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**PENN STATE HERSHEY MEDICAL CENTER: OPERATING ROOM UTILIZATION**

**PSU Hershey**

**Final Report**

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Submitted to: Penn State Hershey Medical Center

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Yes No

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**EXECUTIVE SUMMARY**

Operating rooms at hospitals can be one of the most expensive areas, while also serving as a large source of income. Various factors such as cancelled surgeries, emergency cases, and delayed procedures often contribute to scheduling issues and lower utilization of hospital resources. Thus, having the ability to utilize all operating rooms efficiently and effectively is extremely important. The overall objective of this project was to utilize data science and statistical techniques to create a scheduling model of the operating rooms at the Penn State Hershey Medical Center. This model will give employees at Penn State Hershey Medical the ability to simulate possible schedule outcomes to compare to the actual scheduled surgeries. The team used statistical techniques such as kernel density estimation (KDE) and stochastic processing to create a simulation based on past scheduling data and patterns. Ultimately, the team has created a model that works as a foundation for the hospital’s research on operating room utilization. This model allows the user to view days from the past, in the present and future, and view comparisons of predicted and simulated OR schedules versus what truly happened in the OR that day. Having this model allows the user to test different scheduling techniques and capture patterns and other utilization metrics.

# Penn State Hershey Medical Center: Operation Room Utilization

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| **Project Name** | **Penn State Hershey Medical Center: Operation Room Utilization** |
| **Stakeholders** | Penn State Hershey Medical Center |
| **Version, Date, Notes** | Version 1, 05/1/2021 |

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| **Specific Project Terms, Abbreviations or Acronyms** | **Definition** |
| OR | Operating Room |
| KDE | Kernel Density Estimation |
| PDF | Probability Density Function |
| FIFO | First In First Out; a type of bumping policy |
| Bumping Policy | A set of rules OR schedulers follow when reassigning surgeries to new rooms or times after an emergency case comes in that needs priority |
| Monte Carlo Simulation | Repeatedly sampling a distribution to obtain the probability of differing outcomes |
| Regression Model | A statistical learning method that fits an approximated continuous function to a set of data points |

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| **Description** |
| This project yielded a prototype simulation of the scheduling and utilization of hospital operating rooms (OR). The simulation allows its users to test different implementation strategies, such as bumping emergency cases, and scheduling optimization strategies. The project began with building a computer simulation for the start of the day; this allowed a theoretical “planned schedule” to be generated. After this, real-world activity was simulated incorporating emergency cases. The team incorporated concepts of kernel density estimation and stochastic processes to simulate a projected future schedule across all hospital operating rooms. |
| **Business Need and Project Goals/Outcome/Objectives** |
| * OR use is a major cost and source of income for a hospital so having the ability to know how to use the ORs efficiently is extremely important. * The client was looking for the basis of a scheduling model as a foundation for further optimization, as well as implementing more complex scheduling routines in the future. * The team developed a model that takes scheduled OR procedures as well as cancelled procedures, and outputs a projected schedule for any given day as well as a simulation of that projected schedule. * The correctness of the resulting schedule was determined by Hershey Hospital scheduling coordinators. * The output of the model is a table and plot of a given schedule including start/end times, OR rooms, and procedure type. * Overall, the project facilitated the design of a sophisticated OR room scheduling procedure model and will lead to work on optimizing the efficiency of OR room use. |
| **Project Approach** |
| In order to build both the planned and simulated schedule, the team relied heavily on Kernel Density Estimation (KDE) techniques in order to model the OR. For the planned schedule part of the model, probability distributions were generated that reflected the number of cases and the types of cases that would be in a given OR based on the month of the year and day of week. The team sampled from these distributions to build the planned schedule for the day as well as distributions that reflected the length of the surgery, whether a given surgery would be cancelled, and the turnaround time between two surgeries in the same operating room. Given a month and day of week, the first part of the model would output a plausible schedule for how Hershey Medical Center might look that day.  The second part of the model would take in this planned schedule and simulate real world activity to output a simulated schedule for that day. For example, given a planned schedule the team would simulate the effects of surgeries being cancelled, taking longer or shorter than expected, and turnaround times between cases being longer or shorter than expected. This would produce a table and plot that showed the planned cases for the day with their start and end times as well as the simulated cases at the end of the day with the time the cases actually started and ended. This was all done by creating KDE distributions based on historical data from Hershey Medical Center. Each time a schedule was simulated, the model would randomly draw from these distributions and select different values for the types of cases, lengths of cases, and the other variables previously mentioned. This random simulation meant that the project would be useful for running Monte Carlo simulations in the future. The user can simulate a planned schedule many times and see the range of outcomes they might expect to see for the given planned schedule.  The team also incorporated functions to visualize these graphs so the user can clearly see the planned vs. simulated schedule for a day side by side. Additionally, functionality was added for the user to select a historical day in the data set and simulate that schedule too.  The team began further work on a plan to incorporate emergency cases into the model. Emergency cases are a large source of delay at large hospitals, so it was known that they would eventually be very important to add to the model. The team provided a write up with the final code that detailed an approach to adding emergency cases onto the model that was provided to the sponsor. |
| **Results and Discussion** |
| The model was able to take in either a historical day’s schedule or a given month and day of the week combination and output a planned schedule for that day. The planned schedules being outputted was frequently reviewed by the sponsor to check for accuracy and whether they could pass a visual check of something that Hershey Medical Center might schedule for that day.  Additionally, the second part of the model outputted a simulated schedule for how the planned schedule might change by the end of that day.  An example output of the plots that show the planned and simulated schedule for a given day are shown in Appendix B. The model would produce these plots as well as a table that showed each OR room, the planned start and end time of each surgery, and the actual start and end time of each surgery.  Overall, the team thinks that they have developed a successful model for the sponsor to act as a great starting point for further development. The model was able to accurately find and reflect patterns in the scheduling tendencies of Hershey Medical Center and the patterns in how cases get delayed and take longer or shorter than they are planned for based on the day of the week, month, and the department line that surgery is placed in. |
| Conclusion and Future Work |
| The model will be built upon and used by Hershey Medical Center in order to accurately simulate OR use and to design and test new scheduling, bumping, and other policies in order to improve OR efficiency and save money for the hospital. The model is a solid base for this future work, and the next main step this project will need to take is to incorporate emergency cases into the simulation of the schedule. One approach that was designed and presented in a paper to the sponsor was to “step” through the schedule at small increments of time and check if any emergency cases have arrived. If they did, the team would then evaluate the entirety of the current OR schedule and find the best place to put that emergency case into the schedule.  With this project, the team has given Hershey Medical Center the base to continue research on this topic and improve the model. |

REFERENCES

1. Taaffe, K., Pearce, B., & Ritchie, G., “Using kernel density estimation to model surgical procedure duration,” *International Transactions in Operational Research*, Vol. 28(1), pp. 401-418, May (2018).
2. Wong, T., Sarraf, E., Irwin, B.H., Stanley, A. C., Do, H. T., Novak, D. C., & Tsai, M. H., “The ramifications of a first-in first-out bump policy,” *The Anesthesiology Annual Meeting*, Oct. (2020).

# APPENDIX A: PERSONNEL VITAS

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* Olivia Kucenski, Industrial Engineering
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# APPENDIX B: PLANNED VS. SIMULATED SCHEDULE PLOTS



