Vidyodaya J. of Humanities and Social Sci,(2008) Vol. 02 pp 291 - 304

A Case for Accelerating the Simulation Model Development Process: An Empirical Study

S. T. W. S. Yapa

Department of Decision Sciences, University of Sri Jayewardenepura

D. R. Clegg and T. D. S. Perera

Materials and Engineering Research Institute,
Sheffield Hallam University, Sheffield, UK.

Abstract

It is noted through reading the literature on simulation project life cycle that model development is the most time consuming stage. The findings of the questionnaire survey administered among practitioners and academics also support the findings of the literature survey. Further, the questionnaire survey suggests that conceptual model development is the most difficult task in developing the simulation model. Therefore, it is suggested to conduct further research in developing a methodology to accelerate the simulation model development process in the line of improving the understanding between the user and the modeller.

Key words : Simulation model development, Conceptual model

1. Introduction

Simulation is one of the most powerful tools available for engineers and managers in industry to analyse the effectiveness of the as-is and to-be systems. Typically, simulationists follow three generic steps in a simulation project development process. ; i.e. identification of the problem/ problem formulation, model building, and experimentation and implementation. As a part of a research done to develop a novel methodology for accelerating simulation model development process a questionnaire survey was done among academics and professionals. The objective of the survey was to validate secondary data gathered through the literature survey. An e-mail questionnaire survey was conducted among academics and practitioners. This paper compares the findings of the literature survey with results of the questionnaire survey. Findings from the literature survey are presented in section 2 and a description of questionnaire survey is shown in section 3. Findings of the questionnaire survey are presented in section 4. Those findings are discussed in section

5. and further research identified based on the results of the survey are explained in section 6. Finally, conclusions are drawn in section 7.

2. Literature Review

Even though different authors have divided the simulation model development process into number of stages between 2 and 5, three generic stages can be identified, namely; Conceptual model building, Computer model building and Model verification and validation. A conceptual model is essentially a model where mathematical and logical relationships are defined (Oakshott, 1997; Sargent,2000; Banks, 2000). It is seen as a model that is formulated completely independent of any programming language or simulation language (Arons, 1999). According to Mehta (2000) it is extremely useful to map out or structure the model on paper before building the model. According to Robinson (1994), a day on paper saves a month on a computer. Practitioners are having the view that many of the pitfalls in the latter stages of the simulation model development process can be avoided by structuring conceptual model before building it on the computer (Robinson, 1994; Shannon, 2000; Mehta, 2000).

Once the conceptual model is built, it is translated into the computer model. Computerized model is the conceptual model implemented on a computer (Sargent, 2000). According to Shannon (1998), modellers have three generic choices in formulating the computer simulation model, namely:

- Build the model in a general-purpose language such as C++ or Visual Basic
- Build the model in a general purpose simulation language such as SIMAN or GPSS
- Use a special purpose simulation package (simulator) such as WITNESS or EXTEND

More than fifty simulation software, simulators and simulation languages, are available in the market from various vendors at different prices ranging from less than US$50 - US$48,000 and almost all of them are PC based and Windows compatible (Swain,2001). Programming-like commands and interfaces with programming languages are features which make a simulator flexible. But the distinction between simulators and simulation languages is blurring. They are moving toward each other by offering special features (Nikoukaran and Paul, 1999).

With the wide spread use of Windows environment in PCs in 1990s graphical user interface (GUI) entered in to the simulation software. This involved the use of graphical objects or icons to represent parts of the model. The model could then be developed by linking these icons together in a logical fashion. They often incorporate a range of functions to assist in data input and output analysis (Oakshott, 1997). Modern simulation software such as ARENA and AUTOMOD combine the ease of use of a simulator with the power and flexibility of a simulation language (Kelton et. al, 1998; Rohrer, 2000). However, according to Koh et al. (1996) simulation modelling still requires a high level of training, expertise and time, despite the availability of user-friendly simulators with their graphical use interface (GUI) modelling environment.

Even though simulators have received wide acceptance among simulation users a recent survey conducted among academic and industrial simulation users has shown that majority of them still use simulation languages as well (Hlupic, 2000). The findings of the above research suggest that still modellers face difficulties in developing models by using simulation languages and/or simulators. Another reason for the use of general-purpose languages on simulation model development may be the high cost of simulation software. For example Arena standard version costs US$ 13,500, AUTOMOD standard costs US$15,000 and ProModel costs US$ 18,500 (Swain, 2001).

After building the computer model, it is to be tested to find out syntax and logical errors. Debugging a simulation model that is developed using a simulation language can be tedious and time consuming (Oakshott, 1997; Sadowski and Grabau, 1999; Sargent, 2000). Further, it is an iterative process (Robinson, 1994). Several versions of a model are usually developed prior to obtaining a satisfactory valid model (Sargent, 2000; Oakshott, 1997). Often when simulation is used to validate a system design, the design itself will change multiple times. This in turn forces the model to be reworked, or sometimes even recreated (Johnson, 1999). Sometimes the modeller even has to re-work the model from scratch.

Model building and experiments are the most time consuming stages of a simulation project (Robinson, 1994). Literature suggests that deriving a simulation model from an understanding of the system to be simulated is perhaps the most complex and time-consuming task of the simulation life-cycle. (Sakthivel and Agrawal, 1992; Trybula,1994; Umeda and Jones, 2001; Brown and Powers, 2000; Arons, 1999).

In a panel discussion done at the 2000 Winter Simulation Conference on the topic *Simulation In The Future*, all 8 panellists (simulation consultants) emphasized the need for providing more modelling capabilities to users of simulation software. Their suggestions include tighter integration with other software, web based simulation and library driven simulation models (Banks, 2000).

The simulation models created are typically of the "analysis and throw away" type. In other words these models were developed, validated, experimented and filed away (Koh et al., 1996). Often multiple models are built to simulate similar systems that have small differences (Brown and Powers, 2000). In the field of simulation of manufacturing systems this issue often occurs, when different systems with some similar features have to be managed. According to Kovács et al. (1999) the basic components of different FMS and FMCs (Flexible Manufacturing Cells) are the same type of machine tools, robots, transfer equipment etc. In the relevant aspects they usually differ from each other only in their quantity and working parameters. As pointed out by Arons (1999) the modeller constantly has the feeling that he is reinventing the wheel again and again despite the advance tools provided by simulation languages. However, Paul and Taylor (2002) point out that in the world of COTS [commercial-off-the-shelf] simulation packages, it is difficult to see practically how one can trust a model without detailed verification that may be more costly than developing the model from the start. Therefore, authors have different opinions about reuse of simulation models.

The introduction of low-cost simulation tools has diversified the customer base for discrete-event simulation (Stanford and Graham, 1998). According to Umeda and Jones (2001) recent advances in number of technologies have provided industrial users with high performance computer hardware and graphical user interfaces (GUI). These advances have made possible to run simulation tools on desktop computers. Rathburn and Weinroth (1999) have identified two categories of the impediments to providing *desktop simulation* to managers. First, the manager's lack of technical skill in the development of the simulation code often limit the ability of the decision maker to develop appropriate models. Second, current simulation model development methodology discourages exploration of variations in the model. Especially with the entry of non-experts into the simulation field in areas such as business process re-engineering, a gap had been created between domain experts, those who are having a good knowledge about the system to be modelled, and simulation experts, those who are modelling and analyzing the system. According to Benjamin et al. (2000), recent advances in the area of simulation modelling represent important advances for improving the productivity of simulation modellers, but do little to aid the non-simulation trained-decision maker.

In this context we believe that there is a need for simulation software which provide efficient and simple methods which may lead to accelerate the simulation model development process. To justify our belief and to find a direction for a new approach for accelerating simulation model development process the following assumptions were made based on the literature.

- Model building is the most time consuming phase of the simulation project life cycle.
- A conceptual model is built before the computer model is built.
- There is a tendency to undertake simulation projects by persons having non-engineering/mathematics background as well.
- Previously built models can be re-used to build new models
- Simulationists use simulation languages and general purpose languages instead of or in conjunction with simulators.

However, since all the mentioned assumptions were solely based on the literature, a e-mail survey was conducted among academics and practitioners in the simulation area in order to verify the facts collected through literature survey. Details of the questionnaire survey and the results are presented in the next section.

3. Questionnaire Survey on Simulation Model Development

Concise questionnaire was designed to collect information of respondents regarding their current profession, degree/professional qualifications, number of simulation models built, their perception about the difficulty of each stage of the simulation project life cycle, percentage time required to complete each stage of the simulation project life cycle, the types of software used to develop simulation models (Special Purpose Simulation Languages/Simulators/General Purpose Language), type of software used to model development/experimentation (MS_Excel, MS_Access, Visio, VBA). Further, one question was included to measure the agreement with certain statements regarding the simulation model development process based on the literature.

The questionnaire was distributed to electronic mail boxes of the members of the SIGSIM simulation group (520 members), one of the largest simulation groups sponsored by Association for Computing Machinery and the participants of the Winter simulation conference (377 e-mail addresses), one of the largest conferences of the world on simulation. Fifty-four of the recipients returned filled questionnaire. The findings of the survey are discussed in the following section.

4. Findings of the Questionnaire Survey

Table 4.1 shows the percentage of respondents having different qualifications. The majority of the respondents have a qualification/degree in operations research.

Qualification	Total	%(out of 54)
Production Manufacturing Engineering	7	12.96
Mechanical Engineering	3	5.56
Operations Research	**27**	**50.00**
Systems Modelling	9	16.67
Software Engineering	13	24.07
Business Management	9	16.67
Other (Chemical Eng)	1	1.85

Table 4.1: Qualification/Degree held by respondents

The experience of the respondents in the simulation area is shown in table 4.2. Even though it is not conclusive, it appears that simulation has lost its popularity during the late eighties and early nineties and gained it during the mid nineties. Since 81% of the respondents have at least 5 years of involvement with simulation it is believed that the respondents gave an informed answers to the questions posed.

Experience	Total	%(out of 54)
Under 5	10	18.52
5-10 Yrs	11	20.37
10-15 Yrs	6	11.11
15-20 Yrs	12	22.22
Over 20	15	27.78
Total	54	

Table 4.2: Duration of involvement of respondents in the simulation area

The objective of the next question was to measure the difficulty of each task during a simulation project. Respondents were asked to indicate the perceived difficulty of each stage in a scale from 1 to 5 (1-Most difficult to 5-Least difficult). The results reveal that conceptual model development is the most difficult task while experimentation is the least difficult task.

Stage	Mean Difficulty
Problem/Objective Definition	2.87
Conceptual Model Building	**2.51**
Simulation Model Development	2.74
Experimentation	3.6
Project Completion and implementation	3.19

Table 4.3: Mean difficulty of each stage of the simulation project

Table 4.4 shows that the model building is the most time consuming task among the stages of the simulation project life cycle. This concurs with the findings of the literature survey.

Stage	Mean%	Min %	Max %
Problem/Objective definition	18.8	10	40
Model building and testing	**40.7**	**10**	**70**
Experimentation	25.3	10	60
Project completion and Implementation	20.8	5	50

Table 4.4: Percentage times needed for different stages of the life cycle

Tables 4.5, 4.6 and 4.7 show the percentage of respondents use different simulation languages, simulators and general-purpose languages for model development respectively.

Simulation Language	Number	As a % of total
SIMAN	11	20.37
SLAM	6	11.11
SIMSCRIPT	3	5.56
GPSS	5	9.26
Other	5	9.26
None	24	44.44

Table 4.5: % of respondents use different simulation languages

As shown in table 4.6, Arena is the most popular simulator.

Simulators	Number	% of total
Arena	22	40.74
Extend	7	12.96
Promodel	7	12.96
Automod	3	5.56
Witness	3	5.56
SImul8	3	5.56
AweSim	3	5.56
Emplant	3	5.56
Quest	1	1.85

Table 4.6: % of respondents use different simulators

Since no questions were posed to the respondents regarding the reasons for selecting simulation software it is impossible to derive any reasons for popularity of one language or a simulator over the others. However, possible reasons may be that the length of period they were in the simulation software market, inclusion of certain software into curriculum of the first degree courses, marketing strategies of different companies, user friendliness, availability of free or low cost student versions, availability of literature and user groups, easiness of leaning and animation capabilities.

Table 4.7 reveals that still general purpose languages are widely used for simulation model development. Nine of the respondents, (17%), use solely a programming language (neither simulation language nor simulator) for simulation model development process.

Language	Number	% of Total
C++	26	48.15
VB	13	24.07
Java	9	16.67
Other	9	16.67

Table 4.7 : % of respondents use general purpose programming languages

Percentage number of respondents use spreadsheet, database or drawing software and VBA to integrate them in simulation model development/experimentation is shown in table 4.8.

Package	Number	% of Total
MS_Excel	39	72.22
Access	15	27.78
VBA	13	24.07
Visio	9	16.67

Table 4.8 : % of respondents use spreadsheet/database/drawing and integration software

The objective of the last question was to know the level of agreement regarding few statements formed based on the contemporary literature. The agreement was varied from strongly agreed to strongly disagreed and was measured in a scale from 1 to 5. Table 4.6 shows the results.
Table 4.8: Agreement with statements (Strongly agree 1 to strongly disagree 5)

Statement	Agreement
Models are frequently simplified due to limited time allocated for projects	2.5
Sometimes I had to reduce time for experimentation because I had spent more time on model building	3
Previously built models are frequently re-used to build new models	3
There are large number of people who have not studied a scientific discipline, building simulation models	3
New issues arose during the experimentation stage lead me to re-build new models/modify built models	2
I build a conceptual model before building a simulation model	2

In section 2 we made several assumptions based on the available literature. The following section discusses whether the findings of the study confirm or nullify the assumptions.

5. Discussion

- Model building is the most time consuming phase of the simulation project life cycle.

As shown in table 4.4, it is perceived that on average 41% of the total project life cycle time spend on model development and testing. Further, when considering the mean difficulty (table 4.3), the most difficult tasks of the simulation model development process are conceptual model development and the simulation model development which are sub-stages of the model building process. Therefore the findings of the survey support this assumption.

- A conceptual model is built before the computer model is built.

In general the respondents agree with this statement. Further, according to the responses conceptual model development is the most difficult task of a simulation project.

- There is a tendency to undertake simulation projects by persons having non- engineering/mathematics background as well.

Generally the respondents do not agree with this assumption. The constitution of the respondents also does not support this idea. Only 2% of the respondents do not have a qualification in a science/mathematics discipline. Further, only 3% of the respondents use **solely** a simulator for simulation model development, i.e. 97% of the respondents use at least one simulation language or a general purpose programming language. This indicates that even with all efforts by simulation software vendors to make their products more user friendly, still simulationists find it difficult to build models only with simulators. This situation may discourage persons without a qualification in a scientific discipline to enter into the simulation field.

- Previously built models can be re-used to build new models.

It is to be noted that authors have mixed opinions about the re-use of simulation models. Findings of the survey do not confirm this assumption. In practice it seems that participants prefer to build models from the scratch rather than re use an existing model. According to Pressman (2000) many software practitioners continue to believe that reuse is "more trouble than its worth". From the findings of the survey, it seems that this expression is also valid in the case of simulation model reuse as well. Theoretically, reuse sounds appealing. However, in practice hardly two models are the same. Therefore, it is very difficult, if not impossible, to find a similar previously built model from a library either manually by the modeller or with the help of a knowledge based system.

- Simulationists continue to use simulation languages and general purpose languages instead of or in conjunction with simulators.

There is strong evidence to support this assumption. As mentioned earlier 97% of the respondents use at least one simulation language or a general purpose programming language. Further 9% of the respondents use only a general purpose language for simulation model development. This indicates that even with all the improvements in simulators, modellers still require the flexibility provided through programming languages for developing simulation models. However, the problem with using a programming language for simulation model development is that the modeller has to spend lot of time learning a programming language. Hence, there is still a need for improving model development capabilities of simulators. This will allow the users to develop simulation models by using simulators rather than learning a new language. Another finding of the survey was that seventy three percent of the respondents use at least one of MS_Excel, MS_Access or Visio either in the model development or experimentation stages.

6. Further Research

As initially suspected through reading the literature and confirmed through the results of the questionnaire survey, model development occupies the greatest proportion of time spent on a simulation project. According to Benjamin et al.(2000), only a fraction of the potential practical benefits of simulation modelling and analysis have reached the potentially large user community because of the relatively high requirement of time effort and cost needed to build and successfully use simulation models. It is therefore proposed that further research be undertaken to reduce the time spent on model development thereby to reduce the total duration of a simulation project.

The respondents of the survey agree with the statement that new issues arose during the experimentation stage lead them to re-build new models/modify built models. The most probable reason for this phenomenon may be that the model built by the modeller may not be the model required and explained by the user. As pointed out by Benjamin et al.(2000), simulation suffers lack of wide acceptance by decision makers due to a number of factors including a) the semantic gap between the description of a system expected by the decision maker and abstract model constructed by the simulation modeller, b) the relatively long lead times and communication efforts required to produce a simulation model and c) the extensive training and skill required for the effective design and use of simulation modelling techniques.

The best way to avoid the understanding gap between the user and the modeller would be to develop a tool which enables the user to develop the model by himself. But the findings of the survey reveal that the simulationists play a major role in simulation model development process. Therefore a new methodology for accelerating the simulation model development process by improving the communication between the user and the modeller is being developed. The respondents of the survey agree with the statement that they develop a conceptual model before building a simulation model. Further, findings revealed that conceptual model building is the most difficult task of the simulation project. Therefore it is believed that if a modeller is provided with tools which support building conceptual model in consultation with the user, he could build the model expected by the user in a shorter period of time than currently able. However, in order to make that the developed conceptual model is not wasted, it is necessary to have a tool to automatically translate the developed conceptual model into the computer model.

7. Conclusion

The literature suggests that even with all the development in simulation software there remains a need for accelerating the simulation model development process. Findings of the e-mail survey conducted too support those suggestions. Therefore there is a need for further research on finding a new methodology to accelerate the simulation model development process. The findings of the questionnaire survey suggest that improving communication between the modeller and the user will reduce the time needed to develop the simulation model. This fact can be used as a guide in developing the new methodology.

References

Arons, H. de S., (1999), "Knowledge-Based Modeling of Discrete-Event Simulation Systems" in the Proceedings of 1999 Winter Simulation Conference Eds. Farington P. A., Nembhard H. B., Sturrock D. T. and Evans G. W., pp 591-597

Banks J. (2000) "Introduction to Simulation", in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., Barton R. R., Kang K. and Fishwick P.A., pp 9-16

Benjamin P. et al. (2000) "A Model-Based Approach for Component Simulation Development" in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., R. R. Barton, K. Kang and P.A. Fishwick, pp 1831-1839

Brown N. and Powers S. (2000) "Simulation in a Box (A Generic Reusable Maintenance Model", in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., Barton R. R., Kang K. and Fishwick P.A., pp 1050 - 1056

Hlupic V. (2000) "Simulation Software : An Operational Research Society Survey of Academic and Industrial Users", in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., Barton R. R., Kang K. and Fishwick P.A., pp 1568-1576

Johnson T. (1999) "Building Data-Driven Template Model", Autosimulation Symposium '99

Kelton W. D., Sadowski R.P. and Sadowski D. A. (1998) "Simulation with Arena", Mc-Graw Hill, Singapore, International Editions.

Koh K.H., de Souza R., Ho N.,(1996) "Database Driven Simulation/Simulation-Based Scheduling of a Job Shop", Simulation Practice and Theory, 1996(4) pp 31-45

Kovács G. L., Kopácsi S., Nacsa J., Haidegger G. and Groumpos P., (1999) " Application of Software Reuse and Object-Oriented Methodologies for the Modelling and Control of Manufacturing Systems", Computers in Industry, 1999(39) pp177-189

Mehta A. (2000) "Smart Modeling-Basic Methodology and Advanced Tools" in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., Barton R. R., Kang K and Fishwick P.A., pp 241-245

Nikoukaran J. and Paul R..J.(1999), "Software selection for simulation in manufacturing : a review", Simulation Practice and Theory, 1999(7), pp1-14

Oakshott L., (1997) Business Modeling and Simulation, Pitman Publishing, London

Paul R.J. and Taylor S.J.E. (2002) "What Use is Model Reuse: Is There a Crook at the End of the Rainbow" in the Proceedings of 2002 Winter Simulation Conference Eds. Yücesan E., Chen C.H., Snowdon J.L., and Charnes J.M, pp 648-652

Rathburn T. A. and Weinroth G. J. (1991) "Desktop Simulation : Modeling for Managers" Simulation, 1991 (56) 5 pp 316-320

Robinson, S. (1994) "Successful Simulation : Practical Approach to Simulation", McGraw-Hill, Berkshire

Rohrer, M. W. (2000) "Automod Tutorial" in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., R. R. Barton, K. Kang and P.A. Fishwick, pp 241-245

Sadowski D. A. and Grabau M. R.(1999) "Tips for Successful Practice of Simulation" in the Proceedings of 1999 Winter Simulation Conference Eds. Farington P. A., Nembhard H. B., Sturrock D. T. and Evans G. W., pp 61-66

Sakthivel S. and Agarwal R. (1992) "Knowledge-based model construction for simulating Information Systems" Simulation, 1992 (59) 4 pp 223-236

Sargent R. G.,(2000) 'Verification, Validation, And Accreditation of Simulation Models", in the Proceedings of 2000 Winter Simulation Conference Eds. Jones J.A., Barton R. R., Kang K. and Fishwick P.A, pp 50-59

Shannon, Robert E., (1998) "Introduction to the Art and Science of Simulation" in the Proceedings of 1998 Winter Simulation Conference Eds. Medeiros D.J., E. F. Watson, J. S. Carson and M. S. Manivannan, Washington, pp 7-14

Stanford M. and R. Graham, "Are Business Managers and Non-Technical Consultants Ready for Low Cost Discrete-Event Simulation? A Survey of Users" in the Proceedings of 1998 Winter Simulation Conference Eds. Medeiros D.J., Watson E. F., Carson J. S. and Manivannan M. S., Washington, pp 1333-1338

Swain J., (2001) "Simulation Software Survey", OR/MS Today, February 2001.

Trybula W. J. (1994) "Building Simulation Models Without Data", Stand for IEEE, pp209-214.

Umeda S. and Jones A., (2001) Simulation in Japan: State-of-the-Art Update, http://www.nist.gov/msidlibrary/doc/survey.htm