FURSCA End of Summer Report

Optimizing Campus Living Space Turnover Performance

Using Operations Research (OR) Methods

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Introduction

Student housing plays a crucial role in college life, and improving its operations can enhance the overall campus experience. This research project focuses on the challenging housing turnover period at Albion College and aims to design an efficient mathematical model using operations research and optimization techniques. The research follows five phases of operations research to address the housing turnover problem. The phases involve identifying the problem, formulating a mathematical model, which is the current stage of the project, analyzing and refining it, testing with previous data, and applying the model if possible. The primary focus lies on the beginning and end of the summer housing turnover at Albion College. This report outlines progress and how the research project has provided valuable insights into the complexities of optimizing the housing turnover process.

Results

In the first two weeks, I worked with the CLO, observing and gathering data on the actual 2-week housing turnover process. The data collected included information on buildings, apartment size, number of units, fixed person-hours, turnover person-hours, and shifts for custodial, maintenance, and assessment teams.

During the third week, I began formulating the deterministic model using real data provided by Community Living, with the objective of minimizing the cost of operation for the turnover process. This model includes 53 living spaces going through turnover, with two main activities: custodial and maintenance. To break down the time, I divided each day into 20 working hours, and the entire housing turnover process spans 14 days.

For this model, I introduced decision variables denoted as x_{ijklm}, where:

- *i* represents the room number (e.g. from 1 to 9).
- *j* represents the room type (e.g., single, double).
- *k* represents the process (custodial or maintenance).
- *l* represents the hour of the day (from 1 to 20).
- *m* represents the day of the housing turnover (from 1 to 14).

The total number of decision variables for this model is approximately 29,680 (53 rooms * 2 types * 2 processes * 20 hours * 14 days).

I also created a small-scale version of the model to be used to establish "proof of concept", focusing on only 6 living spaces that all go through turnover on the same day, with a limited number of working hours and workers. In this case, I was able to eliminate the index *m*, resulting in the decision variable simplifying to x_{ijkl}. The primary objective function for the model represented the total cost of the turnover process, which was to be minimized. The constraints in my model cover several aspects, including the number of workers available to work at the same time, the limited hours a worker is allowed to work each day, and the requirement that each room must be cleaned and maintained once.

A substantial challenge in the problem that I encountered in my research arose from the fact that some decision variables' indices depended on other indices. This dependency complicated the formulation of the mathematical model and, at present, interferes with the efficient scaling of the OR algorithm to arbitrarily large numbers of rooms, tasks, and labor. Additionally, while conducting my research, it became apparent that my initial approach did not align with Community Living's primary objective of minimizing the turnover time within the 2-week period. Consequently, I needed to adapt my model approach and reformulate the problem with a shift in focus toward human resource scheduling rather than resource distribution.

From week 4 onwards, I delved into researching more applicable methods, especially ones suitable for addressing scheduling and human resource optimization. This search led me to a promising framework (Ranjbar, Hosseinabadi & Abasian, 2013) I am currently implementing - Resource Constraints Project Scheduling Problem (RCPSP) minimizing total weighted late work

The mathematical model I was able to develop includes 14 activities, denoted by $N = \{0,1,2,...,12,13\}$. Activities 1 to 6 represent the cleaning process for rooms 1 to 6, while activities 7 to 12 represent the maintenance process for the same rooms. Activities 0 and 13 are dummy activities representing the start and end of the entire project. The model's key parameters are f_i, d_i, and δ_i, where f_i represents the finishing time for activity i, d_i is the duration of activity i, and δ_i denotes the due date for activity i (which is set to 0 in this context). The model also defines T_i as $max(0, f_i - \delta_i)$ and Y_i as $min(T_i, d_i)$, representing the lateness for each activity. Another parameter that is the set $A=\{(1,7),(2,8),...,(6,12)\}$ indicating the order of activities, where $f_i \leq f_j - d_j$ for each (i,j) pair in A as maintenance can only happen after custodial.

The objective function aims to minimize the total lateness of the project, denoted by Y_T, which is the sum of all Y_i values for i ranging from 1 to 12. The decision variables are represented by x_{it}, which are binary variables determining if activity i finishes at time t (time slots representing 30-minute intervals). Additionally, there is a binary variable z_i, where $z_i = 1$ if $T_i \leq d_i$ and $z_i = 0$ if $T_i > d_i$. The constraints of the model involve ensuring the proper completion of activities within the given time frames. These include constraints related to the sum of x_{it} for all i in N being equal to 1, constraints relating to the maximum allowed time for an activity (sum of $t*x_{it}$ $\leq$ *sum of* $t*x_{jt}$ - d_j for each *(i,j)* pair in *A*), and constraints defining the relationship between Ti, Yi, and zi.

As the 8-week research period was coming to an end, I was learning and coding this model on *Mathematica* and *R* using the Gurobi Optimizer Package. Despite the discontinuation of my access to *Mathematica* after the traditional FURSCA summer period ended, I plan to devote my free time during the summer and possibly conduct another project during the fall semester to accomplish my goals.

Conclusion

In conclusion, although this research project's aim of designing and implementing a comprehensive mathematical model for optimizing the housing turnover process was not fully completed, significant progress was been made in understanding and formulating a small-scale model to represent the idea. The objective is to achieve the least time-consuming allocation of resources while informing administration staff of the required order and personnel for maintenance, renovation, and cleaning which will continue to be explored through future endeavors.

Although I did not develop as complete of a solution as I would have liked for my project, I am confident that this journey has provided valuable hands-on experience in practical problem-solving, enhanced coding skills, critical thinking, and other academic expertise. This knowledge will undoubtedly be instrumental in my future career path. With the aim of utilizing this research for my honors thesis and participation in the annual Elkin Isaac Research Symposium, I remain committed to continuing my learning and refining the mathematical model to ultimately achieve efficient housing turnover at Albion College.

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References

Ranjbar, M., Hosseinabadi, S., & Abasian, F. (2013). Minimizing total weighted late work in the resource-constrained project scheduling problem. *Applied Mathematical Modelling*, *37*(23), 9776–9785. https://doi.org/10.1016/j.apm.2013.05.013