AC 2011-2339: A CASE STUDY: EDUCATING TRANSPORTATION ENGINEERS WITH SIMULATION SOFTWARE

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A Case Study: Educating Transportation Engineers with Simulation Software

Introduction

When transportation engineers study air travel, they often consider facility design, air traffic management, environmental impacts, capital financing mechanisms, and other factors. However, there is often little or no discussion of airlines themselves, despite their significant role in air travel! During a semester long undergraduate and graduate class on airports and freight, a new curriculum was developed to fill this void. Specifically, the AIRLINE Online simulation software was used to introduce students to the financial and operations perspectives of a major US airline. Teams of students were asked to make decisions as if they were their own airline. In developing their airlines, students considered scheduling, staffing, fleeting, advertising, setting air fares, and maintaining their fleet. The curriculum culminated with the airlines students created competing against each another in a simulation environment.

More specifically, the class was divided into 21 groups and the 21 groups were split into three batches. Each group or “airline” was charged with the task of creating an airline that would compete against 6 other airlines in the AIRLINE Online platform. Each “airline” had to make several very important financial and operational decisions in starting up their airline. Each “airline” was given a list of airports it was permitted to fly in and out of, specifications of different aircraft that would enable each group to choose a fleet, fundamentals of different scheduling strategies used by airlines, information on passenger preference and how that feeds into service level selection, as well as background on the impact of advertising on business operations. Using this wealth of knowledge, as well as research completed by each team on the history and current state of the airline industry, groups set up operations for their airlines. Each group staffed their airline, selected their fleet, purchased or rented terminal space, scheduled their aircraft, set service levels for each flight, and determined the most appropriate marketing scheme for their airline. Once the airlines were set up, a simulation representing one year of operations was run. Afterwards each group was given their ranking within their batch of seven airlines as well as their profit/loss statement. Each airline was then given the opportunity to change their business plan, before a second year of simulation was run. Again, each airline was given their ranking and their profit/loss statement after the second year of simulation.

Each group was required to produce several deliverables. First, the groups were required to document their business decisions. Groups were then asked to reflect on how they did after a year of simulation. In instances in which groups succeeded at making a profit, they were asked to comment on why they thought they were successful. In instances in which groups were not as successful, they were asked to comment on what they thought could have hindered their ability to make a profit. Groups were then asked to document any changes they made before the second year of simulation. After the second year of simulation, groups were asked to reflect on how the changes they implemented affected their performance. Finally, students were asked to submit a paper on “lessons learned” from this experience.

This project was unique and rewarding. It gave students a broad understanding of tradeoffs that are made, not only by airlines, but by any organization that make decisions. The project fostered healthy competition between students, which in turn motivated students to investigate many different strategies airlines implement when making decisions. This module was very well received; consequently, co-authors Dr. Laurie Garrow, Brittany Luken, and Susan Hotle worked with Rusty Shirley, a high school teacher, over the summer to develop a similar module for high school students. The module was piloted on high school students that were conducting research on Georgia Tech's campus during the summer. The high school teacher also took parts of the curriculum and implemented them into a 3-week module he rolled out this past fall. A week-long summer camp introducing high school students to the airline industry is being planned for Summer 2011 or Summer 2012.

Curriculum Details

This section provides an overview of the curriculum used to complete the simulation module. Leaning objectives, materials needed, and an overview of the activity are provided. To use this curriculum in your own classroom please access a copy of the introductory presentation and the student and teacher instruction packets at http://transportation.ce.gatech.edu/node/2071.

Learning Objectives

During the Airline Online simulation activity, students will learn:

- How simulations work and their uses in real life
- How to apply knowledge about economics to build and maintain a successful business
- How the organization of an airline requires decisions to be made collaboratively
- How business plans vary across existing airlines
- What elements are used in scheduling flights
- How to balance the costs and benefits of hiring certain employees and managers
- How to quantify tradeoffs made by airlines

Materials List

- Computer with internet access for each team
- License to AIRLINE Online
- Student and teach instruction packets

Overview of Activity

The overall goals for the project should be described. Each group is to create the airline with the highest profit at the end of the simulation. Students will use the simulation program AIRLINE Online to create their airline. Specifically, they will access AIRLINE Online through the internet and input each of their group's decisions regarding the organization of their airline. Each group will also record the decisions made in their packets. There is also room for each group to comment on why they made specific decisions when creating their airline.

To achieve the aforementioned objectives, first a background presentation should be given to the class. Then students should be divided into small teams of 2 or 3 students. Each team will receive a packet of directions that includes the steps on how to create and maintain a functional airline, a map of the airports available in the simulation, a chart of the airplane types and specifications that will be in the simulation, and a chart of origin-destination markets that each airline will be allowed to serve.

During the design of their airline, each team will think through the following questions. As shown through this thought process, the activity has been designed to be as realistic as possible:

What type of airline will be most profitable?
Before starting, each team needs to come up with a business plan for their airline. Each airline can decide to carry passengers, cargo, or both. The success of each business plan is partially based on other airline's decisions. For example, if only one airline in the simulation is a cargo carrier the airline will have a monopoly of the cargo market.

What aircraft should be purchased?
Students are instructed to purchase only used airplanes because the simulation lasts shorter than the ten years needed to receive a newly ordered plane. Teams are given specifications for each aircraft with respect to the aircraft's range, fuel economy, speed, capacity, engine type, and length of runway needed for landing and takeoff. Thus, the when determining which aircraft to purchase teams must evaluate the tradeoffs between aircraft that are more fuel efficient and aircraft that are faster. Similarly, they must assess which aircraft can land at which airports, and which aircraft can travel between which airports. This is because larger aircraft require longer runways and only a subset of airports have those long runways. When building up an entire fleet of aircraft, the team must also consider that maintenance bases must be purchased for ever type of engine and their staff must be hired according to the aircraft types purchases.

How should the airplane be configured?
The teams are also responsible for configuring each aircraft, or in other words, designing the interior layout of each of their planes. This only applies to airlines that have decided to carry passengers. This step includes determining the number of seats in each class, how much legroom to give passengers, and which electronic devices should be offered (audio entertainment systems, movie screens, video games, in-seat phones, etc). Although this step seems trivial, the layout does impact the quality of service perceived by the passengers in the simulation. Thus, the demand for seats on an airline with more legroom (all other factors being equal) will be greater than an airline with less legroom.

What amenities should be provided on each airplane?
Each team also decides what amenities to provide to their customers. These amenities include complimentary meals, newspapers, and movies to name a few. Teams trying to make a profit will have to decide between offering (1) lower fares and little to no extra services (mimicking the business strategy of a low-cost carriers) or (2) higher fares with extra perks (similar to the business strategy of traditional carriers).

What staff should be hired?
Each airline must first determine which managers to hire. The directions students receive list how an airline will profit from hiring each of eight possible managers. For instance, if the Purchasing Maintenance Manager is hired, the simulation will reduce the airline's final quarterly maintenance cost by 10%. Once hired, a manager can only be let go by charging the airline a

separation fee. Other staff to be hired (pilots, maintenance staff, support staff, cargo handlers) is determined using the planes in the airline's fleet.

Where should maintenances bases, cargo handling centers and offices be located?
In the Airline Online platform, airplanes must undergo four different kinds of maintenance checks (A, B, C, and D). If an airplane does not receive a required maintenance check it cannot fly. For example, the most frequent maintenance check each airplane must undergo is the "A" maintenance check. Generally, an airplane will have to undergo the "A" maintenance check about twice a week depending on the hours flown per week. Thus each team should purchase maintenance bases at airports so that each plane visits an airport with a maintenance base at least twice a week.

The best locations for cargo handling centers and offices are less arbitrary. A cargo handling center is to be purchased at every airport that handles cargo and an office can be purchased at any of the airports, as long as the sum of all the capacities of the offices can hold the entire hired staff.

When do airplanes need to visit maintenance bases?
The scheduling of maintenance checks are a function of the number of hours flown since the last check of the same kind. Each team will have to calculate which planes will exceed the number of hours flown on any of the checks within the next quarter using the schedule they make for each plane. If a plane needs to be checked, each team will have to make sure the plane is scheduled to land at an airport with a maintenance base and that there is enough time for the check to be completed. ("D" checks, for instance, require 25,000 man hours to be completed.)

In what markets should airlines compete?
Although each team will be instructed on which airports they can use, airlines are not necessarily forced to compete in any market. Using the charts provided, they can see which markets they have or nearly have a monopoly in. These markets generally coincide with small airports and low-demand. Thus the teams will have to decide between scheduling airplanes in low-demand, low-competition markets or high-demand, high-competition markets.

How should fares be set?
Airline Online has a menu that publishes the average market fare from all the competing airlines. In instances when an airline is operating in a monopoly, that airline has more leverage on how high to set the fare because they do not risk losing demand to a competitor.

How much should be invested in advertising and how should advertising be allocated among different media types?
The teams will decide how much money to spend on advertising and what percentage of the money will go to each media type (radio, television, print, sponsorship, and billboard). Airline Online shows how effective each media type is on a graph, with television usually being the most effective.

Evaluations

Evaluations are provided for the two instances that the curriculum has been employed: during an undergraduate and graduate freight and airports class offered at the Georgia Tech during the Fall 2009 semester and during a four week summer camp for where high school students were doing research on Georgia Tech's campus.

Freight and Airport Class (Fall 2009)

A total of 78 undergraduate and graduate students took a class on freight and airports. Students in a group setting were asked to complete the assignment described in this paper that uses the simulation program AIRLINE Online. The following evaluation findings were derived from the "lessons learned and conclusion" sections of the students' reports.

A majority of the student groups reported that this was "*a very interesting learning experience*." The most valuable lesson they learned from the simulation was that the theory and reality of operating an airline are two very different things. Students reported that the simulation helped them apply the theory to a real life setting, thereby providing a better understanding of the concepts involved in managing an airline. Furthermore, they felt that learning from a simulation setting was a good way of understanding the cause and effect relationship of each variable that is related to an airline operation. Students also stated in their reports that being involved with the entire process of managing an airline was a valuable lesson that they can apply to future "real life" situations. They also gained knowledge and an understanding of how such modeling techniques can be useful in real life experiences. As one group reported: *"We came to understand that a model simulation is a representation of reality based on a computer program. We felt that this simulation is an excellent tool that can be used by stakeholders in the planning process of an airport system."* Another group reported a similar sentiment: "*Our experience with the Airline Online simulation has shown that it can be a powerful tool in helping airlines develop business and operation plans by better understanding the competitive element of the airline industry*." Lastly, the groups also reported that this project was very accurate in projecting today's airline industry trends. *"This airline simulation exercise did help us get an inside view of the everyday operations that are involved in the airline industry. The exercise was a very accurate representation of today's industry also."*

Students also emphasized that they had a deeper understanding and appreciation of the complexities involved in managing an airline after participating in the AIRLINE Online program. Students felt that they learned about the intricate details of running an airline and what actually happens in the process. It was a "*worthwhile*" experience as the simulation could be easily related to other business models. Here are some significant quotes from the group reports:

"This exercise gave us a solid exposure and better understanding of the complexities in the airline industry. There are many factors that must be combined to construct a solid operation plan, many of which were not immediately apparent at the beginning of the project; however, during the project we developed a good sense of different factors that might have an impact on the results."

Students felt the most critical challenges involved in designing an airline involved the following: complexities of scheduling aircraft service and maintenance, the amount of capital investments that needed to be made, and the difficulty in designing a profitable airline. Furthermore, according to group reports, the most time consuming aspect of the simulation was scheduling aircraft arrivals and departures and making sure that aircraft maintenance was up-to-date. Students also learned that external events may have an impact on the decision making process. For example, "*the problems caused by the rising price of fuel became apparent to our group after the first year simulation. The only way to combat the rising fuel prices is to raise the ticket prices and/or lower the services offered in flight. Thus, we learned that today's economy plays a big role in operating an airline.*"

In conclusion, the reports also showed that students were deeply engaged with the simulation project, learned to interpret and respond to many aspects of their airline's operation, made collaborative decisions in dealing with a variety of challenges, and developed a range of decision making skills.

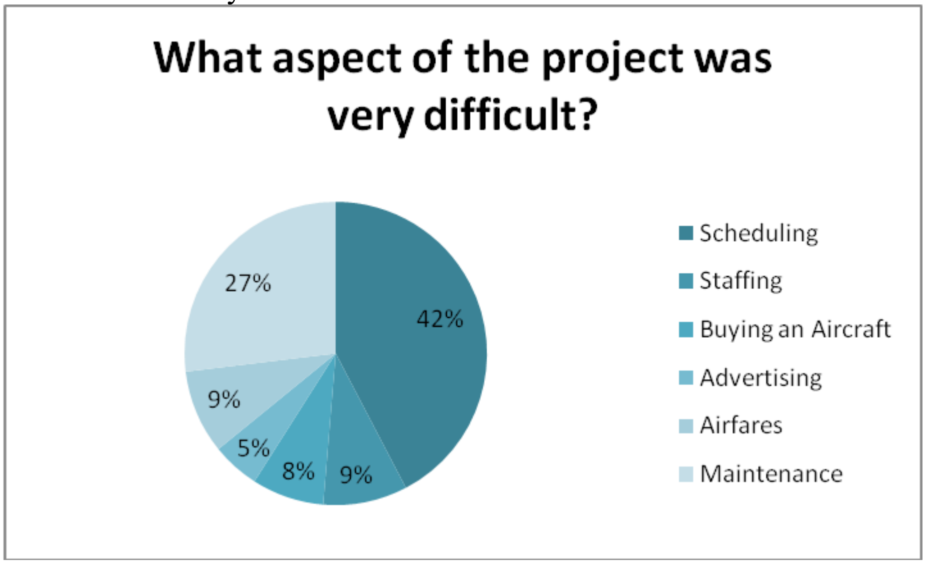
An online survey was also used to obtain more information about the effectiveness of the AIRLINE Online simulation program. The survey was administered using a survey software program called Survey Monkey. The response rate within a few weeks of the initial e-mailing was 69%. This survey was used to evaluate three components of the simulation project: (1) the overall effectiveness of the airline simulation project, (2) the most difficult task, and (3) the future implications of students' involvement in the airline simulation project. A total of 54 students completed our survey; 74 % were male and 26% were female. The class itself was comprised of 22% females and 78% males. Thus, the survey response rate was slightly higher for females than males. The following tables summarize the students' responses to the survey:

Table 1: Undergraduate and Graduate Student's Evaluation of Airline Simulation Assignment

To what extend do you agree with following statements?	**Mean**	**Strongly Disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**
The airline simulation project helped me understand the real-world decision making process involved in building an airline.	4.20	1.85% (1)	1.85% (1)	5.56% (3)	55.56% (30)	35.19% (19)
After completing the airline simulation project, I had a deeper understanding and appreciation of the complexities involved in managing an airline.	4.18	1.85% (1)	3.70% (2)	7.41% (4)	48.15% (26)	38.89% (21)
The airline simulation project was a very positive learning experience.	4.07	1.85% (1)	0% (0)	12.96% (7)	59.26% (32)	25.93% (14)
I have learned to interpret and respond to many aspects of airline's operation.	3.78	3.70% (2)	1.85% (1)	25.93% (14)	50% (27)	18.52% (10)
During the airline simulation project, I enjoyed making collaborative decisions in dealing with a variety of challenges.	3.94	1.85% (1)	5.56% (3)	14.81% (8)	51.85% (28)	25.93% (14)
Active simulation applications are the best way to learn in engineering.	4.03	3.70% (2)	5.56% (3)	12.96% (7)	38.89% (21)	38.89% (21)
The airline simulation project felt "real" in the sense that it simulates as closely as possible real world situations.	3.80	7.41% (4)	1.85% (1)	25.93% (14)	33.33% (18)	31.48% (17)

** parenthesis indicates the number of responses*

Table 2: Difficulty Level



Our survey results highlight some very import points. Eighty-five percent (85%) of the participants agreed or strongly agreed that the airline simulation project was a very positive learning experience. Additionally, a majority of the students (91%) agreed that the simulation project helped them understand the real-world decision making process involved in building airlines. A similar distribution of responses was observed when asked if they had a deeper understanding and appreciation of the complexities involved in managing an airline. The results indicated that approximately 87% of the students answered this question affirmatively. When asked if they enjoyed making collaborative decisions in dealing with a variety of challenges, 78% agreed with this question, and 15% were neutral. However, only 68% of students felt that they learned how to interpret and respond to many aspects of the airline's operation. This is also revealed in comments from the students: *"This exercise would have been useful if we could run the simulations every week, then students can interpret and respond to different components of the airline operation. We can learn better from the mistakes and different settings of the simulation."* Additionally, 78% students agreed that active simulation applications are the best way to learn in the field of engineering. One student commented *"this was the most enjoyable part of the class. A great activity in an engineering class, I think other engineering courses can use a similar approach."* Another student reported "*it can be a worthwhile exercise as the simulation could be related to other engineering business models in the future."* Lastly, when students were asked if they could see themselves managing and operating an airline, 67% responded affirmatively. In that regard, one student commented that *"after this exercise, I feel that this is what I would enjoy doing after completing my degree."*

Scheduling arrivals/departures and maintenance of the airplanes were also ranked as the most difficult aspect of the simulation study, with 62% and 39% responses, respectively.

Overall, the comments and responses to survey questions showed that student experience with the airline simulation was very positive, and that the simulation is a powerful tool in helping students to understand the challenges involved in developing an airline business and operation plan. Students gained a much better understanding of the competitive element of the airline industry.

High School Summer Camp (Summer 2010)

The simulation curriculum was adapted and piloted with a group of 9 high school students who were conducting research on Georgia Tech's campus. At the end of the four week summer research session, nine students completed the survey: 6 were male and 3 were female. The following survey summarizes the students' thoughts about using the AIRLINE Online software.

Table 3: High School Student's Evaluation of Airline Simulation Assignment

To what extend do you agree with following statements?	**Mean**	**Strongly Disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**
The simulation project helped me to understand the real-world decision making process involved in building an airline.	4.88	0% (0)	0% (0)	0% (0)	11.1% (1)	89% (8)
It was challenging working as a group.	3.22	22.2% (2)	11.1% (1)	11.1% (1)	33.3% (3)	22.2% (2)
I enjoyed the Airline Simulation project.	4.55	0% (0)	0% (0)	0% (0)	44.4% (4)	55.56% (5)
I liked investigating real-world Airline issues in a group setting.	3.88	0% (0)	0% (0)	33.3% (3)	44.4% (4)	22.2% (2)
The simulation helped me to better understand the consequences decisions have in the real world.	4.00	0% (0)	0% (0)	33.3% (3)	33.3% (3)	33.3% (3)
Active simulation applications are the best way to learn.	3.22	11.1% (1)	0% (0)	44.4% (4)	44.4% (4)	0% (0)
This activity felt "real" in the sense that it simulates as closely as possible real world situations.	3.55	11.1% (1)	0% (0)	11.1% (1)	77.78% (7)	0% (0)

** parenthesis indicates the number of responses*

All students agreed that the simulation project helped them to understand the real-world decision making processes involved in building and managing airlines (mean=4.88). Additionally, they enjoyed the airline simulation project (mean=4.55). Since the AIRLINE simulation software offers interactive learning opportunities for students and requires ongoing decision making skills, we asked students if it was challenging working as a group. Approximately 56% of the students agreed that working as a group was difficult. Furthermore, 67% agreed that this simulation activity helped them to better understand the consequences decisions have in the real world sense (mean=4.0).

Students were also asked to rate the level of difficulty when making a decision for each aspect of the simulation project: scheduling, staffing, buying an aircraft, advertising, airfares, and aircraft maintenance. Students reported that scheduling arrivals and departures was the most difficult task.

Several students also reported that "*the decision-making process is very important.*" The context of this airline simulation provided an environment in which students learned to interpret and respond to many different challenges involved in an airline's operation; made collaborative decisions in order to deal with these challenges; and developed a range of critical thinking skills. The feedback in the surveys showed that students enjoyed working collaboratively and making complex decisions in which they realized that they needed to consider a range of complex factors. They also indicated that more time was needed to complete and understand the simulation procedure. Lastly, when students were asked if this simulation study increased their interest in this kind of work, 4 of 9 students answered affirmatively.

Conclusions

The curriculum developed was well received across high school, undergraduate, and graduate students studying or interested in transportation engineering. It provided a unique perspective on how difficult operating an airline can be, and fostered communication about the interaction between the transportation network and the airlines themselves. As noted in one of the themes for the 9th Annual ASEE Global Colloquium on Engineering Education "our grand challenge programs require our engineers to be able to better understand issues that transcend disciplinary boundaries and to offer effective solutions". Traditionally, civil engineering education has been constrained along its disciplinary lines. However, this curriculum presents a unique way to incorporate cross-disciplinary concepts into a civil engineering course. Specifically, it boasts success in educating transportation engineers about the dynamic environment of airline operations. Using this curriculum in two separate classroom environments was mutually beneficial to Simulate! Pty. Ltd. as the company has incorporated some points raised by student's experience in improving aspects of the software interface. We have began adapting the simulation program piloted this past summer into a week-long summer camp for high school students interested in transportation engineering and the airline industry.

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