The Allen Bradley Operating Room
Student Simulation Project

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Executive Summary

The Allen Bradley Operating Room was modeled and analyzed to improve system performance. The provided system was analyzed on a few measures: average and maximum inpatient/outpatient time and system work-in-progress. Then, multiple arrival patterns were tested and the best was selected (arrival scenario 3, where inpatient arrivals are distributed evenly over the respective day and outpatients are evenly distributed over a seven hour time period). Last, multiple resource schedule sets were created (via inspection of utilization plots) and tested– resource scenario 4 was the best. From the original system to the improved system, the bottleneck, PreOP Beds, decreased from 51.35% to 15.75% and the employee bottleneck, PreOP/PACU RNs decreased from 35.33% to 29.48%.

Problem Introduction

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 and are visited by the anesthetists, some patients are sent to the Block Room, if needed; (3) Operating Rooms (OR), where the surgery occurs; and (4) Post-Anesthesia Care Unit (PACU), where recovery takes place. Outpatients are then routed to the changing room where they are prepare to go home and receive post-surgery instructions. Inpatients are routed to their respective post-surgery rooms elsewhere in the hospital.

Assumptions and Methodology

The Allen Bradley Operating Room was modeled with many assumptions and simplifications to permit a feasible and workable model of the system to be produced. Lab Techs and Anesthetists are not utilized in the model because the provided schedule had a capacity of zero. Some decision points were not implemented for one of two reasons: (1) there was no data provided to warrant the decision point, or (2) decision points were forgone to make the model more feasible. 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, and all beds are procured before the patient is moved to the next step. If a patient has a surgery type that can be facilitated by a specialty operating room and the patient is assigned to the all-purpose OR queue because all of the respective specialty rooms are in-use, the patient cannot jump queues if a specialty OR room becomes available first.

To determine current system bottlenecks, the Rufus and Friends Allen Bradley

Operating Room model was run with a warm-up period of six months, a total run time of twelve months and ten replications. These parameters were determined by observing the count of patients remaining in the system (work-in-progress, WIP) over several durations, up to five years. Graphs revealed that any spike in WIP was due randomness and that the system is steady. A six month warm-up period was observed and implemented to provide realistic results and ten replications to reduce variability.

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. To best utilize the system, arrival patterns were altered to evenly spread patients throughout the day while keeping the total number of inpatients and outpatients constant. Many arrival patterns were tested and compared on the basis of average and maximum outpatient time in the system, average and maximum inpatient time in the system, and average and maximum total WIP in the system – with the smallest being the best.

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 and the best resource schedule set was selected on the basis of smallest resource scheduled-hours (excluding beds), smallest average and maximum outpatient time in the system, smallest average and maximum inpatient time in the system, and smallest average and maximum total WIP in the system.

Scenarios and Experiments

Arrival Patterns

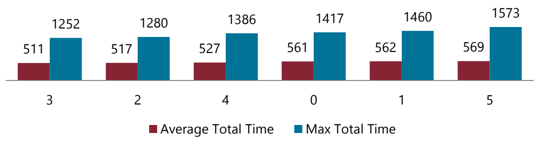
Including the original arrival pattern, six different arrival scenarios were run. These scenarios were then judged on outpatient time in the system (maximum and average) and WIP in the system (maximum and average) with the scenario yielding the smallest value in each of these measures being the best.

Table 1: Arrival Pattern Scenarios

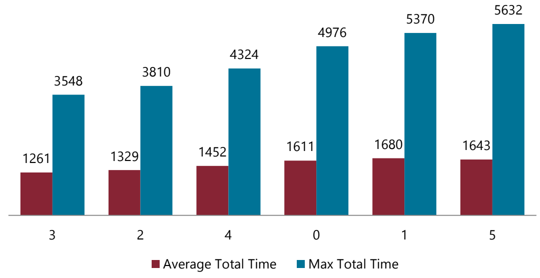
Scenario Number	Description
0	Original, provided by Rockwell
1	Outpatient arrivals were evenly distributed over the existing time period
2	Outpatient arrivals were evenly distributed over an 8 hour time period
3	Outpatient arrivals were evenly distributed over a 7 hour time period
4	Outpatient arrivals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

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.

Graph 1: Inpatient Total Time

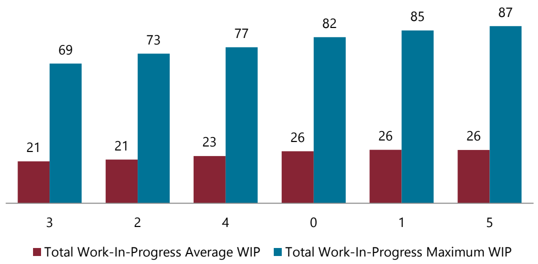


Graph 2: Outpatient Total Time



Graph 1 and graph 2 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: scenario 3 yielded the smallest value for both average and maximum patient time in the system.

Graph 3: Total Work-in-Progress



Graph 3 shows that scenario 3 is the best of the six scenarios that were run on the basis of total work-in-progress in the system. Although scenario 3 has an equivalent average WIP as scenario 2, scenario 3 has a smaller maximum WIP than scenario 2. Scenario 3 has the smallest total WIP than all other scenarios.

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 is at the earliest assigned arrival by Rockwell.

Resource Schedules

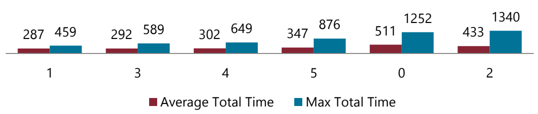
Including the original resource schedule, six different resource scenarios were run. These scenarios were then judged on total resource scheduled-hours (excluding beds), outpatient time in the system (maximum and average) and WIP in the system (maximum and average) with the scenario yielding the smallest value in each of these measures being the best.

Table 2: Resource Schedule Scenarios

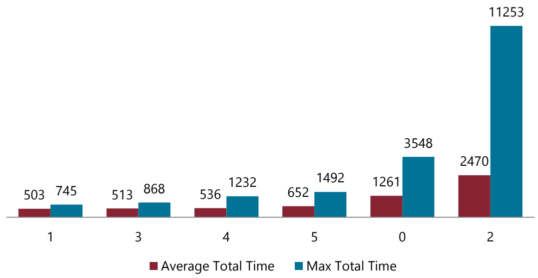
Scenario Number	Description
0	Original, provided by Rockwell
1	Full capacity for each resource
2	Schedule set 1 made by modelers
3	Schedule set 2 made by modelers
4	Schedule set 3 made by modelers
5	Schedule set 4 made by modelers

For scenarios 2 through 5, beds were considered as a fix cost and as such, their capacities were not altered from full capacity.

Graph 4: Inpatient Total Time

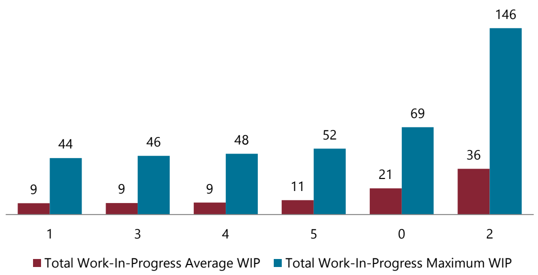


Graph 5: Outpatient Total Time



Excluding scenario 1, which is a resource schedule set with full capacities, graph 4 and graph 5 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. Scenario 3 yielded the smallest value for both average and maximum patient time in the system and had results most near scenario 1– which produces the system's optimal throughput.

Graph 6: Total Work-in-Progress



Excluding scenario 1, graph 6 shows that scenario 3 is the best of the six scenarios that were run on the basis of total work-in-progress in the system. 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 instantaneous utilization of the PreOP beds was 51.35%. After the new arrival pattern was introduced (arrival pattern scenario 3), the utilization decreased to 47.64%. Last, after the new resource schedule was implemented (resource scenario 4), the utilization decreased to 15.75%.

The most used employees of the Allen Bradley Operating Room are the PreOP/PACU RNs. In the original model, the instantaneous utilization of the PreOP/PACU RNs was 35.33%. Then, the utilization decreased to 34.52% and again to 29.48% after the introduction of arrival scenario 3 and resource scenario 4, respectively.

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. With the arrival and resource scenarios mentioned above, the model performs the best– minimizing resource scheduled-hours while minimizing patient time in the system as well as patients remaining in the system.

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.

Implementation Plan

Recommended arrival patterns and resource schedules can be implemented as a result of this project (or after cost consideration). In addition, this model can be used as a tool for periodic review of arrival patterns and resource schedules.