



INFORMS Transactions on Education

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

Teaching OR/MS with Cases: A Review and New Suggestions

Matthew J. Drake

To cite this article:

Matthew J. Drake (2019) Teaching OR/MS with Cases: A Review and New Suggestions. *INFORMS Transactions on Education* 19(2):57-66. <https://doi.org/10.1287/ited.2018.0204>

This work is licensed under a Creative Commons Attribution 4.0 International License. You are free to copy, distribute, transmit and adapt this work, but you must attribute this work as “*INFORMS Transactions on Education*. Copyright © 2019 The Author(s). <https://doi.org/10.1287/ited.2018.0204>, used under a Creative Commons Attribution License: <https://creativecommons.org/licenses/by/4.0/>.”

Copyright © 2019, The Author(s)

Please scroll down for article—it is on subsequent pages



With 12,500 members from nearly 90 countries, INFORMS is the largest international association of operations research (O.R.) and analytics professionals and students. INFORMS provides unique networking and learning opportunities for individual professionals, and organizations of all types and sizes, to better understand and use O.R. and analytics tools and methods to transform strategic visions and achieve better outcomes. For more information on INFORMS, its publications, membership, or meetings visit <http://www.informs.org>

Teaching OR/MS with Cases: A Review and New Suggestions

Matthew J. Drake^a

^a Palumbo-Donahue School of Business, Duquesne University, Pittsburgh, Pennsylvania 15282

Contact: drake987@duq.edu,  <http://orcid.org/0000-0002-7777-8916> (MJD)

Received: May 8, 2018

Accepted: October 11, 2018

Published Online in Articles in Advance:
February 11, 2019

<https://doi.org/10.1287/ited.2018.0204>

Copyright: © 2019 The Author(s)

Abstract. Teaching cases have become a cornerstone of operations research and management science (OR/MS) education since the early 1990s, when the focus of the pedagogy largely shifted to an applied, model-building emphasis. I provide a review of the literature related to the use of teaching cases in general as well as their use specifically within OR/MS courses. I discuss the pedagogical benefits and the challenges in using teaching cases to teach OR/MS methods and their application. I conclude by offering some practical suggestions to assist instructors looking to implement cases in their classrooms for the first time or to improve their effectiveness in using teaching cases.

History: This paper has been accepted for the *INFORMS Transactions on Education* Special Section on Innovative Strategies for Teaching OR/MS Using Cases.



Open Access Statement: This work is licensed under a Creative Commons Attribution 4.0 International License. You are free to copy, distribute, transmit and adapt this work, but you must attribute this work as "INFORMS Transactions on Education. Copyright © 2019 The Author(s). <https://doi.org/10.1287/ited.2018.0204>, used under a Creative Commons Attribution License: <https://creativecommons.org/licenses/by/4.0/>."

Keywords: OR/MS education • case studies • active learning

Introduction

Operations research and management science (OR/MS) is inherently an applied scientific discipline. INFORMS (2018) defines operations research as "the application of scientific and mathematical methods to the study and analysis of problems involving complex systems." Similarly, The OR Society (2018) in the United Kingdom defines it as "the discipline of applying advanced analytical methods to help make better decisions." OR/MS is closely related to the popular field of analytics, which INFORMS (2018) defines as "the scientific process of transforming data into insights for making better decisions." All these definitions of the field emphasize the application of analysis to problems or decision-making scenarios. As a result, educational efforts to teach OR/MS to students should emphasize this practical application of the analytical methods presented.

This applied focus is further justified by the knowledge domains developed during the establishment of INFORMS' Certified Analytics Professional certification program in 2012. The domains, which were developed via a job task analysis of the work required by current practitioners in the field, include such applied skills as problem framing, data management, approach selection, model building, model deployment, and model life cycle management (Nestler et al. 2012). These subject matter domains reflect the skills required of analytics professionals, and OR/MS programs should ensure that their curricula adequately prepare their students to enter the field as successful, effective professionals. Of course,

PhD programs often (appropriately) have the objective of educating future academics and researchers as opposed to practitioners, but undergraduate and many Master's degree programs are filled with students whose primary goal is to enter the field as a practitioner upon graduation.

A common way to teach the application of models, tools, and techniques to practical scenarios is through the use of teaching case studies in the classroom. Case studies have been used in the business school classroom since Dean Wallace P. Donham encouraged the use of case studies at Harvard Business School in 1919 (Shugan 2006). The adoption of case teaching in business schools has not been uniform, however. Some schools, such as Harvard, Ivey, Darden, and Stanford, have fully adopted the case teaching method as the primary method of instruction in their programs, whereas many other schools use cases infrequently (Anderson and Schiano 2014), perhaps several cases used throughout a course to provide students with an opportunity to apply tools and concepts discussed in a lecture.

Although cases have become ubiquitous (at least to some degree) in many business school classrooms, OR/MS is a boundary-spanning field whose tools and techniques are taught in other schools and departments such as mathematics, computer science, and engineering. The use of case studies is not as common in these other settings. In addition, the case studies that may be appropriate in a general management class are not necessarily the same as the ones that lend themselves to

OR/MS methodology, and the way they are best implemented into a course could be different as well.

The purpose of this paper is to review the literature related to the specific application of case studies in the OR/MS classroom while also providing additional practical suggestions from the author's personal experience. In the next section, I discuss the value of teaching with case studies in general, and I highlight research specifically related to teaching OR/MS with case studies in the following section. Then I present detailed scenarios in which instructors used cases innovatively to teach OR/MS. I conclude with the author's additional recommendations for instructors looking to integrate case studies into their OR/MS courses.

The Value of Teaching with Case Studies

In their seminal article in *Harvard Business Review*, Bennis and O'Toole (2005) lamented the evolution of business schools into more scientifically focused institutions, such as physics departments, and away from the path of professional schools, such as law schools and medical schools. The latter group actively engages with practitioners in the field, whereas the former focuses on generating future scholars and downplaying the practical implications. They emphasize that business professionals need to develop their skills in *judgment* related to complex decision scenarios. To address this issue, Bennis and O'Toole (2005, p. 104) recommend that the business curriculum should "be infused with multidisciplinary, practical, and ethical questions and analyses reflecting the complex challenges business leaders face." Case studies are a practical way to implement this suggestion into many courses.

The main benefit of using case studies in the classroom is that they simulate the complex decision scenarios that managers and other decision makers face in practice. These scenarios provide students with an opportunity to apply theories or analysis to the scenario so that they can develop the kind of judgment required of effective managers and practitioners (Anderson and Schiano 2014). Cases can also increase students' ability to recognize the significant issues and considerations within a particular complex decision scenario (Lundeberg et al. 1999). Other benefits of using case studies in the classroom include improving students' ability to reason and to solve complex problems using higher-order thinking (Levin 1997, Gabel 1999) and to identify diverse stakeholder interests in the outcome of a specific decision (Lundeberg et al. 1999).

Cases also provide a practical benefit in the business classroom over using textbook materials. The publication lead time for case studies is significantly less than that of traditional textbooks; therefore, using cases is one way for instructors to incorporate cutting-edge topics and scenarios into the classroom. For example, the application and benefit of blockchain technology in

supply chains is currently a major focus at all industry-related conferences and in all industry trade publications. I have not seen more than a brief mention of the topic in any supply chain management textbook, but a quick search of Harvard Business Publishing's (2018) catalog shows that eight cases have been published on the topic within the past 12 months.

In general, pedagogical research has shown that case-based teaching is most effective at teaching the application of methods and problem solving as opposed to simply teaching students the concepts themselves. For the latter, lecturing has been shown to be similarly effective (Fasko 2003). Böcker (1987) found that case teaching is more effective than lecturing based mainly on the result that it leads to higher levels of a student's motivation to learn. Moreover, this motivation leads to students' learning to apply tools and concepts rather than memorizing information.

This is not to suggest, however, that case-based teaching is the best or only method of teaching applied decision-making skills. Problem-based learning methods whereby students engage in a largely unstructured, real-world problem or scenario to develop a recommendation have been shown to be just as effective as case studies in teaching concepts themselves as well as their application (Katsikitis et al. 2002). Problem-based learning methods require students to analyze and synthesize concepts, theories, and tools from multiple business disciplines to develop practical business recommendations to resolve complex decision scenarios, a competency that employers value significantly in applicants (Sroufe and Ramos 2015).

These problem-based learning methods are often executed with the participation of an outside client who supplies the scenario and data that the students use to conduct their analysis and provide their recommendations. Instructors typically take a secondary role as a guide for students as they complete their analysis rather than the traditional role as a content deliverer. See Williams and Dickson (2000) and Martonosi (2012) for a detailed description of problem-based learning methods with real-world, external client projects and suggestions for incorporating those projects into OR/MS courses effectively.

The May 2018 issue of *INFORMS Transactions on Education* (volume 18, issue 3) is a special issue focusing on field-based education. Gorman (2018) provides a survey of the literature on field-based education. Speier-Pero (2018) presents the theoretical foundation supporting the use of such projects and experiences in the classroom, and Konrad (2018) offers some suggestions for successfully engaging an industry partner in a classroom project. A similar approach to using external client projects that is popular in entrepreneurship programs is a practicum in which students start and operate a small business (see, e.g., McCord et al.

2015). Although using case studies in the classroom instead of a traditional lecture does increase the instructor's preparation workload somewhat, it does not compare with the additional work required for an instructor to facilitate a problem-based course project. Through the use of case studies, students can gain exposure to the application of foundational concepts and techniques while requiring an often reasonable amount of extra preparatory work from the instructor (Prince and Felder 2006).

Case Teaching in the OR/MS Classroom

Before I discuss best practices for using cases in the OR/MS classroom, I must first consider strategies for teaching OR/MS overall. Cochran (2009) provides a detailed history of OR/MS pedagogy through the years. Until the 1990s introductory courses in OR/MS focused primarily on presenting the mathematical foundations of various solution algorithms for specific problems, such as the simplex method, duality in linear programming, algebraic sensitivity analysis for changing parameters in linear programming, and the Hungarian method of solving the transportation problem. Ackoff (1979) famously accused OR/MS academics of ignoring interesting scenarios in their courses and instead presenting specific scenarios to which their chosen OR/MS models could be applied. Little emphasis was placed on the development of models to analyze particular practical scenarios and to provide information that could be used to make better decisions. One exception is that of Borsting et al. (1988), who recommended that introductory OR/MS courses accentuate problem formulation.

The traditional view of OR/MS education began to change in the early 1990s, however, as instructors began to develop introductory courses that were less focused on the mathematics behind the solution algorithms and instead emphasized model building. Cochran (2009, p. 163) identifies the impetus for this change as the "academic backlash against operations research" based on students' perceptions of the field as a set of mathematical tools that they could never apply to real-world problems because their technical skills were not advanced enough. As these students graduated and became managers and later executives, they maintained this prejudice against the field of OR/MS and were telling the academic programs they advised that businesses had no need for OR/MS in practice. This perception soon spread to administrators and finally to the Association to Advance Collegiate Schools of Business, which eliminated OR/MS as a required component in the MBA curriculum in 1991 (Cook 2003).

The shift of instructors toward a focus on model building in their classes was a gradual attempt to regain relevancy within the business and particularly the MBA curriculum. Although several OR/MS innovators such

as Morris (1967) and Woolsey (1984) had advocated such an approach for many years, the emphasis on model building and the practical application of OR/MS methods to real-world problems became commonplace after the turn of the last century. These efforts consist of many different pedagogical methods, such as active learning and simulations; case studies are one such prominent way to incorporate such a perspective into an OR/MS course.

The literature includes many resources that discuss the case teaching method and provide useful recommendations for instructors who are novices with facilitating case teaching. There are entire books dedicated to the subject (e.g., Anderson and Schiano 2014). The major case libraries, such as Harvard Business Publishing, Ivey Business Publishing, and The Case Centre, each offer workshops and seminars dedicated to helping instructors learn how to teach with the case method. For instructors considering the addition of case studies into their OR/MS courses, however, it is essential to ponder whether there is anything significantly different between the way that cases should be used in OR/MS courses compared with those in other fields.

Before addressing that question, however, I must first step back and discuss what is meant by the term "teaching case." Herreid (1997, p. 92) defines teaching cases as "stories with a message. . . . They are stories to educate." These narratives, however, can take different forms. The two main types of classroom cases (as opposed to live cases that are conducted with an external client) are *demonstration cases* and *problem cases* (Böcker 1987, Georgiou et al. 2008). Demonstration cases describe the implementation of theories and concepts by real-world organizations. This sort of case would likely be used in a general management or leadership course or perhaps in a course within a functional area, such as to demonstrate the impact of a failed marketing campaign. For OR/MS, however, problem cases are typically more appropriate because they present complex scenarios that students must analyze and then provide recommendations to a decision maker (Böcker 1987, Georgiou et al. 2008).

As Herreid (1997) notes, case studies are simply one teaching tool available within an instructor's arsenal. The goal of any pedagogical approach is to facilitate the students' development of certain desired knowledge, insight, or skills. Within OR/MS, therefore, it is essential to understand what exactly students are supposed to know. I suspect that all OR/MS instructors would agree that students must be comfortable with building and applying analytical models at least to some degree; but what else should students know or be able to do?

Ormerod (2002, 2014) identified three core competencies for OR/MS professionals: (1) conducting analysis, (2) managing process, and (3) understanding context.

Murphy (2005, p. 313) echoed these competencies by suggesting that “expertise in the context of OR practice consists of technical knowledge, institutional knowledge, and procedures and heuristics for bringing that knowledge to bear on the problem at hand and organizational issues.” Experts in OR/MS pedagogy have largely reached an agreement that OR/MS professionals should be proficient in more than just technical analysis. They should understand the organizational context and stakeholder implications of their recommendations, as well as the process steps involved in implementing the recommendations. Some of these additional considerations have been thoroughly addressed in the literature on problem structuring methods and “soft OR.” See Rosenhead (1996), Georgiou (2008), Mingers and Rosenhead (2011), and Ackermann (2011a, b) for a more complete discussion of problem structuring methods and soft OR, because further details are outside the scope of this paper.

Problem cases are one effective way to address these three OR/MS competencies in the classroom. Although problem-based methods with live clients can also accomplish this objective (Prince and Felder 2006, Ackermann 2011a), teaching cases have the advantage of requiring less facilitation effort on the part of the instructor. Problem cases often require students to determine the important criteria in making a recommendation, conduct the technical analysis required to evaluate different alternatives, and justify the recommendation and develop a plan to implement it in practice (Georgiou 2008). Incorporating various stakeholders’ concerns and considerations into the development of recommendations from quantitative models generates better, more well-rounded decisions in practice (Drake et al. 2011). Case studies provide opportunities for students to identify and consider these stakeholder interests. They also require students to develop essential skills in communicating results and recommendations both verbally and in written form (Keller and Kros 2000). The next section presents specific instances of authors using cases in the OR/MS classroom in different ways.

Case Studies on Using Case Studies in the OR/MS Classroom

As OR/MS instructors shifted their focus from the technical mathematics behind algorithms and heuristics to an emphasis on model building and problem structuring in the early 1990s, several authors published results of their experiences in using case studies in the OR/MS classroom. Two of the most thorough examples are those by Cochran (2000) and Bell and von Lanzenauer (2000), which happened to be published in the same special issue of the *Journal of the Operational Research Society*.

Cochran (2000) discusses the use of teaching cases in an introductory undergraduate OR/MS course. He

begins by explaining that the traditional way he had taught this introductory course led students to question the usefulness of OR/MS techniques in practice. These students were also not able to identify which analytical technique was appropriately used to analyze a given scenario, nor were they able to formulate even moderately complex models or interpret the models’ results. To address these issues, Cochran decided to utilize case studies in his course through a case methodology he specifically designed for his introductory undergraduate course. Students were instructed to (1) identify the problem presented in the case, (2) determine the appropriate methodology that could be used to analyze the problem as well as any assumptions that they had to make, (3) explain the results of the analysis in a nontechnical way, as well as the likely impact from implementing the recommendation, and (4) discuss the limitations of the quantitative analysis they performed and suggestions for improving it. He reports that students initially agonized over their perceived need to determine the “right” solution to the case, but they gradually became more confident and motivated once he assured them that there were multiple acceptable approaches. Overall student performance on examinations in the course improved significantly in semesters during which he used the case studies, and student evaluations of the course and the cases were overwhelmingly positive.

Bell and von Lanzenauer (2000) describe their experiences in using a specific case study (St. Swithin’s Hospital written by Bell and von Lanzenauer 1992) to teach decision analysis and decision trees at the Ivey School of Business at the University of Western Ontario. It should be noted that Ivey is one of the prominent schools (along with Darden School of Business at the University of Virginia, discussed by Bodily 1996, and Harvard Business School) that teaches courses primarily using the case method and whose faculty have developed a large number of cases for distribution through the school’s publishing arm. The case concerns the decision of the hospital investing in the equipment and staff members required to conduct new diagnostic tests for deep-vein thrombosis. Although the structure of the decision tree is relatively straightforward according to the description in the case, the real value of the case is the requirement for students to consider various stakeholders’ (e.g., physicians, patients, administrators, etc.) concerns and incentives to determine appropriate pay-offs for the branches of the tree. Bell and von Lanzenauer (2000) suggest that considering these multiple stakeholder perspectives leads to a more complete analysis of the problem and a better overall recommendation, insight as echoed in Drake et al. (2011).

Standridge (2000) details his application of case studies to teach simulation analysis to undergraduate and graduate students in a manufacturing engineering

program. This example is particularly interesting because the use of case studies generally has not permeated engineering schools the way that it has business schools. He describes the use of a methodology similar to that developed by Cochran (2000) to conduct the analysis, interpret the results, and make recommendations to the decision maker. The entire course is designed to cover only those simulation methods that can be appropriately applied to analyze the selected case studies effectively. This contrasts with traditional courses in which instructors or departments identify the methods that should be taught in the course and then find exercises or case studies to illustrate their use.

Carlson (1999) describes his use of case studies within a statistics course that is required for undergraduate economics majors at a private liberal arts college. He requires students to follow a methodology similar to that suggested by Cochran (2000) to present the results of their analysis in a written report. To allow class time to be devoted to the presentation of essential statistical methods, he shifted the case assignments to a laboratory period in which students ask questions of the instructor and teaching assistants regarding their analysis of the cases. He reports that students' understanding of the statistical methods and their application have increased with the incorporation of teaching cases into the course, but he suggests that the most significant impact of the cases has been on increasing students' motivation to learn the methods because they have a greater appreciation for their practical application.

Begen et al. (2012) offer the only recently published in-depth discussion of using cases to teach OR/MS concepts and tools. They describe their case-based approach to teaching OR/MS at the Ivey School of Business at the University of Western Ontario, the same setting as that of Bell and von Lanzanauer (2000). They provide significant detail about how they design and execute their case-based quantitative courses, as well as examples of the kinds of preparation that students are expected to complete before class and how they manage the flow of in-class sessions to accomplish the desired learning objectives. They also offer some benefits and challenges of teaching OR/MS with cases that are echoed by other authors referenced herein.

The papers discussed thus far in this section are the most detailed examples in the literature of instructors using case studies to teach OR/MS. Many other authors have advocated using the case method for teaching OR/MS without discussing specific details regarding their use in courses (e.g., Zanakakis et al. 1980, Gunawardane 1991, Starr 1997, Kao et al. 1997, Lovejoy 1998, Al-Zawahreh and Cox 2009, Arora 2016). Aggarwal and Khera (1978) argue the need for OR/MS courses to use shorter cases that are more focused on a specific decision scenario as opposed to the long, detailed,

strategic cases typically published by Harvard Business Press. Their rationale is that OR/MS methods are commonly used by line managers who do not necessarily have a strategic focus in making decisions. Martin (1980) critiques this thinking by recalling the delineation between the "manager" and "model builder" roles that MBA graduates can assume in practice, which were first proposed by Churchman and Schainblatt (1965). Martin agrees that Aggarwal and Khera's short cases are sufficient to introduce OR/MS models and analysis to those students who will undertake the manager roles, but asserts that longer, more detailed cases are required for those students who will become true OR/MS practitioners—model builders—upon graduation. Čibej (2002) echoes this recommendation by emphasizing the need for different OR/MS content, case studies, and general approaches to teach Churchman and Schainblatt's (1965) managers and model builders effectively.

A recent survey by Penn et al. (2016) investigated the use of case studies to teach OR/MS in United Kingdom institutions. The results of this survey coincide with OR/MS core competencies discussed above, finding that case studies are primarily used to develop analytical skills, to help students determine which analytical approaches are appropriate for the given scenario, to understand the problem and identify the important issues and considerations, and to explain results and recommendations in written form. They also enumerate the advantages (increasing student motivation and retention and providing experience in implementing OR/MS methods in practice) and disadvantages (increased workload for instructors and students, the challenge of identifying appropriate cases for a given topic or method, and defining the expectations of students when analyzing a case) that were discussed in the literature overall.

Additional Recommendations for Using Cases in the OR/MS Classroom

In this section I present several additional recommendations for successful use of cases in the OR/MS classroom. These strategies are primarily based on my experiences in using cases with business students at the undergraduate and graduate level for more than 10 years, but I have included external references whenever other authors have advocated similar methods. These recommendations are largely general; for more detailed suggestions about using cases in the OR/MS classroom (such as course design or the flow of a class period), see Begen et al. (2012).

Case Use Is Flexible

Most teaching cases are accompanied by detailed teaching notes that the authors prepared when writing the case. These teaching notes will often include a suggested teaching plan for instructors so that they can

get a feel for how the case could fit into their particular course. It is important to remember that these guides are merely *suggestions*. Instructors can use cases in any way that they deem appropriate for their course. I have taken very detailed cases and instructed students to focus on only one small part of the case to fit the type of analysis that we were covering in my course. In other situations, I have taken different cases and have had students expand the analysis by asking them to consider additional factors or issues that were not found in the original case. It is the instructor's responsibility to determine how best to utilize a particular case in his or her course, regardless of what the teaching notes may suggest.

Consider Breaking Up Complicated Cases into Several Parts

In my introductory MBA management science course I use the "Idiopathic Pulmonary Fibrosis" case published in this journal by Kopcsó et al. (2016) to illustrate the application of decision analysis to the pharmaceutical development process. The case describes various stages of the development and approval process for a new drug to treat idiopathic pulmonary fibrosis and asks the students to determine the value of the firm's option to license the drug to another company at various stages in the process. Because I only have time to introduce decision analysis in one class session before assigning this case, the analysis of the complete case in my view is too complicated for many of my students to complete on their own. Instead, I give students the assignment to consider the development of one drug from among two options, with all the payoffs and probabilities collapsed into the single decision and random outcome (whether the selected drug development is successful). This is the first part of the analysis that the authors suggest in the case's teaching notes. Once the students have submitted this assignment, which they usually are able to complete with little issue, I then work through the complete model of the various stages and the licensing decision together with them during a later class. This approach allows students to gain confidence in applying the decision tree model to a simpler scenario and enables them to follow the discussion of the more complex complete model in class. This use of the case is similar to the interrupted case method, whereby students are given a portion of the relevant case information for their initial analysis and recommendation and then must adjust the analysis to include the remaining information that is revealed to them at a later time (Herreid 2005).

I use a similar strategy with my undergraduate students in my Global Transportation & Logistics course, when I use the case "Contracting for LTL Services at Hankey Industries" that I wrote for my case book (Drake 2016). In the first part of the semester I have the students determine the applicable less-than-truckload (LTL) rate

for each of the 51 sample shipments provided in the case with respect to the case's four LTL contract proposals when the customer commits to using only each carrier for all of its LTL shipments (single sourcing). The students complete this task in groups as an out-of-class graded assignment. Later in the semester, once I have covered optimization models for distribution network design, I revisit the case and together in class, we solve the complete integer program, where they can consider selecting from individual location rates or combination rates for multiple locations offered by the carriers.

Consider Taking an Active Role as the Analyst Within the Classroom

In my undergraduate course covering forecasting, production planning, and inventory management, I have been using the case "Forecasting Offertory Revenue at St. Elizabeth Seton Catholic Church" (Drake and Demirag 2014) for many years. The case requires students to develop forecasting models to predict the monthly donations that a church will receive, and accurately predicting the timing of the donation receipts is critical because the church has significant cash flow problems. Avoidable expenses that would occur in months that collections are low must be deferred to months with higher collection levels. The major insight of the case is that students have to realize that the high and low collection months can largely be predicted by recognizing whether the month has four or five Sundays, because that is the day when collections typically occur.

I wrote this case on the basis of my personal experience on a finance committee, so I choose to present the case by walking students through my mindset as I analyzed the situation in real life. I ask them questions along the way about how I should handle various dynamics in the data and which variables I should include in the regression models I develop. The students gain insight into how I would approach this open-ended forecasting scenario so that they can emulate the same kind of thinking when they face these scenarios. I understand that it might seem like I could only use this approach because I wrote the case about one of my personal experiences. I concede that this certainly helps me to make the presentation richer, but there is no reason why I could not use a similar approach with a case that someone else authored.

Many OR/MS case studies present the students with complex, open-ended decision environments. Undergraduates and introductory Master's students can get overwhelmed quickly by such scenarios, causing them to get mired in the minute details of the case and miss the bulk of the learning opportunity that the case provides. Using this approach, whereby the instructor navigates them through the analysis and solicits ideas from the students about how to model various aspects of the scenario, can make more complex OR/MS

cases accessible and valuable to these specific student populations.

Consider Writing Your Own Cases

Early literature on using cases in the OR/MS classroom often lamented the lack of appropriate case studies to use in courses [e.g., Aggarwal and Khera (1978), Goffin (1998), and even some more recent studies, such as Penn et al. (2016)]. Today, vast case libraries such as Harvard Business Publishing, Darden Business Publishing, Ivey Business Publishing, and The Case Centre provide instructors with access and the ability to use thousands of cases in their courses. The insights that Bodily (1996) noted more than 20 years ago rings even more true today—if instructors find difficulty identifying case studies that serve as applications of a particular OR/MS methodology, that particular methodology must not be used often in practice.

That said, instructors may find difficulty identifying case studies that require the appropriate level of analysis from their students or represent the application in an interesting field or industry. A case could be extremely well written and pedagogically sound, but if it is set within the context of a dull or obsolete industry, students may not develop the kind of motivation to apply the analytical tools that they otherwise would for a case set within a more interesting and relevant context (Schmedders and Stephens 2001).

One solution to this challenge is for instructors to develop their own case studies. In fact, many of the authors whose experiences were discussed in the previous section (such as Carlson 1999, Bell and von Lanzanauer 2000, and Cochran 2000) described scenarios involving the use of case studies that they authored themselves. A self-authored case provides the instructor with additional insight into the decision scenario that often makes it easier to facilitate the use of the case study in the classroom. I have found that students appreciate the additional insight into the scenario that I can provide for the self-authored cases that I use in my courses. Authors can also benefit academically by publishing the case study in an outlet such as *INFORMS Transactions on Education* and/or entering the case into annual case competitions, such as those conducted by INFORMS and the Decision Sciences Institute at their annual meetings.

Although an in-depth discussion of strategies for writing an effective case study is outside the scope of this article, there are several approaches that can lead potential case authors down a successful path. One suggestion is to consider using practice-based OR papers, such as those published in *Interfaces* and other journals as the inspiration and scenario for a teaching case. Bell and von Lanzanauer (2000) used a published article by Venta and Venta (1987) as the basis for their decision analysis case, St. Swithin's Hospital, described

in their paper. Authors can also consider their own consulting projects or their students' external client projects as possible sources for case study scenarios and decision environments (Schmedders and Stephens 2001). Students can also be asked to develop case studies within the context of a given course as a way to further demonstrate their understanding of the appropriate application of a given methodology (Laditka and Houck 2006). For a more detailed discussion of suggestions for writing effective teaching cases, see Gutman (1993), Bodily (1996), Kim et al. (2006), and Begen et al. (2013). Those authors particularly interested in developing effective teaching cases may consider attending a case writing workshop such as the ones offered by The Case Centre and Ivey Business Publishing.

The Flipped Classroom Can Provide Additional Opportunities for Case Use

One of the challenges of using case studies in the OR/MS classroom is the time that must be devoted to analysis and discussion. As additional cases are used in a course, a smaller amount of time remains for the instructor to cover the OR/MS methods themselves. This may not be a major issue in OR/MS programs that have dedicated case study courses, but it is of concern to instructors who would like to incorporate some case study analysis and discussion into courses that traditionally teach the OR/MS methods of analysis.

Instructors may choose to free up class time for case study analysis and discussions by using the flipped classroom approach, whereby traditional content is covered outside of class time, often by having students watch instructor-recorded videos or other media. Although a flipped classroom approach is not the only way to free up time to include case study analysis and discussions within a crowded list of course topics (e.g., instructors could use reduce the coverage of some individual topics themselves and use case studies to integrate the topics to cover more advanced concepts and stimulate higher-order thinking), I have found it to be an effective method for doing so, as have the recent research studies discussed below.

A flipped classroom approach frees up class time for more problem examples, interactive activities, and case study discussions (Herreid and Schiller 2013). Asef-Vaziri (2015) reported that student performance was significantly higher in flipped versions of his operations management courses compared with those taught traditionally (i.e., in-class only with no out-of-class videos or presentations). Swart and Wuensch (2016) found that a flipped classroom environment in a quantitative course reduced students' perceived barriers between themselves and other students, between themselves and the instructor, and between themselves and the instructional technology used in the course, as well as improved their satisfaction with the course.

Like case study teaching itself, the flipped classroom is not an all-or-nothing approach. Hesitant instructors can start slowly by “flipping” one or two topics and then replacing their coverage during class time with analysis of a case study or another interactive activity. If that goes well, the instructors could consider shifting the content of more topics outside of class time. I use this approach in my undergraduate supply chain management courses, which are not (as of yet) designed to be fully flipped. I have selected specific topics in both my Global Transportation & Logistics course as well as my Forecasting, Production Planning, and Inventory Management course that I can effectively cover in several online videos. The students watch those videos before coming to class on a given day and complete a short assignment usually consisting of several (approximately five) conceptual questions that they should be able to answer after watching the videos. Then in class, I either conduct an interactive activity or simulation or discuss a case study.

This approach to slowly “flipping” the course provides less risk and up-front investment for the faculty member. Transforming an entire traditional course to one that utilizes the flipped approach requires a significant up-front time investment. The incremental approach I described allows instructors to focus on developing one or two quality presentations or videos at a time to minimize the up-front cost in any one semester while increasing the likelihood of the materials being of high quality and effective in teaching the tools or concepts to the students. If the instructor creates materials for the flipped lesson (e.g., videos, presentations, etc.) that are effective, they can be used in future sections of the course or in other courses where appropriate. Asef-Vaziri (2015) cautions that videos should be used in classes for no more than two years, but I have found that they can be utilized effectively for a longer period of time, especially if they are illustrating foundational quantitative tools or concepts that do not change over time. I prefer to make my videos as short as possible (usually approximately 10 minutes and no more than 20 minutes) in a kind of modular form, so that I can keep using the ones that are still effective and only rerecord the ones that need to be updated.

Plan How You Will Limit the Risk That Students Will Obtain Unauthorized Access to the Case Solutions

As cases age once they are published, unfortunately the likelihood increases that students will discover and share the solutions to the required analysis found in the teaching notes. All case libraries as well as *INFORMS Transactions on Education* do everything they can to restrict access to the teaching notes to only qualified instructors, but it is very likely that someone will post the solutions online for anyone to discover or that student groups or fraternal organizations will share

solutions from one year to the next. This can limit the effectiveness of instructors’ use of the same case in successive semesters.

Although instructors can limit this risk by adopting only newly published cases whose solutions have less of a chance of having been posted online already and using them in courses for only one semester, this approach increases the preparation workload on the instructor significantly, especially if the course includes several cases. I typically use two strategies to combat this issue.

The first strategy is to try to use cases only once per academic year. If I teach a particular course in the fall and spring semesters, I prefer to use each case only one time if possible. This requires that I have a cadre of appropriate cases that adequately cover various topics, but this is usually possible for general OR/MS tools, such as linear programming, network modeling, decision analysis, simulation, and multicriteria decision making. The idea is that students may be inclined to share materials with their friends in the same academic grade level who may be taking the course one semester later than they are, but I have found that my students are less inclined to share materials across multiple academic years. I often end up with one set of cases that I use in the fall semester version of a course and a different set that I use in the spring version of the course. Of course, if it seems like the students have obtained access to the solutions (typically because they perform the analysis exactly as it is discussed in the teaching notes), I will retire the case from the rotation or use the second strategy discussed below.

The second strategy is to take a case and change the assignment that I give students to complete based on the information provided in the case. Changing the focus of the scenario described in the case ensures that no two semesters’ assignments are alike and drastically reduces the chance that students are able to complete the assignment without going through the analysis on their own. This approach is best illustrated by the way I use the case “Vehicle Routing at Otto’s Discount Brigade,” which I wrote for my first case book (Drake 2014).

This case presents a typical vehicle routing problem in which the analyst must develop delivery routes to 15 store locations from a single warehouse subject to vehicle capacity limits. In one semester of my global transportation and logistics course each year, I have the students analyze the case as it is written. In the other semester’s version of the course, I use a subset of the travel network presented in this case and ask students to develop a “Traveling Salesperson Tour” of six of the locations (five stores and the terminal, with the five stores being different each semester) in the network. I tell the students that the company has determined that the company has specified that deliveries to these five

store locations should be made by the same truck, and their job is to determine how to route the truck to minimize the distance traveled. This approach enables me to use the same basic scenario each semester with less risk of the solutions to the analysis being shared.

I use a similar approach in my introductory MBA management science course with the case “Redesigning Pittsburgh Port Authority’s Bust Transit System” (Korpeoglu and Kilinc-Karzan 2016). The case asks students to develop a network of park-and-ride hub locations that will serve various neighborhoods at minimum total cost. In addition to the basic network model, the case includes various extensions whereby the network must meet additional requirements; for example, that two specific neighborhoods must be assigned to the same hub, or two other neighborhoods cannot be assigned to the same hub. Every semester I change the constraints in the assignment I give to the students by selecting different pairs of neighborhoods upon which to place these restrictions.

Conclusion

The general shift of the focus of OR/MS education from technical mathematics to model building and application has cemented the position of teaching cases as a mainstay in the OR/MS classroom. The use of teaching cases emphasizes the relevancy of OR/MS methods and helps students to develop an understanding of how the tools can be applied to assist decision makers in real-world scenarios. This practical focus increases the students’ motivation to learn the methods themselves and their applications and enhances their appreciation of the field of OR/MS so that they can be effective users of the information that these methods provide to help them make better decisions.

References

- Ackermann F (2011a) Getting “messy” with problems: The challenges of teaching “soft” OR. *INFORMS Trans. Ed.* 12(1):55–64.
- Ackermann F (2011b) Teaching soft OR/MS methodologies: What, why, and how. Cochran JJ, Cox LA, Keskinocak P, Kharoufeh JP, Smith JC, eds. *Wiley Encyclopedia of Operations Research and Management Science* (John Wiley & Sons, Hoboken, NJ), 1–9.
- Ackoff RL (1979) The future of operational research is past. *J. Oper. Res. Soc.* 30(2):93–104.
- Aggarwal R, Khera I (1978) Short cases for teaching management science: Their role in closing the gap between theory and practice. *Interfaces* 9(1):90–94.
- Al-Zawahreh AAS, Cox MAA (2009) Teaching and training operations research in Jordanian universities: An empirical study. *Internat. J. Inform. Oper. Management Ed.* 3(1):54–67.
- Anderson E, Schiano B (2014) *Teaching with Cases: A Practical Guide* (Harvard Business School Publishing, Boston).
- Arora N (2016) Dealing with challenges in teaching decision sciences. *Internat. J. Advance Res. Innovation* 4(1):32–36.
- Asef-Vaziri A (2015) The flipped classroom of operations management: A not-for-cost-reduction platform. *Decision Sci. J. Innovative Ed.* 13(1):71–89.
- Begen MA, Krishnamoorthy S, Wilson J (2012) Teaching ORMS/ analytics with cases. Cochran JJ, Cox LA, Keskinocak P, Kharoufeh JP, Smith JC, eds. *Wiley Encyclopedia of Operations Research and Management Science* (John Wiley & Sons, Hoboken, NJ), 1–13.
- Begen MA, Krishnamoorthy S, Wilson J (2013) Writing ORMS/ analytics cases. Cochran JJ, Cox LA, Keskinocak P, Kharoufeh JP, Smith JC, eds. *Wiley Encyclopedia of Operations Research and Management Science* (John Wiley & Sons, Hoboken, NJ), 1–10.
- Bell PC, von Lanzanauer CH (1992) *St. Swithin’s Hospital*. 9-92-E003 (Ivey Publications, Richard Ivey School of Business, University of Western Ontario, London, ON, Canada).
- Bell PC, von Lanzanauer CH (2000) Teaching objectives: The value of using cases in teaching operational research. *J. Oper. Res. Soc.* 51(12):1367–1377.
- Bennis WG, O’Toole J (2005) How business schools lost their way. *Harvard Bus. Rev.* 83(5):96–104.
- Böcker F (1987) Is case teaching more effective than lecture teaching in business administration? An exploratory analysis. *Interfaces* 17(5):64–71.
- Bodily SE (1996) Teachers’ forum: Teaching MBA quantitative business analysis with cases. *Interfaces* 26(6):132–138.
- Borsting JR, Cook TM, King WR, Rardin RL, Tuggle FD (1988) A model for a first MBA course in management science/operations research. *Interfaces* 18(5):72–80.
- Carlson WL (1999) A case method for teaching statistics. *J. Econom. Ed.* 30(1):52–58.
- Churchman CW, Schainblatt AH (1965) The researcher and the manager: A dialectic of implementation. *Management Sci.* 11(4):B69–B87.
- Čibej JA (2002) Operations research education for forgotten populations. *Eur. J. Oper. Res.* 140(2):225–231.
- Cochran JJ (2000) Introductory business OR cases: Successful use of cases in introductory undergraduate business college operational research courses. *J. Oper. Res. Soc.* 51(12):1378–1385.
- Cochran JJ (2009) Pedagogy in operations research: Where has the discipline been, where is it now, and where should it go? *ORiON* 25(2):161–184.
- Cook TM (2003) Revised MBA guidelines. *OR/MS Today* 30(3):6.
- Drake MJ (2014) Vehicle routing at Otto’s Discount Brigade. Drake MJ, ed. *The Applied Business Analytics Casebook* (Pearson/FT Press, Upper Saddle River, NJ).
- Drake MJ (2016) Contracting for LTL services at Hankey Industries. Drake MJ, ed. *Advances in Business, Operations, and Product Analytics* (Pearson, Old Tappan, NJ).
- Drake MJ, Demirag OC (2014) Forecasting offertory demand at St. Elizabeth Seton Catholic Church. Drake MJ, ed. *The Applied Business Analytics Casebook* (Pearson/FT Press, Upper Saddle River, NJ).
- Drake MJ, Gerde V, Wasieleski DM (2011) Socially responsible modeling: A stakeholder approach to the implementation of ethical modeling in operations research. *OR Spectrum* 33(1):1–26.
- Fasko D (2003) Case studies and method in teaching and learning. Presentation, Annual Meeting of the Society of Educators and Scholars, April, Louisville, KY.
- Gabel C (1999) Using case studies to teach science. Presentation, Annual Meeting of the National Association for Research in Science Teaching, March 28–31, Boston, MA.
- Georgiou I (2008) Making decisions in the absence of clear facts. *Eur. J. Oper. Res.* 185:299–321.
- Georgiou I, Zahn C, Meira BJ (2008) A systematic framework for case-based classroom experiential learning. *Systems Res. Behav. Sci.* 25: 807–819.
- Goffin K (1998) Operations management teaching on European MBA programmes. *Internat. J. Oper. Production Management* 18(5):424–451.
- Gorman MF (2018) A survey of research in field-based education: A summary of process, best practices, and lessons learned. *INFORMS Trans. Ed.* 18(3):145–161.

- Gunawardane G (1991) Trends in teaching management science in undergraduate business programs. *Interfaces* 21(5):16–21.
- Gutman JA (1993) Developing cases and scenarios for anticipatory learning. *J. Management Development* 12(6):53–60.
- Harvard Business Publishing (2018) Catalog. Retrieved August 18, 2018, <http://hbsp.harvard.edu/educator>.
- Herreid CF (1997) What is a case? *J. College Sci. Teaching* 27(2):92–94.
- Herreid CF (2005) The interrupted case method. *J. College Sci. Teaching* 35(2):4–5.
- Herreid CF, Schiller NA (2013) Case studies and the flipped classroom. *J. College Sci. Teaching* 42(5):62–66.
- INFORMS (2018) Operations research & analytics. Retrieved April 25, 2018, <https://www.informs.org/Explore/Operations-Research-Analytics>.
- Katsikitis M, Hay PJ, Barrett RJ, Wade T (2002) Problem vs. case-based approaches in teaching medical students about eating disorders: A controlled comparison. *Ed. Psych.* 22(3):277–283.
- Kao C, Yeh Q-j, Tsai Y-c (1997) Teaching undergraduate operations research in some of the business schools in Asia. *Interfaces* 27(5):93–103.
- Keller C, Kros J (2000) Teaching communication in an MBA operations research/management science course. *J. Oper. Res. Soc.* 51(12):1433–1439.
- Kim S, Phillips WR, Pinsky L, Brock D, Phillips K, Keary J (2006) A conceptual framework for developing teaching cases: A review and synthesis of the literature across disciplines. *Medical Ed.* 40(9):867–876.
- Konrad RA (2018) Effectively engaging industry partners within the classroom. *INFORMS Trans. Ed.* 18(3):174–182.
- Kopcsó DP, Simon H, Gao A (2016) Case—Idiopathic pulmonary fibrosis. *INFORMS Trans. Ed.* 16(3):107–109.
- Korpeoglu E, Kilinc-Karzan F (2016) Redesigning Pittsburgh Port Authority's bus transit system. Drake MJ, ed. *Advances in Business, Operations, and Product Analytics* (Pearson, Old Tappan, NJ).
- Laditka SB, Houck MM (2006) Student-developed case studies: An experiential approach for teaching ethics in management. *J. Bus. Ethics* 64(2):157–167.
- Levin B (1997) The influence of context in case-based teaching: Personal dilemmas, moral issues or real change in teachers' thinking? Presentation, American Educational Research Association Annual Meeting, April, Chicago, IL.
- Lovejoy WS (1998) Integrated operations: A proposal for operations management teaching and research. *Production Oper. Management* 7(2):106–124.
- Lundeberg M, Levin B, Harrington H (1999) *Who Learns What from Cases and How? The Research Base for Teaching and Learning with Cases* (Lawrence Erlbaum Associates, Mahwah, NJ).
- Martin MJC (1980) Short cases for teaching management science: An extended comment. *Interfaces* 10(2):10–12.
- Martonosi SE (2012) Project-based ORMS education. Cochran JJ, Cox LA, Keskinocak P, Kharoufeh JP, Smith JC, eds. *Wiley Encyclopedia of Operations Research and Management Science* (John Wiley & Sons, Hoboken, NJ), 1–15.
- McCord M, Houseworth M, Michaelsen LK (2015) The integrative business experience: Real choices and real consequences create real thinking. *Decision Sci. J. Innovative Ed.* 13(3):411–429.
- Mingers J, Rosenhead J (2011) Introduction to the special issue: Teaching soft O.R., problem structuring methods, and multi-methodology. *INFORMS Trans. Ed.* 12(1):1–3.
- Morris WT (1967) On the art of modeling. *Management Sci.* 13(12):707–717.
- Murphy FH (2005) ASP, the art and science of practice: Elements of a theory of the practice of operations research: Expertise in practice. *Interfaces* 35(4):313–322.
- Nestler S, Levis J, Klimack B (2012) Certified analytics professional. *OR/MS Today* 39(5):16–21.
- Ormerod RJ (2002) On the nature of OR: Taking stock. *J. Oper. Res. Soc.* 53(5):475–491.
- Ormerod RJ (2014) OR competencies: The demands of problem structuring methods. *Euro. J. Decision Processes* 2(3/4):313–340.
- Penn ML, Currie CSM, Hoad KA, O'Brien FA (2016) The use of case studies in OR teaching. *Higher Ed. Pedagogies* 1(1):16–25.
- Prince MJ, Felder RM (2006) Inductive teaching and learning methods: Definitions, comparisons, and research biases. *J. Engrg. Ed.* 95(2):123–138.
- Rosenhead J (1996) What's the problem? An introduction to problem structuring methods. *Interfaces* 26(6):117–131.
- Schmedders K, Stephens M (2001) Time to update teaching cases. *OR/MS Today* 28(1):14.
- Shugan SM (2006) Save research—Abandon the case method of teaching. *Marketing Sci.* 25(2):109–115.
- Speier-Pero C (2018) Leveraging experiential field projects—Discovery learning in a Masters in Analytics program. *INFORMS Trans. Ed.* 18(3):162–173.
- Sroufe R, Ramos DP (2015) Leveraging collaborative, thematic problem-based learning to integrate curricula. *Decision Sci. J. Innovative Ed.* 13(2):151–176.
- Standridge CR (2000) Teaching simulation using case studies. Joines JA, Barton RR, Kang K, Fishwick PA, eds. *Proc. 2000 Winter Simulation Conf.* (IEEE, Piscataway, NJ), 1630–1634.
- Starr MK (1997) Pedagogical challenge: Teaching international production and operations management courses. *Production Oper. Management* 6(2):114–121.
- Swart W, Wuensch KL (2016) Flipping quantitative classes: A triple win. *Decision Sci. J. Innovative Ed.* 14(1):67–89.
- The OR Society (2018) Learn about O.R. Retrieved April 25, 2018, <http://www.learnaboutor.co.uk/>.
- Venta E, Venta L (1987) The diagnosis of deep-vein thrombosis. *J. Oper. Res. Soc.* 38(7):615–624.
- Williams T, Dickson K (2000) Teaching real-life OR to MSc students. *J. Oper. Res. Soc.* 51(12):1440–1448.
- Woolsey RED (1984) Modeling the modeling process. *Interfaces* 14(3):24–28.
- Zanakis SH, Austin LM, Nowading DC, Silver EA (1980) From teaching to implementing inventory management: Problems of translation. *Interfaces* 10(6):103–110.