Selection of a Simulation Language for an MBA Modeling and Simulation Course

By

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MBA MODELING AND SIMULATION COURSE

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ABSTRACT

A study was carried out with two student sections of an MBA modeling and simulation course, to examine the feasibility of switching to a different simulation language from the one currently used. Data collected during the study also indicated the value of a project-oriented approach in the course, and indicated that more emphasis could be placed on learning the simulation language by self-teaching, leaving more class time for learning other aspects of simulation.

Subject Areas: Education, Systems, and Simulation.

INTRODUCTION

Simulation has become a widely recognized technique for studying the behavior of complex business and industrial systems. For this reason, modeling and simulation have become regular topics in both undergraduate and graduate business programs. The Curriculum Committee on Information Systems of the Association for Computing Machinery (ACM) has included modeling and simulation in its recommended program [14] although these topics represent only about half of one of the recommended courses (IS7: Modeling And Decision Systems) for a graduate MBA program in information systems. The ACM recommendations also suit the general requirements of the AACSB (American Assembly of Collegiate Schools of Business).

While it is important to develop minimum standards for material taught in business system simulation courses, the advance of technology and the development of newer simulation packages with improved features require a constant effort to upgrade and advance the material taught in these courses.

In the McMaster University MBA program, the Modeling and Simulation course Q715 is a regularly scheduled course available for students enrolled in any of the three classifications (full time, part time and co-op) in the MBA program. This course is normally taken by most of the students electing the Information Systems, Operations Management, or Management Science academic streams, and occasionally by students in other streams such as Finance, Marketing and Accounting. The enrolment in this course fluctuates between 20 and 40 students each year, and it is offered in both evening and day sections.

The writer has taught the modeling and simulation course for a number of years, using GPSS as the simulation language. Recently, due to the expressed interest of students taking the
course and due to the ongoing evolution of a wide variety of general purpose simulation languages, a study was undertaken to reorganize the course, with major attention being given to the possibility of replacing GPSS with a more versatile language. This paper reports on the results of that study.

THE STUDY

Modeling and Simulation (Q715) is a second year MBA one semester course. Prerequisites include a beginning course in statistics and an introductory course in computer programming (BASIC or FORTRAN) and management science or its equivalent. The mark weight is 30% each on midterm and final exams, 30% on the project, and 10% on assignments. The general course outline is given in Table I.

Table I

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction to modeling and simulation</td>
<td>2</td>
</tr>
<tr>
<td>2. Introduction to the simulation language used in the course</td>
<td>4</td>
</tr>
<tr>
<td>3. General procedures for planning and carrying out a simulation project</td>
<td>1</td>
</tr>
<tr>
<td>4. Statistical considerations</td>
<td>3.5</td>
</tr>
<tr>
<td>5. Survey of other simulation languages</td>
<td>1</td>
</tr>
<tr>
<td>6. Class presentations of projects</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

Students are required to form groups of from one to three persons to undertake real simulation projects. The project customer can be either off or on campus. Typical projects undertaken during the past few years have included a simulation of earth moving at a major construction project, scheduling transcription work at a hospital, bus scheduling, planning for airport expansion, cafeteria operations, etc. A total of over 150 projects of this type have been undertaken.

Planning and development work on the class projects are monitored carefully, especially during the early phases. Student groups must prepare their proposals early in the term for approval, and care is taken to prevent students from taking on projects which are too ambitious. Near the end of the term, each student group makes a class presentation of its project. The purpose of this presentation is two-fold: to permit students to gain from the experience of others, and to allow students to benefit from
constructive criticism from the instructor and other students.

As mentioned previously, one of the main objectives of this study was to determine if a simulation language other than GPSS would be suitable for the course. There is a wide variety of simulation software available to satisfy just about every practical need, with more constantly being made available. For example, articles by unknown authors in Simulation [22] [23] list the characteristics of some 48 simulation packages available for a variety of machines. A large number of these packages will also run on various types of microcomputers, thus keeping simulation methodology abreast with the evolution of computer systems. However, these listings are by no means exhaustive and not all of these packages are sufficiently general or otherwise suitable for business students.

The general preference for particular simulation languages has a direct impact on the material to be found in the introductory texts available in the field. A sampling of some of the more recent general texts on simulation, along with the languages discussed in reasonable detail in these texts, appear in the table below.

<table>
<thead>
<tr>
<th>TEXT</th>
<th>FORT</th>
<th>GPSS</th>
<th>SMCSP</th>
<th>SLAM</th>
<th>SIMULA</th>
<th>CSMP</th>
<th>DYNMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maryanski [13]</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Law and Kelton [12]</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FORTRAN is included as a simulation language in two of these texts, although it is unlikely that business students would be taught simulation with FORTRAN, given all the power available in the general purpose simulation languages. Law and Kelton, and Banks and Carson also give summaries and comparisons of several of the languages mentioned, respectively. These authors also tend to focus on GASP IV as well as SLAM, but since GASP IV is a precursor of SLAM, their evaluation of GASP IV can also be helpful when considering SLAM.

From the point of view of the beginning user, the graphical modeling language available with GPSS, the network models of SLAM, and the flow models of DYNAMO [5] are helpful in planning simulation solutions. Unfortunately there are no standards for modeling languages such as these, as there are no standards for simulation languages. However, for planning a simulation
solution, there is nothing to prevent the user from using a flowchart to lay out a simulation model in any language.

Table II above includes some of the more popular general purpose simulation languages in use in North America. SIMULA was considered in this study since it is fairly widely used in Europe, although it is not currently popular in North America.

Since one of the main objectives of the search was to find a language that was flexible enough to handle both discrete and continuous simulations, the continuous simulation languages CSMP and DYNAMO were ruled out. Of the three remaining alternatives, SIMULA and SLAM can handle both discrete and continuous problems, and although SIMSCRIPT is a discrete simulation language, Delfosse [3] has developed a version which can handle both discrete and continuous simulations. After a cursory consideration, SIMULA was ruled out because of its cost and its lack of wide acceptance in North America, and SIMSCRIPT was ruled out because of its cost. SLAM was selected for further investigation because of its flexibility and its low cost, and also because there are indications that it is beginning to become a popular pedagogical language, as indicated by its mention in several more recent general texts on simulation [2] [12].

Other workers have compared the relative merits of GPSS and other simulation languages. For example, LaPara and Whitehouse [11] compared GPSS with Q-GERT (one of the ancestors of SLAM) and found on balance that GPSS had more desirable characteristics than Q-GERT. Fortunately, most of the defects in Q-GERT mentioned in this paper appear to have been remedied in the SLAM implementation.

By way of background on SLAM (the candidate language), and GPSS (the currently used language), some history on the development and origins of each language is useful in understanding their properties and capabilities.

GPSS (General Purpose Simulation System) was developed at IBM by Geoffrey Gordon, beginning in 1960 [8]. The technique of block diagram models for discrete simulation which is familiar to the GPSS user is roughly equivalent to flowcharting. In GPSS, each program statement has associated with it a special symbol which can be used to map out the model before it is necessary to convert it to a program. This approach is useful in the initial planning of a simulation program. GPSS has available more than 50 different block types, a daunting prospect for the beginner, although many of these block types are rarely used in a beginning course. But, as in any other programming language, internal program documentation is better in the long run than block or flow diagrams for documenting the operations of the program.

GPSS V, the most widely used version of GPSS, has been adapted by a number of vendors (most versions are written in assembly language) to run on a variety of machines, including most mainframe and supermini systems of IBM and other vendors. A more
recent version, GPSS/H [9] is available for IBM systems, and is claimed to execute faster than GPSS V. Two excellent introductory texts for GPSS V are by Gordon [6] and Schriber [20].

SLAM (Simulation Language for Alternative Modeling) is a descendant of two other simulation languages, GASP and Q-GERT. GASP was originally developed by Kiviat [10] for discrete simulation. It evolved into GASP IV which is a combined discrete and continuous language in which the user writes FORTRAN subroutines to accomplish the simulation within the GASP IV framework. The GASP approach to modeling is very flexible, but it is tedious to model standard activities and events in this manner, and it requires a good knowledge of FORTRAN. The Q-GERT simulation language is a process-oriented language which uses standard statements to handle a set of network-oriented processes. Q-GERT and GASP IV were both developed by Alan Pritsker [16] [15]. SLAM is the refined combination of Q-GERT and GASP IV, with suitable additional capabilities to allow full interaction among the different modes (network, discrete event and continuous). This gives the user full flexibility in SLAM to handle many of the standard processes encountered in discrete simulation problems. For many discrete models, there is no need to go beyond the network mode in order to solve problems satisfactorily (see Appendix II for an example). The network mode is roughly equivalent in programming power to GPSS. The network symbols associated with this mode are often helpful in planning simulation programs, as are the block symbols in GPSS.

SLAM was developed by A. Pritsker and C. D. Pegden, and introduced in 1979. The developers also authored the primary reference for SLAM [17]. The current version of the software package, SLAM II, is available from Pritsker and Associates, and will run on a variety of machines, including the IBM personal microcomputer. Little adaptation is required among machines because the package is written in Fortran 77.

In order to compare SLAM and GPSS in compatible environments, the languages were each used for one section of the modeling and simulation course. The course outline, examinations, assignments and project approach were the same in each case, with the only difference being in the language used by the students in each section. The day section of 14 students used GPSS and the evening section of 9 students used SLAM. To a certain extent bias could arise in student attitude towards the language, because the majority of the evening students were part-time, and most part-time students taking this course tend to have engineering backgrounds, while the full-time students tend to be more balanced between engineering and other backgrounds.

To monitor the perceptions and performance of students taking the course, a questionnaire was administered at the beginning of the course, followed one week later by an identical questionnaire to measure instrument reliability. A third questionnaire was administered at the end of the course to measure attitude changes or preferences in the two groups of students.
RESULTS OF THE STUDY

Section A of the appendix lists four questions which appeared on each of the questionnaires, followed by a statistical analysis of the responses to the questions. In terms of change in student attitudes during the course, the day students showed a significant attitude change towards feeling that modeling and simulation could be more useful in business and industry than they originally thought, but they also felt that modeling and simulation in their future careers would be less useful than they originally expected. Responses by the evening students indicated a perception that modeling and simulation could be used in a wider variety of problems than they expected at the beginning of the course.

Section B of the appendix lists the results of an analysis of some of the other questions asked on the final questionnaire. In question 5, students ranked the most likely application areas of modeling and simulation in their future careers. The top ranked application is "project planning and control systems", which should be taken to mean "the use of modeling and simulation in planning and controlling systems" rather than what might be the more obvious meaning of such applications as PERT techniques, since the latter is an application which was mentioned only in the evening class.

In question 6, students indicated that a combined discrete/continuous application of simulation would likely be most useful to them in their future careers, and in question 7 students indicated that their interests in modeling and simulation had increased as a result of taking the course. Although this indicates a positive attitude towards the course, this finding is not corroborated by the finding in question 1 of section A of the appendix, which indicated there was no significant change in student interests during the course.

Question 8 asked students to rank the factors in the course which contributed to their learning about modeling and simulation. This question contributed a great deal to an understanding of the learning process in the course. Considering all the students, three of the four top-ranked learning activities were project-related, and doing assignments was the second-ranked learning activity. Attending lectures ranked fifth overall, but tied for second rank for the evening students. This difference may be related to the fact that the GPSS text used for the day class [6] is an excellent beginning text and requires very little extra explanation in lectures. The text used for the evening class [17] is more condensed as well as being advanced and difficult to follow for beginners. Hence lectures are needed to bring out important aspects of SLAM as well as to clarify points not mentioned in the text. However, a great deal of additional material not directly related to the simulation language is also used in the course, and this is covered in lectures as well as being made available as background material on library reserve. The SLAM II text is a good reference on this material, but the
GPSS text used in the course contains only information on the GPSS language.

Question 9 was answered only by the evening students (SLAM users) and indicated that only a rudimentary knowledge of FORTRAN would be required for most of the applications of interest to the students. This is not sufficient, of course, for users wishing to use the continuous modeling capability or the advanced discrete capabilities of SLAM, but only two student groups out of the eight evening class groups chose to carry out continuous modeling projects, and only two other groups used any of the advanced discrete functions in the form of FORTRAN subroutines.

The response to question 10 is not surprising, where day students ranked GPSS as their top choice and evening students ranked SLAM as their top choice for the simulation language to be taught in the course, since they would normally choose the language with which they were familiar. However, a lecture was given to each class on the comparative capabilities of the simulation language being used by the other class.

As expected, in question 11 the day students ranked the Gordon GPSS textbook higher in terms of usefulness than the evening students ranked the Pritsker and Pegden SLAM text, since the latter text is more advanced and is rather terse in its discussion of the network simulation capability of SLAM. This capability happens to be very important for teaching introductory discrete modeling and simulation.

Appendix II includes a sample simulation problem and its solution in both GPSS V and SLAM. The most notable difference between the two solutions is the need in GPSS to include the piecewise continuous functions to approximate the random variable distribution functions. Unfortunately, this is necessary even for theoretically known distribution functions such as the negative exponential and the normal distributions shown here. Archer [1] has discussed the problem of fitting empirical distributions to piecewise continuous functions, so this need not create a problem with empirical data. In fact, this overcomes the necessity of having to make assumptions about the underlying probability distribution.

Some of the major faults that may be found with the GPSS language are its lack of flexibility in satisfying unusual user requirements, and its restriction to the use of an integer time clock. To solve the flexibility problem, various techniques have been used, including the standard HELP blocks, and the development of similar packages in more flexible form such as GPSS-FORTRAN by Schmidt [19]. The use of an integer clock requires careful scaling of time in each simulation problem solved. However, the major drawback to GPSS in this course is that it cannot handle continuous or combined continuous-discrete simulation problems.

To compare the resource implications of SLAM and GPSS, six simple
class assignment problems were coded in both languages (network mode in SLAM) and the execution times were compared. The average number of statements, including the piecewise continuous function statements in GPSS, were quite comparable, being 26 and 27 respectively for GPSS and SLAM. If the GPSS function statements are not included, then the average instruction count for the GPSS programs drops to 22. For CPU execution time, GPSS is clearly superior. Running GPSS V/6000 on a CDC Cyber 730 computer, the average CPU time for the GPSS programs was 3.6 seconds, and for the SLAM II package on the same computer the average was 12.5 seconds. This is probably due to the fact that SLAM in the network mode basically functions as an interpreter written in FORTRAN. No attempt was made to code the SLAM programs in discrete (equivalent to GASP IV) mode, but this mode could be expected to execute considerably faster. GPSS, although it is also interpretive, is written in assembly language. A factor which may have added to the number of program statements and its slower execution speed is our own inexperience with SLAM. On balance, however, although Gordon [8] has expressed concern about the execution speed of GPSS, it is still far faster than SLAM in network mode, by a factor of about 3. Presumably GPSS/H [9] is even faster yet.

DISCUSSION

Table III is a comparison of some of the characteristics of GPSS and SLAM. Some of the comparison criteria were paraphrased from Shannon [21], but more criteria were added which seemed relevant pedagogically. SLAM has a clear advantage over GPSS in its flexibility for handling either discrete, continuous, or combined simulations. Its process-oriented network option is very closely equivalent to GPSS, as can be seen in the problem solved in Appendix II. On balance, the flexibility of the SLAM language makes it attractive for an MBA course where students need to be given a wide degree of freedom in selecting project topics. In this first use of SLAM in the course, three student groups selected projects which would have been virtually impossible to carry out with a standard discrete simulation language. Two of these projects involved strictly continuous processes, and one was a study of a project scheduling problem.

The data gathered on student attitudes did not indicate any decided differences in attitude toward modeling and simulation between the two student sections as a result of taking the course. The decision on the language to use in the course can thus be based on other factors such as language flexibility which are not necessarily important to the first-time user of a simulation language. The general conclusion is that SLAM is a suitable simulation language for the course, both pedagogically and from the perceptions of the students taking the course. The lack of a suitable introductory language text for SLAM must be dealt with by the development of a set of class notes.

Another very useful result gleaned from this study is that students regard project undertakings as very important in
learning the course material. The importance of projects in teaching has been recognized by others [18] [24] [25]. In particular, Zahedi [25] has pointed out the importance of projects in Management Science/Operations Research courses in teaching students the difficulties faced in handling real problems. To accomplish this, students must be involved in real problems as part of their MS/OR training. This may take place in a variety of ways, including project work in their courses.

A final observation from the data is that students can and do learn the simulation language on their own, and they value assignments in learning course material. Thus, there is less need to cover the points made in the text on the simulation language, and more emphasis can be placed on teaching useful hints and taking up assignment solutions in class. This in turn will free up more time for teaching the statistical aspects of simulation, including the gathering and analysis of data, planning experiments, analyzing and interpreting simulation output, and variance reduction. Time must also be taken to discuss simple analytical models both for analyzing simple real problems and for checking simulation models. There is a substantial body of good reference material in all of these important areas of interest for modeling and simulation, much of which is covered in the texts referenced in Table II.

| Table III |
|---|---|---|
| **Comparison Of GPSS And SLAM** | **GPSS** | **SLAM** |
| **Criterion** | | |
| Event-scheduling approach | No | Yes (Discrete) |
| Process interaction approach | Yes | Yes (Network) |
| Combined discrete-continuous | No | Yes |
| Natural framework (modeling language) for simulation modeling | Yes | Yes (Network) |
| Language flexibility | Fair | Excellent |
| Handle arbitrary random variable distributions | Excellent | Excellent |
| Mechanism for generating theoretical random variables easily | No | Excellent |
| Built-in statistics gathering functions | Very good | Good |
| Ease of producing standard reports | Very good | Excellent |
| Ease of producing special reports | Fair | Good |
### Comparison of GPSS and SLAM (continued)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>GPSS</th>
<th>SLAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output data analysis package</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ease of learning language</td>
<td>Excellent</td>
<td>Very good</td>
</tr>
<tr>
<td>Knowledge/experience to carry out straightforward simulation projects</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Programming effort required</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Application examples in literature</td>
<td>Very good</td>
<td>Good</td>
</tr>
<tr>
<td>Texts and manuals incorporating the language</td>
<td>Excellent</td>
<td>Fair</td>
</tr>
<tr>
<td>Ease of debugging (diagnostics, trace routines, etc.)</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Degree to which coding is self-documenting</td>
<td>Very good</td>
<td>Very good (Network)</td>
</tr>
<tr>
<td>Widespread availability and use of language in industry</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Language availability on new computers</td>
<td>Fair</td>
<td>Excellent</td>
</tr>
<tr>
<td>Portability of language</td>
<td>Fair</td>
<td>Excellent</td>
</tr>
<tr>
<td>Availability for different computers</td>
<td>Very good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Computer time efficiency (GPSSV)</td>
<td>Good</td>
<td>Fair (Network)</td>
</tr>
<tr>
<td>Computer time efficiency (GPSS/H)</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>Relative software package cost</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Quality and speed of maintenance support</td>
<td>Good</td>
<td>Very good</td>
</tr>
</tbody>
</table>

### ACKNOWLEDGEMENTS

Most of the examples used in this study were coded by Mr. Robert Dalgleish. This project was supported in part by a Hooker Fund Teaching and Learning grant from McMaster University, and partly by the Natural Sciences and Engineering Research Council of Canada.
REFERENCES


References (continued)


APPENDIX I

A. Change In Student Attitudes During The Course

Following are four of the questions which were used in the questionnaires. An analysis of the student responses follows.

1. My interest in modeling and simulation is

   [ ] very substantial
   [ ] substantial
   [ ] moderate
   [ ] little
   [ ] none at all

2. I feel that modeling and simulation in business and industry applications can be

   [ ] very useful
   [ ] useful
   [ ] somewhat useful
   [ ] only occasionally useful
   [ ] not at all useful

3. Computer modeling and simulation

   [ ] can be used on a very limited class of problems
   [ ] can be used on a reasonable variety of problems
   [ ] can be used on a wide variety of problems

4. I feel that modeling and simulation as an applied tool in my future career will be

   [ ] very useful
   [ ] useful
   [ ] somewhat useful
   [ ] only occasionally useful
   [ ] not at all useful
Analysis Of Results

The reliability coefficients shown in the following table are Spearman rank correlation coefficients $r_s$, used to compare the test-retest results for the preceding four questions. The Wilcoxon matched pairs signed ranks test was used to measure significance of attitude change between the beginning and end of the course.

<table>
<thead>
<tr>
<th>Question</th>
<th>Reliability $r_s$</th>
<th>Significance of Change During Course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Day</td>
</tr>
<tr>
<td>1.</td>
<td>.84</td>
<td>N</td>
</tr>
<tr>
<td>2.</td>
<td>.57</td>
<td>(.04)$^a$</td>
</tr>
<tr>
<td>3.</td>
<td>.60</td>
<td>N</td>
</tr>
<tr>
<td>4.</td>
<td>.79</td>
<td>(.08)$^c$</td>
</tr>
</tbody>
</table>

Note:
(X) implies significance level
N indicates not significant

For those questions in which the change in student opinion during the course appeared to be significant, the direction of change is as follows:

a  towards more useful
b  towards a wider variety of problems
c  towards less useful
B. Student Perceptions After Completing The Course

Responses by students to questions on the final questionnaire were summarized by using sum of ranks or majority voting methods. Note that Day and Evening student response is shown separately only when there was a difference in the responses by these two classes.

5. Application areas for modeling and simulation in my future career would probably include the following (rank in order of importance, starting with 1 as the most important, 2 as the second most important, etc.).

Rank

3  Systems of office functions and activities
2  Systems such as traffic, assembly lines, computers, etc.
4  Flow systems such as chemical plants, refineries, etc.
5  Macro-models of the economy, input-output systems, large scale urban systems, etc.
1  Project planning and control systems

6. Rank the class of simulation below in the order of usefulness to you in your future career, if you were to use simulation in business/engineering applications. Assume that you would have full knowledge of whichever language you required. Rank the most useful as 1, the second most useful as 2, and the third most useful as 3.

Rank

3  Discrete (e.g. GPSS or discrete/network SLAM models)
2  Continuous (e.g. SLAM or DYNAMO models)
1  Combined discrete/continuous/network (e.g. SLAM model)

7. As a result of taking Q715, my interest in modeling and simulation has

Rank

1  Increased
2  Stayed about the same
3  Decreased

Note: No students selected "Decreased".  

(continued)
8. Rank in order those factors through which your learning about modeling and simulation was most enhanced in Q715, ranking the most important factor as 1, the second most important factor as 2, and continuing on down to the least most important factor.

<table>
<thead>
<tr>
<th>Rank</th>
<th>All Day Eve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planning the project</td>
</tr>
<tr>
<td>3</td>
<td>Gathering and analyzing project data</td>
</tr>
<tr>
<td>4</td>
<td>Writing and debugging the simulation program</td>
</tr>
<tr>
<td>7</td>
<td>Preparing for and presenting the results of the project verbally</td>
</tr>
<tr>
<td>6</td>
<td>Writing the project report</td>
</tr>
<tr>
<td>5</td>
<td>Attending lectures</td>
</tr>
<tr>
<td>2</td>
<td>Doing assignments</td>
</tr>
<tr>
<td>8</td>
<td>Studying for examinations</td>
</tr>
</tbody>
</table>

9. Please answer this question only if you used SLAM in Q715. I think that to use SLAM in most situations of interest to me would require

<table>
<thead>
<tr>
<th>Rank</th>
<th>Eve Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>A detailed understanding of Fortran</td>
</tr>
<tr>
<td>1</td>
<td>Only a rudimentary understanding of the Fortran language</td>
</tr>
<tr>
<td>3</td>
<td>No understanding of Fortran at all</td>
</tr>
</tbody>
</table>

10. Based on an objective evaluation of information presented in class on the simulation languages GPSS and SLAM, I think the following would be the best language to use in Q715:

<table>
<thead>
<tr>
<th>Rank</th>
<th>All Day Eve</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1 3 GPSS</td>
</tr>
<tr>
<td>1</td>
<td>2 1 SLAM</td>
</tr>
<tr>
<td>3</td>
<td>3 2 Combination as used this year (GPSS in day class and SLAM in evening class). Note that this allows a limited choice for full-time and co-op students and no choice for part-time students. (continued)</td>
</tr>
</tbody>
</table>
11. The textbook used in this course was

<table>
<thead>
<tr>
<th>Rank</th>
<th>Day Eve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>4.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Note: No students checked either of the last two categories.

Because the Day and Evening students used different texts, the "All" column is not relevant to this question.

APPENDIX II

Sample Simulation Problem

Problem Statement.

People arrive to use a single telephone at the average rate of one every 10 minutes. The time between arrivals is an exponentially distributed random variable. A call takes a random amount of time which is normally distributed with a mean of nine minutes and a standard deviation of two minutes.

If the telephone is busy at the time of arrival of a customer, half the customers decide to wait, while the other half go away for five minutes and then come back to wait until they do make their calls. People who decide to wait in the first place go ahead of anyone who left. Simulate the completion of 100 calls.

(over)
**GPSS Solution**

* SAMPLE TELEPHONE BOOTH PROBLEM.

* SIMULATE

* EXP FUNCTION RN1,C24
  0,0/.1,104/.2,.222/.3,355/.4,509/.5,.69
  .6,.915/.7,1.2/.75,1.38/.8,1.6/.84,1.83/.88,2.12
  .9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2/.97,3.5
  .98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9997,8

* NORM FUNCTION RN1,C25
  0,-5/.00003,-4/.00185,-3/.00621,-2.5/.02275,-2/.06681,-1.5
  .11507,-1.2/.15866,-1/.21186,-.8/.27425,-.6/.34458,-.4.42074,-.2
  .5,.1.57926,.2/.65542,.4/.72575,.6/.78814,.8/.84134,1/.88493,1.2
  .93319,1.5/.97725,2/.99379,2.5/.99865,3/.99997,4/1.5

* GENERATE 10,FN$EXP ARRIVING CUSTOMERS
  TRANSFER BOTH,PHON,WAIT USE PHONE IF NOT IN USE
  WAIT TRANSFER .5,LEAV,QUE HALF DECIDE TO WAIT
  LEAV ADVANCE 5 GO AWAY FOR FIVE MINUTES
  QUE ADVANCE WAIT TIL PHONE AVAILABLE
  PHON SEIZE PHONE START USING PHONE
  ADVANCE VI
  RELEASE PHONE FINISHED WITH CALL
  TABULATE 1 GATHER TIME STATISTICS
  TERMINATE 1

* FVARIABLE 8+2*FN$NORM TELEPHONE CALL TIME
  TABLE M1,0,5,30 TOTAL TIME DISTRIBUTION

* START 100 RUN FOR 100 CUSTOMERS
END

**SLAM Solution**

GEN,ARCHER,PHONE PROBLEM,5/3/84;

EXAMPLE PHONE BOOTH PROBLEM

LIMITS,1,1,100;

NETWORK:
CREATE,EXPON(10.),1,1,1; CUSTOMERS ARRIVE
ACT/1,,NNACT(6).EQ.0,QUE; GO TO PHONE IF NOT BUSY
ACT/2;
GOON,1;
ACT/3,0.5,QUE; HALF DECIDE TO WAIT
ACT/4,5.0,0.5,QUE;
HALF GO AWAY FOR 5 MINS
QUE QUEUE(1);
ACT/6,RNORM(8.,2.); WAIT FOR PHONE
COLECT,INT(1),TIME IN SYSTEM,30/0/5; TIME SPENT ON PHONE
TERM,100; STATS ON SYSTEM TIME
ENDNET; RUN FOR 100 CUSTOMERS
FIN;


Continued on Page 2...


Continued on Page 3...


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