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SIMULATION SOFTWARE: AN OPERATIONAL RESEARCH SOCIETY SURVEY OF ACADEMIC AND INDUSTRIAL USERS

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ABSTRACT

Simulation modeling is being widely used in areas such as manufacturing, health, network communications and military. Such popularity of simulation has resulted in a large number of simulation software tools available on the market. This paper presents the results of a survey on the use of simulation software, which has involved academic and industrial members of the Simulation Study Group of the Operational Research Society of Great Britain. Findings of the survey indicate which types of simulation software are primarily being used, the most common application areas of simulation, users' opinion about software and possible ways of improving simulation software.

1 INTRODUCTION

Due to increasing competitive pressures, many companies are forced to improve efficiency and reduce costs. Simulation modeling is being widely used for investigating possible strategies for performance improvement and alternative system configurations. Such popularity of simulation has resulted in a large number of simulation packages available on the software market. Despite this, it is apparent that there are various limitations and problems associated with these packages, and some user requirements are still not adequately met.

This paper presents the results of a survey of academic and industrial users on the use of simulation software, which was carried out in order to discover how the users are satisfied with the simulation software they use and how this software could be further improved. Participants in this survey are members of the Simulation Study Group of the Operational Research Society of Great Britain both from academic and industrial institutions. Findings of the survey indicate which types of simulation software are primarily being used, which are the most common application areas of simulation, common positive and negative features of software being used, and users' recommendations for further improvement of simulation software.

The paper is structured as follows. Following a brief review of previous simulation software surveys and their main findings, a survey conducted in this research is described. Results obtained from academic and industrial survey participants are presented separately and compared. Conclusions outline the main findings of this research and discuss general issues related to the features of simulation software packages currently available on the market.

2 USER SURVEYS ON SIMULATION SOFTWARE

Several publications related to the users' surveys are found in simulation literature. A dated survey carried out by Kleine (1970, 1971) has examined users' views of eleven discrete simulation languages. The results of this survey showed that it was difficult to interpret the results mainly because a limited number of respondents were proficient in more than one language. In addition, the expertise of some respondents was difficult to specify.

Christy and Watson (1983) have used a survey of non-academic users to explore issues such as the functional area that use simulation, the method of selecting simulation software, the popularity of various software tool for simulation applications etc. This analysis has revealed that, that of the total applications of simulation, 59% are in the area of manufacturing systems. Concerning the simulation software, the results showed that generally there is a reluctance to implement and learn new programming languages for simulation applications.

Kirkpatrick and Bell (1989) have used a survey approach to investigate the issues related to visual interactive simulation in industry. These issues included the types of problems being addressed, reasons for using visual interactive modeling, and the ways in which this type of modeling affects problem solving. The results have revealed that although the some of the participants are

aware of the significant set-up costs and need for learning new software and new methodology, most of them have agreed that visual interactive modeling provides enhanced interaction with decision maker, more useful and easier-to-understand models, and better decisions.

Van Breedam et al. (1990) have conducted a survey in order to evaluate several simulation software tools. They have distributed a questionnaire to experienced users of simulation, who were asked to rate a sample of simulation packages on the various criteria. On the basis of received answers, they have classified the software evaluated into clusters according to the main software features.

MacKulak and Savory (1994) undertook a survey in order to ascertain important features of industrial simulation environments. The results of the survey revealed that some of the most important software features specified by survey participants were consistent and friendly user interface, database storage capability for input data and a troubleshooting section in the documentation.

An analysis of the above presented surveys reveals that although a majority of the survey studies investigate various issues related to simulation software, none of them focus on users' opinions about possible ways to further improve simulation and to reduce some of the inherent problems associated with developing computer simulation models.

3 SIMULATION STUDY GROUP SURVEY

3.1 Objectives of the Survey

The main objectives of the survey were to investigate the user requirements of simulation software, the most common application areas of simulation and users' opinion about possible ways of improving current simulation software tools and better satisfying their needs.

The questionnaire distributed to the participants in survey consisted of nine questions dealing with the type of simulation software used (1), the specification of particular packages used (such as WITNESS, SIMFACTORY II.5, SIMAN/CINEMA, ProModelPC, XCELL+, INSTRATA or other) (2), the purpose of use of simulation (3), general opinion about each software used (4) and the application areas of simulation (5). Other questions include an estimation of how successful the simulation studies carried out were from the point of view of the software used (6), where users had to declare whether substantial approximations had to be made due to limitations of software, or whether all desirable features of the systems under consideration could be modeled. The participants were also asked to list the main weaknesses and limitations of software used (7), as well as the most important positive features included in software used (8). The last question relates to specification of the most important features that should be included in the existing simulation packages that were to their knowledge not yet provided (9). A majority of the questions regarding the opinion about the software and possible ways of its improvement (questions 4,6,7,8 and 9) were open-ended instead of providing several alternatives to select from. It was believed that this approach would avoid any suggestions to the participants and give better and unprejudiced response.

3.2 Survey Sample

The survey sample includes members of the Simulation Study Group (special interest group) of the Operational Research Society of Great Britain, both from industry and academic institutions. It was believed that survey participants were actively involved in simulation (the results of the survey have confirmed that assumption) and/or had a substantial interest in simulation. A number of academics from universities across Great Britain have participated in the survey as well as participants from the industry working for various manufacturing, service, consulting and research companies.

The survey sample was not selected by any formal statistical method. The participants, for whom it was known or believed to be regular users of simulation, were selected deliberately. On the other hand, a response rate was reasonable 25% out of 220 distributed questionnaires. The ratio of responses from universities and responses from industry is about 66% to 33%, although an approximately equal number of the questionnaires was distributed to each group of users. Not only the response rate was significantly higher from the users from universities, in average each response from academic participants provided more information then the response from the users in industry. All these facts might raise the question of statistical significance of obtained results. However, it is believed that intentional selection of survey participants experienced in simulation enhances the importance and representativeness of results.

4 RESULTS OF THE SURVEY

The responses of the survey are classified in two groups, distinguishing academic users and users in industry. The main reason for this was to discover whether and how the purpose of use influences the requirements of the simulation software.

4.1 Responses from Academic Users

With regard to the type of software used, 83.3% of the users at universities use simulators, and at the same time 61.1% use simulation languages as well. Analysis of the specification of simulation software tools used reveals that 27.7% of the users use only one software tool, 27.7% use two software tools, and the rest use up to seven different software packages. Table 1 summarizes results obtained

regarding specific packages being used, whilst Table 2 shows the results related to the number of simulation packages used.

Table 1: Specific Simulation Packages Used by Academic Participants

SIMULATION PACKAGE	*PERCENTAGE OF USERS (%)*
Simul8	44.4%
WITNESS	38.8%
Siman/Cinema	33.3%
SIMFACTORY II.5	27.7%
MicroSaint	27.7%
ProModelPC	16.6%
VS7	16.6%
XCELL+	11.1%
Arena	11.1%
MODSIM	11.1%
INSTRATA	11.1%
G.R.A.S.P.	11.1%
WORKSPACE	11.1%
HOCUS	11.1%
Taylor II	11.1%
VS6	11.1%
OPTIMA	11.1%
Process Charter	11.1%
PC-model	11.1%
SIMSCRIPT	11.1%
SIMULA	11.1%
GPSS/H	11.1%
NETWORK II.5	11.1%
SLOOP/TERMINAL	11.1%

Table 2: The Number of Simulation Packages Used by Academic Participants

NUMBER OF SIMULATION PACKAGES USED	*PERCENTAGE OF USERS (%)*
1	27.7%
2	27.7%
3	11.1%
4	11.1%
5	11.1%
6	5.5%
7	5.5%

With regard to the purpose of simulation, 77.7% of participants use simulation for modeling real systems, 100% use simulation for education (77.7% of the users use simulation both for modeling real systems and education), 11.1% of participants use simulation for research and 5.5% use simulation for consulting work.

Common elements from the responses regarding the general opinion about the software used are summarized in Table 3, together with the percentage of users that have specified a certain software feature.

Table 3: A Summary of Users' General Opinion about Software (Academic Users)

SOFTWARE FEATURES	*PERCENTAGE OF USERS (%)*
Lack of modeling facilities /flexibility	44.4%
Extensive modeling facilities /flexibility	38.8%
Easy to use	27.7%
Difficult to learn	22.2%
Good for teaching	22.2%
Inexpensive and good value	16.6%
Expensive	16.6%
Easy to learn	16.6%
Dated	16.6%
Good for developing models of real systems	16.6%
Good graphical interface	11.1%
Models are easy to develop	11.1%
Difficult to link to other software	11.1%
Lack of language interface	11.1%
Lack of good user interface	5.5%
Average modeling facilities	5.5%
Slow to run	5.5%
Good speed	5.5%
Poor logic facilities	5.5%
Simple	5.5%
Good automatic statistics collection	5.5%

The analysis of the results related to application areas of simulation reveals that manufacturing is significantly dominant (83.3%). Other application areas include, for example, health, service industry, oil terminals and traffic modeling. Table 4 illustrates the application areas in which simulation is used and the percentage of participants involved in a specific area.

When being asked about the success of modeling, 41.2% of participants declared that they have been able to model desirable features of the systems being modeled, whilst 58.8% had problems in modeling due to the software limitations and inflexibility.

Table 5 summarizes the responses regarding the main limitations and weaknesses of the software used including the percentages of the certain responses, whilst Table 6 summarizes the responses regarding the most important positive features of software used.

Finally, a summary of the features that users would like to be incorporated in the simulation software that could improve the software they use is presented in Table 7.

Table 4: The Application Areas/Type of Simulation (Academic Users)

APPLICATION AREAS OF SIMULATION	*PERCENTAGE OF USERS (%)*
Manufacturing	83.3%
Health	27.7%
Service industry	11.1%
Queuing modeling	11.1%
Oil terminals	11.1%
Defense	11.1%
Business processes	5.5%
Office systems	5.5%
Agricultural and food automation equipment	5.5%
Chemical industry	5.5%
Traffic	5.5%
Satellite ground segment	5.5%
Communication systems	5.5%
Waste processing	5.5%

Table 5: A Summary of Users' Opinion about the Main Limitations of Software Used (Academic Users)

SOFTWARE LIMITATIONS	*PERCENTAGE OF USERS (%)*
Limited standard features/flexibility	33.3%
Difficult to learn	22.2%
Expensive	16.6%
Inadequate guidance in experimentation	16.6%
Lack of software compatibility	11.1%
Lack of output analysis facilities	11.1%
High cost of support and training	5.5%
Use of dongle	5.5%
Lack of on-line help	5.5%
Lack of complex languages within the package	5.5%
Inadequate processing power	5.5%
Inadequate graphical accuracy	5.5%
Lack of real-time accuracy	5.5%
Poor logic	5.5%
Too much distracting emphasis on animation	5.5%
No access to system events	5.5%
Poor facilities for developing own user interface	5.5%
Slow	5.5%
Dated	5.5%
Difficulty of validating models	5.5%

Table 6: A Summary of Users' Opinion about the Most Important Positive Features of Software Used (Academic Users)

MAIN POSITIVE FEATURES OF SOFTWARE	*PERCENTAGE OF USERS (%)*
Ease of modeling	61.1%
Good animation/visual facilities	50.0%
Flexibility/linking to external code	22.2%
Modeling speed	16.6%
Graphical interface	11.1%
Input and output analysis features	5.5%
Linking to other packages	5.5%
Low price	5.5%
Ease of statistics collection	5.5%
Interactivity	5.5%
Variable animation speed	5.5%
Modularization of models	5.5%

Table 7: A Summary of Users' Opinion about the Features that should be Included in Simulation Software (Academic Users)

DESIRED SOFTWARE FEATURES	*PERCENTAGE OF USERS (%)*
Further developments making packages easier to learn and use	16.6%
Better experimentation support	11.1%
Better analysis of results and data displays	11.1%
Extensive standard features	11.1%
Internal system for creating user logic	11.1%
More but easier flexibility	11.1%
Output design and analysis	11.1%
Iconic programming/graphical model building	11.1%
Better presentation of the model on the screen and in the printout	11.1%
An "intelligent" interface that would advise in number of replications, warm up period, batch size etc.	5.5%
Virtual reality	5.5%
Complete accuracy with the physical world	5.5%
Real-time animation	5.5%
Access to system events	5.5%
Good facilities for developing own user interface (to create sub-simulators)	5.5%
Better links with other packages	5.5%
Facilities for batch running and collection of statistics	5.5%
Better Graphical User Interface	5.5%
Better statistical facilities	5.5%
Multimedia features	5.5%

4.2 Responses from the Users in Industry

Considering the type of software used, 55.5% of the users in industry use simulators, and 22% use simulation languages. The remaining users either use ad hoc programs in general purpose language or spreadsheet. Over half of survey participants (55.5%) use only one software tool, 33.3% of participants use two software tools, and finally 11.1% use three different software packages. None of the participants indicated that more than three packages are used.

Considering the purpose of simulation, 88.8% of participants use simulation only for modeling real systems, and the remaining participants use simulation for research, whilst nobody is using simulation for educational purposes. Table 8 shows which packages are used by survey participants from the industry.

Table 8: Simulation Packages used by Industrial Participants

SIMULATION PACKAGE	*PERCENTAGE OF USERS (%)*
WITNESS	22.2%
ProModelPC	11.1%
Simul8	11.1%
Factor/Aim	11.1%
SES/Workbench	11.1%
Extend	11.1%
BATCHES	11.1%
SIMULA	11.1%

Analysis of the responses regarding the general opinion about software used is summarized in Table 9, together with the percentage of users that have specified a certain software feature.

Table 9: A Summary of Users' General Opinion about Software (Industrial Users)

SOFTWARE FEATURES	*PERCENTAGE OF USERS (%)*
Powerful tool	33.3%
Comprehensive package	22.2%
Not flexible	22.2%
Lack of hierarchical/modular approach	11.1%
Ease of animation	11.1%
Difficult to learn	11.1%
Easy to use	11.1%
Good value for the price	11.1%
Expensive	11.1%
Flexible	11.1%
Presentable	11.1%
Easy to create reusable code	11.1%
Inadequate graphic front end	11.1%

Table 10 summarizes information related to application areas of simulation indicated by industrial survey participants.

Table 10: Application Areas/Type of Simulation (Industry)

APPLICATION AREAS OF SIMULATION	*PERCENTAGE OF USERS (%)*
Manufacturing	33.3%
Communications	22.2%
Distribution	22.2%
Trading	11.1%
Analysis of statistical sampling problems in surveys of industry	11.1%
Stock control of stocks of cash for a multi-branch bank	11.1%
Packing halls	11.1%
Customer service	11.1%
Compiler networks	11.1%
Business processes	11.1%
Repair	11.1%

Concerning the success of modeling, 75% of participants report that they have been able to model desirable features of the systems, whilst 25% had problems in modeling because of the software limitations and inflexibility.

Tables 11 and 12 summarize the responses regarding the main limitations and weaknesses of software used and the responses regarding the most important positive features of software used, respectively.

Table 11: A Summary of Users' Opinion about the Main Limitations of Software (Industrial Users)

SOFTWARE LIMITATIONS	*PERCENTAGE OF USERS (%)*
Expensive	22.2%
Data input	22.2%
The lack of ability to build a modular type of simulation	11.1%
Crude results package	11.1%
Need to have more work entries in a model then correspond to reality the use of dummy work-centers	11.1%
Dated	11.1%
Lack of the integration of scheduling and simulation packages	11.1%
Initialization	11.1%
Statistical features	11.1%
Output analysis	11.1%

Table 12: A Summary of Users' Opinion about the Most Important Positive Features of Software (Industrial Users)

MAIN POSITIVE FEATURES OF SOFTWARE	*PERCENTAGE OF USERS (%)*
Visual/graphics	33.3%
Speed of model development/testing.	33.3%
Ease of use/ ease of model building	22.2%
The results summary	11.1%
VR functionality	11.1%
Number crunching	11.1%
Unlimited functionality via C coding.	11.1%
Easy to create reusable code	11.1%
Flexibility	11.1%
Interactivity	11.1%
Portability	11.1%
	11.1%

Table 13 presents a summary of the features that industrial users would like to be incorporated in simulation software, and which to their knowledge does not yet exist in software they use.

Table 13: A Summary of Users' Opinion about the Features that should be Included in Simulation Software (Industry)

DESIRABLE SOFTWARE FEATURES	*PERCENTAGE OF USERS (%)*
The integration of scheduling and simulation packages	22.2%
Experimentation managers across scenarios/project	22.2%
A several purpose library of facilities to extract ready-built components of simulation	11.1%
Ability to do IF/THEN/ELSE logic	11.1%
A facility to print out by one command, all the parameter values, object specifications and routings/logic within a model	11.1%
A cross referencing capability, that is providing ready answers to questions such as where are all references to a given attribute to be found	11.1%

5 AN ANALYSIS OF SURVEY RESULTS

The results of the survey could be viewed with caution, as survey sample is relatively small. Nevertheless, these results reveal that there are both similarities and differences in the responses obtained from two different groups of users. A certain degree of consistency in responses identified in both groups of survey participants could imply that some of the responses could be applicable to a wider simulation community.

Concerning the type of software being used, over three-quarters of academic users use simulators and over half of them use simulation languages as well. On the other hand, just over half of industrial users use simulators, and the rest use simulation languages, general purpose programming languages or spreadsheet. The reason for a high percentage of academics using both simulators and simulation languages is the fact that about three quarters of these participants use more than simulation package (up to seven different packages), whilst over half industrial participants use only one software tool and nobody uses more than three packages. Many academic participants are combining education, research and real life projects, and they have probably obtained most of these software tools with an educational discount. On the other hand, users in industry tend to use more flexible simulation and general-purpose languages, have less tools at disposal and they usually have to pay a full price of the package.

With regard to the purpose of simulation, it is interesting that over three quarters of users at universities (77.7%) use simulation both for education and modeling real systems, which indicates that many of academic participants in the survey are involved in research and working on real life projects. As it could be anticipated, almost 90% of industrial users use simulation for modeling real-life systems, and nobody uses simulation for educational purposes.

An analysis of the open-ended questions regarding the general opinion about the software used, positive, negative and desirable software features reveals that users in universities have listed the features that are to a certain extent similar to those specified by users in industry, although some differences are also apparent. The main reason for similarities is involvement of majority of academics in modeling real systems in addition to teaching. Simul8 is the most widely used package by academic participants followed by WITNESS which is most widely used package by industrial survey participants.

A general opinion about the software used shows that the main objection by academic users is that software is lacking extensive modeling facilities and flexibility (although at the same time a slightly smaller percentage of academic users indicated the opposite, i.e. that packages do provide extensive facilities and flexibility). A significant percentage of academic participants indicated that software is in general easy to use and good for teaching but also difficult to learn. Over a third of industrial participants consider software they use to be powerful, and the equal slightly smaller percentage of participants consider software to be both comprehensive and not flexible.

An analysis of the application area of simulation for both groups of users reveals that manufacturing is dominant, especially for academic users (83.3%). One third of

academic users also use simulation for modeling health-related systems (such as clinical treatments or hospital clinics), and only 5.5% use simulation for modeling business processes. In addition to manufacturing, industrial users use simulation for communications and distribution modeling and some other less notable application areas.

The main software limitations for academic users are limited software flexibility and difficulty of learning, whilst limitations indicated by industrial users are first of all high price and problems with data input. A complaint about the lack of flexibility could be caused by a high percentage of academics using simulators that are believed to be less flexible than simulation or general purpose languages (used more often by industrial participants). Data input is probably a problem for industrial participants because they would normally have to handle large quantities of data when real systems are being modeled, and industrial companies would not qualify for educational software discount.

The consensus between two groups of survey participants is apparent when positive software features are considered. Both groups predominantly stated that the main positive features are ease/speed of model development and visual facilities. However, the survey results reveal that there is no consensus even within the same group of participants with regard to desirable features that users would like included in software, which is also a result of an open-ended style of questions. These features vary considerably within each group, showing that software preferences are to a large extent matter of an individual taste and expectations. The only common features specified by both groups are better links with other packages (software compatibility) and more assistance in experimental design.

6 CONCLUSIONS

The above presented simulation software users' survey reveals to what extent the users who participated in this survey are satisfied with software and how they would like this software to be further improved. A general analysis of all results obtained shows that simulation software currently being used by all participant in this survey is predominantly easy to use, with good visual facilities, but too limited for complex and non-standard problems and too expensive. A substantially dominant application area of simulation is manufacturing for both groups of users, although it is apparent that simulation can be used successfully in other domains such as business process modeling (Hlupic 1998). There are a variety of features that users have requested that dominantly refer to more assistance in experimental design, better flexibility and improved software compatibility.

The results of the survey also reveal that there is more consensus between academic and industrial survey participants with regard to positive and negative feature then with regard to desirable features to be included in packages. It is apparent that no single package could possibly incorporate all desirable features, being at same time very easy to learn and use, inexpensive, with excellent graphical facility, extensive flexibility and standard features, and intelligent features for experimental design and output analysis. This statement could be substantiated by comments made by one of the survey participants claiming that packages are hard to use well on problems that diverge even a little form that the designer had in mind, and off the shelf software means the answer to somebody else's problem.

Nevertheless, despite problems indicated the desirable features specified by survey participants could be a useful indicator of users' needs that software developers might want to use in order to further improve simulation software by providing more flexibility achieved by less modeling efforts.

REFERENCES

Christy, D.P. and H.J. Watson. 1983. The Application of Simulation: A Survey of Industry Practice. *Interfaces* 13(15):47-52.

Hlupic, V. 1998. Business Process Re-engineering and Simulation: Bridging the Gap. Proceedings of the *European Simulation Multiconference ESM'98*, Manchester, United Kingdom, June 1998, (Ed.by Zobel R. and Moeller D.), SCS:641-645.

Kirkpatrick, P. and P.C.Bell. 1989. Visual Interactive Modelling in Industry: Results form a Survey of Visual Interactive Model Builders. *Interfaces* 19(5): 71-79.

Kleine; H. 1970. A survey of users' views of discrete simulation languages. *Simulation* May 1970: 225-229.

Kleine, H. 1971. A survey of users' views of discrete simulation languages (the second survey). *Simulation* August 1971: 89-94.

Mackulak, G.T. and P.A. Savory. 1994. Ascertaining Important Features For Industrial Simulation Environments. *Simulation*, 63 October 1994:211-221.

Van Breedam, A. 1990. Segmenting the Simulation Software Market. *OR Insight* 3(2): 9-13.

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