The Allen Bradley Operating Room Student Simulation Project

Institute of Industrial Engineers and Rockwell Automation Student Simulation Competition

OHIO UNIVERSITY 1804

Create for Good.
THE RUSS COLLEGE OF ENGINEERING AND TECHNOLOGY

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Problem Introduction

Statement

The Allen Bradley Operating Room Student Simulation Project comprised three components:

(1) modeling the provided operating room system,
(2) identifying the system bottlenecks, and
(3) improving the performance of the operating room system via the altering of arrival patterns and resource schedules.

The Allen Bradley Operating Room system processes inpatients and outpatients. Inpatients arrive to the surgery floor and spend the night in the hospital to recover after their operation. Outpatients arrive to the hospital for surgery, but leave the same day. The system consists of four major areas:

(1) Same Day Surgery (SDS), where outpatients check-in, change their clothes, and have preliminary diagnostics taken;
(2) Pre-Operative Holding block (PreOP), where inpatients enter the system and both patients have pre-operation processes performed;
(3) Operating Rooms (OR), where the surgery occurs; and
(4) Post-Anesthesia Care Unit (PACU), where recovery takes place.

In the end, outpatients are routed to the changing room where they are prepare to go home. Inpatients are routed to their respective post-surgery rooms elsewhere in the hospital.

Objectives

+ Determine current system bottleneck
+ Suggest new arrival patterns to improve system performance
+ Suggest new resource schedule to improve system performance

Methodology

Assumptions

+ Beds are cleaned by the respective nurse (e.g. SDS RNs clean the SDS beds)
+ Operating rooms have their own set of beds that are cleaned in unison with the OR
+ Before the patient is moved to the next area, a bed (SDS, PreOP, OR, PACU) is procured to ensure availability when the patient arrives
+ Once a patient enters a queue, the patient cannot move to another queue

Model Building

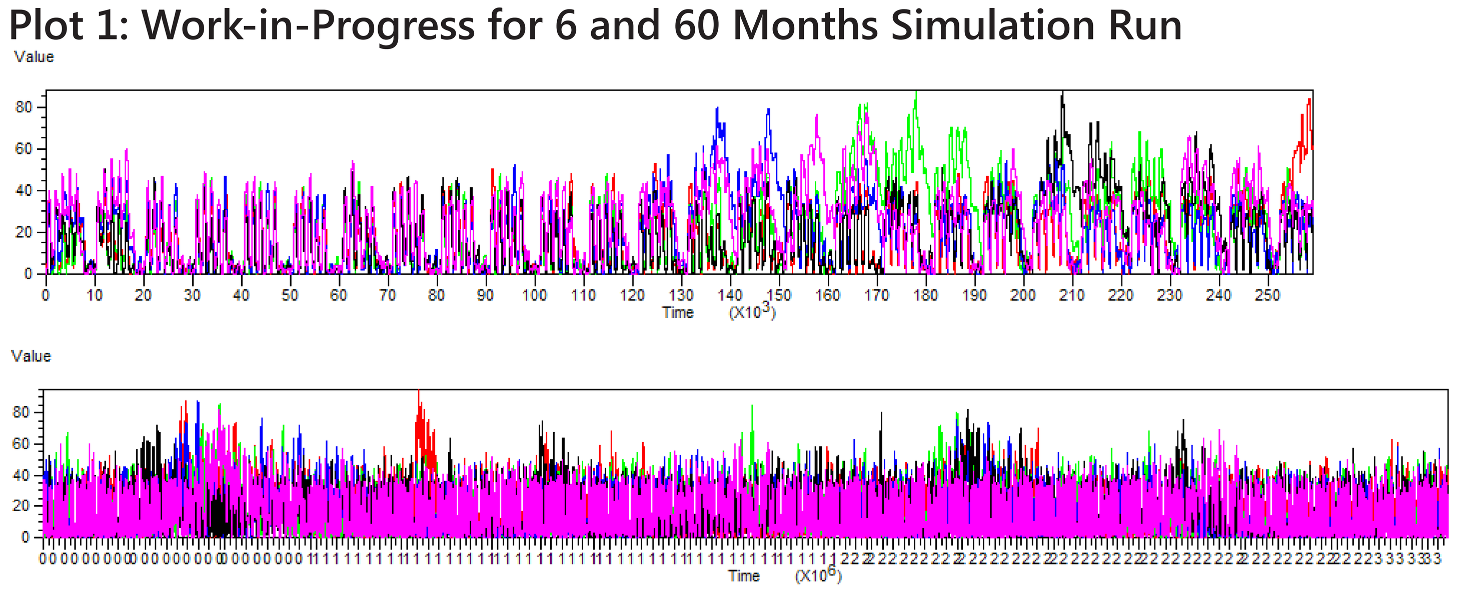
+ A simulation model of the proposed system was implemented in Arena
+ Ten (10) submodels were created for major areas in the system
+ Model was verified to accurately represent Allen Bradley Operating Room

Replication Parameters

+ Six (6) month warm-up
+ Twelve (12) month replication length
+ Ten (10) replications

The plots below show that the system is in steady-state, the six month run would seem to imply that accumulation occurs in the system; however, after observing the longer durations, accumulation does not occur and the work-in-progress (WIP, count of patients remaining in the system) spikes can be attributed to randomness in the simulation model. Ten (10) replications were used to reduce variability.

Plot 1: Work-in-Progress for 6 and 60 Months Simulation Run



Performance Goals and Measures

+ Minimize average/maximum inpatient time in the system
+ Minimize average/maximum outpatient time in the system
+ Minimize total work-in-progress at end of replication run
+ Minimize number of resource scheduled-hours

Scenarios and Experiments

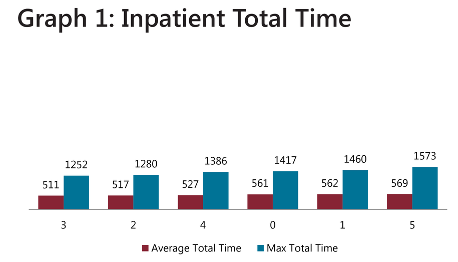
Arrival Patterns

After observing the provided arrival patterns for inpatients and outpatients, it was noted that the outpatients arrive for only a few hours each weekday with high concentration early in the day and inpatients arrive throughout the entire week. For scenarios 1 through 5, inpatient arrivals were distributed evenly throughout the respective day and for outpatient arrivals, the first arrival is at the earliest assigned arrival by Rockwell.

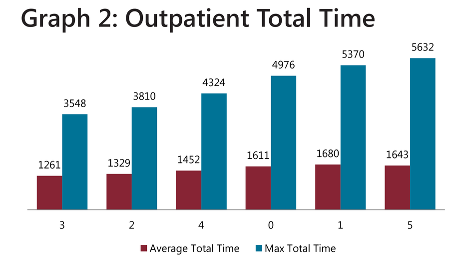
Table 1: Arrival Pattern Scenarios

Scenario	Description
0	Original, provided by Rockwell
1	Outpatient arrivals were evenly distributed over existing time period
2	Outpatient arrivals were evenly distributed over an 8 hour time period
3	Outpatient arrivals were evenly distributed over a 7 hour time period
4	Outpatient arrivals were evenly distributed over a 6 hour time period
5	Outpatient arrivals were evenly distributed over a 5 hour time period

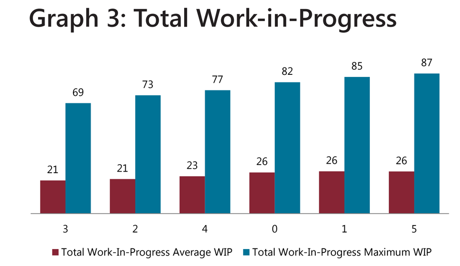
Graph 1: Inpatient Total Time



Graph 2: Outpatient Total Time

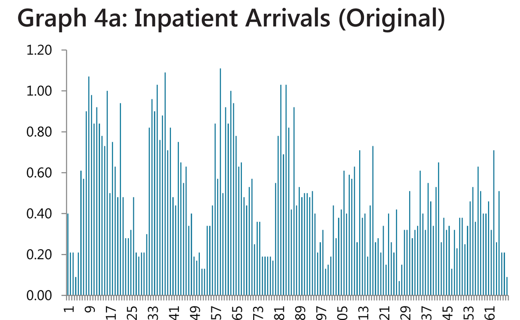


Graph 3: Total Work-in-Progress

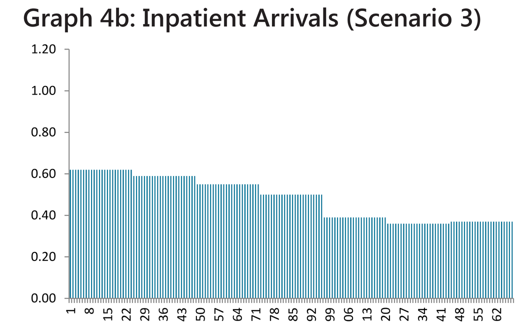


Because scenario 3 yielded the best results on all six measures, scenario 3 was chosen to be moved forward in the experiment. Scenario 3 evenly distributes inpatients over their respective day and evenly distributes outpatients over a 7 hour time period, with first arrival at the earliest assigned arrival by Rockwell.

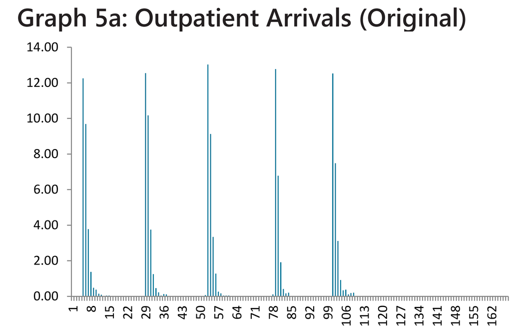
Graph 4a: Inpatient Arrivals (Original)



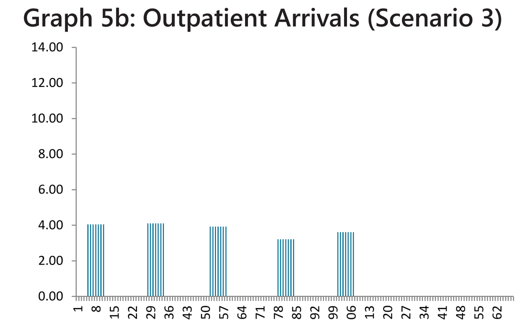
Graph 4b: Inpatient Arrivals (Scenario 3)



Graph 5a: Outpatient Arrivals (Original)



Graph 5b: Outpatient Arrivals (Scenario 3)



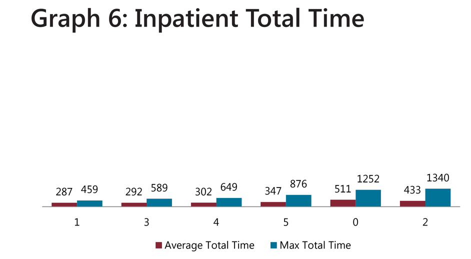
Resource Schedules

Once a best arrival pattern was selected, a few resource patterns were created to further improve the system. First, the provided resource pattern was implemented to gain an understanding of the system. Then, the model was run with a schedule that had maximum capacity for each resource: this provided insight which allowed the modelers to create a set of resource schedules for each type of resource that best followed resource need – four of these types of schedules were made. Each resource schedule set was run with the new arrival pattern (Arrival Scenario 3).

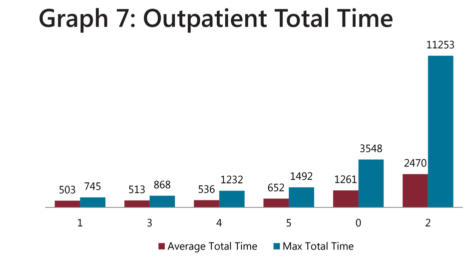
Table 2: Resource Schedule Scenarios

Scenario	Description
0	Original, provided by Rockwell
1	Full capacity for each resource
2	Schedule set 1 made by modelers
3	Schedule set 2 made by modelers
4	Schedule set 3 made by modelers
5	Schedule set 4 made by modelers

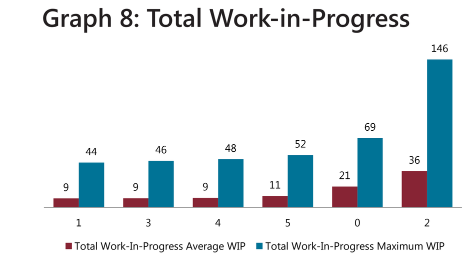
Graph 6: Inpatient Total Time



Graph 7: Outpatient Total Time



Graph 8: Total Work-in-Progress



Excluding scenario 1, which is a resource schedule set with full capacities, graph 6 and graph 7 show that scenario 3 is the best of the six scenarios that were run on the basis of inpatient and outpatient time in the system. From graph 8, scenario 1 shows WIP if the system had schedules at maximum capacity for the entirety of the system duration. Scenario 3 is most near scenario 1 which indicates that scenario 3 is best and most feasible.

Table 3: Resource Schedules Scheduled-Hours

Scenario	2	4	0	5	3	1
Resource Scheduled-Hours per Week	4,653	5,087	5,199	5,254	5,726	13,776
Ranking	4	1	3	5	2	6

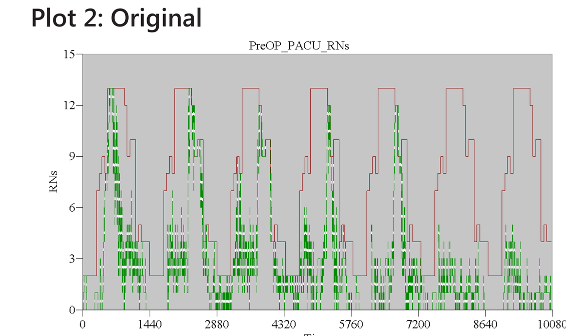
After examining average and maximum inpatient time in the system, average and maximum outpatient time in the system, total WIP in the system, and resource scheduled-hours for the system, resource scenario 4 was chosen as the best. Although scenario 3 outperformed scenario 4 as displayed in graphs 4 through 6, scenario 4 had ~600 less resource scheduled-hours than scenario 3. Because there is a variable cost associated with the number of employees scheduled, it is important to minimize resource scheduled-hours while minimizing patient time in the system as well as WIP– scenario 4 does this well.

Conclusions and Recommendations

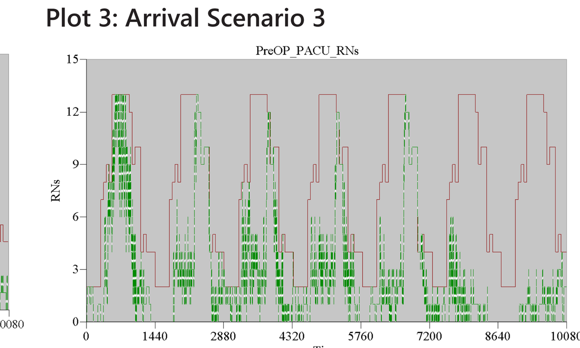
The PreOP beds were the bottleneck in the original Rufus and Friends Allen Bradley Operating Room model. The most used employees of the Allen Bradley Operating Room are the PreOP/PACU RNs.

	Original	Arrival Scenario 3	Resource Scenario 4
PreOP Beds	51.35%	47.64%	15.75%
PreOP/PACU RN	35.33%	34.52%	29.48%

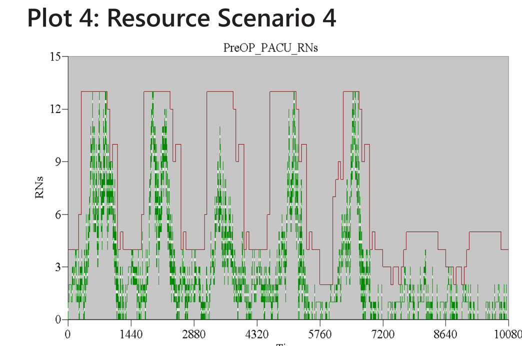
Plot 2: Original



Plot 3: Arrival Scenario 3



Plot 4: Resource Scenario 4



** Results in resource scenario 4 used resource schedule scenario 4 and arrival pattern scenario 3.*

After analyzing multiple arrival patterns and resource schedules, a best model was created: this used arrival scenario 3 and resource scenario 4. In arrival scenario 3, outpatient arrivals are evenly distributed over a 7 hour time period, with the earliest arrival as assigned by Rockwell. In resource scenario 4, the schedule set was created after investigating the utilization of resources with maximum capacity.

It is recommended to plan resource schedules on patient arrivals and that patient arrivals are as evenly distributed through the day (or time period) as possible. This simulation model can be easily used to experiment with different scenarios using changing arrival patterns and resource schedules. This simulation model can be easily used to experiment with different scenarios using changing arrival patterns and resource schedules.