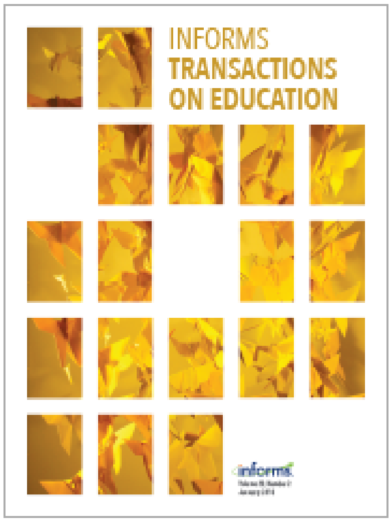

INFORMS Transactions on Education

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

Case Article—Production and Distribution Optimization of Beach Equipment for the Marinero Company

Andrea Manno, Laura Palagi, Simone Sagratella

informs
http://pubsonline.informs.org/journal/ited/
INFORMS TRANSACTIONS ON EDUCATION
Vol. 19, No. 3, May 2019, pp. 152–154
ISSN 1532-0545 (online)

Case Article—Production and Distribution Optimization of Beach Equipment for the Marinero Company

Andrea Manno,[a] Laura Palagi,[b] Simone Sagratella[b]

[a] Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Milano, Lombardia, Italy; [b] Dipartimento di Ingegneria Informatica Automatica e Gestionale A. Ruberti, Sapienza Università di Roma, Roma 00185, Italy

Contact: andrea.manno@polimi.it, http://orcid.org/0000-0001-5410-7039 (AM); laura.palagi@uniroma1.it, http://orcid.org/0000-0002-9496-6097 (LP); sagratella@dis.uniroma1.it, http://orcid.org/0000-0001-5888-1953 (SS)

Received: October, 2017
Accepted: September, 2018
Published Online in Articles in Advance: May 20, 2019

https://doi.org/10.1287/ited.2018.0202ca

Abstract. We present a mixed integer nonlinear mathematical programming model, covering a broad range of operations research (OR)-related topics. The case is designed to allow students to use knowledge acquired from OR and management science classes to model, analyze, and provide concrete solutions for the considered problem. Because of its high practicality, this exercise is an ideal tool to make the OR domain more accessible and to learn how to balance a problem's complexity with the availability of algorithms for its solution. The case has been proposed as a competitive challenge and has been assigned both to students pursuing a bachelor's degree in management engineering and students pursuing a master's degree in industrial engineering. Students were grouped into working teams, and all teams competed against each other to get the best solution to win the challenge. Both the work-in-team and the challenge settings have been enjoyed by the students. During three lectures of 90 minutes, a brief review of OR-related tools and a detailed description and analysis of the case study have been provided to the students. Successive periodic debriefing meeting sessions have been scheduled to engage and monitor students during project development.

Supplemental Material: Online supplemental files are available at https://doi.org/10.1287/ited.2018.0202ca.

Keywords: active learning • developing analytical skills • teaching modeling • teaching with projects • teaching min min and min max piecewise linear functions • spreadsheet modeling • AMPL modeling

1. Introduction

In this paper we present a comprehensive (fictitious) case study, with the aim of introducing students to several modeling principles of nonlinear, linear, and integer programming problems in a proactive and integrative manner. This case study consists of a multifaceted problem that incorporates multiple operations research (OR) topics. Indeed a major challenge in teaching OR classes, in particular to students for whom OR is not the primary field of study, is to motivate them to acknowledge the need for OR tools in decision making (e.g., Beliën et al. 2013). Project-based learning is gaining momentum in many schools (e.g., Dobson and Tilson 2016, and references therein). Nonetheless, running projects with real-world companies is often a difficult task, taking too much time. Furthermore, examples based on specialized engineering applications generally require understanding of the technical background and lead to highly complicated models, so that students lose track of the OR/management science aspects when drowning in the details (Trick 2004).

This case was designed to offer the benefits of a project experience in a scalable format, primarily for students of the School of Engineering. The case results to be a reasonable compromise between a realistic and a compact and manageable scenario. Indeed, it provides a challenging and enjoyable way for students to practice OR. The challenge setting, in which each team competed to get the best solution of the OR mathematical problem, was shown to be a stimulating factor, encouraging the students to get used to OR techniques.

The case presents different decision levels. Modeling the full case would lead to a very complicated mixed integer nonlinear model. Students should discuss different simplification approaches to be able to use standard linear programming (LP)/mixed integer linear programming (MILP) software.

In addition, we have provided solution assessment software that encompasses the full case study problem and that can be used to check whether a given solution can actually be implemented (solution feasibility) and its "value" in terms of overall revenue together with all details in terms of costs and profit (solution performance). This allows for an unbiased tool to evaluate the proposals and compile a ranking among the student teams. The solution assessment software can also be made available to teams to check whether their work-in-progress results match with the actual values returned by the solution assessment tool. From a pedagogical point of view this allows teams to have autonomous revisions of their modeling and algorithmic choices.

2. Use Case

The case is designed to be (possibly) conducted with students organized into teams (as suggested also in Metters et al. 2009). In this way hard and soft skills complement each other. Actually, technical understanding of the underlying model goes hand in hand with arguing and sharing strategic decisions, representing the main ingredients of success. Each team should select a leader who has the role of presenting strategic and operational choices during the debriefing session and the final consultation.

As already mentioned, we have organized the case as a challenge (e.g., a call for a project). The case has been presented as divided into stages so that students can go through increasingly challenging problem steps:

a. brief review of OR tools;
b. case description (reading the client's call);
c. details of the demand as a function of prices and advertising (framing the client's problem);
d. data analysis;
e. presentation of the solution assessment tool that is used to evaluate a decision choice.

Presentation of parts a through e was spread over three 90-minute class meetings. During the first lecture the text of the project was made available to the teams, and the deadline for the final submission of teams' proposals was communicated.

Modeling tricks for tackling, for example, activation costs, economies of scale, and closure of centers have been explained during the three lectures on much simpler examples, so that teams had the basic tools for mathematical modeling of any aspect of the project.

After these lectures, debriefing meetings are scheduled and the game started. Each team should define its own strategy and choose the mathematical model they want to fit. For the solution they can use standard software, either student or professional versions if available.

The first debriefing meeting with the teams is scheduled one week after the last lecture. Successive debriefing meetings are scheduled every 15 days until the deadline is reached (three or four debriefing meetings are scheduled). Substantial learning occurs during these consultation sessions because students have already tried to accomplish what they could on their own, so that they have quite precise questions and remarks. Hence they are able to understand the suggestions. Of course each team may follow different ways of attacking the problem, and the role of the teacher stays in pointing out the strengths and weaknesses of their point of view rather than correcting their model or approach. The use of the solution assessment tool allows the team to check the improvement or the deterioration of their changes.

At the deadline each group must submit its proposal by email. The teacher calculates the teams' rankings using the solution assessment tool that encompasses the full case study problem. The solution provided by a team is acceptable if it satisfies all the restrictions on resource availabilities as hard constraints; the ranking is based on the value of the corresponding revenue. A day after the deadline, the final meeting is scheduled, during which each team must present its own result. The teams must prepare a twenty-minute presentation, during which they discuss their strategic and operational choices, the mathematical model underlying the submitted solution, and the software used for the solution. The ranking is not made available until all the teams have discussed their projects. The winning team is nominated at the end of all the presentations as the one that got the highest revenue.

3. Pedagogical Goal

The model discussed in this paper is a simple and easily understandable OR model that can be used in a teaching session to promote activity and collaboration among students. Through discussions and careful choices of parameters, variables, constraints, and objective, this example aims at convincing students that a model is a useful abstraction of a real-life problem. The pedagogical approach for this example can be classified as a proactive learning process coupled with collaborative learning (see Prince 2004). Indeed, proactive learning requires student activity and engagement during the learning process. Because the problem formulation is built up through lectures and debriefing meetings, it requires student activity from start to end. On the other hand, development of the proposal in a team constitutes a form of collaborative learning because it promotes students interacting and working toward a common goal. Indeed, the interaction between students is central for strategic and operational choices and helpful in the construction of the mathematical model.

The teacher has observed that during the first debriefing meetings the students' moods may change from optimistic to disappointed whenever they have the opportunity to submit their solution to the solution assessment tool to check the actual quality of their proposal. Indeed, in most cases the first attempts led to hard simplifications and/or presented mistakes in the formulation, so that there was no correspondence between the values of profit returned by the solution assessment tool and the values they expected. In many cases at the very beginning the solution provided by the student was not even acceptable because it did not respect the restrictions on resource availabilities. During debriefing meetings with the teacher they have the chance to discuss their choices and understand the reasons for discrepancies between the values returned by their models and the ones of the solution assessment tool. This established a positive reaction and encouraged alternative choices.

4. Classroom Experiences

We used this exercise in the last four years for different classes of the Engineering School, which have different knowledge levels of OR topics. In particular, we used the case for a qualifying examination on the Operations Research Project Exam for both Management Engineering (Bachelor of Science) and Industrial Engineering (Master of Science) Schools. The course was 13 weeks in an academic semester, and the teacher met students at least once every two weeks either in a class or in a debriefing meeting as explained in Manno et al. (2019).

The project is developed in a course including the following in the syllabus: simple linear programming (LP) and integer linear programming (ILP) models (including among others: assignment, knapsack, multiplant multi-item production, and blending problems), *What if* analysis, basic sensitivity analysis, and use of Boolean variables to model piecewise linear functions. Regarding the background, it is required that students have a basic knowledge of LP theory, including strong duality, the basics of the simplex method, and the basics of ILP. In this regard the classes that experimented with the project were quite different in terms of background. In the case of the Bachelor class in Management Engineering, students had already attended two further OR classes covering in depth theory and algorithms of LP, convex programming, basics of nonlinear programming, and ILP. Further, they had learned the AMPL modeling language (Fourer et al. 1989), and had a good background in programming. On the other hand, Master classes in the Industrial Engineering School had only a basic course in OR, no background in AMPL, and quite basic programming skills.

Students were grouped into small working teams of approximately three to four people.

Actually we have modulated the difficulties of the problem to be effective for students with different backgrounds.

A simplified version of the problem has been developed essentially by reducing the number of variables involved but also simplifying some tricky modeling aspects (see the teaching notes; Manno et al. 2019). We provide the solution assessment tool both for the full case and for a simplified version.

Students were asked to solve the full/simplified problem tackling nonlinearity of the demand with heuristic choices. It may happen that the size of the mixed integer nonlinear program model for the full problem is beyond the limits of the student versions for commercial software [e.g., AMPL (Fourer et al. 1989)], so that teams might need to implement simplifications to tackle this situation.

Students in Industrial Engineering, with no background in AMPL, were asked to solve a simplified version of the problem using spreadsheets. Even the simplified version might exceed the size limits of a standard Excel Solver. In this case students might have the chance to make further simplifications on their own or to install the OpenSolver toolbox for Excel (Mason 2012).

5. Conclusion

The main objective of this classroom exercise is to provide students with an opportunity to gain a deeper and more practical understanding of the OR tools than traditional lectures can provide. The case helps students to understand the challenges of properly managing a call for a project using mathematical programming tools. Students were asked to fill anonymous surveys on the project, and most of the students were strongly positive about the overall experience. Hence we can witness that the case achieved its objectives in a relevant, flexible, and enjoyable way.

Acknowledgments

We thank an anonymous referee for the careful reading, which improved the paper significantly.

References

Beliën J, Colpaert J, Boeck LD, Eyckmans J, Leirens W (2013) Teaching integer programming starting from an energy supply game. *INFORMS Trans. Ed.* 13(3):129–137.

Dobson G, Tilson V (2016) Case article—Medication waste reduction in an in-hospital pharmacy: A case that bridges problem solving between a traditional case and an industry project. *INFORMS Trans. Ed.* 16(2):68–70.

Fourer R, Gay DM, Kernighan B (1989) AMPL: A mathematical programming language. Wallace SW, ed. *Algorithms and Model Formulations in Mathematical Programming* (Springer, New York), 150–151.

Manno A, Palagi L, Sagratella S (2019) Case—Production and distribution optimization of beach equipment for the Marinero company. *INFORMS Trans. Ed.* 19(3):155–159.

Mason AJ (2012) OpenSolver—An open source add-in to solve linear and integer progammes in excel. Klatte D, Lathi HJ, Schmedders K, eds. *Operations Research Proceedings 2011* (Springer-Verlag, Berlin), 401–406.

Metters R, Vargas V, Weaver S (2009) Case article—Motherland air: Using experiential learning to teach revenue management concepts. *INFORMS Trans. Ed.* 9(3):124–126.

Prince M (2004) Does active learning work? A review of the research. *J. Engrg. Ed.* 93(3):223–231.

Trick M (2004) Using sports scheduling to teach integer programming. *INFORMS Trans. Ed.* 5(1):10–17.