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OPERATIONS RESEARCH AND SIMULATION IN MASTER'S DEGREES: A CASE STUDY REGARDING DIFFERENT UNIVERSITIES IN SPAIN

Alex Grasas
Helena Ramalhinho

Dept. of Economics and Business
Universitat Pompeu Fabra /
Barcelona GSE
Barcelona, 08005, SPAIN

Angel A. Juan

Dept. of Computer Science
IN3 – Open University of Catalonia /
Autonomous University of Barcelona
Barcelona, 08018, SPAIN

ABSTRACT

This paper presents several experiences regarding Operations Research (OR) and Simulation education activities in three master programs, each of them offered at a different university. The paper discusses the importance of teaching these contents in most managerial and engineering masters. After a brief overview of existing related work, the paper provides some recommendations –based on our own teaching experiences– that instructors should keep in mind when designing OR/Simulation courses, either in traditional face-to-face as well as in pure online learning models. The case studies exposed here include students from business management, computer science, and aeronautical management degrees, respectively. For each type of student, different OR/Simulation tools are employed in the courses, ranging from easy-to-use optimization and simulation software to simulation-based algorithms developed from scratch using a programming language.

1 INTRODUCTION

Operations Research (OR) can be defined as the application of advanced analytical methods to support complex decision-making processes. Among others, some of these analytical methods are: simulation, data analysis, mathematical optimization, and metaheuristics. Thus, OR is an interdisciplinary area which borrows methods and techniques from many fields, including: mathematics, computer science, statistics, and business management. The objective of OR is to provide optimal or as-good-as-possible solutions to decisions encountered in an endless number of real life applications. These applications can be found everywhere, from natural and social sciences to engineering, which explains why OR is taught at universities and colleges worldwide. Their importance became very relevant in the past decades and even business schools found the need for offering OR courses. Borsting et al. (1988) emphasize the value of teaching OR in business programs as it prepares students to be OR consumers or motivates them to learn further to become OR producers. In the end, managers need to solve problems and make decisions, so they should understand the entire decision-support process. Horner (2003) gives ten top reasons for which OR should be incorporated in business schools. According to him, studying OR builds analytical and problem-solving skills that also help in other courses, and provides competitive advantage. This author also mentions that OR is a dominant technology that exploits the computer/communications revolution. Moreover, he declares Simulation within the top ten topics or techniques that should be included in an OR course for business students.

Simulation is a crucial tool in OR, and according to practitioners and academics one of the three most important quantitative techniques –together with statistics and mathematical programming– (Lane, Mansour, and Harpell 1993). Originally, it was mainly used to explore different management scenarios and system designs. Thus, traditional applications of simulation cover topics such as project planning, inventory control, production, logistics, queuing, or scheduling (Pritsker et al. 1994). Today, due to the improved computer processing power, simulation also yields pseudo-optimal solutions to ill-structured problems, thus helping in real-world decision-making processes. Simulation is usually employed when systems cannot be analytically modeled, or when data cannot be directly collected. It allows studying the impact of changes in the system, as well as performing what-if analysis on alternative model designs, which may not be possible to do using the real system itself.

In this paper we present several teaching experiences that involve OR and Simulation in master courses at three Spanish universities: the Barcelona School of Management that belongs to the Universitat Pompeu Fabra (from now on, BSM–UPF), the Open University of Catalonia (UOC), and the Autonomous University of Barcelona (UAB). In the first experience at BSM-UPF, we use a simulation game to teach a resolution method for a well-known OR problem in the area of logistics, the vehicle routing problem. In the second experience at UOC –a purely online university–, we explain how Java-based simulation and simulation with Opnet are employed as driving tools in final degree projects associated with a master in computer science. Finally, the third experience at UAB discusses the use of spreadsheet-based simulation and the Simio simulation software to understand complex processes in an aeronautical management master. The remainder of this paper is structured as follows: Section 2 provides a short overview of related work; Section 3 describes our experiences with business management students at BSM-UPF; Section 4 describes online teaching practices with computer science students at UOC; similarly, Section 5 exposes simulation teaching activities with aeronautical management students at UAB. Finally, Section 6 highlights some relevant aspects of the aforementioned teaching practices which can be useful for other simulation instructors worldwide.

2 RELATED WORK

As discussed in Faulin et al. (2009), teaching OR/Simulation is always a challenging task due to the probable heterogeneity of the students with regards their mathematical and programming backgrounds, especially in non-mathematical programs where students can come from very different fields of knowledge. Despite this diversity, in many cases most of these students have little (or no) knowledge of OR. The same can be said about simulation, heuristics, or programming skills. This plays an important role in the design, delivery and success of a course: the course must start from the very basics of the subject. Another possible risk is the students' lack of motivation for technical disciplines. Engaging students is then an indispensable condition, and simulation just happens to provide such a condition.

Simulation is widely used to teach topics or skills in many different areas such as architecture, business ethics, child development, interviewing skills, laboratory management, medicine, physics, engineering, etc. Many studies conclude that "simulation games helped students increase their awareness of real world issues and comprehension of course subjects" (Deshpande and Huang 2011). Chwif and Barretto (2003) discuss the use of simulation games in Operations Management, and claim that they should be used "not to substitute formal instructional methods but to serve as a complement". According to them, students usually spend more time on the analysis and alternatives than the minimum required by the instructor, which shows the motivation they have for this type of tools. Ezz, Loureiro-Koechlin, and Stergioulas (2012) provide a good review of the benefits that simulation tools offer in different educational fields, and they focus on simulations in management. They also discuss the impact of simulations and cite papers that measure various outcomes of a simulation game.

According to Freimer et al. (2004), a first course on simulation at a master level should aim to present "fundamental issues and technologies that are critical to a successful simulation project" not to create simulation experts. After all, most of the students will have to make professional decisions relying on simulation results to some extent. Altiok et al. (2001) discuss goals and educational strategies for teaching simulation. They expose what should and should not be in a simulation course. Another interesting reference is that of Stahl (2007), who explains his teaching experience in simulation for over 30 years at different universities and countries, and in different programs at undergraduate, graduate, and executive levels. Finally, Fonseca et al. (2009) discuss some teaching experiences regarding simulation courses at different universities using Internet-based education –both pure online and blended learning models.

3 SIMULATING A VEHICLE ROUTING PROBLEM AT BSM–UPF

3.1 Context

The Universitat Pompeu Fabra is a young, public and modern university founded in 1990. It structures its studies on three main fields of knowledge, namely: *(i)* social sciences and humanities; *(ii)* health and life sciences; and *(iii)* communication and information technologies. It has about 15,000 students and offers 22 undergraduate degrees, and about 25 official masters. In 2010 UPF launched the Barcelona School of Management to take one step forward in the internationalization of training in business leadership and management. The BSM offers 7 Masters of Science (MSc), an MBA, about 30 executive masters and various postgraduate programs.

The first simulation experience we relate has been implemented in the course "Management Science and Business Information Systems" of the Master of Science in Information and Communication Technologies (ICT) Strategic Management offered at the Barcelona School of Management for the first time in the academic year 2012-2013. This master was created on merging two pioneering international groups within the Universitat Pompeu Fabra, the ICT Department and the Economics and Business Department. Its aim is to train professionals specialized in the use and management of information and communication technologies, something that has become increasingly important with the advent of Internet, the convergence of technologies and the new generation of personal devices. Its students have either an Economics or Business background or come from more technical degrees like Computer Science, Engineering, Mathematics or Physics. The program consists of four terms (15 months) that include a total of 19 courses. In the first term, there are two parallel tracks recommended for each of the two main student profiles (economics/business and engineering/science). The second and third terms offer a selection of strategic management subjects and tools. The last term consists of a part-time or full-time internship and development of the final project.

The course "Management Science and Business Information Systems" is offered in the second term and has a duration of 30 lecture hours, distributed in 20 hour-and-a-half sessions. The course focuses on the use of quantitative analysis and information systems technology for decision making in problems from a myriad of different areas like health, finance, logistics or marketing. The course covers topics like business analytics, linear programming, location and distribution problems, scheduling and simulation. In its first edition, the class was composed of 18 students from 11 different nationalities. Most of these students had some working experience.

3.2 Course Contents

One of the OR tools studied in the course are heuristic methods and their applications to business problems. One such a problem is the vehicle routing problem (VRP), which is a logistics problem faced by many companies in numerous industries. All tangible products –raw materials, components, manufactured goods, etc. – must be transported and distributed to other factories, warehouses, distribution centers, stores, or customers' homes. Therefore, companies must design routes to deliver all these products. Typically, there is a central depot that delivers goods to a set of geographically dispersed customers that have placed orders. A fleet of vehicles based at the depot is available to serve these orders. The VRP aims at finding a sequence of deliveries (routes) for each vehicle so that all customers are served and the total distance traveled by the fleet is minimized. This problem has been studied for over 50 years (Laporte 2009) and has dozens of variants that incorporate additional constraints faced in real life. Solving a VRP optimally is very difficult as the problem size increases. Since exact methods can handle up to 50 or 75 customers only, one must resort to heuristic methods for relatively large problems. One of the most fundamental and commonly used heuristic is the Clarke and Wright (1964) savings (CWS) heuristic. This method uses the concept of savings associated to merging two different routes. At each step, all savings resulting from feasibly merging pairs of routes are computed. The algorithm takes the link with the greatest savings and joins the two routes as long as the new merged route is feasible. The merging procedure continues until no more routes can be merged. There exist many more heuristics that build on this savings heuristic to enhance its performance or to solve variations of the standard VRP.

3.3 Application and Insights

The simulation of the VRP is played over two consecutive lectures. Grasas and Ramalhinho (2013) offer a complete and detailed description of this application and its supporting material. In this simulation game, students will be responsible for route planning in a fictitious company. They will be competing to each other to see which group can find the best results. To complement this exercise, an open web-based tool was developed. Figure 1 shows a screenshot of the webpage, which can be found at http://vrp.upf.edu/. In the first lecture, there is a brief discussion on logistics and the importance of vehicle routing problems for companies. At this point, no solution method or heuristic has been introduced yet. Students are then presented a small case in which a manufacturer needs to distribute its products to a network of 20 stores located at different shopping malls in the Northeast of Spain. The case contains the postal addresses of each mall, the demand for each store, and the capacity of the available trucks. The students are grouped in teams and given 30 minutes to manually design the routes to deliver the products to all stores without violating the truck-capacity constraints. After this, each team must provide a set of routes. Our VRP webpage allows checking the feasibility and cost of the routes proposed by all groups. It is not rare to find groups unable to find a feasible solution within 30 minutes. Students recognize the need for finding some kind of methodology to approach this type of problems as they can imagine the difficulty of solving a real problem instance –e.g., a company having to distribute goods to hundreds of stores.

In the second lecture, the VRP is described and formulated. Students now know the complexity of the problem and its optimal resolution. To cope with that, we explain that there exist heuristic methods that can find relatively good solutions in little time. This is where we describe the CWS heuristic, and use it to solve an even smaller example with 8 customers. The webpage we developed has also a section showing a step-by-step application of the algorithm. To conclude the class, we solve the initial case with 20 stores altogether using the webpage again.

The objective of this simulation game is twofold. On one hand, students learn and apply one of the most used heuristics in vehicle routing problems. On the other, they realize how important the use of advanced analytical tools is for decision making. These tools, or what is known as Business Analytics, are the core of most information systems that companies use. The game had a good acceptance among the students. Putting them in a situation that could be faced by a real company, and challenging them to resolve it in 30 minutes was an excellent way to motivate the problem. These types of hands-on experiences work really well in a class. It is a dynamic and interactive activity that breaks the monotony of regular lectures. In addition, it usually makes an impact on the participants, becoming what they remember the most from a course.

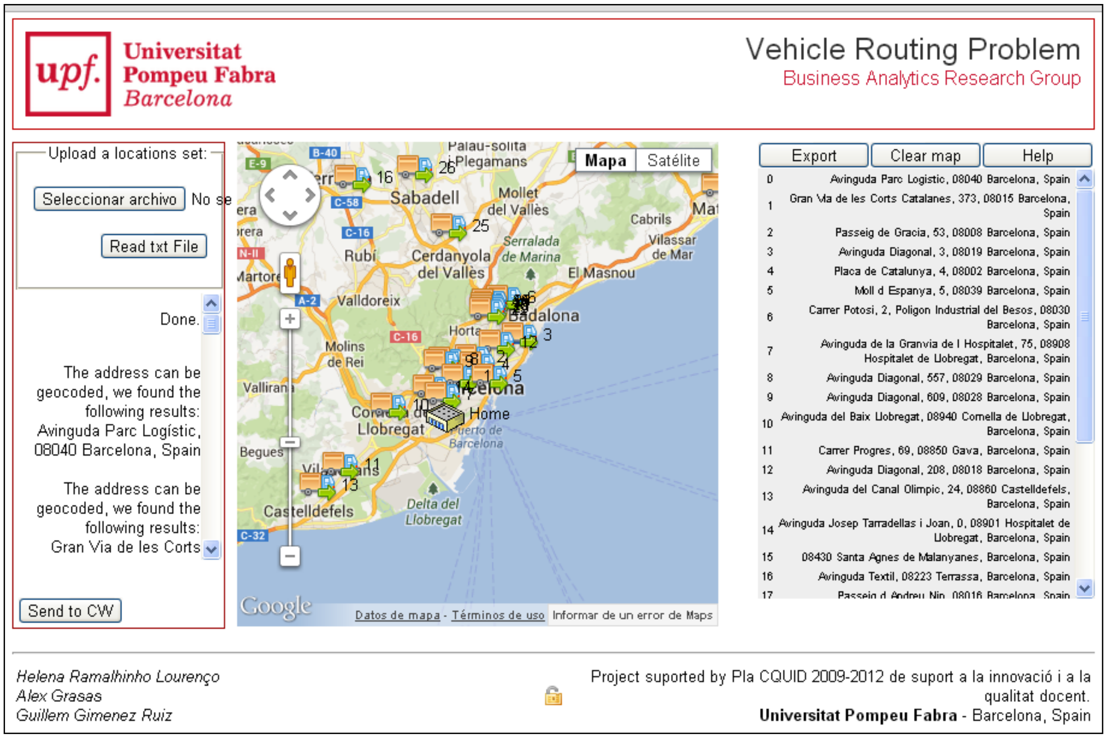

Figure 1: Web-based VRP tool (http://vrp.upf.edu/).

4 TEACHING SIMULATION ONLINE AT UOC

4.1 Context

The Open University of Catalonia (UOC) is a fully online university with headquarters in Barcelona, Spain. It was founded in 1995 by the Catalan Government with the mission of "providing people with lifelong learning and education through intensive use of information and communication technologies". According to official data, UOC offers educational services over the Internet to more than 50,000 students, distributed in several undergraduate and graduate programs. UOC students belong to different parts of the world, but they are mainly located in Spain and South America. About 60% of UOC undergraduate students are adult students (over 30 years old) that typically combine their professional activity and/or family responsibilities with their academic duties. Educational services are delivered by a team composed of more than 2,200 instructors –including UOC faculty and UOC online collaborators, most of these professors from other Spanish universities– and 550 management staff. UOC uses an asynchronous and student-centered educational model and has already received several international prizes, such as the 2001 ICDE Prize for the best virtual and distance university in the world or the 2004 OEA Prize for educational quality. Currently, up to 22 accredited degrees and official masters are offered via the UOC Virtual Campus, a learning management system entirely developed and maintained at UOC. Some of the most popular degrees (in number of registered students) offered at UOC are as follows: Computer Engineering, Business Administration and Management, Psychology, Telecommunications, Information and Communication Sciences, Law, and Humanities.

4.2 Course Contents

MISIO (Modeling and Simulation in Operations Research) is an OR course that is offered at UOC. The main goal of MISIO is to introduce basic OR concepts and techniques to computer science students. The course syllabus is divided into three main blocks: linear programming (LP), discrete-event simulation (DES) and decision-support systems (DSS). These blocks are developed and evaluated in four online collaborative projects, which are distributed along the semester. The first project is related to the LP part, the second and the third ones are related to the DES part, and the fourth project is related to the DSS part. The MISIO course begins with a general overview of the OR discipline and with an analysis of the basic linear programming concepts and techniques. This first part of the course allows students to introduce themselves into the OR world and its potential applications for solving decision-making processes in engineering and business management. In this part, students develop their first collaborative project, which usually consists of the modeling and solving of a set of linear programming problems. The second part of the course focuses on discrete-event simulation. Here, the course introduces the student into the three main paradigms of discrete-event simulation –event scheduling, activity scanning and process interaction. In this second part of the course, which spans over eight weeks, students develop two collaborative projects, one related to the process interaction approach and another related to the event scheduling approach. Finally, in the third part of the course, students develop their final project. The main objective of this final project is to combine optimization and simulation techniques to create a complete DSS. Usually, this project requires the combined use of both LP and Simulation techniques in order to develop a DSS able to provide good solutions for a proposed routing or scheduling problem.

4.3 Application and Insights

Students can select among several areas related to simulation to develop their MSc thesis. One of these areas is linked with the development of models related to networks and distributed computer systems in the so called Castelldefels Project (Juan et al. 2007a). This project consists of the development of a simulation model that accurately represents the real computer system that gives support to the e-learning environment at the UOC. This model must be developed with the help of network simulation software such as OPNET Modeler (http://www.opnet.com). The main target of the Castelldefels project is to provide the computer system's managers with a realistic simulation model of their system. This model will allow managers to: *(i)* analyze the behavior of the current system in order to discover possible performance problems such as bottlenecks, weak points in the structure, among others; and *(ii)* perform what-if analysis regarding future changes in the system, including the addition of new Internet-based services, variations in the number and types of users, changes in hardware or software components, etc. By involving themselves in this project, computer science students learn not only simulation but also how this can be useful in the computer network arena.

Another exciting area is related with the development of new simulation-based algorithms for different combinatorial optimization problems in the fields of logistics, transportation, and scheduling (Faulin et al. 2008; Gonzalez et al. 2012; Caceres et al. 2012). These algorithms can be used as an efficient alternative to other approaches based on mathematical programming or even metaheuristics –e.g., Simulated Annealing, Tabu Search, Genetic Algorithms, etc.–, which usually are more difficult to be used in practice since they require complex fine-tuning processes. Here, the students' goal is to collaborate with their instructors in the designing, implementation and testing of new algorithms and their applications to routing or scheduling problems. Usually, Java is the programming language employed to develop these algorithms, basically due to its object-oriented properties, and its balanced relationship between development-time and execution-performance (Figure 2). Other areas are related with the use of simulation to improve queuing models –such as contact centers– (Faulin and Juan 2005), or to estimate reliability and availability functions in time-dependent complex systems, networks and structures (Juan et al. 2007b, 2009). The assessment methodology uses the principle of continuous evaluation based on scheduled homework. At each milestone, students must send their deliverables to the instructor, who reviews them according to the initial goals and provides the corresponding feedback to each student.

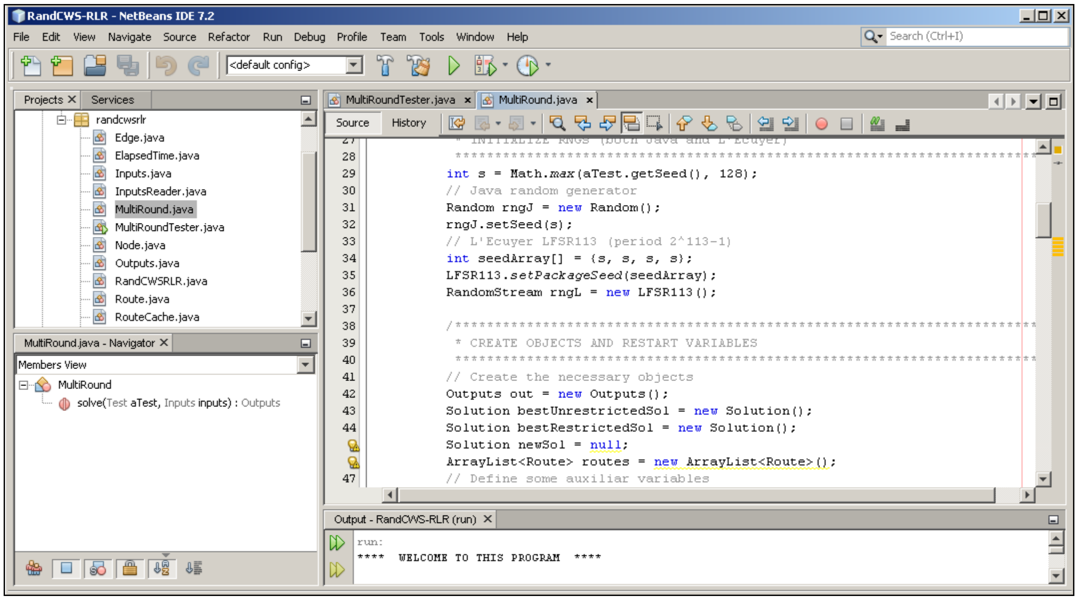

Figure 2: Developing simulation-optimization solutions in Java.

5 SIMULATION EXPERIMENTS AT UAB

5.1 Context

The Autonomous University of Barcelona was born in 1968 with the motto of establishing the following four principles of autonomy: faculty hiring, students' admission, study plans development, and university's capital administration. It consists of 57 departments in the experimental, life, social and human sciences. UAB has more than 40,000 students and more than 3,600 academic and research staff, and it offers almost 200 qualifications among first degrees, diplomas, engineering degrees, doctoral and other postgraduate programs. UAB is considered the best University in Spain by the 2012 QS World University Rankings.

5.2 Course Contents

In a first course on simulation addressed to students of a master in aeronautical management, the focus is centered on the potential applications of simulation for supporting decision-making processes at airports and aircraft management, i.e., the instructors' effort is oriented to illustrate the benefits that simulation techniques offer to analyze, understand, and improve complex aeronautical systems. Thus, we usually employ a state-of-the-art simulator –such as Simio, Arena, ExtendSim, etc. – in order to facilitate the rapid development of interactive models which allow students to experiment with their parameters and estimate the system performance under different scenarios (Figure 3).

5.3 Application and Insights

As stated before, simulation courses at UAB allow students to familiarize themselves with some modeling tool which also allows them to perform what-if analysis on a computer model by considering different values for its parameters. Typical systems analyzed include: access control points, check-in points, baggage handling systems, boarding strategies, etc. Additionally, some advanced students who decide to complete their final project master's degree in this field are also able to develop their own software simulators –usually employing spreadsheets in combination with MS Visual Basic for Applications– to be used in complex stochastic optimization issues such as the aircraft boarding problem or the aircraft turnaround problem. In the first problem, the best boarding strategy must be found among several alternative policies (Mas et al. 2013). Of course, several random behaviors associated with boarding passengers need to be considered here –e.g., speed, number and weight of suitcases, number of passengers with specific needs, etc. In the second problem, also characterized by several random behaviors, the take off scheduling of an airplane must be decided having into account several trade-off factors, i.e., costs of each extra minute the aircraft is not flying and costs of each extra minute the plane is delayed with regards its scheduled departure time (Silveiro, Juan, and Arias 2013).

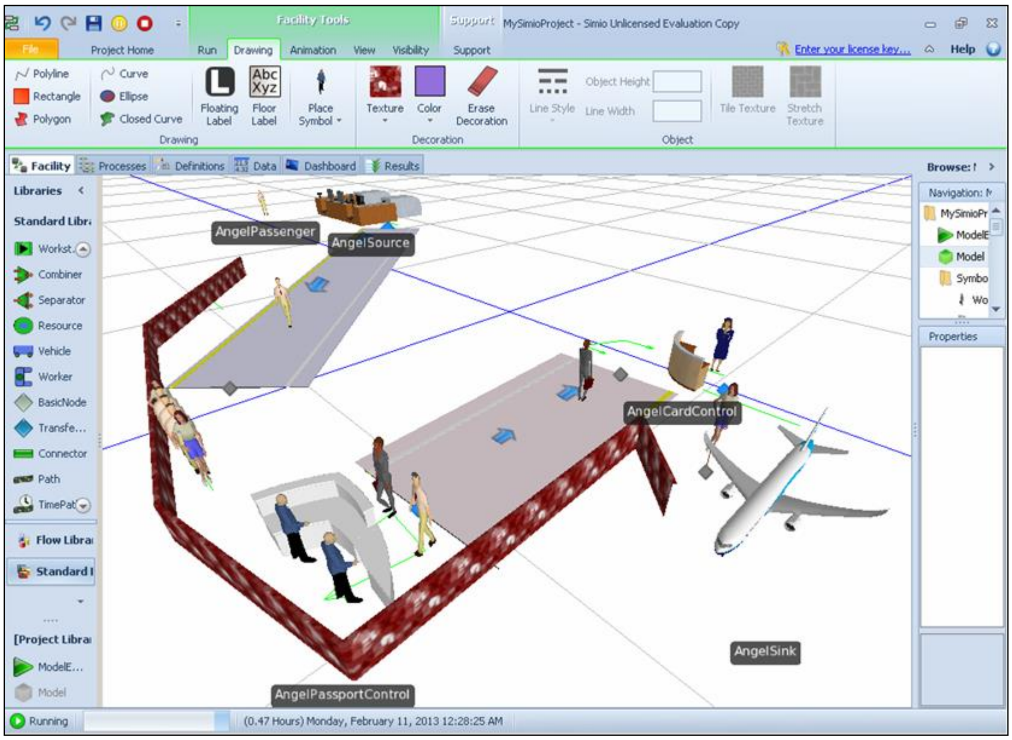

Figure 3: Modeling and simulation of an airport control point with Simio.

6 CONCLUSIONS

This paper has described several experiences regarding OR/Simulation courses in master degree programs. These experiences refer to three different universities located in Spain, two of them using a traditional face-to-face learning model and one using a pure online learning model. Some of the main lessons that can be derived from these cases are the following: *(i)* the use of a professionally-oriented approach is highly recommended in most OR/Simulation courses, especially in those masters with a noticeable management focus, i.e., instructors must ensure students understand the real potential of OR/Simulation tools applied to solving real-life problems; *(ii)* as the amount of OR/Simulation software available for education is large, one of the goals of any course should be showing different alternatives to students; *(iii)* the OR/Simulation software selected for a given course should depend on the specific master degree, e.g., in the case of management students, the use of easy-to-use and general-purpose simulators might be preferable, while in the case of engineering students an object-oriented programming language can be a good option to develop simulation-base algorithms from scratch; and *(iv)* in all cases, the use of illustrative case studies and a continuous assessment model is highly recommended, since they increase students' motivation for the course and also contribute to promote a correct development of the learning process.

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REFERENCES

Altiok, T., W. D. Kelton, P. L'Ecuyer, B. L. Nelson, B. W. Schmeiser, T. J. Schriber, L. W. Schruben, and J. R. Wilson. 2001. "Various Ways Academics Teach Simulation: Are They All Appropriate?" In *Proceedings of the 2001 Winter Simulation Conference*, edited by B. A. Peters, J. S. Smith, D. J. Medeiros, and M. W. Rohrer, 1580–1591. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Borsting, J. R., T. M. Cook, W. R. King, R. L. Rardin, and F. D. Tuggle. 1988. "A Model for a First MBA Course in Management Science/Operations Research." *Interfaces* 14(5):72–80.

Caceres, J., A. Juan, S. Grasman, T. Bektas, and J. Faulin. 2012. "Combining Monte-Carlo Simulation with Heuristics for Solving the Inventory Routing Problem with Stochastic Demands." In *Proceedings of the 2012 Winter Simulation Conference*, edited by C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A. M. Uhrmacher, 274. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Chwif, L., and M. R. P. Barretto. 2003. "Simulation Models as an Aid for the Teaching and Learning Process in Operations Management." In *Proceedings of the 2003 Winter Simulation Conference*, edited by S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, 1994–2000. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Clarke, G., and J. Wright. 1964. "Scheduling of Vehicles from a Central Depot to a Number of Delivering Points." *Operations Research* 12(4): 568–581.

Deshpande, A. A., and S. H. Huang. 2011. "Simulation Games in Engineering Education: A State-of-the-art Review." *Computer Applications in Engineering Education* 19(3):399–410.

Ezz, I., C. Loureiro-Koechlin, and L. Stergioulas. 2012. "An Investigation of the Use of Simulation Tools in Management Education." In *Proceedings of the 2012 Winter Simulation Conference*, edited by C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A. M. Uhrmacher, 134. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Faulin, J., M. Gilibert, A. Juan, X. Vilajosana, and R. Ruiz. 2008. "SR-1: A Simulation-Based Algorithm for the Capacitated Vehicle Routing Problem." In *Proceedings of the 2008 Winter Simulation Conference*, edited by S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, and J. W. Fowler, 2708–2716. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Faulin, J. and A. Juan. 2005. "SimuCall: an Excel Add-In for Call Centers Simulation." *Computers in Higher Education Economics Review* 17:17–24.

Faulin, J., A. Juan, P. Fonseca, L. Pla, and S. Rodriguez. 2009. "Learning Operations Research Online: Benefits, Challenges, and Experiences." *Int. J. Simulation and Process Modelling* 5(1):42–53.

Freimer, M., L. W. Schruben, T. M. Roeder, C. R. Standridge, C. M. Harmonosky, and I. Stahl. 2004. "You Are Going to Teach Simulation - Now What?: Tips and Strategies." In *Proceedings of the 2004 Winter Simulation Conference*, edited by R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, 2057–2065. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Fonseca, P., A. Juan, L. Pla, S. Rodriguez, and J. Faulin. 2009. "Simulation Education in the Internet Age: Some Experiences on the Use of Pure Online and Blended Learning Models." In *Proceedings of the 2009 Winter Simulation Conference*, edited by M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin, and R. G. Ingalls, 299–309. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Gonzalez, S., A. Juan, D. Riera, M. Elizondo, and P. Fonseca. 2012. "Sim-RandSHARP: A Hybrid Algorithm for Solving the Arc Routing Problem with Stochastic Demands." In *Proceedings of the 2012 Winter Simulation Conference*, edited by C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A. M. Uhrmacher, 275. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Grasas, A., and H. Ramalhinho. 2013. "Distribution Planning for OM students: A Problem-based learning approach." Working Paper, Department of Economics and Business, Universitat Pompeu Fabra, Barcelona, Spain.

Horner, P. 2003. "Course of Action." *OR/MS Today* 30(4): 26–29.

Juan, A., J. Faulin, J. Marques, and P. Fonseca. 2007a. "Castelldefels Project: Modeling and Simulation of the Computer System that Gives Support to the Virtual Campus of the Open University of Catalonia." In *Proceedings of the 2007 Winter Simulation Conference*, edited by S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, 2364–2364. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Juan, A., J. Marques, J. Faulin, M. Sorroche. 2007b. "J-SAEDES: A Simulation Software to Improve Reliability and Availability of Computer Systems and Networks." In *Proceedings of the 2007 Winter Simulation Conference*, edited by S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, 2285–2292. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Juan, A., A. Monteforte, A. Ferrer, C. Serrat, and J. Faulin. 2009. "Applications of Discrete-event Simulation to Reliability and Availability Assessment in Civil Engineering Structures." In *Proceedings of the 2009 Winter Simulation Conference*, edited by M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin, and R. G. Ingalls, 2759–2767. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Lane, M., A. Mansour, and J. Harpell. 1993. "Operations Research Techniques: A Longitudinal Update." *Interfaces* 23(2):63–68.

Laporte, G. (2009). "Fifty Years of Vehicle Routing." *Transportation Science* 43(4): 408–416.

Mas, S., A. Juan, P. Arias, P. Fonseca. 2013. "A Simulation Study Regarding Different Aircraft Boarding Strategies". Springer Lecture Notes in Business Information Processing, Vol. 145.

Pritsker, A. A. B., C. E. Sigal, and R. D. J. Hammesfahr. 1994. *SLAM II Network Models for Decision Support.* San Francisco: Scientific Press.

Silveiro, I., A. Juan, P. Arias, P. 2013. "A Simulation-Based Approach for Solving the Aircraft Turnaround Problem." Springer Lecture Notes in Business Information Processing, Vol. 145.

Stahl, I. 2007. "Teaching Simulation to Business Students – Summary of 30 years' Experience." In *Proceedings of the 2007 Winter Simulation Conference*, edited by S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, 2327–2335. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

AUTHOR BIOGRAPHIES

ALEX GRASAS is an Assistant Professor of Operations Management in the Department of Economics and Business at Universitat Pompeu Fabra, Barcelona, and affiliated professor of the Barcelona GSE. He holds a M.S. and a Ph.D. in Industrial and Systems Engineering from University of Florida (USA), and a B.S. degree in Industrial Engineering from Universitat Politècnica de Catalunya (Spain). He is also a researcher of the Business Analytics Research Group at Universitat Pompeu Fabra. His research interests include retail operations management, product assortment planning and vehicle routing. His e-mail and web addresses are alex.grasas@upf.edu and http://www.econ.upf.edu/~agrasas/, respectively.

ANGEL A. JUAN is an Associate Professor of Simulation and Data Analysis in the Computer Science Department at the Open University of Catalonia, Spain. He holds a Ph.D. in Industrial Engineering, an M.S. in Information Technologies, and a M.S. in Applied Mathematics. His research interests include computer simulation, educational data analysis and mathematical e-learning. He is an editorial board member of the Int. J. of Data Analysis Techniques and Strategies, and a member of the INFORMS society. His e-mail and web addresses are ajuanp@gmail.com and http://ajuanp.wordpress.com/, respectively.

HELENA RAMALHINHO is an Associate Professor in the Department of Economics and Business at Universitat Pompeu Fabra, Barcelona, and affiliated professor of the Barcelona GSE. She has a Master in Statistics and Operations Research from the University of Lisbon, Portugal, and a Ph.D. in Operations Research from Cornell University, New York, USA. She is currently a researcher of the Business Analytics Research Group and the Economics Healthcare Research Centre at Universitat Pompeu Fabra, and also of the Centre for Operational Research at the University of Lisbon. Her e-mail and web addresses are helena.ramalhinho@upf.edu and http://www.econ.upf.edu/~ramalhin/, respectively.