Proceedings of the 2007 Winter Simulation Conference
S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, eds.

WHAT I WISH THEY WOULD HAVE TAUGHT ME (OR THAT I WOULD HAVE BETTER REMEMBERED!) IN SCHOOL

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ABSTRACT

This panel reflects upon their experiences as simulation professionals and shares their thoughts regarding elements of their simulation education that they have found most helpful in their work as well as things they *wish* they would have learned. With diverse backgrounds and simulation application areas, their perspectives may provide food for thought to simulation course developers and to those in the midst of their educational process.

1 CHARLES R. STANDRIDGE: TEACH STUDENTS TO BE SIMULATION CONSULTANTS

Students need to learn how to do realistic simulation projects, that is become simulation consultants. Thus, the simulation methods students need to know depend on the requirements for doing a simulation project in their area of interest. Students must be instructed in these methods as well as given the opportunity to apply them, ideally in an industrial setting. Since this is not always possible, case studies and problems (Richards et. al 1995) that are realistic metaphors for industry based projects can be employed. Using this approach for simulation instruction was first proposed by Shore and Plager (1978). One implementation of this approach is discussed in Standridge (2000).

This perspective has been used to develop three courses in the Product Design and Manufacturing Engineering Program in the School of Engineering at Grand Valley State University as discussed by Standridge (2006).

1. EGR 440 Production Models – A required undergraduate course.
2. EGR 640 Production Operations Models – A required graduate course.
3. EGR 642 Facilities Layout and Materials Movement – A required graduate or elective undergraduate course with either EGR 440 or EGR 640 as the pre-requisite.

As a part of developing these courses, the following methods were considered necessary to performing simulation projects in the production and logistics areas:

1. A simulation project process. The process includes requirements definition, modeling building with data collection, experimentation, review of results, and implementation. Emphasis is on the iterative nature of the process. For example, the review of results may result in modification to the models as well as new experiments and further reviews.
2. The importance of and techniques for building credibility with those sponsoring a simulation project. Emphasis is placed on including project sponsors in requirements definition, conceptual model building, verification, validation, and review activities in a timely manor.
3. Modeling, both the process world view and the resource graph method of Hyden, Roeder, and Schruben (2001). The latter is important for concurrently modeling the movement of workers and parts in work cells for example.
4. Modeling specific items in the application area of interest. For production operations and logistics, these include workstations, finite inter-

station buffers, inventories, one-piece flow, kanban system information flow, worker movements, and shipping by train and truck.

5. The importance of being skeptical about any model that is built as well as using quantitative verification and validation techniques to resolve that skepticism. For example, the inventory at the end of a simulation run should equal the beginning inventory minus the total customer demand plus the production. These computations can be built into a simulation model and reported.
6. Design and analysis of terminating simulation experiments. For example, approximate t-confidence intervals can be computed as an interval estimate for the true mean of each performance measure and the paired-t method employed to pairwise compare simulated alternatives as described in Law (2007).
7. Experimentation methods for finding values of model parameters that yield good values for performance measures of interest. For example, suppose that the WIP on a new serial line producing two products is controlled by a CONWIP system (Hopp and Spearman 2000). An experiment is need to find the smallest CONWIP level (model parameter) that maximizes throughput (performance measure). As the CONWIP level increases throughput should asymptotically approach its maximum.
8. The importance of using simple analytic models to help set lower and upper limits on project, and thus simulation model, parameter values. Consider again the example in the previous point. The average time cycle time for the line to produce a part can be approximated with a simple equation. Suppose demand is met from a finished goods inventory and is Poisson distributed. A replacement part is produced whenever a part is removed from the finished goods inventory. Then the amount of inventory needed to achieve a given service level for the average cycle time to replace one part is easily computed. Since the cycle time is a random variable, this value is a lower bound on the inventory level needed to meet the specified service level.
9. Selecting a distribution to model a random quantity both using data and in the absence of data. Continuing the example in the previous points, the average demand per time period can be estimated by system experts. A conservative assumption (high variance) is to use a Poisson distribution to model the demand and thus an exponential distribution for the time between demands.

EGR 440 and EGR 640 include case studies concerning serial lines, job shops, kanban systems, work cells, and flexible manufacturing systems. EGR 642 includes case studies concerning conveyors systems, AS/RS systems, AGV systems, and the movement of material between plants. All of these case studies employ the above simulation methods as needed.

2 CARLEY JURISHICA: BACKGROUND

As a 2001 graduate of Northwestern University in Evanston, IL, I was introduced to the concept of stochastic modeling and simulation by professor Barry Nelson. A complex subject seemed conquerable as taught by professor Nelson. Consequently, the fundamentals of simulation were present when I began my simulation career using Rockwell Automation's Arena simulation software. The expected learning curve of mastering the software was certainly a hurdle that my education did prepare me for. However, I have found a less concrete challenge as I work with many young engineers. Specifically, there can be significant barriers to actually practicing robust simulation techniques once in industry. The unforeseen challenge is justifying to senior management teams that simulation initiatives are worthwhile, effective and worth the investment.

As industrial engineers and operations research students, in school, we are provided a tool-box of problem solving approaches and exposure to various software packages to assist us with tackling industry issues. Once we reach the corporate world, as if the actual problems we are to address are not complex enough, there is a struggle internally to justify additional expenditures to equip us with the appropriate tools. Specifically, as simulation experts, we require a more robust simulation tool than an Excel spreadsheet, as well as training and time to race up the learning curve and develop our expertise. Industrial engineers are typically hired for their ability to solve problems and assist with process improvement initiatives. Many employers fail to realize that the potential of their eager engineer may be compromised if only a laptop and simple Microsoft tools such as Excel, Word and Access are provided to enable them to do their work. In the comfort of academia, students do not realize these barriers in their soon to be corporate world settings, where approval on budgeting for software, additional simulation training, and time spent on simulation initiatives will be a struggle.

Some typical frustrations include the following:

- I "…set-up a training webinar for those in my group who were not familiar with Arena. I must say that not everyone bought into the usefulness for what we do. I still remain convinced but I haven't been able to convince those who sign the checks." *–Plant Engineer, mining industry*

- "I am a recent IE graduate who really enjoyed simulation and would like to continue learning and developing simulation skills. The company that I am with does not have any interest in purchasing and/or implementing simulation software…I have not had any luck selling management on simulation…But I still try to it bring up when applications arise." *-Manufacturing Engineer, oil and gas industry*
- "The approval process has been temporarily stalled due to senior management not yet seeing the potential benefit from this software." *-Industrial Engineer, air service industry*

The impact that simulation can make is clearly being prohibited in some organizations. Why are some companies resistant to simulation? There are several reasons:

1. **It is new and different**. For many companies that have never used simulation before, there may be a history of solving problems by gut feel and with simple spreadsheet analysis. The people in these companies may feel threatened by this new approach and resistant to the change. They are likely to perceive the analysis as risky and non value-added.
2. **Simulation has failed before**. Many companies have purchased simulation tools in the past. They have seen their expensive investment sit on a shelf, unused. Additionally, a company may have had unsuccessful project experiences, where models were not be validated, scope was too extensive and/or too much time was exhausted.
3. **Too expensive and time consuming**. Managers might view simulation software and employee training as too expensive. Major expenses must be budgeted for, and without a high priority, simulation gets passed over. Additionally, simulation acumen takes time. From employee training to project completion, managers must understand that immediate return on a simulation investment is not realistic.
4. **Lack of knowledge.** Many key decision-makers do not know exactly what simulation is, and most importantly how it can provide bottom line savings. It is hard to get purchase buy in without this key understanding.

Why are students not prepared for such resistance and what can be done to increase readiness? Basically, this is a tough concept to teach and primary focus is on ensuring students are provided technical skills. Not all students will find such resistant to simulation in the real world. There are no hard and fast rules regarding corporate politics. The best solution is to make students aware of the potential problem and provide possible steps to breaking down the resistance. Student consideration of each of the following might be appropriate:

1. **While simulation many be new to an area, it can provide opportunity for improvement never before seen at a company.** Young college graduates are hired for their fresh ideas. Simulation can be a key and strategic tool for a company as it can provide assistance with most process improvement initiatives. Additionally, while simulation may be new to a particular environment, it is not an untested tool in any industry. Connecting with the simulation community is advised. From academia to real world users, to professional organizations and software and solution vendors, engineers should reach out to their peers. Winter Simulation archives alone, provide a wealth on information on how simulation has been effectively used.
2. **Simulation may have failed at a company before, but understanding why the endeavor failed will be the first step in dispelling this argument.** At the least, a successful simulation study needs knowledgeable people, a valid project and an appropriate simulation engine. Any project initiative is risky. Without the right combination of people and products, a project's risk increases. Future endeavors should ensure key resources.
3. **Simulation is an investment, long-term savings must be highlighted before any buy-in will result.** After training and software, the initial simulation purchase might be more than a manager expected. Long term realizations from projects must be identified. Additionally, trained and knowledgeable engineers can complete simulation projects across the entire enterprise for a company. Savings will quickly add up and greatly surpass the initial investment over time. A clear communication of this is key.
4. **Inform key decision makers about simulation, how it is different from other problem solving techniques and specific case studies in your industry where simulation was successful.** Until companies see why simulation is effective, it will be hard to get a green light on a project initiative. The good news is that there are thousands of case studies and projects that have been completed successfully and documented. A clear comparison between how simulation offers an advantage over a standard spreadsheet analysis or gut feel analysis is typically good starting place. Decision makers will be most interested in the ROI of the investment.

The theories of stochastic modeling and simulation cannot end in the classroom. Students must be able to realize these skills to benefit their work in the corporate world. As students leave school, it is important that they are confident as they enter their new careers. Although there might be resistance, engineers must believe that they can make a difference using their education.

3 DANIEL A. FINKE: BACKGROUND

I took one basic simulation course in my undergraduate coursework and two additional advanced simulation modeling courses while attending graduate school. In addition to these coursework learning experiences, I was also a research assistant on a team that developed a detailed simulation model of a proposed facility in the shipbuilding industry.

The basic simulation course I took as an undergraduate provided the foundation for application and further learning in the field of simulation modeling and analysis. This introductory course focused on the basics of simulation modeling: event lists, random numbers, and on building an understanding of the specific tool. Of course there was a project component to the course that highlighted the data collection, analysis, and customer interaction aspects of simulation modeling and analysis.

My graduate level simulation courses focused on two areas, further advanced simulation modeling and experimenting with simulation models. Advanced simulation modeling and analysis emphasized input distribution analysis, random number generation, and other advanced modeling techniques. The experimentation with simulation models course was a mixture of design of experiments, simulation, and statistical modeling techniques as well as system optimization. All of which built upon the two previous courses in addition to utilizing the relevant statistics and probability courses, design of experiments, etc.

My first "real world" experience with simulation modeling was as a participant on a team that developed a simulation model of a proposed facility in an effort to understand capacity, throughput, staffing, etc. The project lasted roughly two years answering several production capacity and requirements questions, served as an engine for a simulation based scheduling tool and proved to be a very valuable marketing tool to upper management.

After graduate school, I started working for the Applied Research Laboratory (ARL) at the Pennsylvania State University. The first three project activities I was involved in were simulation models for applications in the shipbuilding industry. These models had some non-traditional modeling elements to them, for example assembly sequence planning, floor space allocation, complex assembly modeling, etc. The models were developed to study and analyze assembly sequences , proposed facility requirements, and shipyard material flows.

The following sections discuss the things that I wish I knew or would have retained from my academic work that would have helped in me the workplace.

3.1 Approach

I felt adequately prepared in general simulation knowledge from both my undergraduate and graduate coursework in simulation. The technical preparation for model development (input distributions, processing time distributions, output analysis, etc.) has been very beneficial.

Although I had adequate training from my coursework, there are a few things that I feel that could have been covered more thoroughly or that I wish that I had remembered. I feel that I could have been more prepared in the following topic areas:

1. Programming proficiency
2. Modeling scoping and scaling
3. Data collection

All of my "real world" modeling experiences have been in the ship building industry and I believe that some of my deficiency in these areas stems from the characteristics of the industry. However, greater emphasis on these topic areas could be beneficial to all pre-professional students learning about simulation modeling.

The shipbuilding industry is somewhat different from many industries in that the final products in the shipbuilding industry are large, complex products that have very long processing times (months and years), and very low production rates. Often the intermediate products are one off and are comprised of hundreds if not thousands of piece parts. Modeling in this industry is a combination of building construction modeling (project-type modeling) and low volume production modeling. Developing simulation models for the shipbuilding industry is rarely straight forward and requires a large amount of data. Runtime issues often arise in simulation models when large amount of piece parts are generated. All of my modeling experience has been in the shipbuilding industry, which may or may not be an influence on the following descriptions of the three content areas.

3.1.1 Programming Proficiency

In my undergraduate education, we were required to take one course in computer programming. Unfortunately, for me, this course was during my freshman year and at my university it was a time of transition from Fortran to C++. I was part of the last class to learn Fortran and most textbooks in future classes were geared toward C++. Combine all of this with a general dislike for programming and it results in a lack of programming proficiency. In addition, the basic simulation course did not emphasize programming and focused primarily on model development using the user interface constructs.

The models that I have helped develop usually require custom logic that is not directly available in the user interfaces of the modeling packages. This requires additional code development and was not an easy transition at the outset of my "real world" applications. In addition, the programming style can have a dramatic effect on the runtime of the model. Efficient programming style can be package dependent, but an understanding of event generation is transferable to many general simulation packages.

For me, programming proficiency came from both the development of a complex model and the graduate course in simulation modeling. I wish that I had taken a greater interest as a freshman in computer programming and actually retained the programming skills. Basic to intermediate programming skills are very beneficial when developing complex models.

3.1.2 Model Scoping and Scaling

I have come to find that building a simulation model that is at the right level of detail can be quite difficult. Teaching this may be even more difficult, because it is so dependent upon the application. My belief is that finding the correct level of detail is more an art than science.

Scoping and scaling of the simulation model is emphasized by group project components of the course work. In my experience with class projects, this has been one of the most difficult components and is usually left up to the project team to determine (usually with some consultation from the professor). Missing the mark on scope and scale can lead to models that are too general to be of any use or so detailed that they take too long to construct and thus are of little use.

I think that it would be very difficult to teach how to develop the scope and scale of a model. However, this is definitely a critical component of any modeling project that must be set at the beginning of development.. I have found on several occasions that after development has begun, the level of detail is checked with the initial scoping of the model and analysis to ensure a successful project. In addition, data and information collection efforts are more efficient if the scope is correct.

3.1.3 Data Collection

Data collection is also a critical component of model development. In my opinion, data collection is not just collecting arrival rates, processing times, etc. but also information like process logics, routing information, and part attributes. When collecting data or process information the modeler should be able to perform time studies, informational interviews and even some data pruning.

Typical data collection efforts focus on collecting arrival rates of entities to a system and processing times of those entities. Time study (or similar efforts) development and execution should be and usually is a skill that is gained in simulation courses.

Informational interviews are also necessary when developing a simulation model. Domain experts are important sources of information and a good simulation modeler will get as much information from them as possible. The difficulty that I had in my first modeling experience was that I did not ask the questions in a way that made sense to the expert. This resulted in short "yes/no" type answers that did not take full advantage of their knowledge.

In some applications required simulation data is available in databases that have vast amounts of information. Using database data can save a considerable amount of time in collection efforts and even give much better estimates for the distributions. The downside of all this data is that it is often not relevant or must be modified for use in the simulation model. Data pruning and analysis are necessary when there is too much data.

I wish that I paid more attention during the time studies lessons and probability and statistics courses. Model development projects in most simulation courses are generated from case studies that usually have just the right amount of data or enough data to get the point across, however this is rarely the case in practice. For students, the interviewing skills and abundance of data are also learned/practiced in semester projects with support from the professor. Addressing the issues of too much data and practicing the interviewing techniques could be improved in the classroom setting.

3.2 Summary

In my experience, the three weakest areas in my academic preparation were programming skills, model scoping and scaling and data collection. I feel that the simulation coursework provided an adequate foundation for future development, but I wish that I had paid attention or retained more of the programming, statistics and other first and second year courses that are essential for simulation modeling. Simulation courses are packed full of topics and some of the critical components in model development are left as indirect learning objectives of the semester projects. I believe that additional emphasis on these three areas within the context of a simulation course would improve the modeling capabilities of the students and new practitioners.

4 DAVID M. FERRIN: INTRODUCTION

"What I wish they would have taught me (or that I would have better remembered!) in school" has two parts. The first, what I wish they would have taught me in school, will be addressed more fully than the second, what I wish they would have better remembered in school.

4.1 What I Wish They Would Have Taught Me In School

The first topic I would wish for would be more 'applied' parts to each course, especially 'applied statistics.' I enjoy statistics tremendously. Moreover, to be worth your salt in the field of simulation, I feel one must at least 'like' stats. Infatuation is not necessarily a bad thing, especially if one is going to make a career in this field. The hard thing for most engineers is knowing when to stop. We could spend a lifetime studying one model, building it and analyzing it. The downside is that the budget usually doesn't last that long!

The other applied topic I'd like to see taught is an 'applied life' course. An applied life course would include many of the other topics which follow but would focus especially on:

- Understanding priorities in life,
- Knowing what your priorities in life mean,
- Understanding the cost of keeping your priorities.

I see many people in the business world that either don't know what their priorities are or have really messed up priorities. In the case of the latter, chasing the almighty dollar is usually near the top of their priority list. They neglect the basics of constructing one's list which should include:

- Social value,
- Ethics,
- Courtesy,
- Kindness,
- Trust,
- Integrity and
- Loyalty (sounds a bit like the Scout Oath).

In regards to this list, a partner in our firm taught me a significant lesson for the 'priorities of life' category. He said that if I could 'feed the greed' and keep my personal integrity I would be successful in the firm. The integrity part of that equation was the more difficult lesson to be learned and applied.

The cost of keeping one's priorities and values depends on how deeply one believes in them. One thing is certain, your priorities, values and integrity will be tested. The cost of the test is up to us.

My next wish relates to the 'consulting lifestyle.' Over the last few years I've seen a significant increase in the number of students wanting to get into consulting right after graduation. Most don't know what consulting involves or have the necessary credentials to be of value to a firm. Consequently, they are relegated to "less enjoyable' work.

Many of these students want to make the big bucks and be promoted quickly. My father once told me that employers always get what they pay for. As a leader in one of the largest simulation groups within the largest of the final four consulting companies, he was right. Entry level analysts/consultants must be billable **all** the time. Hours are long and travel is high. Travel is not as enjoyable as most believe. Today for example, after staying up until 1:00 am packing, I got up at 6:30 am and began my weekly commute. The taxi picked me up at 8 am for my 10 o'clock flight. I checked my bags and made my way through security. After boarding I finally got settled into my seat assuming that I would enjoy working on my flight which was due to arrive at 4:30 pm crossing three time zones in the process. A flight attendant came over and asked me to go back to the desk in the gate area. Not a good sign by the way. They asked me if I went through security, as if it's possible NOT to go through security in a post 9-11 airport. Long and short of it, I have to go back through security and be **fully** scanned. Again, not a good thing. Of course, after running through the airport, I miss my flight which has my consulting team on board. The next flight is eight hours later and will get me into my destination airport at 1 am in the morning. After getting my luggage I should get to my hotel about 3:30 am. I'll then get three hours sleep and get to my client's office where they expect a seasoned, well-rested, principal-level consultant, ready for action. Oh, the life of a consultant!

The next topic I'd like to see taught is 'real life in the office.' This class would be closely aligned with the following courses:

- How to survive your first layoff,
- How to survive your second layoff,
- How to do your first layoff (management perspective),
- The value of networking,
- How do you spell "entrepreneur,"
- What's a pension?

The last topic is one taught but I wish was remembered better. It is the Utility Curve for Model Complexity shown in Figure 1.

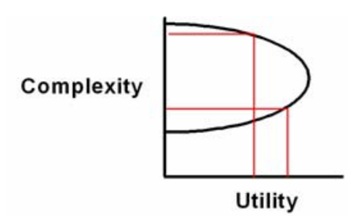

Figure 1: Utility Curve For Model Complexity

The basic premise is that during the modeling process, there exists a point at which more complexity in the model yields less utility or value. Most engineers have a hard time believing that more is less. Experience has shown me that this is a good curve. Finding that 'point' is the hard stuff.

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