CONCEPTUAL MODELING FOR DISCRETE SIMULATION OF SUPPLY CHAIN

Martin Gesvret
University of Defence in Brno, Czech Republic
E-mail: martin.brunclik.me@gmail.com

Pavel Foltin
University of Defence in Brno, Czech Republic
E-mail: pavel.foltin@unob.cz

Received: May 26, 2019
Received revised: September 25, 2019
Accepted for publishing: September 26, 2019

Abstract

Modeling and simulation is very powerful technique for studying complex systems. There exists increased concern of this phenomenon, generally through workshops, conferences and special journal issues during last several decades. Despite a number of case studies and books written, there is still some gap within methodology of modeling itself. Plenty of authors concerns much more on particular simulation study, its system and results and they do not dedicate a lot of attention to the methodology. The aim of this article is scope on the conceptual modeling for discrete-event simulation for supply chains as a vital part of whole simulation study. It concerns about the framework of conceptual modeling and conceptual model and their definitions and requirements and gives a guidance on conceptual modeling independently of the computer model coding.

Key words: Conceptual modeling, conceptual model, simplification, validity, credibility, utility, feasibility

1. INTRODUCTION

Modeling and simulation are very popular tool used for decision making by the manager in wide spectrum of business, mostly in production and services, transportation, supply chain management, hospitals, military etc. This continuous spreading of this method is supported by the hardware and software development. Computers with adequate or sufficient performance became accessible for more users, and even more people can prepare its modeling studies without knowledge of coding due to variety of modeling and simulation software.

Despite the spread of modeling and simulation, increasing number of conferences and workshops, papers and studies, there is still lack of books or studies focused at the conceptual modeling as the method itself. The main part of published studies pay attention mostly to whole case studies instead detail analysis and methodology of particular part of the simulation study preparation, such as conceptual modeling, experiments preparation and settings, result interpreting, although the understanding of each phase of modeling process and its contains is vital in order to reach expected output.

This paper focuses on the conceptual modeling and simulation for supply chain management. The aim is discuss the meaning of conceptual modeling as a method itself, description of the request on the conceptual model considering the aim of the model study and setting the its frame.

2. CONCEPTUAL MODELING

Conceptual modeling for discret event simulation deals with abstraction of the real system to the model, when the simulation models are simplifacion of the reality (Zigler, 1976). Subject of the conceptual modeling is the appropriate abstraction of reality (Pidd, 2003). These definitions indicate the meaning of conceptual modeling in general overwiev. The question is, how can be the terms conceptual model and conceptual modeling define precisely.

Generally, the meaning of conceptual modeling, used in studies of modeling and simulation, is rather vague than precise including different interpretation of terms. Usually, they agreed about the placement of the conceptual modeling to the early phase of the simulation study. This suggests a process from defining the problem to be solved by simulation to determining what is actually modeled and how.

Balci (1994) divides the initial stage of the modeling process into several steps - problem definition, assessment of simulation options, system definition and simulation goals, model formulation, model representation and programming, but does not indicate which of these steps are part of the conceptual modeling process and which not.

Similarly, Law (2007) defines the various steps in simulation processing - problem formulation and its understanding, data collection and model definition, model validation, model building and programming, initial simulation, model validation, experiment definition, implementation, analysis of outputs and usage results and dossier processing. However, it does not specify which of these steps belongs to the conceptual model preparation phase.

Nance (1994) separates the ideas of the conceptual model and the communication model. Such a conceptual model is then one that is in the mind of the modeler and the communication model represents the exact representation of the conceptual model. At the same time, it separates the conceptual model from the final model, in other words, the conceptual model does not deal with how the model will be programmed.

Significant debate over conceptual modeling was also conducted among modelers of military simulations. Pace (2000a) identifies the information provided by the conceptual model as a set of assumptions, algorithms, characteristics, relationships between elements and data. At the same time, it separates the conceptual model from the computer model and its programming. Furthermore, Robinson (2002) says that modeling of military simulators can be very different from business-oriented models.

Military models are often very large and are often developed by program developer teams. At the same time, these models are often required to be reused. Business-oriented models can be, in scope, simpler and at the same time one-time, as they are processed to address specific and specific systems. Although conceptual modeling requirements and procedures should be the same for both areas, it is advisable to keep this distinction in mind.

Based on the approach of individual authors, key elements of conceptual modeling and conceptual model definition can be identified:

• conceptual model is a simplified representation of the real system

• the conceptual model is independent of the model programming or the software used

• Conceptual modeling is a process from problem analysis to model requirements, modeling object definition and modeling methods

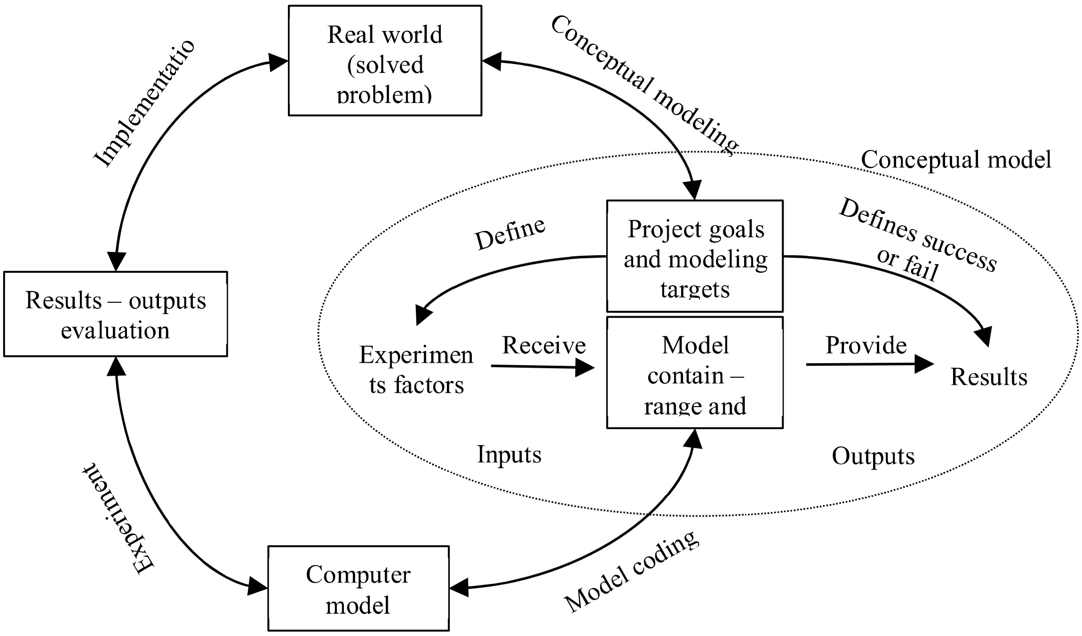
• the conceptual modeling process is iterative and repetitive in the ongoing review of the model study during its solution,

• For the conceptual modeling, both the client's perspective and the modeler's and expert's views, who can be involved in the study, play a role.

2.1. Definition of the Conceptual model

Figure 1 shows the conceptual model in the ellipse following the discussion in the previous chapter, incorporated into the broader context of the simulation study (Robinson 2004). The scheme includes key elements of the process in preparing and using simulation: conceptual modelling, model programming, experiments, and model implementation. At the same time, it shows the outputs of individual processes: conceptual model, computer model, results for improvement of the solved situation and own improvement of the solved problem. Bidirectional arrows represent mutual interaction, which means that, despite the logical sequence of individual implementation steps of the model simulation solution, situations arise where the findings in the sub-processes call for a revision of some attributes for correct modelling in order to obtain and valid model and relevant outputs.

Figure 1. Conceptual modelling in the framework of simulation study



Source: Robinson (2004)

As shown in this scheme, the conceptual model derives from an understanding of the real situation (the problem addressed). The interaction between the problem solved and the conceptual model suggests the fact that the modeller can, by querying the solved and modelled issues, bring the client into another possible view of the problem and thus influence the perception of this problem and adjust the simulation goals. The conceptual model itself consists of 4 main components - goals, inputs (experiment factors), outputs and model content.

The modelling goals set their own reason for model preparation and simulation. The general objectives of the project define the general nature of the model, in particular the time frame for its implementation, the requirements for flexibility, the visualization of results, the level of complexity of the operator, etc.

The definition of the project objectives is crucial for the actual elaboration of the model, which determines the final nature and use of the processed model. To put it simply, different project goals can lead to different outcome models when solving the same system. For this reason, goals are included as definitions of the conceptual model. The model simulation inputs are the variables that can change during the experiments, in order to evaluate their changes or in order to understand the behaviour of the system under different conditions and should be defined by the model objectives. The outputs are the results of the execution of each simulation experiment and have two main purposes: first, to determine whether the simulation objectives have achieved, secondly to identify the reasons why the model objectives have not achieved.

The content of the model includes the model's own elements and their behaviour, the links between them and the direction of their interaction, and the model content can be viewed on two levels – model range and model detail. The model range defines the part of the real world (its boundary), that is processed into this model, and the detail level specifies the level of details definition of the properties of all model components. The contents of the model derives from the required inputs and outputs and their accuracy, in order to be able to receive and process the required inputs and provide appropriate outputs with a given accuracy while allowing a correct and comprehensible interpretation of the results obtained. The definition of the model content, necessary prerequisites and simplification should be recorded in its dossier for further use.

Based on these ideas, a conceptual model definition can be formulate. **The conceptual model is then a specific description of the real system, processed outside the simulation software, to process its computer form, which describes inputs, outputs, content, assumptions and levels and methods of simplification**.

This definition directly states that the conceptual model is not proceed in the simulation program. In doing so, he says that the essence of the conceptual model is to design the appropriate model regarding its goals, regardless of how it will proceed by computer, so its processing should not be primarily influenced by the way it is programmed (programming in a particular programming language or its processing in selected simulation program). This is not denying the use of other programs for processing a conceptual model such as decision processors and development diagrams for a clear and illustrative flowchart, programs for drawing the system, spreadsheet for data preparation and definition of variables, or text editors for processing documentation to the entire model. In reality, however, we encounter a situation where the modeller has one or two simulation tools (or can use them) and his ability to process the computer version of the model according to his conceptual version then backwards the modifications of the conceptual model as shown in the figure by a two-way arrow. Limitation of modellers capability of coding or software application can bring more adverse effect to the whole model or simulation results.

It is worth noting that the definition does not state the form and detail of the documentation of the conceptual model. However, in view of the fact that the definition emphasizes the separation of the conceptual model from its numerical form, explicit processing in some form of formal document is beneficial and in some cases necessary to achieve and demonstrate compliance between the client, the modeller and any experts involved in the processing a conceptual model. At the same time, the importance of processing this documentation is to capture all the adjustments to the project objectives that have occurred in the conceptual modelling process, to understand and agree with all stakeholders. This documentation allows for precise processing of the resulting model in the simulation program, and subsequently evaluates whether the processed model corresponds to the objectives of the study commissioning by the contracting authority and thus eliminates possible disputes during its presentation and handover to the customer.

An equally important benefit of the explicit processing of the conceptual model, including its documentation, is the definition of all model components, its characteristics, and the links between them. This enables, if necessary, independent verification and validation of the model, utilization of the model or its part to solve similar or identical systems with different targets (desired outputs). The quality of the processed documentation significantly helps to understand the model, compare the goals achieved with the planned ones, and at the same time, it enables the understanding of the processed algorithms and the ligament for the solving team members.

In conclusion, an explicitly elaborated and clearly defined conceptual model provides an appropriate tool for communication between all stakeholders during the implementation of the entire simulation study. In this way, it enables correct understanding of the situation and the correct character of the model, the course of its simulation and consequently its application in practice.

2.2. Conceptual model requirements

Modelling as such is not a simple matter because it is difficult to define measurable criteria, to evaluate this process or the model's own value. Nevertheless, it is recommended to have a set of criteria that help us to maintain the planned direction of the study in the modelling process and indicate whether the model is appropriate to the objectives of the study. Setting criteria for models and modelling has been discussed in a wide-ranging review by authors, such as Gass and Joel (1981), Robinson and Pidd (1998) and Balci (2001), but their focus was rather on setting criteria for the constructed model than on their own conceptual modelling. In terms of setting the criteria for conceptual modelling, let's mention, for example, Willemain (1994), which lists 5 properties: validity, usability, customer value, feasibility, and suitability for solving the problem however, there are other studies that even list up to 11 criteria. Taking into account individual studies, we will focus on four main requirements, namely validity, credibility, usefulness and feasibility.

In general, there is a consensus that a valid model is a model that accurately describes the problem addressed. In a situation where we consider that the conceptual model does not necessarily have numerical outputs, **we can define validity as a possibility of processing a conceptual model into a computer model that displays reality with sufficient precision from the modeller's perspective**.

The ability to process into a computer model as one dimension of validity shows the fact that the conceptual model itself is a simplified description of reality and not just its computerized version. The validity of the model, as defined above, emphasizes that this is the modeller's opinion, while taking into account the fact that each model is designed for a specific purpose that provides a framework for self-evaluation.

The credibility of the model can be considered similarly as validity, but rather from the perspective of the customer rather than the modeller. Then, similarly, we can say that **credibility is the possibility of processing a conceptual model into a computer model that displays reality with sufficient accuracy from the perspective of the customer.**

It expresses the fact that it must be convinced that the model is sufficiently precise to solve the desired problem, i.e. it contains all the required elements of the system with all the proper features and links. At the same time, it is essential that the customer understands the model and its results.

Validity and credibility distinguished differently, because of a different view of the final model. There might be a situation, where the model author is convinced of its validity and the submitter is not. In this case, the model should be adjusted by additional elements or details, which do not affect its validity, but will increase its credibility on the part of the client. Extending the model for credibility is not inherently a negative phenomenon, but the modeller should not allow such an extension of the model to lead to an overly complex and confusing model.

The third requirement for a conceptual model is its usability. Here we can define **the possibility of processing a conceptual model into a computerized form, which will be usable as a tool for decision-making in a given situation, both from the client's perspective and from the perspective of the modeller.**

It is a consistent attitude of both the customer and the modeller to evaluate the model with respect to the objectives and purpose behind which the entire simulation study is being proceed. The main question here is no longer the accuracy of the model, but the suitability and accuracy of the final model as required. It can include customer-friendliness, flexibility (the ability to change some model components or variables), and simulation speed, visual processing of results, or in some cases the ability to use the entire model or part of it to solve other problems.

As part of the simulation studies, a conceptual model can be developed, which is valid from the perspective of the modeller and trustworthy from the customer's point of view, however, due to its complexity, time-consuming or cumbersome nature, its usability is limited or zero.

The last of the conceptual model requirements discussed is feasibility. **This can be defined as the conviction of the client and the modeller that the conceptual model can be converted into its computerized form at the scheduled time, with the given resources and available data.**

There can be countless situations, which have a major impact on the feasibility of a simulation study. During the analysis of the study objectives, we can find that we do not have enough information about the real system or that the modeller does not have sufficient skills to process a computer model, obtaining the necessary data can be difficult or impossible, etc. Another factor may be the mutual misunderstanding of the study with it can lead to the extension of the study award, thereby increasing the time and financial resources to implement it.

These conceptual model requirements are not isolated but generally related and they need the evaluation on a case-by-case basis. In some cases, we can find that the solved model is not, in its scope, feasible by means of a computer simulation, but a conceptual model that has been designed can be useful for understanding the real system. On the contrary, a simulation study is finalize to a computer model, but with the passing of time, its purpose can expire or disappear for some unforeseen reason.

3. LESSON LEARNT

We started to prepare several models at the University of Defence concerning the military supply chain, mainly in the foreign operations of the Army of the Czech Republic and during the lessons with our students. According our specialization, we are not real coders, but logisticians and managers, what is the main reason we have to use the modelling a simulation software instead model coding.

During our first models, students did not follow precisely the conceptual model methodology; mainly they did not clarify the questions, which should the simulation response and they started immediately design the model in available software without preparation of the conceptual model. This caused them huge loss of time due to the repeated changes of the model design.

The second problem were changes of the model´s setting during validation due to misunderstanding the function of the model validation. They tried to change several elements of model and its behaviour in order to receive like hood or expected results instead to do proper analysis of the results and finding why the results are different from expected one and its justification.

Just the student does not do mistake. My personal experience from the deviation of the methodology was also negative Brunclik, Vogal and Foltin (2018). We prepared particular model for the conference and due to some delay during the modelling; we did not note immediately changes or adjustment to its documentation. In that case, we spent a lot of additional time during the paper preparation and justification the final model settings.

Specific situation occurred very often even with the over expected possibility of the simulation regarding the model details. We started prepare the model and put there immediately lot of details. During the phase of the construction of the model, we decided to put less effort about the model run animations, and we put more effort in order to receive valid and accurate outputs. This decision brought us more time for data analysis and justification of results instead useless animation.

4. CONCLUSION

Despite the wide spread of modelling and simulation to practice we can still register a lack of books, which would not solve particular case studies, but which should be aim to the methodology of modelling and simulation itself. However, not precise or vague definition of all phases of modelling study and its misunderstanding by a client or a solver leads to repeating problems or incomprehension during solving of the study, repeating changes of requested outputs, expected objectives etc. Those causes considerable loss of time and money during the study and they even cause its fail.

Extensive study of discrete event models and simulation is not important just for the solving of study cases, but especially for further development of this method and avoiding its degradation to "executing case study in software", how it is very often taken by the public without deeper understanding of the whole problematics.

The design of a conceptual model for discrete event simulation has its own place in the process of simulation study. The separation of this part from model coding by simulation software or by the code, underlines its value and importance in analytic a conceptual phase of simulation study, which should be solved by modelling and simulation. It shows that the biggest part of work, including system analytics, system model design, its parts (elements) and links between them, their behaviour etc. have to be done before the coding. Simultaneously, there is the place for discussion, adjustment of objectives and outputs of experiments and other system settings when necessary.

I suggest finishing design the conceptual model before the programing (coding) phase and do not let decrease the quality or approach for solution up to personal knowledge of coding. It does not mean that there is no chance to adjust the structure of outputs during coding phase, but it should be in minimum cases, but the reason should not be personal lack of coding capability, that we can hire another coder with sufficient capability.

The very important part of modelling study is the detailed documentation of the conceptual model and the study itself. The importance of it bases on recording of the approach of problem solution – data resource and data analysis tools, designing the model structure and its description and also the type and structure of outputs. It serves to distinguish if the final model matches with the model requested by the client, what is very important during handover phase of the study. This documentation give the information to solving team about the ongoing phase of the project, so they can check the partial outputs or used methods. In case of necessary adjustment of some procedures, steps or outputs it allows identification of its impact to whole project or specific parts of the project and facilitate the implementation of change if and only if the client agreed.

The documentation remains important event when whole study is finished and the outputs and results are handover to the client, because it is useful, if the modelled system is about being extended or there is important change of parameters within the system. In this case, it can be faster and less expensive to study the previous model and its design in order to execute requested updates than pass the whole process of modelling and simulation with all the time and financial costs.

5. REFERENCES

Balci, O. (1994). Validation, verification, and testing techniques throughout the life cycle of a simulation study. In: BOROS, Endre. *Annals of Operations Research 53*. Springer US, p. 77-120. ISSN 1572-9338.

Balci, O. (2001). A methodology for certification of modeling and simulation applications. *ACM Transactions on Modeling and Computer Simulation (TOMACS)*, *11*(4), 352-377.

Brunclik, M., Vogal, L. and Foltin, P. (2018). Computer Modelling and Simulation of the supply chain in Military operation, Osijek, Croatia, In: 18th International Scientific Conference Proceedings, Oct 2018, ISSN 1849-5931

Gass, S. I., & Joel, L. S. (1981). Concepts of model confidence. Computers & Operations Research, 8(4), 341-346.

Law, A. (2015). M. *Simulation modeling and analysis*. Fifth edition. New York: McGraw-Hill Education, ISBN 9781259254383.

Nance, R.E. (1994). The Conical Methodology and the evolution of simulation model development. In: BOROS, Endre. *Annals of Operations Research 53*. Springer US, 1994, p. 1-45. ISSN 1572-9338.

Pidd, M. (1993). *Tools for Thinking: Modeling in Management Science*, 2nd ed. Chichester, UK: Wiley

Robinson, S. (2002). Modes of simulation practice: approaches to business and military simulation. In: Simulation Modelling Practice and Theory. Elsevier Science B.V., p. 513-523. ISSN 1569-190X.

Robinson, S. (2004). Simulation: The Practice of Model Development and Use. Inglaterra: John Willey and Sons. Inc. Cap, 1(2), 5.

Robinson, S., & Pidd, M. (1998). Provider and customer expectations of successful simulation projects. Journal of the Operational Research Society, 49(3), 200-209.

Willemain, T.R. (1994). Insights on Modeling from a Dozen Experts. In: Operations Research. 42(2), p. 213-222. DOI: 10.1287/opre.42.2.213. ISSN 0030-364X. Available also at: http://pubsonline.informs.org/doi/abs/10.1287/opre.42.2.213

Zeigler,B.P., Praehofer, H. and Kim, T.G. (2000). Theory of modeling and simulation: integrating discrete event and continuous complex dynamic systems. 2nd ed. San Diego: Academic Press, ISBN 0127784551.