Teaching Revenue Management in an Engineering Department

Abstract: Revenue management is one of the newly emerging topics in the area of systems engineering, operations research, industrial engineering, and engineering management. While it is not expected to become a part of the core curriculum in any of these disciplines in the near future, it is being taught in many universities in the business schools that have programs in operations research. Since the ideas underlying revenue management are rooted in operations research, they can certainly be taught to engineering students. It took a long time for supply chain management to make its way from business schools to engineering schools, and engineering professors have mixed feelings about the fact that it took such a long time. It will be interesting to see if revenue management follows a similar route, and if it ever does how long it takes to make this journey. An outline of the course that was taught in an engineering department, along with a description of the course contents, will be presented. What the instructor learned while teaching the course will also be described. In addition, specific areas that were treated in detail and the projects provided for students will be discussed.

1. Introduction

Revenue management is a newly emerging topic in engineering management, business management, and operations research that is being taught as an elective in business schools of numerous universities in the US and Europe (Columbia University and Northwestern University in the US and INSEAD in Europe to name a few). Revenue management is a relatively new topic in operations research. It was born in the 1970s out of the pioneering work of Littlewood[4]. It was loosely associated with a bunch of techniques used by airlines to intelligently price their seats. However, it was in the mid-eighties that it gradually developed into a science. In those days, it was called "yield management." American Airlines played a critical role in popularizing yield management in their operations.

Yield management for the most part attacked the pricing problem actually by solving a capacity-allocation problem. It was recognized in the 1990s that the classical pricing problems in which price was directly optimized *without* capacity considerations – an issue hitherto studied primarily by economists – had an important relationship with the yield-management

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(capacity allocation) strategies of airline companies. It was the interaction of the classical pricing problems and the capacity-allocation problems that gave birth to what is now called "revenue management." It was also recognized that these two issues could not be studied in isolation and that in fact they were inter-dependent to a certain extent.

In this paper, I will describe my experience with teaching revenue management in an engineering department. The course was advertised as a "systems engineering course" in an industrial and systems engineering department at the 500 level, which was open to advanced undergraduate students and graduate students. I believe there is no research in the literature that documents what such a course offering can lead to in an engineering setting. Hence, I believe that an analysis of the resulting outcomes should fill a gap in the literature on teaching in systems engineering.

The rest of this article is organized as follows. Section 2 discusses the need for teaching such a course in an engineering department. Section 3 outlines the contents of the course taught. Section 4 presents some of the outcomes that resulted from teaching the course. Section 5 concludes the paper with a discussion of the lessons learned.

2. Need for teaching revenue management:

The first question that needs to be addressed here is whether there is a genuine need for teaching such a course in an engineering department. It is the case that pricing and capacity-allocation issues that arise in driving the business models of airlines, hotels, car-rentals and retailers are typically *not* taught in our industrial engineering (IE) curriculum. The question that arises is as follows: Is revenue management simply an application of well-known operations-research principles? The answer to that question has to be in the negative because much of what is taught in operations research in IE focuses on *reduction of costs*. Revenue management for the most part looks at the *revenue* side of the equation, and uses techniques that are significantly different than those taught in any of the typical IE courses, such as production planning, facilities designing, and quality control. There are, in my opinion, other good reasons to teach this course. First, a vast majority of personnel who work for airline and cruise-line firms in their revenue-management departments are trained in IE departments and have IE degrees. Second, revenue management is not just another buzz word. For instance, many believe that "supply chain" is a new buzz word for production

planning and the "lean" principle is a new fashionable name for good old industrial engineering or "cost-effectiveness." Regardless of whether the above is true, it can be stated without any doubt that revenue management is not a new name for any subject that has been taught in the past. And yet, it is rooted in operations research, which happens to be one of the core courses in IE. A third reason is that IE departments have not revised their curricula with the same frequency as have chemical, electrical, mechanical or civil engineering departments. And this course provides IE departments with an opportunity to teach a topic that has not been taught traditionally.

There are some valid reasons for not teaching this course, and I will enumerate some of these next. The course is closer in spirit to marketing than it is to cost effectiveness. Typically, IE departments do not teach marketing. A part of the course deals with forecasting, which is generally taught in IE departments either as a full course or a part of a production planning course. Finally, at this time, it is not clear if revenue management will remain an important strategy for many of the airlines and retailers that are rapidly changing their business models.

On the part of this instructor, one of the reasons for teaching this course was a verbally expressed demand for it from his students. And yet, teaching a course in an engineering department that has only been recently introduced in business schools turned out to be a challenge from the very beginning. The course had to be approved at the Dean's level in the university administration, where a strong case had to be made for its need. This was a regular practice whenever a new course was proposed. Some of the reasons cited above were used to make the case at the Dean's level, where fortunately the course was approved unanimously by a panel.

3. Course contents

The course has mainly three components: Forecasting of Demand, Pricing Optimization, and Capacity Allocation. The typical products that we consider in revenue management are airline seats and retail goods. The product in this industry is a perishable item, whose value becomes zero or nearly zero at the end of a pre-set time horizon. For instance, the airline seat has no value once the airplane takes off, and hence it must be sold before the plane takes off. Similarly, many retail goods, especially fashion items, lose their value at the end of the season.

"Forecasting of demand" of such perishable goods is done with the help of data collected on historical volumes of sales for a given item when the price was fixed at a given value. Typically, what retailers and airlines require though is the quantity of volumes that would be realized if the prices were changed – either raised or lowered to other values. This is done via a technique called "uncensoring" of data. This is a central concept in teaching forecasting in the context of revenue management.

By "pricing optimization," one typically refers to direct price optimization without considerations of the capacity of the resource. This applies to the retail sector, and the methods used are rooted in models studied by economists. A key concept to be taught here is that of direct pricing optimization, where the optimization of the price is performed with some elementary calculus with the revenue function. The so-called "price-response function," the elasticity of demand, and the benefits of "price differentiation" are some of the other key ideas to be communicated to students. Pricing with constrained supply is an additional topic that can be treated if time permits.

"Capacity allocation" is the third central idea underlying revenue management. The main topics that were covered in this context were Littlewood's rule and the Expected Marginal Seat Revenue (EMSR) rule [1] in the context of single-leg capacity allocation problems. The multi-leg network problem was subsequently discussed and the principle of Displacement Adjusted Virtual Nesting (DAVN) was introduced. DAVN was illustrated specifically in the context of networks that arise in airlines and car-rentals. Classroom discussions were reserved for the nature of the traffic associated to carriers and how it affects their business model. In particular, the differences between the multi-leg network carriers, the single-leg point-to-point carriers, and the hybrid carriers that have a mixture of point-to-point and network traffic were illustrated with examples. The linear programming method as an approach to DAVN [2] was explained in detail, because it is employed regularly in the airline industry. The concept of "bucketing" to create the so-called "fare-classes" was also discussed in depth.

It is necessary to highlight the existence of differences between revenue management and the contents of a typical IE course and the challenge this aspect poses to the instructor. The biggest challenge is to get students to understand that via revenue management, as opposed to cost-reduction,

which students study in many of our IE courses, a difference can be made in the revenue side of the profit equation. It is very important to point out that revenue management is unlike classical cost-reduction typically found in operations research problems. This is due to the fact that in revenue management, generally, costs are not a part of the objective function. Furthermore, the nature of the revenue management problem is quite different from that of typical operations research formulations in facilities designing or production planning. Although the techniques used are from operations research, one of the most striking differences lies in the need to model the airline capacity as a decision variable and then construct a price-based objective function. The other challenge is to motivate students to collect data for their projects. Some of the data needed has to be collected via an online exercise of observing how prices for a given route in an airline network change over time. This is not typical of data in our traditional manufacturing courses, where data are either assumed from examples in books or gathered from case-studies. It is likely that it will take time for case-studies to appear on this topic in standard textbooks, and then data-collection exercises of this kind may become unnecessary. Finally, the course is not set in a production (factory) setting, and this in turn necessitates classroom discussions on how different the service economy is from the manufacturing economy. Last, but not the least, this author needs to point out that to the best of his knowledge, revenue management is *not* included in any standard textbook on operations research, optimization, or production planning.

Currently, there are at least two comprehensive textbooks on revenue management. Phillips [5] has been used in the MBA program and is quite suitable for an undergraduate course in an IE department. The text of Talluri and van Ryzin [7] can serve as a text for a graduate class. At the graduate level in addition to the topics discussed above, it is possible to discuss some more advanced topics such as dynamic programming models [6] and simulation-optimization model [3] for seat-allocation.

The projects that were assigned to students included (a) writing computer programs for EMSR, (b) using a combination of DAVN and EMSR to determine the seat-allocation for a small network with 5 legs, and (c) using priceline.com or some other travel website to obtain trends on how airline prices are changed over time by the airlines especially in the last few days before takeoff. Most of the projects had a significant programming

component since practicing revenue managers are expected to be very comfortable with computer programming.

4. Outcomes

Teaching the course resulted in numerous outcomes that will be described here. Unfortunately, no student evaluations were available because the instructor (author) had already resigned from the department and had accepted an offer to join a new department.

Students who took this course were for the most part graduate students in operations research. They had Bachelor's degrees in engineering (mechanical, industrial, electrical, and civil). 7 students got an A grade, one student got an A-, three students got a B+, and one student got a B-. Verbally, a number of students stated that the course helped them in becoming familiar with the revenue management functions of an airline industry. In the context of capacity allocation, among other things, students learned to use Littlewood's rule for allocating seats to fare classes, use DAVN for large networks, and simulate large networks. In the context of pricing, by the end of the course, students were able to set up demand-response functions and optimize prices for retail goods; this was in addition to learning numerous concepts related to price differentiation and markdown pricing.

5. Conclusions

The course was taught over a 16-week semester, and the students enrolled consisted primarily of graduate students. Getting the course approval was the first hurdle to be crossed. Thereafter, selecting the course contents was a time consuming task, given that the material had to be not only suitable for IE students, but also because it was for the first time that such a course was being taught in the department. While I hope to be able to teach the course again in the future, I learned a few lessons which I will enumerate next.

One of the aspects of revenue management is that it is one of the most important drivers of profit and sustainability in the organizations where it is used. Unfortunately, IE students are often resigned to the attitude that industrial engineers can only play a "supportive" role in any organization

and that they "don't make things, but make them better." An instructor of this course needs to drive home the message that as revenue managers they will have the greatest responsibility of ensuring that the organization remains profitable. The other challenge for our IE students is that it is not easy to motivate them to write computer programs in C or MATLAB. A lesson I learned is that it is best to prepare students psychologically for this in the very first week.

Finally, supply chain management is now taught in numerous IE undergraduate programs, usually, as a part of the production or operations planning course. It is unclear at this stage if revenue management will also become an integral part of our IE curriculum in the future. It could be more easily incorporated into a course in marketing or finance than into operations planning. All the indicators show that the service economy is likely to grow in the future, and therefore it is quite possible that revenue management could earn its place in the core of the IE curriculum in the next 10 years.

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