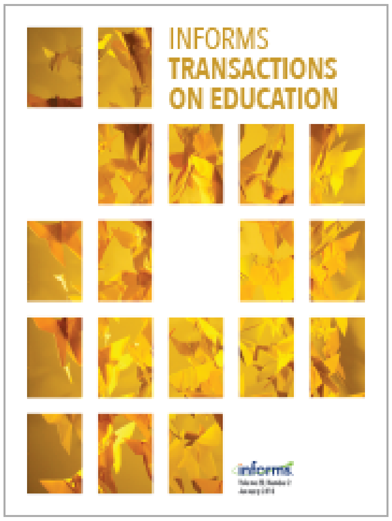

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Case Article

Swirltubs After-Market Product Inventory and Service Case

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Abstract. In the Swirltubs case, students apply expected value decision making to a knapsack problem for appliance repairmen. The case is based on a published research paper on work that was actually implemented for a major appliance manufacturer. The case features three parts: (1) problem understanding and definition; (2) optimization results for a small, test problem; and (3) creation and testing of a heuristic for a large-scale implementation that exceeds the limits of Microsoft Excel®. Optionally, an instructor can add risk-analysis simulation and reoptimization under uncertainty in subsequent parts of the project, making it a total of five parts. The case is highly interactive, owing to the relatively unstructured nature of the problem. I have implemented the case over a two- and three-week period format, with upper-level master's in business administration or master's in analytics students who have been exposed previously to optimization methods. It has been administered to dozens of students with generally positive feedback.

History: This paper has been accepted for the *INFORMS Transactions on Education* Special Section on Cases Based on Real-World Projects from the *INFORMS Journal on Applied Analytics*.

Supplemental Material: Teaching Notes and Excel spreadsheet of solutions are available at https://www.informs.org/Publications/Subscribe/Access-Restricted-Materials.

Keywords: developing analytical skills • developing communication skills • group projects • spreadsheet modeling • teaching optimization

Introduction

A large appliance manufacturer (dubbed Swirltubs in this case and with the pseudonym Alpha in the Gorman and Ahire (2006) article) was concerned about high part inventory levels for after sale service. In particular, Alpha was focused on reducing part inventory that is stored on repairmen's vans. This inventory was perceived as costly—it was stored in rolling warehouses—and poorly tracked by repairmen. Of course, the cost of inventory is high and inventory that is poorly tracked and stored in high-cost locations particularly so.

However, the cost of not carrying inventory is also high. If the technician does not have the required part to complete the repair, a second visit is required after the part is delivered. This eventuality both reduces customer service (time before repair is completed and customer time wasted waiting for the technician, twice) and productivity of the technicians, as the first visit does not complete the repair and a second trip to the customer location is required.

Literature Review

The problem is a basic knapsack problem with a single constraint (truck size). Many similar applied knapsack problem papers have been published. In this context, this problem is often referred to in the literature as the repair kit problem. Smith et al. (1980) modeled the problem as a single-visit cost minimization problem; Graves (1982) approaches the problem as a stocking cost minimization problem with a minimum service constraint. Smith et al. (1980) focuses on lost customer goodwill, whereas Graves (1982) minimizes cost while imposing a constraint on the minimum service level. In this problem, rather than minimizing stocking costs, students weigh those stocking costs against the benefit of avoiding a technician revisit (measured in technician time costs, not including customer dissatisfaction).

Where Graves (1982) assumed truck restocking after each repair, Brumelle and Granot (1993), Heeremans and Gelders (1995), and Teunter (2006) allow for multiple repair visits between restocking, as is the case here. With five days between use and replenishment, many repairs take place that could require a part that was just used in a recent repair. Gorman (2016) discusses the choice of objective function and the assumptions regarding single and multiple visits between restocking.

This problem is ubiquitous, and students readily identify with "waiting for the refrigerator technician." Similar cases on replacement parts inventory and network strategy have been written, such as Johnson and Woodcock (2005), which is based on the Xerox parts network.

Learning Objectives

Students are asked to formulate the problem; solve a small version of the problem to optimality; then create a simple heuristic that can be cheaply, quickly, and easily applied to larger data sets within the Excel environment without add-on software. They are asked to write a professional-quality report on their findings.

As a real-world application that is reproducible for a student, the case shows the power of analytics. As a relatively unstructured problem, it helps students hone their thinking, not just on how to solve the problem but on how to structure it. Importantly, it hones students' ability to express technical material in a nontechnical way.

They are expected to (1) ask probing questions to come to a better, clearer understanding of the problem; (2) formulate and solve an optimization problem that captures the problems; (3) interpret the trade-offs between the costs and benefits of carrying various parts, and develop a heuristic that approximates optimal solutions while comparing it to competing heuristics suggested in the case; and (4) write up a professional summary of the problem and its solution. Optionally, they (5) perform a cost and service risk assessment of the recommended stock and (6) reoptimize under varying demand levels to evaluate the robustness of the recommended stock with respect to part breakdown uncertainty.

Complications in modeling arise from two areas:

1. *Limitations of available commercial solvers:* The case assumes students will solve the problem using Microsoft Excel ®, which has rather severe limitations on the number of integer and binary variables it can handle without purchasing add-ons or special purpose software to solve. As in the actual case study, students are forced to create a heuristic that captures the essence of the knapsack problem solution without the software investment and time to solve the problem for over 1,000 technicians. To implement this solution system wide, Alpha wanted a simple and effective approach that could be easily administered in its production systems.

2. *Uncertainty of future usage:* Of course, if a technician knew he or she was going to need a part, he or she would stock it. Although the average need for a part over a year's time might be somewhat predictable, the timing of the occurrence of appliance failure is almost completely unpredictable. Part needs can vary from technician to technician and year to year. Thus, the decision to hold a part is done with great uncertainty of use. Expected value decision making can be important to the modeling approach.

Students benefit from

a. formulating and solving the binary knapsack problem;

b. comparing heuristic solutions to optimum;

c. solving a large-scale problem using a simple but effective heuristic;

d. comparing various heuristics to a full-scale problem;

e. evaluating the risk of a recommended stock under uncertainty with respect to cost and service;

f. evaluating the robustness of recommended stock under uncertainty with respect to the consistency of the optimal stock recommendation under uncertainty;

g. gaining experience with formal written communications of a problem and modeling results;

h. seeing the benefits of applying multiple analytical methods to a single problem.

Student Comments

This case has been administered in dozens of cases in upper-level undergraduate optimization classes, master's in business administration analytics case study classes, and master's in business administration classes. Because of its modular design, parts of it could be applied in undergraduate courses on students with less technical training. Generally, I find providing the original case to the students after the preliminary discussions to be helpful. They have difficulty formulating an effective heuristic, which is new to them.

> *Running an optimization is a good way to find a starting solution but using a simulation can give you much more insights as to the accuracy of your optimization and the solution that you came up with.*

> *A major takeaway I got from the case is that there are multiple methods and models for finding an answer to the business questions.*

> *While the optimal solution generated by Solver may not be applied at a large scale, the model may be tweaked to determine alternative optimal solutions which may be less optimal but more practical.*

> *The case seeks to combine multiple methodologies into a single case study. Even though it was initially difficult to structure, it really made me think deeply about the problem. I believe the case is a great real-world application of skills we've learned such as problem formulation, linear programming, Solver, Data Table, and simulation models. Also, I enjoyed learning about Macros, which I had never*

used before, and I think the teaching and application of them in this class should be expanded upon.

It was confusing and frustrating because it wasn't clear what to do but after doing it I feel like I can do this on a real problem.

In all honesty, I think this has been my favorite class so far. I really enjoyed working on real world cases, rather than simplified educational examples.

Somewhat surprisingly to me, parts 4 and 5 were most commonly commented as helpful to their learning and understanding of applying optimization. In short, they appreciate that the "best" answer isn't "for sure" and that all results are subject to variability and uncertainty in the input data.

Conclusion

Real-world case studies can be brought into the classroom. This work, based on Gorman and Ahire (2006), applies optimization, heuristics, and simulation to the truck stocking problem for appliance repair. Students see the value of analytics in the published article, and students with the proper training can reproduce the work in a few weeks' time.

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