and cared patients
- The number of accepted emergency calls
- The number of rejected emergency calls
- The number of staying green patients
- The number of staying yellow patients
- All the transferred and rejected patients
- Always red labeled patient waiting time for a doctor
- Number of patients leaving ED due to crowd
- From yellow to red patient waiting time for a doctor
- The number of rejected or transferred red patients who arrived on their own

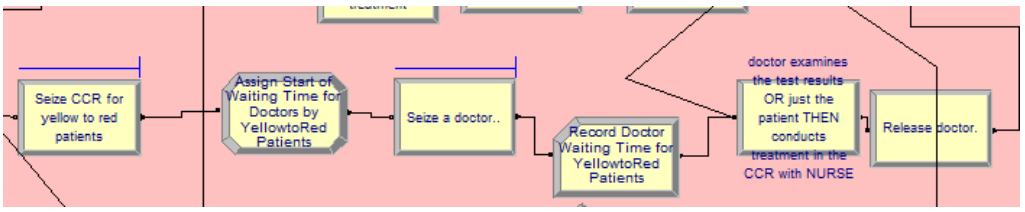
As the manager requested for efficient usage of resources for the target service quality, responses were taken to minimize inefficiency while meeting target values. Performance targets were written to expression blocks as constraints in OptQuest.

## 3. Constraint Section

While doing the OptQuest optimization we have faced some problems. First of all, we were unable to construct constraint #3. We tried to add an assign + record module for red patients' doctor seizing blocks (which can still be viewed in the submitted Arena model, and below) but even though we were able to find the total waiting times of the red patients, we were unable to find the max waiting time value of the red patients for a doctors care therefore we did not put the third constraint into the optimizer.

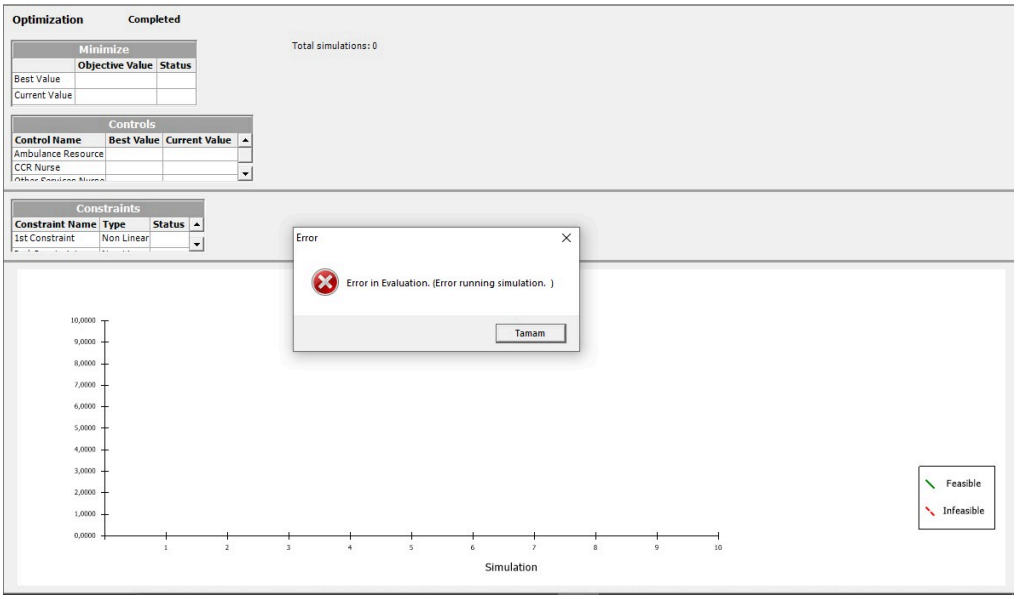



The assign and record blocks for the red patients that came with an ambulance.




The assign and record block for the relabeled red patients that came themselves.

Secondly, we first constructed the constraints #1, #2, #4 and run the optimization before adding #5 since at that time we were second guessing how to write that constraint. That run was successful and gave us outputs with a total of 27 simulation runs. However after trying to add the constraint #5 to the optimizer it did not run as expected and started to give errors. Even if we tried to re-run the optimization process, it resulted as it is shown below.




The screen when the OptQuest is tried to be run with constraints #1, #2, #4, and #5.

Therefore, even though we will be unable to show constraint #5 in the Output Section, we still wrote it in this section and the record module is also viewable in the Arena model.

**Here** are the constraints #1, #2, #4, and, #5:

- For the first constraint we need to check is the first performance target of "At most 15% of the patients should leave ED due to the crowded waiting area". It is written in the optimizer as:

*[Record patients leaving due to crowd] / ( [Record patients leaving due to crowd] + [Record # Staying Green Patients] + [Record # Staying Yellow Patients] ) <= 15/100*

- Our second performance target is "The percentage of rejected emergency calls should be below 7.5%". This constraint is written as:

*[Record # Rejected Calls] / ( [Record # Rejected Calls + [Record # Accepted Calls] ) <= 7.5/100*

- Fourth performance target is "The percentage of patients transferred or rejected should be below 15%". It is written in the formula as:

*[Record ALL the transferred AND rejected patients] / ( [Record ALL the transferred AND rejected patients] + [Record # ACCEPTED and CARED Patients] ) <= 15/100*

- Our fifth and the last performance target is “The number of rejected red patients arriving by their own means must be less than 2”. We wrote this constraint as:

*[Record REJECTED or TRANSFERRED red patients who arrived on their OWN] <= 1*

## 4. Objective Section

Our objective is to minimize the number of ambulances and nurses. In order to do this, we took the sum of these resources and minimized that amount. It is also helpful to remember that all the way since Stage 1, we disregarded the number of observation beds in our model and made our main assumption based on considering they were always in store for patients’ use. Hence our objective function does not include the number of observation beds. Also, we divided the nurses into two categories in our model at Stage 2: CCR nurses and Other Services Nurses. By doing this, we already allowed the distinct allocation of nurses for different uses.

Our objective function in the OptQuest optimization tool looks like this:

*[Ambulance Resource] + [CCR Nurse] + [Other Service Nurses]*

## 5. Outputs

As explained in the Constraint Section, we were unable to get outputs by using all four of our constraints. Instead we got results with three constraints (#1, #2, and #4) and a total of 27 simulation runs.

In this section we will analyze simulation #1, simulation #2 (which gives the best solution in the whole run) and the last simulation, #27, through the screenshots of the Log. file that the optimizer gave.

### Output #1

In our first simulation run, we obtained our objective as 14 which consisted of 4 ambulances, 5 CCR nurses and 5 Other Services Nurses.

There was no one leaving the ED due to crowded area therefore there was no problem for constraint #1. 10% of the emergency calls were rejected in this simulation run therefore the conditions of constraint #2 was not met. 11% of the patients were either transferred or rejected, this percentage is below 15% so the conditions of constraint #4 is also met.

```
Simulation: 1   ****NEW BEST SOLUTION****
6/4/2023 11:55:47 AM
Number of Replications: 3

Values of Decision Variables
Ambulance Resource:  4
CCR Nurse:  5
Other Services Nurse:  5

Values of Output Variables
Record # ACCEPTED and CARED Patients:  1080.33333333333
Record # Accepted Calls:  980.666666666667
Record # Rejected Calls:  119.666666666667
Record # Staying Green Patients:  33
Record # Staying Yellow Patients:  85.6666666666667
Record ALL the transferred AND rejected patients:  143.333333333333
Record alwaysREDPatient Waiting Time for a Doctor:  955.666666666667
Record patients leaving due to crowd:  0
Record yellowtoRED Patient Waiting Time for a Doctor:  16.3333333333333

Minimize # Ambulances and Nurses:  14(Best = 14)
Crowd Constraint:  NonLinear feasible
Call Constraint:  NonLinear feasible
Care Constraint:  NonLinear feasible
```

Simulation #1's output

**Output #2**

By using three feasible constraints we obtained simulation #2 as the optimal output of our simulation model. Our objective was 11 which consisted of 3 ambulances, 4 CCR nurses and 4 Other Services Nurses.

Again, there was no patient leaving due to crowded waiting area so constraint #1 was secured. For the second constraint, 19% of the calls were rejected therefore the 15% level was exceeded. Again the 15% limit was exceeded for the fourth constraint with the percentage of patients rejected or transferred being 18%.

The values can be viewed below for this simulation. And we will discuss these outcomes in the Results section.

```
Simulation: 2   ****NEW BEST SOLUTION****
6/4/2023 11:55:48 AM
Number of Replications: 3

Values of Decision Variables
Ambulance Resource:  3
CCR Nurse:  4
Other Services Nurse:  4

Values of Output Variables
Record # ACCEPTED and CARED Patients:  998.666666666667
Record # Accepted Calls:  892.666666666667
Record # Rejected Calls:  216
Record # Staying Green Patients:  29
Record # Staying Yellow Patients:  68.3333333333333
Record ALL the transferred AND rejected patients:  223.333333333333
Record alwaysREDPatient Waiting Time for a Doctor:  883.666666666667
Record patients leaving due to crowd:  0
Record yellowtoRED Patient Waiting Time for a Doctor:  17.3333333333333

Minimize # Ambulances and Nurses:  11(Best = 11)
Crowd Constraint:  NonLinear feasible
Call Constraint:  NonLinear feasible
Care Constraint:  NonLinear feasible
```

Simulation #2's output

## Output #27

```
Simulation: 27
6/4/2023 11:56:13 AM
Number of Replications: 3

Values of Decision Variables
Ambulance Resource:  5
CCR Nurse:  6
Other Services Nurse:  4

Values of Output Variables
Record # ACCEPTED and CARED Patients:  1070.33333333333
Record # Accepted Calls:  999.666666666667
Record # Rejected Calls:  67.3333333333333
Record # Staying Green Patients:  26.6666666666667
Record # Staying Yellow Patients:  77.3333333333333
Record ALL the transferred AND rejected patients:  105.333333333333
Record alwaysREDPatient Waiting Time for a Doctor:  960.666666666667
Record patients leaving due to crowd:  0
Record yellowtoRED Patient Waiting Time for a Doctor:  13.3333333333333

Minimize # Ambulances and Nurses:  15(Best = 11)
Crowd Constraint:  NonLinear feasible
Call Constraint:  NonLinear feasible
Care Constraint:  NonLinear feasible



Optimization Summary
Optimization started at 6/4/2023 11:55:47 AM and ended at 6/4/2023 11:56:13 AM
Best solution generated at simulation 2 of 27 total simulations.
```

Simulation #27's output

For this last simulation, we obtained our objective as 15 which is higher than the optimal values that were found in simulation #1 and #2.

The number of patients leaving due to crowdedness is again 0 in this simulation run too. The rejected emergency calls makes up the 6% of the total calls so the condition of the constraint #2 is met. Also in this run only 4% of the patients were rejected or transferred.

## B. Results

For the first simulation, two specifications out of total three were successfully satisfied while the objective value was not minimal. Further analyzing the optimization outputs, we have seen that even though the second simulation gives the optimal value (best solution), it was observed that 2 out of the 3 output variables' values did not assure their respective constraints. Similarly, even though simulation run #27 did not provide the best objective solution, it was observed to be the one with all conditions of the constraints being met.

## C. Conclusions

The conflict explained above and considering the inputs and outputs we are given holistically made us conclude that the simulation was not good enough to rely on. We assume this was the case due to the constraints not being fully included in the optimization process. It is also possible because of the errors of the model, if any, we made in the second stage.