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Robert A. Shumsky,



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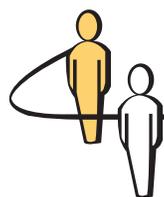
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Case Article

Introductory Integrative Cases on
Airline Revenue Management

Robert A. Shumsky

Tuck School of Business, Dartmouth College, Hanover, New Hampshire 03755,
robert.shumsky@dartmouth.edu

This case article summarizes two case series. Each case series includes three subcases and has an associated teaching note. These six short cases introduce many of the concepts that underlie the practice of airline revenue management: protection levels, overbooking, customer buy-up and buy-down behavior, network controls, bid prices, and the spiral-down effect. The cases are integrative in the sense that they reinforce many of the fundamental concepts taught in business programs, such as the formulation of statistical models, customer segmentation, the meaning of shadow prices in optimization, and the impact of model errors on real-world decisions. The cases also use many of the basic skills and tools taught in business programs: data analysis and forecasting, simulation, and optimization. By applying these tools, the cases move students quickly beyond the standard newsvendor-style formulation of the revenue management problem. Because the cases require students to apply these tools to interesting and relatively complex revenue management problems, the tools themselves gain more credibility among the students.

Key words: revenue management; airlines; forecasting; optimization; simulation

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1. Introduction

We describe and make available six short cases on airline revenue management. This article provides an overview of the cases: the topics addressed in each case, the software needed by the students, how the cases relate to each other, how they might fit into a business curriculum, and how these cases compare with existing teaching materials in revenue management. Two teaching notes (see §6) provide more details on the content and uses of each case. This article and the teaching notes, however, do not provide a thorough introduction to revenue management techniques. Talluri and van Ryzin (2004) and Phillips (2005) provide excellent introductions to the field as well as many more technical details.

These cases are divided into two series of three cases each. Both case series describe revenue management problems faced by BlueSky Airlines, a fictional passenger carrier. The BlueSky Airlines: Single-Leg Revenue Management Case Series focuses on the calculation of protection levels for a single flight leg, given uncertain demand. The BlueSky Airlines: Network Revenue Management Case Series focuses on the allocation of capacity to customers in a hub and spoke network, given a single class of customers and deterministic

demand. Instructors who use both case series should be aware that they provide very different, but complementary, views of airline revenue management. The single-leg case series focuses on the management of capacity in the face of uncertain demand, while the network case series focuses on the management of capacity across a network. The two teaching notes discuss how these two issues are addressed simultaneously in actual revenue management systems.

The two series are independent; either can be used without the other, and the two series may be taught in any order. In addition, some cases within each series are independent. For example, Single-Leg Revenue Management (B) can be used without using the (A) Case from that series. Table 1 lists the cases, supporting spreadsheets that should be distributed to the students along with the cases, and the precedence relationships. Table 2 summarizes the content of each case. Each case has links to common components of MBA, undergraduate business, and manufacturing management curricula. Therefore, whether any particular case is used, and the best sequence of cases, depends on when related topics are addressed elsewhere in the curriculum as well as the goals of the course using the cases.

Table 1 List of Cases, Supporting Spreadsheets, and Precedence Relationships Among Cases

Case series*	Case name	Case predecessor	Supporting spreadsheets (to be distributed to students)
BlueSky Airlines: Single-Leg Revenue Management	(A)**	—	<i>BlueSky Single-Leg (A) demand.xls</i>
	(B)	—	<i>BlueSky Single-Leg (B1).xls</i>
	(C)	(B)	<i>BlueSky Single-Leg (C).xls</i>
BlueSky Airlines: Network Revenue Management	(A)	—	<i>BlueSky Network_Data.xls</i>
	(B)	(A)	
	(C)	(A)	

*All cases and supporting spreadsheets can be found and downloaded from <http://ite.pubs.informs.org>.

**An earlier version of this case, “Revenue Management at SkyJet” was posted in 2004 on epodia.com, a clearinghouse for MBA teaching materials. This version is nearly identical, although the demand data and target flight dates have been updated.

The cases require basic spreadsheet modeling augmented with spreadsheet add-ins. Table 3 lists the required add-ins as well as optional software tools. We have used Crystal Ball for Monte Carlo simulation (Oracle 2009), Solver for optimization (Frontline 2009), and the Sensitivity Toolkit for simulation and optimization sensitivity analysis (Tuck School of Business at Dartmouth 2009). The optional tools listed in the fourth column of Table 3 make solving the problems easier, e.g., by speeding up the search for an optimal protection level. All of the cases, however, can be used without the optional tools.

2. Where Can These Cases Be Used?

BlueSky Airlines: Single-Leg Revenue Management (A) has been used in a number of MBA introductory operations management classes. All three single-leg cases have been used in an MBA service operations management elective. The three network cases have been used in an MBA core decision science class. In general, the cases are appropriate for introductory MBA classes in operations management, management science, and spreadsheet modeling; MBA electives

in service operations and revenue management; and undergraduate and engineering classes on these topics.

To use Single-Leg Revenue Management (B) and (C), students must already be familiar with simulation; the cases have not been designed to teach introductory simulation. Although the case templates and solutions are built with the simulation package Crystal Ball, another simulation package or the spreadsheet’s built-in random number generator may be used. Likewise, to use Network Revenue Management (A)–(C), the students must already be familiar with optimization. Although the case solution is built with Solver, other optimization packages may be used.

3. What Is New in These Cases and What Is Not?

There is much material available for teaching and reinforcing the basic quantitative concepts of revenue management. Examples include the text and exercises in Netessine and Shumsky (2002) and Chapter 13 of Cachon and Terwiesch (2006). These introductory texts use a newsvendor argument to find the optimal protection or overbooking level for a single flight leg with two distinct fare classes. Typical exercises apply the newsvendor-style formula to this canonical airline problem as well as to similar problems faced by hotels and purveyors of media advertising slots.

Real-world applications of revenue management, however, are not limited to the use of the newsvendor-type formula. The cases described here allow novice students to solve more complex problems by taking advantage of the quantitative tools—forecasting, simulation, and optimization—that students acquire during the early stages of many business programs. In addition, use of these cases helps to give the tools themselves more credibility because real-world revenue managers develop and use optimization and simulation models built on the same core principles (although, of course, industrial-strength applications are usually much larger).

Table 2 Summary of Case Content

Case series	Case name	Network type	Customer segments	Demand model	Decision
BlueSky Airlines: Single-Leg Revenue Management	(A)	1 leg	2	Students create a demand forecast, given historical data	Setting a protection level
	(B)	1 leg	2, with buy-up and no-shows	Stochastic (given)	Setting protection and overbooking levels
	(C)	1 leg	2, with buy-down	Stochastic (given)	Avoiding the “spiral-down” effect
BlueSky Airlines: Network Revenue Management	(A)	Small hub and spoke	1	Deterministic (given)	Partitioning capacity among customers
	(B)	Small hub and spoke	1	Deterministic (given)	Accepting/rejecting customers offered by an allied airline
	(C)	Small hub and spoke	1	Deterministic (given)	Optimizing aircraft size

Table 3 Required and Optional Software Tools

Case series	Case name	Software tool required (in addition to basic MS Excel)	Optional software tools
BlueSky Airlines: Single-Leg Revenue Management	(A)	—	Regression/forecasting software, e.g., Excel's built-in regression tool*, S-Plus (Insightful 2009), or SAS (SAS 2009).
	(B)	Monte Carlo Simulation, e.g., Crystal Ball*, Risk Solver (Frontline 2009), or @Risk (Palisade 2009)	Simulation sensitivity analysis, e.g., Sensitivity Toolkit (Crystal Ball Sensitivity*) or Risk Solver's built-in sensitivity tools.
	(C)	Monte Carlo Simulation	Simulation sensitivity analysis.
BlueSky Airlines: Network Revenue Management	(A)	Optimization, e.g., Solver*, Risk Solver, CPLEX (ilog 2009), or LINDO (Lindo 2009).	—
	(B)	Optimization	—
	(C)	Optimization	Optimization sensitivity analysis, e.g., Sensitivity Toolkit (Solver Sensitivity*) or Risk Solver's built-in sensitivity tools.

*These tools were used to create supplementary files and solutions for this case.

In general, the content in these cases is integrative because the cases simultaneously teach students about revenue management while reinforcing concepts introduced in other parts of the business curriculum, such as the formulation of statistical models, customer segmentation, the meaning of shadow prices in optimization, and the impact of model errors on real-world decisions.

These cases, however, are introductory and focus on the quantitative side of revenue management. Cases such as American Airlines, Inc.: Revenue Management (Dhebar and Brandenburger 1989) and Piedmont Airlines: Discount Seat Allocation (Pfeifer 1985, Bodily 1985) also explore the qualitative design and implementation issues faced by airline revenue managers. In fact, some components of Single-Leg Revenue Management (B) are similar to components of the Piedmont Airlines cases, although the BlueSky case has a more quantitative focus.

4. Summary of Case Contents, Related Literature, and Assignments

This section provides capsule summaries of each case and points to the related literature. It then briefly describes how the cases are assigned and used in class. More details on the case content, assignment logistics, and class discussions are in the teaching notes (see §6).

4.1. Case Series: BlueSky Airlines: Single-Leg Revenue Management

4.1.1. Summary of Case Contents

(A) Case: For this case, students build a statistical forecasting model and use the output from the model to determine protection levels and booking limits. To

set protection levels, the students apply a fundamental revenue management formula, *Littlewood's Rule*; see Talluri and van Ryzin (2004).

(B) Case: This case has three subsections.

Part 1: Given a single flight leg with two distinct customer segments, students compare the protection level that maximizes the expected profit generated by a Monte Carlo simulation with the results of Littlewood's Rule. If the work is done correctly, the optimal protection levels from the two models should agree. An instructor may provide the simulation to the students (*BlueSky Single-Leg (B1).xls*)¹ or may instead increase the challenge of the case by asking students to develop their own simulations.

Part 2: Extends the simulation from Part 1 to incorporate buy-up behavior by customers. In this case, it is assumed that some low-fare customers are willing to buy high-fare tickets if a low fare is not available. Students build a new simulation model, use it to find an optimal protection level, and compare the result with the optimal protection level from Part 1. For more information on addressing customer buy-up behavior, see Belobaba and Weatherford (1996) and the summary in Talluri and van Ryzin (2004).

Part 3: Extends the simulation from Part 2 to incorporate customer no-shows and overbooking. For this model finding the optimal solution becomes more complicated, as the students are asked to find the best protection level/overbooking pair. For more, see Talluri and van Ryzin (2004) and Phillips (2005).

(C) Case: This case walks the students through a simple simulation of the *spiral-down effect* that can occur when there is mismatch between the real-world demand process and the optimization model's

¹This Excel spreadsheet file can be found and downloaded from <http://ite.pubs.informs.org>.

assumptions about demand (see Cooper et al. 2006). The students are given a simulation model that incorporates buy-down behavior, (*BlueSky Single-Leg (C).xls*²), but are told to use the simple newsvendor-style formula (with its assumption that customers do not buy down) to calculate protection levels. The students use the model to generate revenue predictions and forecasts of high-fare demand. These forecasts are then used to update the protection levels, and the simulation is run again. If done correctly, protection levels drop far below the optimum, and revenue is lost. The case discussion focuses on why the spiral-down effect occurs in practice and what can be done about it.

4.1.2. How the Cases Can Be Assigned and Used in Class. BlueSky Airlines: Single-Leg Revenue Management (A) may be used as a stand-alone case. When using all three cases, I have assigned the (A) and (B) Cases in advance of class. Class time is then spent discussing these two cases and working through the (C) Case.

4.2. Case Series: BlueSky Airlines: Network Revenue Management

4.2.1. Summary of Case Contents

(A) Case: This case describes a small hub and spoke network with three flights into the hub connecting to three flights out of the hub. Given the capacities, revenues, and deterministic demands on all possible itineraries in the network, the students formulate a linear programming model to determine how capacity should be partitioned among customers. This approach—using a deterministic linear program to partition seats among customers—is described in Talluri and van Ryzin (2004).

(B) Case: This short case asks students to make booking decisions for small groups of additional customers. Discussion focuses on the meaning of the shadow prices generated by the linear program, and the use of these quantities as bid prices. Although the case appears to be trivial, we have found that it can elicit a very rich discussion in class. The use of bid price controls is discussed in Talluri and van Ryzin (2004).

(C) Case: This case extends the linear programming model from the (A) Case to find the optimal aircraft size on each leg. To solve this problem, students must add decision variables to the linear program and adjust the objective function and constraints.

4.2.2. How the Cases Can Be Assigned and Used in Class. I have usually assigned the (A) Case in advance, and asked students to submit a spreadsheet solution before class. During class we work through the (B) and (C) Cases.

² This Excel spreadsheet file can be found and downloaded from <http://ite.pubs.informs.org>.

5. Student Reactions

Most students have responded enthusiastically to the cases. They enjoy seeing how an obscure (to them) a concept such as *shadow price* has a direct connection with something they know well, airline prices. They also appreciate the opportunity to apply concepts and tools from multiple courses to a single problem. For example, a full analysis of BlueSky Single-Leg (A) requires material from a statistics course as well as revenue management concepts, while the concepts in BlueSky Single-Leg (B) and (C) have strong connections to the segmentation and targeting analysis taught in marketing courses. I have found that students who see these connections are excited about the chance to integrate their knowledge. Students who did not see these connections, when exposed to case solutions, may at first be taken aback and even a bit angry (one student accused me of “tricking” him because I did not tell him in advance to use material from other classes). All students, however, eventually appreciate the basic lesson: Outside of school, problems are not delineated by academic boundaries.

6. Teaching Notes and Solutions

Teaching Notes and spreadsheets with solutions for both Case Series can be found and downloaded from <http://ite.pubs.informs.org>.

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