AC 2011-2442: ENHANCED AIRPORT MANAGEMENT INFORMATION SYSTEM FOR SMALL AND MEDIUM-SIZED AIRPORTS: A SYSTEMS ENGINEERING CAPSTONE DESIGN EXPERIENCE

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Enhanced Airport Management Information System for Small and Medium-Sized Airports: A Systems Engineering Capstone Design Experience

Abstract

This paper presents the capstone design course educational process in place within the Systems Engineering Department at the University of Arkansas at Little Rock, emphasized through the work of a group of students that were enrolled in the capstone design sequence during the 2006-2007 academic year. The process includes preparation for the capstone design project in preceding systems engineering courses, the selection of the capstone design project, the actual student work and its validation by the mentoring faculty, the dissemination of the results to all interested parties, and the assessment of the level of achievement of the course learning objectives. As response to the main local airport request for proposal, the students enrolled in the capstone design course proposed a management information system which organizes the airport operations into subsystems corresponding to the main activities that consider the sharing and exchange of information within the airport facilities. Through the automation of the information flow, the proposed system may help small and medium-sized airports improve their operational efficiency and increase their bottom line.

1. Introduction

This paper discusses both the educational aspects, in terms of pedagogical approach to teach the capstone design course and assessment of the course learning outcomes, and the technical aspects of the 2006- 2007 Systems Engineering Capstone Design course at the University of Arkansas at Little Rock (UALR). Teaching systems engineering, in general, and systems engineering capstone design course, in particular, is a subject of continuous debate due to the multidisciplinary nature of the systems engineering discipline and the expectations of the stakeholders involved in the capstone design course[1-2]. This work presents the UALR Systems Engineering Department successful experience in teaching the capstone design course in one of the recent academic years. The paper is structured as follows: Section 2 provides a review of systems engineering education and the approach of the UALR Systems Engineering Department to address the main themes related to teaching systems engineering identified in the literature review. Section 3 presents the methodology of teaching the capstone design course at UALR and provides a review of the technical solution for the industry sponsored project proposed by the capstone design students. Finally, Section 4 presents qualitative aspects of the formal assessment process together with recognition evidence of the performance of the capstone design team.

2. Background and Motivation

The research conducted on systems engineering undergraduate programs offered by colleges and universities in the United States shows that the current program offered by the Department of Systems Engineering at UALR has unique characteristics not found in other programs. The first comparison study on systems engineering programs in the United States identified in the literature review was published in 2000[3]. However, the programs selected for that survey are not anymore characteristic for today's systems engineering undergraduate education since other programs were started and the selected ones may have experienced changes. As an example, UALR Systems Engineering started in the year when the survey was published, so it could not be included in the study. A more recent study, published in 2010[4], provides an updated directory of the systems engineering undergraduate programs in the context of the overall systems engineering discipline, which includes information about professional societies, certification and licensing, program accreditation, and knowledge and publications. The review of the literature also identified another two reports portraying ways to design systems engineering undergraduate curriculum and presenting the implementation results, but neither one of them carried out in an U.S. institution. The first study was conducted at Delft University of Technology in the Netherlands[5], and the second one at Holon Academic Institute of Technology in Israel[6-8].

Generally, the purpose of the capstone design course is to provide students with the opportunity to work on a design project in which they can utilize their engineering analysis and methodology knowledge acquired in other course offerings. One of the main learning objectives is to test their abilities and knowledge necessary to successfully complete a real-world design project. The literature review identified several capstone design experience reports, which highlight this important opportunity for students to develop their skills and learn about new product development. The outcome of capstone design courses is viewed as likely to offer creative design solutions that may, sometimes, result in the creation of intellectual property[9]. However, the main question that surfaces from every study is: "How can a department best ensure that each student assigned to a project has the necessary background and skills to contribute towards a successful conclusion of the project?"[10]. The UALR Systems Engineering Department instituted a unique approach for its Bachelor of Science undergraduate program to answer the above question. At the same time, the Department is following its guiding principle of continuous improvement and is always open to incorporate viable approaches that will further enhance the capstone design education that students receive.

The students enrolled in the Systems Engineering undergraduate program at UALR are introduced to the basics of systems engineering analysis starting with their freshman year in introductory courses of specific engineering specialties. Subsequently, they are exposed to systems engineering quantitative modeling and analysis techniques in several core courses at the junior and senior levels. This approach builds up a promising systems engineering education that reaches its highest point with the required systems engineering capstone design project. At the same time, the current UALR Systems Engineering curriculum gives the graduates a solid engineering education in one of the following four option areas: electrical, computer, telecommunications, and mechanical engineering. This unique approach prepares graduates to become high-quality professionals in one of the above four areas, with the key benefit of building the specialty engineering education on a sound systems engineering foundation.

Being close to graduation, students enrolled in the capstone design sequence expect that the projects selected for the course are part of the real-world such that they can apply the knowledge and skills acquired in their undergraduate program to solving problems that have relevance to real-world organizations, and thus being better prepared to start their career, upon acceptance of a job offer. Students expect to be actively involved with the client organization in data collection, and information sharing with both the management and the engineering department. The client organization also benefits from the capstone design course, since the delivered engineering solution is validated by the expertise of the mentoring faculty.

Students enrolled in the capstone design sequence are also encouraged to exploit the systems thinking skills acquired in the previous core junior and senior courses. According to Senge[11], "systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships and repeated events rather than things, for seeing patterns of change rather than static snapshots." In the same manner, O'Connor and McDermott[12] define systems thinking as "a structured way of thinking that focuses on the relationships between parts forming a connected whole for a purpose" and identify the methodology of systems thinking as thinking in circles rather than in straight lines, using the connections between parts, which form feedback loops, where a feedback loop is defined as a closed chain of cause and effect.

One example of this successful approach is the 2007 systems engineering class. The graduates of the 2007 class had the opportunity to collaborate during their capstone design course with a very important local industry partner: the Little Rock National Airport (LIT). Current business climate demands that small and medium-sized airports obtain real-time information about their operations and expenses to efficiently serve the passengers and associated commercial airlines partners. These pieces of information cannot be obtained manually given the time and expense to collect them. The students enrolled in the capstone design course proposed a management information system which organizes the airport operations into four main subsystems corresponding to the main activities that deal with the sharing and exchange of information within the airport facilities: the gate information subsystem, the ticket counters information subsystem, the flight information displays scattered around the airport, and the runway monitoring subsystem. The proposed system uses information exchange methodologies among the component subsystems and is designed to provide comprehensive reports at the airport management request. As a result of automating the flow of information, the proposed system may help LIT, and other small and medium-sized airports, improve their operational efficiency and increase their bottom line.

3. Methodology

3.1. Capstone Design Sequence Structure. The capstone design experience at UALR is a two-course, full academic year sequence, in which students work typically in small groups or teams on a large-scale type of project. Projects are either industry-sponsored or selected by the students in collaboration with the capstone design faculty mentor. During the 2006-2007 capstone sequence, a group of three students had the chance to work on the industry-sponsored project mentioned above, the Little Rock Airport Project. This section discusses the teaching approach and the proposed technical solution prepared in response to the LIT management request.

The outline of the 2006-2007 *SYEN 4385/4386: Systems Engineering Capstone Design I/II* course sequence is presented below.

- Presentation of the proposed project
    - LIT request for proposal (RFP)

    - Faculty input
- System engineering design and analysis, and systems thinking lectures
    - Systems thinking
    - System conceptual design
    - System functional analysis
    - System preliminary design
    - System detail design and development
    - System production, operation and support
- Meetings with the client at both UALR and LIT sites
    - Acknowledge the need
    - Data collection
    - Identify deliverables
- Literature review
    - Airport operations literature
    - Commercial airport systems
- Software training
    - Arena® simulation environment
- UALR students response to LIT RFP
    - Present proposed solution
    - State deliverables
- Presentations and reports
    - End of semester and other interim presentations and reports

The first lecture included the presentation of the proposed project by faculty, followed by several lectures in systems engineering design and analysis to familiarize the students with the system engineering approach. Students' visits and interaction with the client at their location permitted them to collect the necessary information to start the project. A survey of the literature related to the subject of the project and software tutorials were then scheduled for the remaining part of the first half of the semester. During this period, assignments were given to facilitate the comprehension of the material presented in class and help the students achieve proficiency in using the software tools needed for the project work. In the second part of the first semester the students started to actually work on the system design and were required to give several presentations of their progress towards achieving the stated deliverables. A progress report was scheduled at the end of the capstone design one course and a final report was due at the end of the capstone design sequence. Continuous interaction with the client was encouraged and expected from the students to ensure that the final design meets the client's requirements.

The five weeks of systems engineering design and analysis lectures complemented with systems thinking knowledge provided students the necessary background to approach the capstone project using the systems thinking view and harmonize it with their particular engineering discipline background. Examples were presented during each of the lectures to familiarize the students with real-world project implementations. Building on the above considerations, students began their system design work by acknowledging the need and identifying the system operational requirements in the framework of systems engineering conceptual design. This stage also included the identification of the technical performance measures of the proposed system. With translating the requirements into functions, the system engineering process entered the preliminary design stage, which also included developing system specifications, and trade-off studies of alternative solutions. The in-depth knowledge acquired by each student in their specialty engineering option was then utilized in the detail design stage of the project.

3.2. LIT Request for Proposal. The formal RFP received from the LIT Airport Commission stated the need for an automated system that would enable LIT to obtain the critical information required for their daily operations in a comprehensive format. More specifically, the RFP stated that "the current business climate demands that the airport obtain real-time information about its operation and expenses to better serve the passengers, as well as the many industry partners." And, since this "information cannot be obtained manually given the time and expense to collect (it)," a list of capabilities of the successful design was presented, which included the below ones, among others:

- Develop automated management reports that will give comprehensive operational and financial reports.
- Develop a per-use system for ticket counter and gate usage.
- Provide better customer service to the passengers by providing better flight information displays with accurate information.
- Develop management reports to track real time cost of enplaned passengers either by airline or by total for the airport.
- Develop a runway utilization report by type of aircraft that uses the runway and frequency of use to better plan maintenance and predict the maintenance expenses.

3.3. Technical Solution. In response to the LIT RFP and considering the identified limitations and potential avenues for improvement of LIT airport operations, the solution proposed by the systems engineering capstone design team is an automated system, called Automated Airport Information Management System (AAIMS). The AAIMS top-level architecture is shown in Fig. 1. The system is designed to assist the operations of small and medium-sized airports by

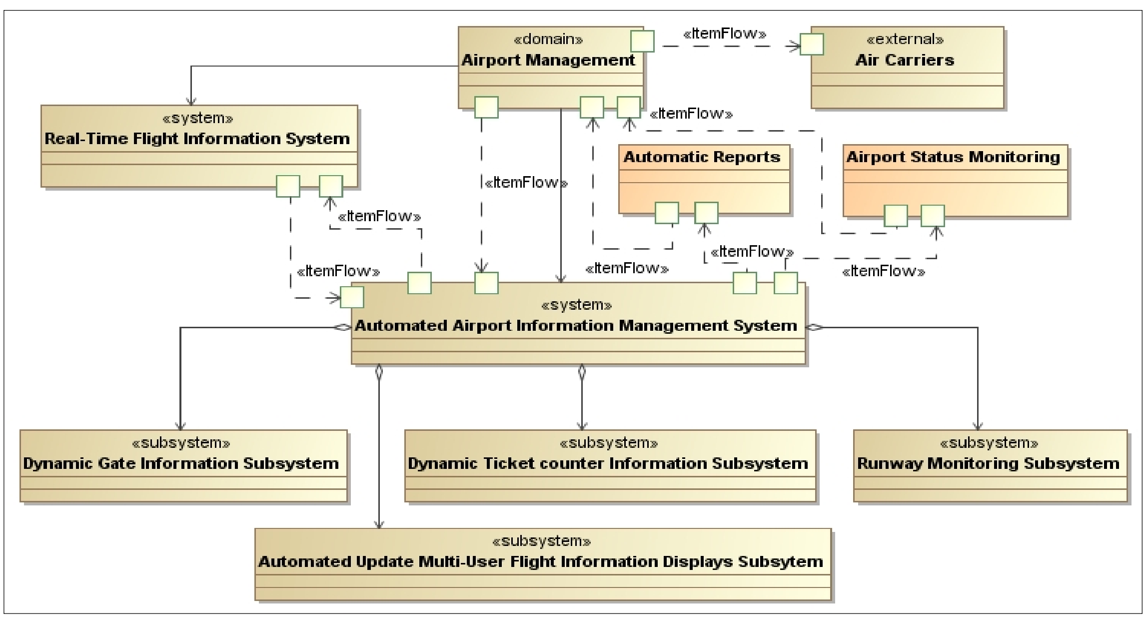


Fig. 1. Automated Airport Information Management System (AAIMS) top-level system architecture.

providing comprehensive reports of activity, automatic capabilities in terms of resource assignments, and real-time information exchange within airport facilities. Composed of four main subsystems: Dynamic Gate Information Subsystem (DGIS), Dynamic Ticket Counter Information Subsystem (DTCIS), Automatic Update MUFIDS Subsystem, and Runway Monitoring Subsystem (RMS), the system collects data from existing airports' infrastructure and newer technology to be acquired by LIT capable of providing real-time flight information for the incoming aircrafts bound to land on LIT premises.

A Real-time Flight Information System provides flight data to the system while the airport management provides general system information such as fees and facility information.
The first subsystem, DGIS, handles all the gate information inputs and outputs, including the gate status information coming from the Real-Time Flight Information System and any gate management and reports needed by AAIMS. The second subsystem, DTCIS, handles dynamic ticket counter assignments, information flow and statistical reports information. The third subsystem is the Automatic Update MUFIDS, which automatically updates the flight information displays using aircraft information received through the flight information system to provide real-time updates. RMS monitors the runway usage by incoming and departing aircrafts and generates reports information to assist in maintaining the runway. The proposed AAIMS system has two functions that display and report the status of automated operations: Automatic Reports and Airport Status Monitoring. The Automatic Reports function provides the airport management with comprehensive financial and operational reports based on the functions controlled by the AAIMS. The Airport Status Monitoring function is a real-time view of the current operations that allows airport managers to view current activities within the system.

AAIMS includes also an innovative solution for the dynamic assignment of airport ticket counters based on individual airline needs. This solution, called per-use policy, assigns the airport ticket counters considering the individual airline needs at any time, where the same ticket counter can be shared at different times by different airlines. To obtain information on the capabilities of the ticket counter per-use policy system, a simulation study was conducted which models both the current standard ticket counter and the proposed DTCIS systems. Current operations at LIT are designed such that all ticket counter locations are fixed by long-term leases to the air carriers. The system simulation model, presented in Fig. 2 and built using the Arena® simulation environment, reflects both these models of operations to provide a means of comparison for future changes and improvements. The difference between the two models lies in the use of the ticket counter scheduling. The number of ticket counters in the current system model is fixed at two ticket counters per air carrier. Each ticket counter has two physical positions and is able to serve two customers at any one time.

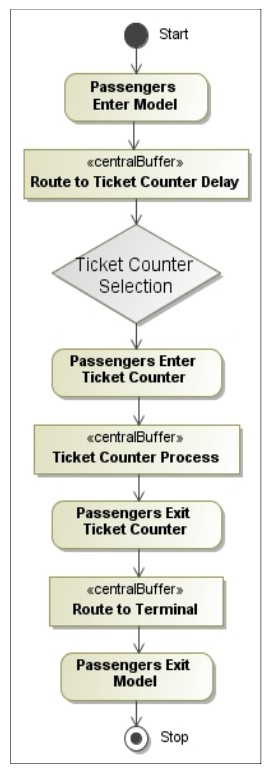
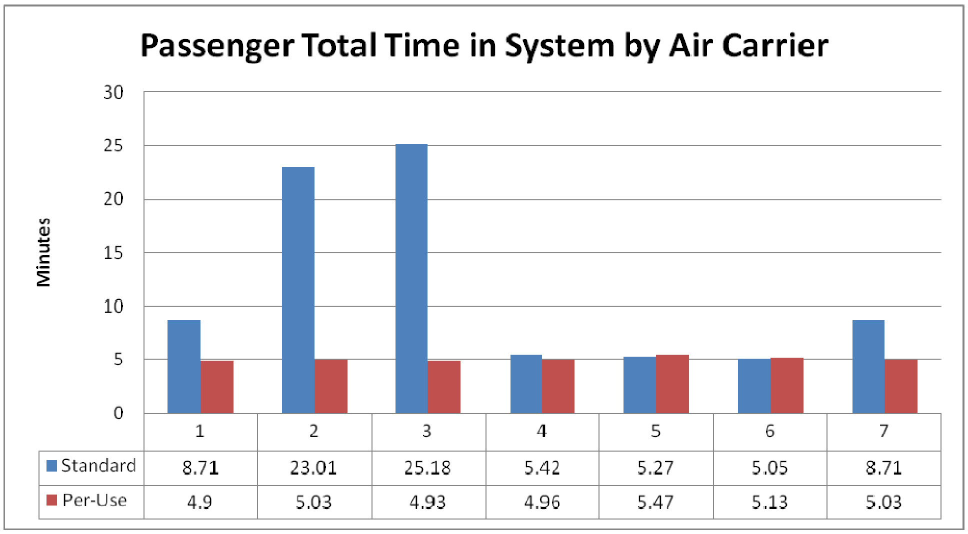


Fig. 2. DTCIS simulation model.

The per-use model was found to scale very well during the simulation experiments. The ability to reassign a ticket counter to a different air carrier in order to meet the passenger input demands greatly reduces high wait time occurrences. The per-use model not only lowers average wait times, but also levels out the passenger wait times to similar values across all air carriers. Fig. 3 shows the passenger total times in system per air carrier. The per-use model is able to lower the average passenger times drastically during times of high influx of passengers. During low volume times, the time averages are similar to the standard system. The main advantage of the per-use model is the superior handling of high passenger flow rates, and the proposed model and simulation results clearly show this advantage.



4. Assessment, Accomplishments, and Significance

4.1. Capstone Design Sequence Assessment. At the time of offering the capstone design sequence presented in this paper, an assessment of the student learning in the course through seven course learning objective (CLO) was in place. The qualitative aspects measured using the CLOs are presented below.

- CLO 1: *Hands-on experience.*
  - Students developed simulation models of the airport operations using Arena® simulation environment. Arena® is a general discrete-event systems simulation software which is appropriate for modeling and simulating the type of problem that the current project involves.
- CLO 2**:** *Designing and testing systems in response to user requirements.*
  - The final report and final presentation addressed all the requirements formulated for the project by the LIT Airport Commission. The industry sponsor was impressed by the final outcomes, the systems engineering design approach, and the modularity of the solution.
- CLO 3**:** *Identifying/formulating problems & developing/implementing solutions.*
  - The students identified several problems and assigned responsibilities/time outline to individual subgroups. Project managers were assigned on a two-week rotation basis to formulate solutions. These problems included, among others, building

simulation models for the ticket counter and security check-in operations, and building an optimization model for the ticket counter system.

- CLO 4: *Oral and written communication.*
    - The students gave the final presentation to an audience made up of the course instructors, industry sponsor, faculty, and teaching assistants. The presentation was very good received by the audience attending it. During the second semester, the students teamed-up with a group of College of Business students and won the third place in the Donald W. Reynolds Governor's Cup Business Plan Competition.
- CLO 5: *Apply state-of-the-art engineering tools.*
    - Students utilized Arena® to reach the final solution for modeling the current airport operations, as well as for the proposed per-use system.
- CLO 6: *Promotion of life-long learning.*
    - Students surveyed state-of-the-art aircraft identification and gate docking technologies and used the knowledge acquired in the design of the overall airport management system. Students assessed the existing systems and considered the output data as inputs for their overall system design.
- CLO 7: *Promotion of contemporary issues in society.*
    - The project encompassed several contemporary issues related to airport operations, such as: ticket counter assignment, updating flight information displays, airline gate assignment.

4.2. Recognition. During the Spring 2007 semester, the Systems Engineering capstone design students teamed-up with a group of MBA students from the UALR College of Business to develop a business plan for the implementation of the airport management information system design and participated in the Seventh Annual Donald W. Reynolds Governor's Business Cup competition, the Arkansas statewide business plan student competition. The student team and their faculty advisor won the third place in the graduate competition with their "*Dynamic Airport Systems*" proposal and were awarded a total of $6,000.00.

Another distinct measure of success was the acknowledgement of the project by several publications of local and national impact, such as *Arkansas Democrat Gazette*, *Associated Press*, *USA Today*, and *Airport Business Magazine*, among others. *USA Today*[13], on 6/5/2007, notes that: "Three college students have come up with a system they say can reduce the time airline passengers have to wait in lines. They developed the system as part of an information systems engineering project. They considered (the) information that airports collect or can collect and came up with a way to better manage space and the airlines that use the space." *UALR Magazine*[14] says in a press article that: "The integrated technology system was coupled with a business strategy created by entrepreneur-thinking MBA students (...) This collaboration of ideas and skills was evaluated by a panel of judges made up of Arkansas business executives who reviewed the written plan and oral presentations. The team was selected as one of six graduate teams to proceed to the final round of competition. Judging was based on overall feasibility, combined with significant capital gains potential, attractive investment possibilities, and actual implementation." Moreover, a professional airline industry magazine, the *Airport Business Magazine*[15], cites Mr. Ron Mathieu, deputy executive director at Little Rock National Airport, saying that: "They (the students) came out here looking for an idea for real-world experience so when they go out in the marketplace, it (wouldn't be) an alien process to them… The things they've done are not busywork. They've done some meaningful work…"

4.3. Continuous Improvement and Significance to System Engineering Education. Besides the accomplishments and recognition achieved as a result of the significant effort of the student team, the project experience depicted in this work also showed that, the capstone design sequence needs several essential pre-requisites to be able to always tackle the complex engineering design required by today's industry projects. Currently, the systems engineering students are exposed to only basic systems thinking methodologies in the material covered in introductory courses. The curriculum also includes systems engineering analysis courses such as: optimization, simulation, and decision analysis. However, the critical knowledge in system engineering lifecycle process which includes systems design, systems analysis, systems evaluation, and project management, is only taught in the first part of the capstone design one course. To address these issues, the Systems Engineering Department plans to introduce a new course covering the above mentioned topics starting with the Fall 2011 semester. The new course, *SYEN 3320: Systems Engineering Design and Analysis*, will benefit all the systems engineering students by providing them with the necessary exposure to the methodological systems engineering lifecycle process, and will fill a gap existing in the curriculum between the traditional engineering design taught in all our four options and the integrated design projects carried out in our capstone design sequence. By providing the undergraduate students entering the capstone design sequence with the exposure to the methodological systems engineering lifecycle process, this new course will give them the systems perspective required for a meaningful project experience. The learning objectives for the proposed course are presented below. By the end of the course, the students will be able to:

- Understand the system lifecycle engineering concept; and, be able to identify it for a new design.
- Understand the stages of the system design process, starting with requirements development and ending with system testing and evaluation; and, be able to apply it on a new design.
- Understand the fundamental methodologies and tools used in the systems analysis process; and, be able to use them for a new design.
- Understand the basic steps in the systems engineering program management; and, be able to develop it for a new design.

Systems thinking skills are acquired mainly through experience and are seldom taught in formal courses in university environments. Infusing the idea of the "big picture" is essential since real-world systems problems may not be optimally solved just by decomposing the system in components and combining the solutions of the individual design problems. To obtain an optimal design, it may be necessary to consider as well, the resulting behavior observed at the system level coming from the interactions between the system components. For systems engineering analysis, the interactions between system components are as important as designing the components. An increased emphasis on systems thinking skills in the capstone design courses may help graduates in better capturing and dealing the "big picture" when confronted with real-world projects at their new positions.

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