

An Integer Programming Approach to Classroom Space Planning at the Faculties of Engineering and Architecture at Dalhousie University

Uday Venkatadri · Srivatsav L. Kripakaran ·
J. Pemberton Cyrus

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Abstract We discuss an Integer Programming model that was developed for classroom space planning at the Faculties of Engineering and Architecture at Dalhousie University. The model will be of interest to any facility planner who is interested in creating a decision making tool for classroom design in a university setting. Many timetabling problems presented in the literature assume that classrooms are already available before courses may be scheduled. However, an important decision for universities is to determine classroom space requirements. The Faculties of Engineering and Architecture at Dalhousie University are at a critical juncture in terms of program delivery and enrollment. The Facilities Management Department at the university wanted to know what the optimum classroom configuration for the two faculties is. To help Facilities Management answer this question, we developed a binary integer classroom space planning model incorporating basic constraints of a timetabling problem. Based on the solution to this model, we analyzed how classroom space can be reassigned. The results of the model were presented for campus planning and our suggestion involved resizing some existing classrooms and building new ones. We studied a number of scenarios and conducted some sensitivity studies.

Keywords University space planning · Classroom space planning · Timetabling · Integer programming

1 Introduction

Dalhousie University is a major university and is located in Halifax, Nova Scotia on the East Coast of Canada. There are campuses of Dalhousie University in Halifax: Studley,

Uday Venkatadri
Department of Industrial Engineering
Dalhousie University
P.O. Box 1000, 5269 Morris Street
Halifax, Nova Scotia B3J 2X4
Canada
Tel.: +1-902-494-3987
Fax: +1-902-420-7858
E-mail: Uday.Venkatadri@dal.ca

Carleton and Sexton. The Studley campus is the main campus of the university and houses faculties such as Arts & Social Sciences, Science, Law, Management, and Computer Science. The Carleton campus houses the faculties of Medicine and Dentistry. Finally, Sexton campus houses two faculties: the Faculty of Engineering and the Faculty of Architecture & Planning. While a significant part of the Faculty of Engineering is housed on Sexton campus, the first two years (also called the core division) of Engineering studies at Dalhousie University are conducted mostly on Studley campus. The final years of Engineering study are conducted on Sexton campus, which also is the main centre for administration, faculty offices and research in Engineering.

The university is going through a strategic space planning exercise to look at future space requirements on Sexton Campus. The exercise was motivated by two considerations:

1. A new building is being planned on Sexton campus mainly for student learning. It will include state-of-the-art classroom, lab, and hands-on learning facilities.
2. There is a proposal to move the core division of Engineering studies to Sexton campus so that Engineering students could have an integrated learning experience and interact better with their seniors.

One of the peculiarities of Engineering studies in the faculty is that large classes (such as those of size 240) are only held in the core division in which basic science and engineering courses are taught. Therefore, if the core division is to be moved to Sexton campus, new facilities will have to be built and this is implicit in the rationale behind points 1) and 2) above.

We were contacted by the Dean of Engineering's office to analyze space utilization in the Faculties of Engineering and Architecture and come up with suggestions on how to better manage space. During the space analysis exercise, we discovered that the average classroom utilization on Sexton campus based on a five-day 55-hour week was roughly 31%; some classrooms had utilization levels of less than 25%. Hence, we concluded that the classroom mix (number and size) on Sexton campus could be improved.

2 Methodology

We realized that the classroom mix determination problem was linked to the timetabling problem, generally modelled in the literature as a binary integer program. We use fixed and variable costs to open classrooms depending on size of the classroom. All classrooms are considered closed in the beginning. The detailed model is presented in [1] and is based on scheduling patterns. For example, a course that requires three hours of instruction and two hours of lab, could be scheduled in the MWF 9:30–10:30am, W (1:30–3:30pm) pattern. That is to say, the lectures are held Monday, Wednesday, and Friday from 9:30am–10:30am and the lab from 1:30–3:30pm. Many such commonly used patterns were developed in consultation with the Associate Dean's office which is responsible for timetabling within the faculty. The constraints then were to assign courses to the patterns in a classroom such that no two courses may be assigned to pattern-classroom that conflict in time. The model has features relating to the reality of scheduling at Dalhousie University such as courses with and without labs, graduate courses, and splitting (teaching a course or lab in sections). We also used a preference function to schedule classes depending on time of day. For example, it allows classes in the morning to be preferred over those in the evening or vice versa.

3 Results

The model developed was solved repeatedly for various scenarios to help in the decision making process. In fact, we realized through the model solution process that the problem was multi-objective in nature. This was because course splitting results in a different number of courses offered. Our final recommendation [2] is shown in the Table 1.

Table 1 Recommendations

Scenario	Number of Courses	No: of Classrooms			Area (m^2) Required
		Required	Built New	Closed	
SE-O-S	234	22	0	8	1641.91
SE-R-US	262	24	0	6	1872.05
M-SR-US	256	24	1	6	2222.68

In the above table, SE-O-S is a scenario where the core division is not moved to Sexton campus and core division classes are taught in sections of 60 students. 234 courses are offered in this scenario, not including the core division. It is recommended that if the core division is not moved, only 22 class rooms are required to maintain a classroom utilization rate of roughly 72%, implying that 8 class rooms could be closed down.

SE-R-US is a scenario where the core division is moved to Sexton campus. In this scenario, core division classes are taught in sections of 120 students. 262 courses are offered in this scenario and for a comparable utilization rate, 6 classrooms need to be closed.

M-SR-US is a scenario where the core division is moved to Sexton campus. In this scenario, core division classes are taught in sections of 240 students. Therefore, only 256 courses need to be offered. However, this scenario needs a large auditorium (that can hold 240 students) to be built. However, 6 classrooms may be closed down.

4 Conclusions

The work outlined offers two advantages to Dalhousie University. First, it may be used to determine classroom mix (size and number). Since we concluded that there is extra classroom space on campus, there are opportunities for reuse of that space. The decision process for the new building and the proposed relocation of the core division is being driven by this work. Second, this effort will gradually lead to the Faculty of Engineering adopting an automated timetabling process to replace the cumbersome manual process currently under use.

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References

1. Kripakaran, S.L., Venkatadri, U., and Cyrus, J.P., An Integer Programming Approach to University Classroom Space Planning, Under revision with INFOR (2008)
2. Kripakaran, S.L., Venkatadri, U., and Cyrus, J.P., Space Planning and Classroom Requirements Analysis for Sexton Campus, Unpublished report submitted to the Dean, Faculty of Engineering, Dalhousie University (2007)