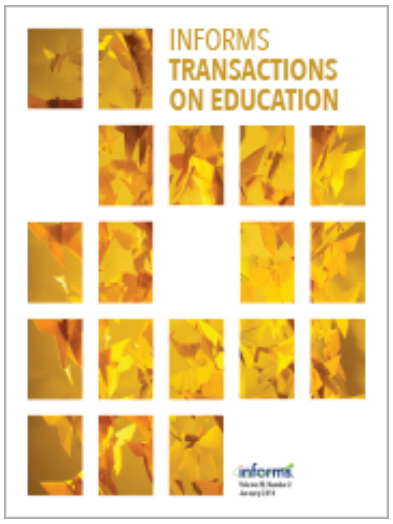

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Case Article

Workforce Scheduling for Airport Immigration on the Island of Tropical Paradise

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Abstract. This case study focuses on modeling and analyzing the practices concerning the staffing of the immigration agency at the Island of Tropical Paradise International Airport, which is responsible for processing arriving passengers into the country. Students are challenged to model the status quo of immigration employee scheduling and analyze various high-level policy changes to determine the reduction in staffing requirements while also being concerned with the wait time of passengers in the queue at immigration. The case has been used in an introductory operations research (OR) course in an engineering curriculum as a term project and was created based on a client of a major consulting organization. The main teaching objective of the case is to have students demonstrate an understanding of how to use OR models and analysis to impact practice. To this end, the case moves the students from standard classroom or textbook examples to an open-ended problem where there is not a single correct model or analysis to tackle it.

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Keywords: workforce scheduling • OR practice • engineering curriculum

1. Introduction and Case Background

The focus of this case is on helping the immigration agency at the Island of Tropical Paradise[1] International Airport (ITPIA) understand the relationships between their workforce scheduling at the immigration desks for incoming passengers to the country and the length of time these passengers spend waiting in the queue at immigration. The case is based on an actual client of Deloitte Consulting and was created in collaboration with a professor of industrial and systems engineering (ISE) teaching an undergraduate operations research (OR) course at Rensselaer Polytechnic Institute.

The case involves analyzing the current practices of the immigration agency at ITPIA, modeling weekly employee shift scheduling, and exploring the impact on the number of employees as target metrics vary in terms of the amount of time passengers spend in the queue waiting to be processed by immigration. Current practices of the immigration agency include the fact that employees follow a five-days-on, two-days-off schedule with respect to the days they work, an employee will have static shifts from day to day (i.e., they will work the same block of time each day), and there are no part-time employees staffed at the immigration agency. Students are challenged to examine the impacts of "high-level" policy changes, which could include, but are not limited to, including part-time employees into the staff, dynamic shifts for employees, and varying the workweek requirements (i.e., a four-days-on, three-days-off week). In addition, students need to grapple with the fact that the monthly data could suggest a different number of employees would be needed in each month. Overall, students are challenged to move from standard classroom and textbook examples of OR to a more open-ended case study where there is not necessarily a "correct" solution and the focus becomes providing insights into the application area. The case was

utilized in an undergraduate OR course, and the focus of the students was on creating various linear integer programming models to analyze it.

When initially scoping the project, the consulting team wanted to share a project that was not only relevant to the course by showing real-world OR relevance, but also from an intriguing client case to highlight the different types of projects in the consulting industry. Once the ITPIA project was confirmed to be used as the in-class case, the consulting team reviewed the standard course project description in tandem with the project summary briefing to understand overlap and attempt to chart the path forward. Finding similarities between the project syllabus and part of the ITPIA project, the consulting team, including a resource who worked directly with the client, worked with the instructor to scale down the information so that it was able to be worked by the students and finished within the semester time constraints. This collaboration involved the consulting team looking to understand the students' scope of work and the professor looking to understand how the consulting project could fit into class, and took about two months of iterations to get the right fit. By the end of the process, the students shared that they enjoyed the case and its real-life application, as it served as an effective example of the types of projects worked on in the consulting industry and it served as a stepping stone out of traditional textbook examples of OR.

Fundamentally, this case involves workforce management/scheduling (see, e.g., Ernst et al. 2004a, b; Disselkamp 2013; Van den Bergh et al. 2013), and related cases have been used in OR classrooms. Trick (2004) discusses how to use examples from sports scheduling to demonstrate that integer programming techniques can be used to capture more than just integer production/staffing decisions. Proano (2016) presents a case on a pandemic on a college campus and, among other inquiries, has students examine the number of doctors and nurses needed at the campus health center. Kopcso and Pachamanova (2018) examine analytics to improve staffing inefficiencies in handling appointments for an investing company.

In many ways, this case focuses on having students gain experience in the practice of using linear integer programming models to provide insights into a problem, and thus complements the approach taken by Konrad (2018) in having students gain hands-on experience with using simulation to provide meaningful insights into industrial problems. It has been observed previously that one of the more difficult transitions from classroom examples to an open-ended application of analytic techniques is the fact that there is not a single correct answer (Hillon et al. 2012), and this case can serve as the foundation for students to gain experience with making this transition. Salo (2012) discusses a seminar course for graduate students to make this transition, and Frances and Terekhov (2018) discuss a similar case-based undergraduate course; the case presented in this paper ties to some of the first models used in presenting linear and integer programming, and thus can be (and has been) integrated into an introductory undergraduate course. Fundamentally, the case does for workforce scheduling what Milburn et al. (2017) does for vehicle routing: it presents an opportunity for students to gain hands-on experience with an open-ended problem in the application area.

The remainder of this case article is structured as follows. We discuss the specific teaching objectives of the case in Section 2 and our experience in using this case in an introductory OR course within an engineering curriculum in Section 3. Building on our experience with the case, we discuss our suggestions for classroom use in Section 4.

2. Teaching Objectives

The overarching teaching objective of this case is for the students to demonstrate an understanding of how to effectively use OR to impact practice. The focus is on moving from the standard classroom or textbook examples where there is a clear-cut model formulation and solution to an open-ended application of OR. Therefore, students should begin to understand that OR provides insights into an application, not necessarily an exact number or solution, which is a critical skill for OR practitioners (see, e.g., Geoffrion 1976). The more specific teaching objectives include the following:

1. Students should be able to work with an open-ended application (without a "correct" OR model) and create meaningful OR models to provide insights into this application. Students should be able to justify the assumptions placed on the application as they create the model, thus providing a solid demonstration that the insights are valid.

2. Students should be able to determine the types of analysis required to provide "enough" evidence to validate their insights and conclusions.

With respect to Objective 1, students need to determine specific impactful characteristics of the application that should be incorporated into their modeling approaches. For example, employees that work a standard day (at least 7.5 hours) should be given two 15-minute breaks and one one-hour lunch break. Students need to determine whether it is necessary to capture the 15-minute breaks, the one-hour lunch break, both, or neither. As another example, full-time employees are given 10 sick days and 18–28 vacation days a year. Students need to determine how to incorporate this fact into their modeling approach and/or analysis; for example, if the students focus on modeling weekly shift schedules,

may they argue that sick days/vacation days might not greatly impact the optimal weekly staffing decisions? Finally, the students should think about whether their decision variables should be required to be integers and the implications that this could or could not have on the approach to their model (and how quickly it could be solved). Typically, homework and/or exam problems in an introductory OR course do not have features that the students may justify not incorporating into the OR model, and therefore, this case suggests students gain a better understanding of the art of OR modeling.

With respect to Objective 2, students need to carefully consider their analysis and how it may likely lead to valid recommendations to the immigration agency at ITPIA. Data have been given on the number of arriving passengers on flights over the course of five months, thus causing students to consider questions such as, Should we run our models and analysis on one month of data? Should we run it on all months of data? What should we suggest when the different months require different numbers of employees? Should we average demand across each distinct day (Sunday, Monday, etc.) in a month to get an "average" week? In addition, students need to consider how to define target metrics with respect to the time passengers spend in the queue for immigration: Should the target metric be focused on the average time passengers from a particular flight require in the queue? Should it be focused on the longest time a particular customer from a flight spends in the queue? Should these be focused on the *worst case* for the flight (i.e., all passengers have "issues") or the *expected case* for the flight? These are not questions that are often asked in homework and/or exam problems for students in introductory OR courses and thus help the students think about how to practically apply the models and concepts from the course.

It should be noted that this case possesses characteristics of both workforce scheduling and queueing theory. However, our focus is on utilizing "basic" characteristics of the behavior of the customs queue (e.g., how many "servers" are necessary to process all passengers from a flight within the target metric) when the processing time of the customer is constant based on their characteristics. From a queueing system perspective, there are several limiting factors of modeling this within the framework typically taught in an introductory OR course. First, customer arrivals come in batches (the flight arrivals) and thus cannot be modeled under the memoryless property. Second, the customers' processing times are heterogeneous (based on their flight and status). Third, service times do not satisfy the memoryless property. Therefore, we believe that analyzing the system from a queueing perspective is likely too complex for an introductory OR course. Alternatively, this case could have potential in a course focused on simulation, where the processing times of the passengers are random variables with means equal to the average processing time present in the data.

3. Classroom Experience

The ITPIA immigration workforce scheduling case has been used in a junior-level undergraduate OR course within an ISE curriculum. This course is the students' first exposure to OR and covers topics ranging from linear and integer programming to network flows to Markov chains and queueing theory. The course often requires a class project (depending on the preferences of the instructor) that has the students apply OR methods to a particular case study, especially in the context of formulating linear and/or integer programming models. The case for the class project is distributed after seven weeks of classes, and the final report on it is due (roughly) eight weeks after it is initially distributed. After seven weeks of classes, the course has covered linear programming, network flows, and integer programming, and, therefore, the focus of the project is on applying these concepts to the case. In addition to the case study description, students were provided the relevant data on flight arrivals and the number of passengers on each flight. A representative from the consulting organization provided a 15-minute virtual presentation of the case.

Students were allowed to work in groups of four on the case and were provided one official 30-minute meeting with the instructor of the course to discuss their OR model(s) and analysis. Furthermore, students were provided with an (ungraded) opportunity to submit a draft of their analysis two weeks prior to the due date of the case, and the instructor provided feedback to them within two days. The majority of project groups used the 30-minute meeting as a preliminary discussion of their draft so that they did not implement models that were not properly justified. In fact, two project groups were able to use their 30-minute meetings to create project drafts that were extremely polished and did not require significant changes to their analyses in preparing their final reports. It should be noted that both these groups were later given an opportunity to present their analysis to the consulting organization.

At first, the students were a bit overwhelmed with the complexity of the ITPIA case and needed direction on where to start the OR modeling and analysis. In particular, students were attempting to incorporate every aspect about the case into an OR model and did not realize that they could provide arguments as to why certain aspects could be ignored. The instructor of the course spent 15 minutes the week after the consultant's virtual presentation and presented a few

examples of simplifying assumptions that could be made. For example, one may assume that the two 15-minute breaks given to an immigration employee could be assigned around the flight schedule and, therefore, the modeling of these breaks was not necessary. As another example, the instructor suggested that it was not necessary to model every possible start time of an employee shift (and may not be desired from a practical perspective). Once students understood that they could make certain assumptions and argue that they would not impact the insights into the case, they felt much more comfortable with approaching the case and beginning their analysis.

Throughout the case study, students tended to need reassurance that their justifications of their assumptions and their analysis were sufficient to provide insights into the case. More often than not, students had made good arguments to their assumptions and provided sufficient analysis but had not yet developed the confidence in their arguments. This may be tied to the fact that the course, like certain other OR courses, was focused on students understanding modeling and methodology, and that the case was their only exposure to using OR to address an open-ended problem. Therefore, the case served as a valuable learning experience in bridging the gap from the classroom to OR practice even if the students needed more of a guide through their analysis than they typically needed for a homework problem.

At the end of the semester, the instructor selected the top two projects and allowed the students to present their analyses to representatives from the consulting organization that worked on the ITPIA immigration scheduling project with the client and helped to scope the project for the class. These students were asked to present their models, assumptions, and analyses while also presenting final recommendations or additional questions that they could ask/give to the immigration agency at ITPIA. The students were pleased to find out from Deloitte Consulting that one of their main recommendations was similar to a recommendation made by the firm to the client, thereby giving these students as close to a "correct" answer to the case as they could hope for. Furthermore, some of the questions that students suggested be posed to the client were similar to those asked during the initial discussions that the consulting company had with the client.

Feedback on the case was mainly gathered through informal conversations with the students (especially during their meeting with the instructor). Students emphasized that initially they were overwhelmed by the project, but once they understood the expectations of the instructor about the case, they began seeing how to approach it. Therefore, for undergraduate OR students, we highly suggest providing a short overview of the types of assumptions that may be made/justified for the case that could still allow sufficient insights into it. This is further important because students did appreciate working with "unstructured" data and problems, because it allowed them to use their ingenuity rather than needing to figure out which OR method "fits the box" of the problem. However, the students needed assurances about the grading scheme for the project because it was so different from the typical homework problems, and there was no single correct solution. Therefore, it is suggested that the project is not weighed too heavily in introductory OR courses (it was worth 15% in this class). Students appreciated knowing that the case was real in the sense that a consulting organization had previously addressed it with an actual client. Finally, although it is not possible to have this opportunity for every case study or every project team, the two student groups that interacted with the consulting organization really appreciated understanding that their approaches were similar to those that were actually deployed.

4. Suggested Classroom Use

This case can be used in either an introductory undergraduate OR course in an engineering curriculum (and possibly a quantitative business curriculum) or advanced elective courses for either senior-level undergraduates or master's students. For the former, the case should be structured to guide the students along the way in terms of understanding how to apply OR to an open-ended problem. For the latter, the "guide" could be more focused on multiple feedback loops so that students understand that there may be several iterations before a client appreciates their models and analysis.

For an introductory OR course, the case can be implemented in a similar way as discussed in Section 3, especially in terms of demonstrating to the students the types of arguments they may make to simplify the real world into a scalable OR model. An initial case presentation and discussion should be done, and then students should be given time to understand the intricacies of the immigration agency at ITPIA. The instructor should then present, in class, examples of the types of assumptions and simplifications that may be made and the arguments required to justify them in order for the students to begin seeing how to use OR in the "real world." It may be beneficial to ask the students to (initially) consider applying their staffing analysis to a single target metric (e.g., every passenger should be able to move through the immigration line within 10 minutes of their arrival to the immigration processing area) because it might allow them to more easily create initial models. We could then suggest

leaving a short amount of time at the end of each class for project questions, in order to keep the students thinking about the case. It may not be possible for instructors to offer the 30-minute instructor-to-group meeting; however, it is important to provide students with the opportunity to receive formal feedback on their analysis, and, therefore, offering the students a chance to review the working drafts of their analysis is important. This may give them further confidence that they are on the right track with the analysis and, in fact, helps make grading the final projects much smoother, because the instructor may see where the students have improved from their draft submissions. It is up to the instructor to discuss whether students should present their analysis in a formal setting. In our classroom experience, we did not require such a presentation at the end of the semester because students were busy finishing homework and studying for the final exam in the course.

For an advanced undergraduate OR course or for a master-level course within an engineering curriculum, the case could be structured as more open ended and/or have more deliverables throughout the semester. The reason for this suggestion is that it allows the students more of an opportunity to develop skills around OR practice than the framework suggested for the introductory OR course. Examples of potential deliverables, in the order of submission, could be (1) a summary of the case and the assumptions placed on it for the OR modeling, (2) a discussion of the OR model(s) and their formulations to be applied to the case, (3) plans for analysis, and (4) a full report that includes revisions of the submitted deliverables for (1)–(3) as well as the conducted analysis. It may also be worthwhile to have the students provide a deliverable that discusses the additional questions they could ask immigration at ITPIA and/or data gathering that they could conduct in order to get them thinking about the process of creating and applying OR models. Consider imposing less structure in the case study; for example, if a target metric for passenger wait time is not specified, students may choose to view passenger wait time and the size of the staff as conflicting objectives in a multiobjective optimization problem. This could be valuable, as these advanced students are closer to being practitioners and, therefore, may be much closer to addressing open-ended questions in their careers than the introductory OR students.

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Endnote

[1] This particular case was motivated by a country that hired Deloitte Consulting to examine its customer workforce scheduling; however, to preserve their confidentiality, we will use this fictitious name.

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