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TEACHING OF SIMULATION AT BUSINESS SCHOOLS

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ABSTRACT

Many business decisions can be ably supported by applications of simulation models of various types, including system dynamics, discrete event, agent based, and Monte Carlo. Many decisions involving large capital investments are made only after the proposed systems have been simulated and the expected return on investment verified using simulation. The applicability of simulation to business decisions would suggest that leading business schools would include teaching of simulation software in their curriculum. While business schools use business simulations extensively in their classes, there appears to be limited interest in teaching how to build such simulations. This paper reports on a survey of teaching of simulation software at leading business school. The prevalence of teaching some simulation types over others and the reasons provided are discussed. Simulation community may want to consider the trends at business schools and the need to influence them.

1 INTRODUCTION

The importance of testing proposed changes in the virtual world before implementing them has been realized in the business world. Most decisions involving large capital investments are typically evaluated first using simulation. For example, all semiconductor plant designs involving well over one billion dollars of investment are evaluated using discrete event simulation (DES) models. In fact, most greenfield manufacturing plant designs in the western world ranging from large to small are generally evaluated through simulation. The performance of new financial instruments in the financial world is tested using Monte Carlo simulation before they are released to the markets. Policy changes are many times evaluated using System Dynamics models. There is increasing use of Agent Based simulation models for evaluating offerings of services and products to consumers.

The applicability of simulation modeling to business decisions requires that graduates entering career paths leading to managerial roles should be prepared to develop and use such models to support decision making. At the very least, the graduates should have a good understanding of simulation modeling to be able to make sound decisions based on results of simulation studies. This line of thinking would suggest that leading business schools include courses on simulation modeling in the required part of their curriculums. The general impression is that this is not the case and in fact, over the years the trend has been towards reducing quantitative courses at least in the required part of business curriculums. Leong and Cheong (2008) point to business schools dropping introductory courses in management science. With reduced emphasis on simulation in business schools, most simulation modelers are usually graduates of industrial engineering, systems engineering, and operations research programs.

Business schools do utilize business simulations extensively. More than a decade ago, it was reported that 97.5% of 236 randomly selected business schools in the U.S. used business simulations (Faria 1998). It should be noted that the study considered the use of business simulations and not the learning of how to develop such simulations. The high use of business simulations underlines the importance business

schools attach to the value of simulations in business situations. It appears though that such interest does not translate into a desire to teach how to build such simulations to the business graduates.

The trend of reducing emphasis on quantitative courses in business school curriculums may have been interrupted and perhaps even reversed in last couple year with the increased emphasis on analytics in the business world. Business schools have added specialized graduate degree and certificate programs focusing on business analytics. The interest in business analytics may also lead to inclusion of simulation modeling in business school curriculums, in particular, in the offerings related to business analytics.

This paper reports on an effort to explore the current practice at leading business schools regarding teaching of simulation modeling. A survey was conducted to identify the teaching of simulation modeling at top 100 business schools around the globe. The results of the survey confirm some of the general impressions and provide information of interest to the simulation community. The next section briefly presents related efforts. Section 3 describes the survey parameters and the questionnaire development. The results of the survey are provided in Section 4. Section 5 concludes the paper.

2 RELATED WORK

There has been some interest in the topic of teaching of simulation in business schools at past Winter Simulation Conferences. The topic was discussed at a panel discussion in 1994 Winter Simulation Conference (Jacobson et al. 1994). The industry representative at the panel indicated the need for graduates to have DES in their toolbox while the academia representatives highlighted the need for teaching simulation in the context of business need such as process analysis to motivate business students. Both these perspectives are valid and perhaps even more so two decades later! Stahl (2000 and 2007) strongly supported teaching of discrete event simulation at business schools for multiple reasons including simulation as a desirable management science approach, developing an understanding of flows of physical goods and their connection to financial flows, and importance of understanding impact of uncertainty for financial planning.

Leong and Cheong (2008) propose teaching modeling using Excel as the appropriate way to teach modeling skills to business school students, though their focus is on teaching undergraduates. They state that many university professors have adopted spreadsheets for management science courses.

Liberatore and Nydick (1999) point to limitations of spreadsheet for modeling complex systems and recommend teaching of DES software to MBA students and point to the increasingly user-friendly features in DES software. Since their recommendation more than a decade ago, while the spreadsheets have improved and gained the benefit of more add-ons supporting Monte Carlo simulation, the DES software have improved much more in their user-friendliness. Their recommendations hence are more valid now than they were in 1999.

Yan and Xu (2009) support teaching systems dynamics simulation in business schools to help students understand bounded rationality and impact of dynamics.

No survey was found in the literature that reported on teaching of simulation software in business schools. Surveys have been reported on use of simulations and games to support teaching in academia, but they did not include teaching students how to build simulations. Lean et al. (2006) report on a survey of use of simulation and games by academics at a particular higher education institution and conclude that activities are needed to build awareness of such approaches.

3 SURVEY DESIGN AND EXECUTION

The goal of the survey was to assess the prevalence of teaching simulation software in business schools. The results should be of interest to business schools considering offering new/ continuing/ discontinuing current classes that include teaching of simulation software. The survey questions were designed keeping this goal in mind. The survey design used primarily a quantitative approach with questions providing a set of options for respondents to choose from. Many of the questions provided options for respondents to provide responses outside of the predefined set. A few questions at the end

were primarily open-ended to allow respondents a chance to comment freely. While some may consider the inclusion of open-ended options and questions leading to a mixed-strategy approach, Bryman (2006) argues against such a classification. The survey should hence be considered as following a quantitative approach.

Faculty members at a business school considering addition or deletion of teaching simulation software as a topic in a course or as a course itself may want to know the related teaching practices at leading business schools. This view point was used to develop the questions for the survey. The questions were arranged in 9 sections as listed below.

1. Current teaching of simulation software
2. Class(es) including teaching of DES software
3. Class(es) including teaching of System Dynamics simulation (SDS) software
4. Class(es) including teaching of Agent Based simulation (ABS) software
5. Class(es) including teaching of spreadsheet based Monte Carlo simulation (MCS)
6. Class(es) including teaching of other type of simulation
7. Past teaching of simulation software
8. Future teaching of simulation software
9. Concluding questions

Section 1 focused on determining the objectives for teaching simulation or reasons for not teaching simulation. If no simulation is being taught, the survey logic jumped directly to section 7. If simulation is being taught the questions continued to determine the type of simulations being taught. Sections 2-6 collected information on the classes involving teaching of simulation software. The sections contained the same 22 questions each except they focused on different types of simulation. Information was requested on the class including the title, textbook used, contact hours devoted to the class and teaching the software, enrollments, use of class projects, student feedback, and anticipated future use of the skills in the students' careers. Section 7 and 8 elicited information on past teaching of simulation software and future plans respectively. Section 9 concluded the survey with questions allowing opportunity for commenting in general on the survey and for providing contact details. Sample questions from sections 1 and 2 of the survey questionnaire are provided in appendices A and B respectively.

The survey was executed via Qualtrics survey website. The website provides a convenient way for conducting on-line surveys including sending invitation and reminder e-mails to respondents. Invitation e-mails were sent to one selected faculty member at each of the global top 100 business schools. The 2014 Financial Times rankings of global business schools was used as a way to identify the top 100 schools (FT.com 2014). The particular list was used as it provided a convenient way of selecting a target respondent group.

One faculty member was identified at each of the top 100 business schools based on one of the following: (i) prior knowledge of the author that the faculty member is active in simulation either through their past publications or participation in past Winter Simulation Conferences, (ii) information on school website indicating that the faculty member teaches classes that include simulation or does research involving simulation and modeling, and, (iii) chair or leader of operations management area with the thought that they will either be aware of the requested information or forward the survey request to the right faculty member. The population of potential respondents at 100 was relatively small compared to past surveys with somewhat related interest. However, the efforts taken to create a focused group appears to have contributed to a relatively high response rate with 49 surveys completed, including one for author's own institution. The distribution of respondents across the top 100 global business schools is presented in Figure 1, while Figure 2 presents the distribution across the continents. As comparison for the response rate, the survey of academics regarding use of simulation and gaming done by Lean et al. (2006) reached out to a wider audience of 963 but had a response rate of 16.4 percent. A prior larger survey by Faria and Wellington (2004) on the use of simulation by academics achieved an even lower response rate at 8.4 percent.

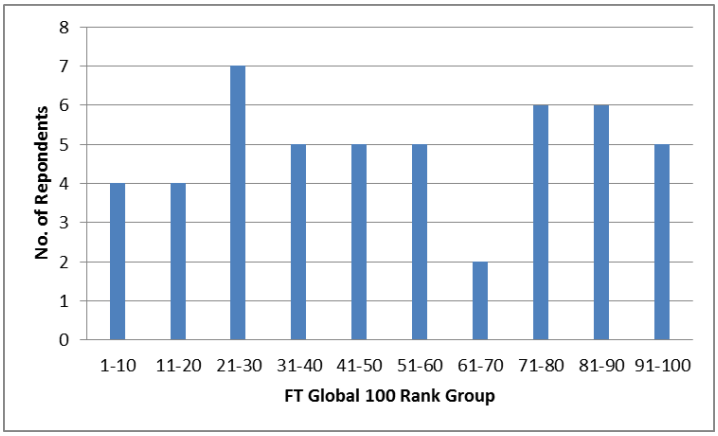

Figure 1: Distribution of respondents across the global 100 business schools per the Financial Times (FT) ranking.

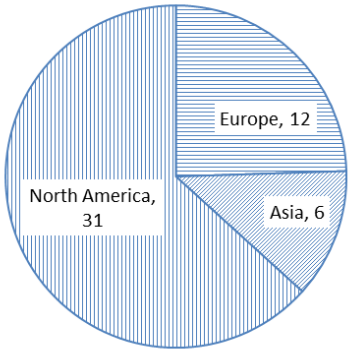

Figure 2: Distribution of respondents across continents.

4 SURVEY RESULTS

The results of the survey are presented in following sub-sections using the structure presented in section 3. Responses to selected questions deemed of interest to the participants of the Winter Simulation Conference are presented.

4.1 Current teaching of simulation software

A large percentage (87%) of business schools responding to the survey have classes that include teaching of simulation software but as many of the readers may be able to guess the majority of the classes involved teaching of spreadsheet based Monte Carlo simulation. Figure 3 shows the percentage of respondents with classes on different types of simulation out of those that answered yes to having classes that include teaching simulation software. The percentages do not add up to 100% since an institution may select multiple options. Classes including DES, SDS, and ABS successively follow MCS in decreasing order of percentage of business schools with classes in simulation. The respondents opting for "other" referred to risk analysis/stress testing in Excel, SAP, R, Littlefield and Beer games.

Figure 4 presents the percentage of respondents selecting among provided reasons for including learning of simulation software in the curriculum. Again, the percentages are of the respondents who answered yes to having classes with simulation and they do not add up to 100% since multiple options could be selected. Almost two-thirds of schools opted for including simulation in curriculum as it was expected to be useful for some of the careers that their students go to. The next reason selected by 44% of the respondents was that simulation is considered essential for business analytics career reflecting the recent trend. The respondents opting for other included helping students understand probability and for satisfying students' learning and curiosity among the reason for including simulation in their curriculum.

Among the small percentage (13%) of responding schools that do not have any classes with teaching of simulation software, about three-fifths of them selected the reason that simulation was not considered important for typical jobs their graduates sought. Nearly a third of the respondents opted for the reason that their typical students didn't have the coding skills required for building simulations. And a sixth selected the reason that graduates can seek specialized help for building simulations when needed in their careers. Among the other reasons provided was lack of a good textbook for business students to follow and lack of awareness of anyone teaching such classes and the reason.

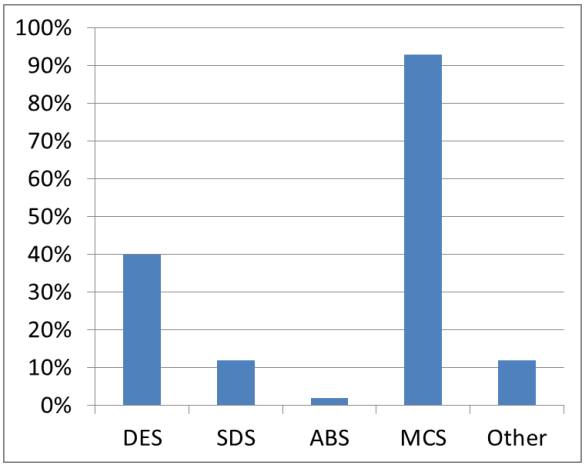

Figure 3: Percentage of respondents with classes on different types of simulation out of those that do have classes with simulation.

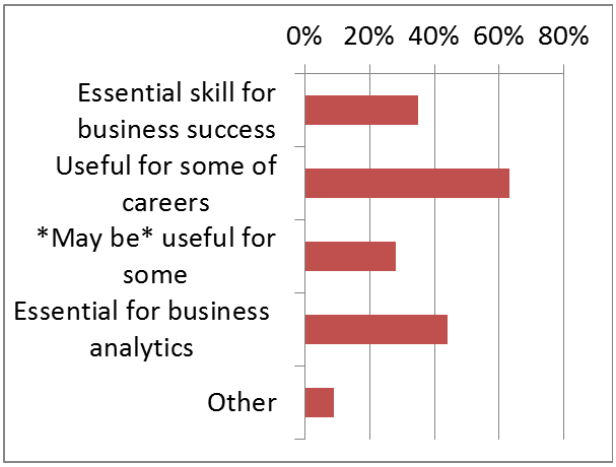

Figure 4: Percentage of respondents with identified reasons for including simulation in curriculum out of those that have classes with simulation.

4.2 Class(es) including teaching of DES software

The percentages mentioned in this sub-section are out of those 40% of the respondents who acknowledged having classes that included DES software as shown in Figure 1. In some of the figures actual counts are used to allow readers to relate to the number of business schools selecting an option. Figure 5 shows the DES software used in classes at the business schools that do teach use of such software. Figure 6 shows the reasons identified by percentage of respondents for selecting the specific software used. Again, with the option to select multiple reasons the percentages do not add up to 100%. As one would guess, software suitability assessed by the instructor was the reason selected by almost three-fourths of the respondents that have classes with DES. Half of such respondents included the reasons of the instructor being knowledgeable in the selected software and the availability of a textbook that integrated the topic and the simulation software.

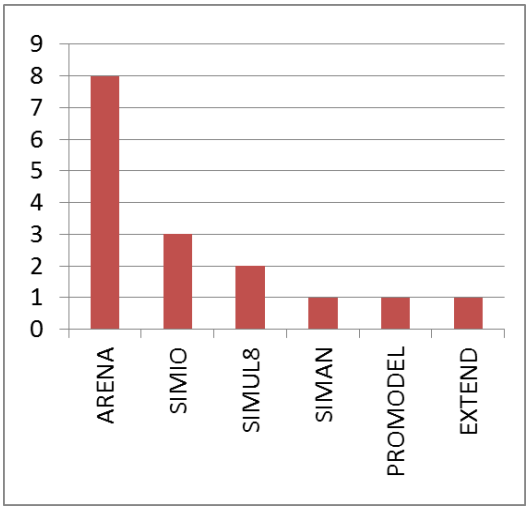

Figure 5: Number of respondents with identified DES software among those that do have classes with DES.

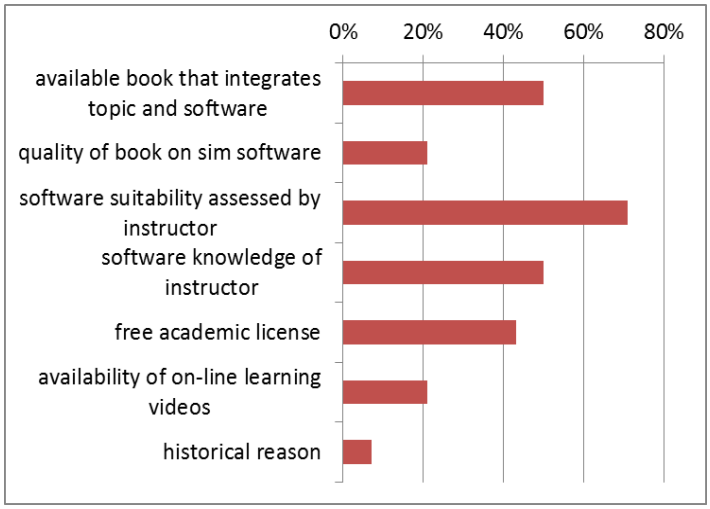

Figure 6: Percentage of respondents with identified reasons for selecting specific software out of those that have classes with DES.

4.3 Class(es) including teaching of SDS software

There were fewer respondents reporting the use of system dynamics simulation than for DES. The corresponding graphs for the software used in class and the reasons for the selection of the software are presented in Figures 7 and 8. The group of respondents used only two of the potential software named in the survey. Also, similar to DES software selection reasons, the reason most favored by respondents for selection of the specific SDS software was the assessment of the suitability of the software by the instructor. Interestingly, availability of the books on software or integrating software with the topic were not selected at all. This may suggest that the SDS concepts are generic in nature and can be implemented using any of the software for the purpose easily. Hence the instructors do not have to be constrained by the availability of software specific book.

4.4 Class(es) including teaching of ABS software

Unfortunately there were no responses registered for detailed questions on use of agent based simulation software by the respondents who reported classes that utilized such software in the first section of the survey. Perhaps ABS software require more coding skills than the other types of simulation software and hence are not suitable for business school curriculum.

4.5 Class(es) including teaching of MCS software

Classes that include teaching of spreadsheet based Monte Carlo simulation were found to be the most popular among the different simulation types as reported in section 4.1. Figures 7 and 8 show the graphs for the MCS software used in classes and the reasons for selecting the software.

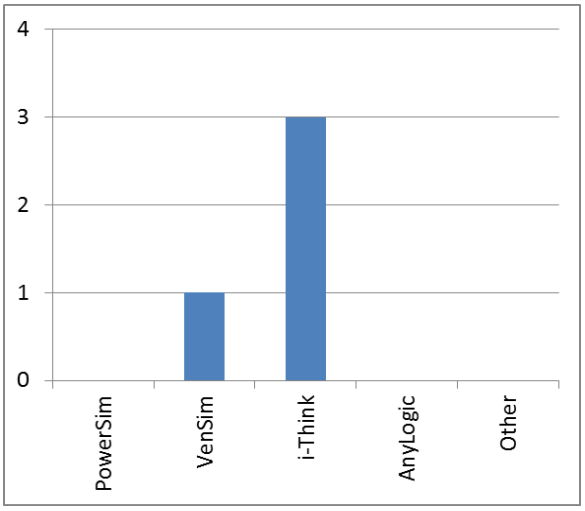

Figure 7: Number of respondents with identified SDS software among those that do have classes with SDS.

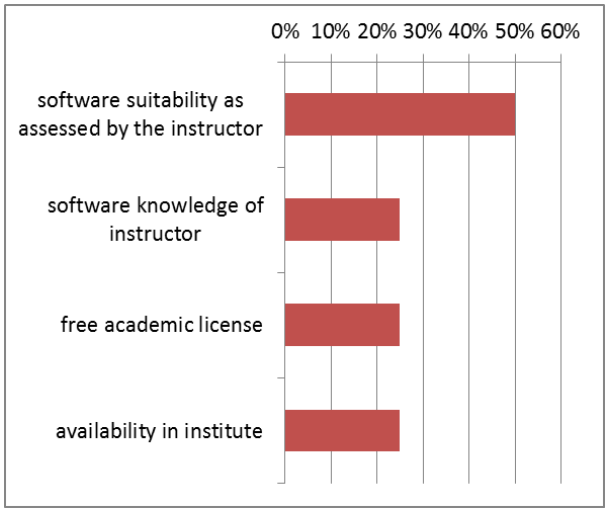

Figure 8: Percentage of respondents with identified reasons for selecting specific software out of those that have classes with SDS.

As one might guess, a large number of respondents use MS Excel as the software for MCS simulation as shown in Figure 9. In fact, the number is in favor of MS Excel even more so if the number reporting use of MS Excel Solver are combined together with those reporting use of MS Excel (implied as without the Solver). The two other named software are also add-ons for MS Excel indicating that classes using MCS overwhelmingly use MS Excel as the platform. The tools mentioned by respondents in the "other" category included XLsim, ASPE, and R.

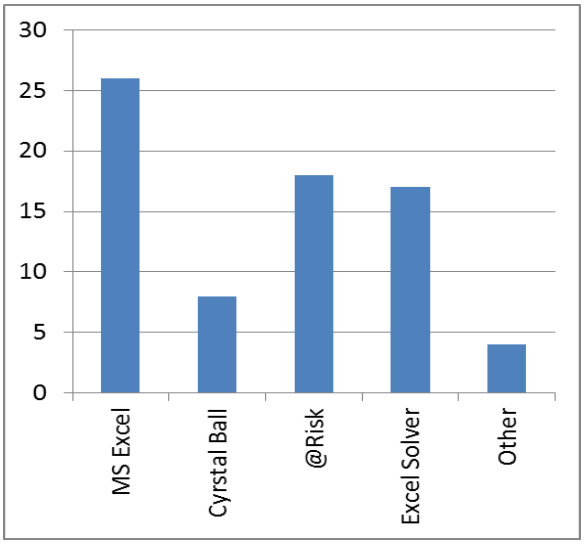

Figure 9: Number of respondents with identified MCS software among those that do have classes with MCS.

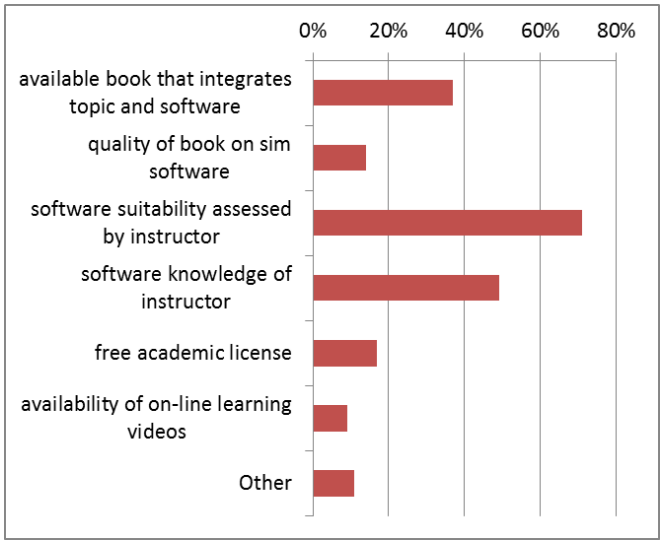

Figure 10: Percentage of respondents with identified reasons for selecting specific software out of those that have classes with MCS.

The pattern of Figure 10 showing percentage of respondents with identified reasons for selecting specific MCS software is somewhat similar to the pattern of figure 4 showing the reasons for selecting specific DES software. The major difference understandably is for the availability of free academic license since that is not a major concern for MS Excel as most business school faculty members and students have the software installed on their computers already.

4.6 Past and future teaching of simulation software

The responses to the two sections focused on past and future teaching of simulation software in business schools reveal that while there has been a transition from teaching of other simulation types to spreadsheet based Monte Carlo simulation, there appears to be some interest in adding the other simulation types back to the curriculum in near future.

5 CONCLUSION

Simulation modeling is important for supporting business decisions and hence one would think that development of simulation models would be considered an important skill for business school graduates. Business schools interested in adding simulation modeling to their curriculums would want to consider the thinking and practice in this regard by other business schools. This paper reported on a survey to elicit such practices at leading business schools around the world. The survey provides data for this important topic and allows going beyond anecdotal data. While the prevalence of teaching of spreadsheet based Monte Carlo simulation software could be anticipated, the survey shows that there is a sizeable community interested in teaching of discrete event simulation software and an appreciable interest in teaching of systems dynamics simulation software. The reasons supporting teaching of simulation software are reported as are the reasons behind selecting simulation software of different types for use in class. Simulation community may want to consider the results of this survey and devise strategies to increase appreciation of simulation model development skills among business school faculty and students.

ACKNOWLEDGMENTS

The author is very appreciative of the colleagues at 48 business schools around the globe who took the time to complete the survey. The author also appreciates the colleagues at all 99 business schools that were approached for their patience with the multiple e-mail messages sent over the month while survey was active, and those who forwarded the e-mails to the appropriate faculty members for this survey at their respective schools.

A APPENDIX: SECTION 1 OF SURVEY QUESTIONNAIRE

Section 1 of survey questionnaire is provided below. Please note that conditional logic used in the survey ensured that only the relevant questions are presented to the respondent. For example, respondents answering "Yes" to Q1.2 will be presented with Q1.4 next skipping Q1.3.

Q1.1 The goal of the survey is to assess the prevalence of teaching simulation software in business schools. The results should be of interest to business schools considering offering new/ continuing/ discontinuing current classes that include teaching of simulation software. The survey collects information on classes in business schools that include teaching of simulation software (discrete event, system dynamics, agent based, spreadsheet-based Monte Carlo, or other types of simulations). Teaching the students how to develop models using simulation software should be one of the objectives of such classes. The survey is also intended for collecting information on specific simulation software and textbooks used for such classes. Please note the survey is not intended to collect information on classes just using simulations that were built by publishers/ others.

Q1.2 Are classes currently offered in your business school that teach the students how to build simulations using software ?

- ❍ Yes (1)
- ❍ No (2)

Q1.3 Reasons for not including simulation in curriculum now (select as many as applicable):

- ❑ simulation modeling not important for typical jobs that our business school graduates seek (1)
- ❑ simulation modeling important but our graduates can use specialized help for building models when needed, (2)
- ❑ simulation important but building models requires coding skills that our typical student doesn't have (3)
- ❑ classes are available through the engineering school for those who want it (4)
- ❑ other (specify) (5) _____

Q1.4 Reasons for including simulation in curriculum (select as many as applicable):

- ❑ simulation modeling is essential skill for business success now (1)
- ❑ simulation modeling is useful for some of the careers that our students go to (2)
- ❑ simulation modeling *may be* useful for some (3)
- ❑ simulation is essential skill for those going for business analytics career (4)
- ❑ Other (5) _____

Q1.5 The classes that include learning of simulation software are offered in the following programs (select as many as applicable):

- ❑ Regular MBA (1)
- ❑ Specialized MBA (2)
- ❑ Specialized Masters (such as MS in Business Analytics, MS in Finance, etc.) (3)
- ❑ Others (4) _____

Q1.6 Classes provided include building the following kind of simulations (select as many as applicable):

- ❑ Discrete Event Simulation (such as ARENA, PROMODEL, SIMIO, etc.) (1)
- ❑ System Dynamics Simulation (such as Powersim, Vensim, i-Think, etc.) (2)
- ❑ Agent Based Simulation (such as Repast, etc.) (3)
- ❑ Spreadsheet-based Monte Carlo simulation (e.g. Lotus-1-2-3, MS Excel, etc. with plug-ins such as Crystal Ball, @Risk, etc.) (4)
- ❑ Others (5) _____

Q1.7 Simulations other than spreadsheet-based Monte Carlo simulations are not taught due to the following reasons: (select as many as applicable):

- ❑ Other types of simulation modeling software not important for typical jobs that our business school graduates seek (1)
- ❑ Other types of simulation modeling software important but our graduates can use specialized help for building models when needed, (2)
- ❑ Other types of simulation modeling software important but building models requires coding skills that our typical student doesn't have (3)
- ❑ classes are available through the engineering school for those who want to learn other types of simulation software (4)
- ❑ other (specify) (5) _____

Q1.8 None of the listed Simulations types are taught due to the following reasons: (select as many as applicable):

- ❑ Listed types of simulation not important for typical jobs that our business school graduates seek (1)
- ❑ Listed types of simulation important but our graduates can use specialized help for building models when needed, (2)
- ❑ Listed types of simulation important but building models requires coding skills that our typical student doesn't have (3)
- ❑ classes are available through the engineering school for those who want to learn listed types of simulation software (4)
- ❑ other (specify) (5) _____

B APPENDIX: PART OF SECTION 2 OF SURVEY QUESTIONNAIRE

A part of section 2 on class(es) teaching DES software is provided below. Again, please note that conditional logic used in the survey ensured presenting only the relevant questions to the respondent.

Q2.1 Reasons for including learning to build discrete event (DE) simulation models in curriculum (select as many as applicable):

- ❑ DE simulation modeling is essential skill for business success now (1)
- ❑ DE simulation modeling is useful for some of the careers that our students go to (2)
- ❑ DE simulation modeling *may be* useful for some (3)
- ❑ DE simulation is essential skill for those going for business analytics career (4)
- ❑ Other (5) _____

Q2.2 What's the title of the class(es) that include teaching the discrete event simulation software?

Q2.3 Please provide webpage link(s) to the syllabi for such classes if publicly available:

Q2.4 What is/are the title of textbooks that are used for the class (topic book, and sim. software book if separate)?

Q2.5 What are the total contact hours for the class? (since some schools use semesters while others use quarters, please answer in total hours -- no. of sessions times the duration of each session)
_____ Total contact hours (1)

Q2.6 Approximate %age of the class time across the term devoted to teaching the simulation software?
_____ %age (1)

Q2.7 What simulation software are taught? (select as many as applicable)

- ❑ ARENA (1)
- ❑ PROMODEL (2)
- ❑ EXTEND (3)
- ❑ SIMIO (4)
- ❑ Other (5) _____

Q2.8 Reasons for selection of the software (select as many as applicable):

- ❑ availability of a book that integrates the topic and the software (1)
- ❑ quality of book on sim software (2)
- ❑ software suitability as assessed by the instructor (3)
- ❑ software knowledge of instructor (4)
- ❑ free academic license (5)
- ❑ suggested by a collaborating organization (6)
- ❑ availability of on-line learning videos (7)
- ❑ Other (8) _____

Q2.9 Does the class include a project that involves building a large simulation model?
- ❍ Yes, as a team project (1)
- ❍ Yes, as an individual project (2)
- ❍ No (3)

Q2.10 The system to be modeled using the simulation software in the class project is usually a:
- ❍ Hypothetical system (1)
- ❍ Real system based on the data provided by a company (2)
- ❍ Other (3) _____

Q2.11 What are the pre-requisites for the class? (select as many as applicable)
- ❑ None (1)
- ❑ Beginning Statistics (2)
- ❑ Advanced Statistics (3)
- ❑ Software concepts (4)
- ❑ Other (5) _____

Q2.12 Simulation is taught in these classes primarily thru: (select as many as applicable)
- ❑ in-class instruction (1)
- ❑ lab sessions conducted by teaching assistants (2)
- ❑ students self-teach using on-line videos and other on-line material (3)
- ❑ students self teach using simulation software book and software tutorials (4)
- ❑ Other (5) _____

Q2.13 How long has the class been offered?
- ❍ less than 5 years (1)
- ❍ for last 5-10 years (2)
- ❍ more than 10 years (3)

Q2.14 What is the average number of students registering for the class in each term it is offered?
_____ Average enrollment per term (1)

Q2.15 Is the class required or an elective for MBA programs?
- ❍ Required (1)
- ❍ Elective (2)
- ❍ Not applicable/ Not available to MBA students (3)

Q2.16 what percentage of MBA graduates do you think will become practitioners (even if only part time) of discrete-event simulation?
_____ %age that will become DES practitioners (1)

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