Computer Simulation Using Excel without Programming

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To Mother & Father
To my Teachers, Family and Friends

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ABSTRACT

Defining Simulation in its broadest aspect as embodying a certain model to represent the behavior of a system, whether that may be an economic or an engineering one, with which conducting experiments is attainable. Such a technique enables the management, when studying models currently used, to take appropriate measures and make fitting decisions that would further complement today's growth sustainability efforts, apart from cost decrease, as well as service delivery assurance. As such, the Computer Simulation technique contributed in cost decline; depicting the "cause & effect", pinpointing task-oriented needs or service delivery assurance, exploring possible alternatives, identifying problems, as well as, proposing streamlined measurable deliverable solutions, providing the platform for change strategy introduction, introducing potential prudent investment opportunities, and finally providing safety net when conducting training courses. Yet, Simulation Development process is hindered due to many reasons. Like a rose, Computer Simulation technique, does not exist without thorns; of which the length, as well as, the communication during the development life cycle. While Computer Simulation technique proves to be highly specialized, nevertheless, it is task-oriented. Moreover, it reflects real life problems; hence, it addresses numerous scenarios with handful of variables. Not only is it costly, as well as, liable for human judgment, but also, the results are complicated and can be misinterpreted.

Within this context, the researcher attempts to employ a method, using spreadsheets as simulation environment while simplifying the program code, and thus surmounting the aforementioned problems. The idea of this method is defined as follows; one procedure is defined for *beginning* any activity, one procedure is defined for *ending* any activity, and one procedure is defined for any activity *process*. This is attainable by using each entity as a parameter being passed from one procedure to another utilizing the Object Oriented programming language Visual Basic. Consequently, a computer simulation system, *E3P-Sim*, is realized.

E3P-Sim is programmed based on: Three-Phase Discrete event, Activity Cycle Diagram (ACD), Object Oriented Language, and Microsoft Excel. *E3P-Sim* is a general-purpose package, and not a task-oriented package. *E3P-Sim* accepts the model, built using interactive ACD on Excel spreadsheet. As such, *E3P-Sim* is built using Three-Phase, to bypass the deadlock problems, Object Oriented Language during simulation package programming, in order to simplify the code and relieve the modeler from such chore. Intentionally, this package uses Microsoft Excel as a reporting tool, since Excel is a popular reporting and analysis tool.

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Chapter 1

INTRODUCTION

Introduction

The Computer Simulation technique proved to be of an immense importance in today's growth sustainability; enabling the management to take appropriate measures and make fitting decisions, when studying models currently used, in order with the aim of enhancing performance competence, through avoiding extra cost resulted from repetitive experimentation, conducting different scenarios while controlling time, comprehending the "cause & effect", pinpointing task-oriented needs or service delivery assurance, exploring possible alternatives, identifying problems, as well as, proposing streamlined measurable deliverable solutions, providing the platform for change strategy introduction, introducing potential prudent investment opportunities, and finally providing safety net when conducting training courses. Yet, Computer Simulation technique is task-oriented, although it is highly specialized. Moreover, since it reflects real life problems, hence, it addresses numerous scenarios with handful of variables. Not only is it costly, as well as, liable for human judgment, involving lengthy channels of communication, and requiring special training, thus not user friendly, but also, the results are complicated and can be misinterpreted.

Throughout this thesis, the researcher addresses these issues through employing a state of the art method that involves using spreadsheets as simulation environment while simplifying the program code, thus realizing a computer simulation system that is based on Three-Phase Discrete Event, Activity Cycle Diagram (ACD), Object Oriented Language, and Microsoft Excel will be made. It is a general-purpose system, and not a task-oriented one, as others that have been investigated throughout this research, as such, it is built using Three-Phase, to bypass the deadlock problems, Object Oriented Language during simulation system programming, in order to simplify the code and relieve the end-user from this chore. Intentionally, this system uses Microsoft Excel as a reporting tool, since Excel is a popular reporting and analysis tool, bearing in mind that using excel in simulation is not new, in fact 15 out of the examined 56 system, have used Microsoft Excel as a reporting tool. In conclusion, it is worth mentioning that the efforts to attain this system were based on a published research paper.

Thesis Objective & Contribution

The objective of this research is to develop a general purpose computer simulation system, named *E3P-Sim* that needs no programming interventions from the user, through using Three-Phase Discrete event, Activity Cycle Diagrams (ACD), Object Oriented Language, and Microsoft Excel. As such, the contribution of this work is illustrated through combining the four elements concomitantly, without undermining the fact that each element was used either combined with another or alone, in one way or another, yet none of the investigated 56 systems used all four as stated in chapter 4 of this research. In general, the system would serve as a model that doesn't require programming intervention, thus reducing model building time, in the same token; it allows the modeler to experiment with different scenarios and input models easily, as well as, efficiently. Equally the *E3P-Sim* offers self-explanatory and reliable results that can be manipulated using the Microsoft Excel tools.

The researcher chose to try out the efficiency, validity and liability of this system, using the "Convenience Sample" (Mason and Gunst and Huss, 1989, p15) through examining this package against well known published simulation problems that amounted to approximately ten published problems, comprising different service delivery institutions that include; PUB, Port, Supermarket, clinic, restaurant, call center, and airport.

James Henriksen stated in a panel discussion during the winter simulation conference 2003 that "software vendor's primary goal should be to maximize the following expression [Henriksen, 2003]:

$$\frac{\text{Functionality X Ease-of-Use}}{\text{Cost X Complexity}}$$

The system used Three-Phase simulation approach for the sake of ridding the system from deadlock dilemma from which other simulation approaches may suffer as seen in chapter 2; therefore, such approach will increase the functionality described by Henriksen. On another note, the *Factory Explorer* is very close to *E3P-Sim* yet Factory Explorer uses Event Based simulation approach. In the Event Based simulation approach "there are only two phases then all events are mixed then the method is not parsimony, which means it is very hard to enhance" [Pidd,1998] as explained in chapter 2.

The Activity Cycle Diagrams (ACD) is known for some qualities that made it compelling to use. First, ACD is very simple with only two symbols for the modeler to remember, which makes ACD very easy to use. Second, ACD is parsimonious as described by [Pidd, 1998]. Third, ACD is very "useful for understanding and communication" [Elsheikh, 1987]. Fourth, ACD has two extra desirable aspects "comprehension, communication and generality (Doukiis, 1985)" [Elsheikh, 1987]. Because of those qualities and their affect on Henriksen's function the ACD was used.

The use of Visual Basic, which is object oriented language, simple and easy to use language and not propriety, will decrease the complexity factor mentioned by Henriksen and will decrease the cost. Also Visual Basic accentuates the "mean stream" idea mention by [Booch et al, 1999]. Also the use of object oriented language will eliminate Brittle, long, hard to maintain code [Booch et al, 1999]. The aim of using Visual Basic is to Aid in simplifying the code of the Three-Phase simulation approach as suggested in the research by [Abu-Taieh, 2004].

The decision to use Microsoft Excel was made based on many reasons. First, the use of Excel is not new 15 packages out of 56 packages studied for this purpose use Excel as reporting tool. Many suggested such idea like [Leathrum et al., 2000], [Amico, 2000], [Seila, 2001], [Evans, 2000], [Diab, 1997], and [Hill, 2002] to name a few. [Hill, 2002] recited 5 good reasons to use Excel: "run statistical analysis, conduct mathematical modeling, import and export data, and a means to store and manage data". In addition, Excel is well known package and familiar to users. Within this context, the closest to *E3P-Sim* is *Crystal Ball* simulation system in the sense of making use of Microsoft Excel and Visual Basic, yet *Crystal Ball* is based on Monte Carlo which "can be loosely described as statistical simulation methods" [CSEP Web, 1995].

The use of the aforementioned not only does it increase the two nominator factors of Henriksen's expression, but also reduces the two denominator factors simultaneously, which will only maximize Henriksen's expression, thus stirring the motivation throughout this research.

Outline of Thesis

First, a comprehensive explanatory platform of simulation background is stated in chapter 2. As this chapter comprises of five sections, it reviews simulation definitions, forms of models,

the need for simulation, simulation approaches and modeling notations. Simulation definition is essential, in order to set research boundaries. Moreover, the chapter discusses forms of models: scale model of the real system, or discrete and continuous models. Subsequently, the chapter states a documentation of several reasons by different authors pertaining to the question of "*why simulate?*", Followed by a thorough discussion of Modeling Approaches in respect to general considerations. Considering that simulation modeling approaches are discussed with special emphasis on the discrete-events types only: process-interaction, event scheduling, and activity scanning, yet, a slight comparison is made between the different approaches. Furthermore, the chapter discusses the different modeling notations Activity Cycle Diagram (ACD) with different versions of the ACD: Extended Activity Cycle Diagrams (X-ACD) and Hierarchy Activity Cycle Diagrams (H-ACD). Furthermore, the chapter discusses sampling methods (input modeling).

On another note, the second section of chapter 2 embarks on further discussing Petri Nets. Although it conducts concurrent discrete events dynamic systems simulation which is outside the scope of this thesis, nonetheless, various simulation packages that are discussed in chapter 4, namely *Optsim (Artifex)*, use Petri Nets. Therefore, it is imperative to discuss Petri Nets, particularly that the idea of Petri Nets was developed to answer the question of concurrency, which naturally arises constantly when discussing simulation. The Petri Nets will be discussed by interpreting the formal definition of Petri Nets, describing the classical Petri Nets and the different classification of Petri Nets. Furthermore, the third section of this chapter will be directed to identify and categorize the sampling methods available in the simulation and statistical world, as many simulation packages, discussed in chapter 4, pride themselves about the number of sampling function available to the user. Moreover, the fourth section of chapter 2 tackles three interrelated topics: *sampling methods* and their taxonomy, *Monte Carlo simulation* that represents part of the sampling methods taxonomy, which is particularly important since 4 simulation packages use it; namely: *Crystal Ball, BuildSim, Decision Script* and *Decision Pro* (see chapter 4). *Neural Network*, which is the third topic discussed, particularly since many simulation packages use the idea of neural network as fitter functions. Finally, the fifth section of chapter 2 entails providing the idea of object oriented simulation, while being compared to algorithmic perspective. Discussing object oriented perspective entails reviewing the web based technology, as such, this section tackles three topics: first, web based simulation, which illustrates all three different types of simulation and modeling, second, the different

programming languages and environments, through which simulation can be done with object oriented perspective, third, the principles and aims of modeling from an object oriented perspective is introduced.

Second, chapter 3 demonstrates the methodology, which has been followed by the researcher in an attempt to employ a state of the art method that involves using spreadsheets as simulation environment while simplifying the program code, thus realizing a computer simulation system that is based on Three-Phase Discrete Event, Activity Cycle Diagram (ACD), Object Oriented Language, and Microsoft Excel will be made. As such, the contribution of this work is illustrated through combining the four elements concomitantly, without undermining the fact that each element was used either combined with another or alone, in one way or another, yet none of the investigated 56 systems used all four as stated in chapter 4 of this research. In general, the system would serve as a model that doesn't require programming intervention, thus reducing model building time, in the same token; it allows the modeler to experiment with different scenarios and input models easily, as well as, efficiently. Equally the *E3P-Sim* offers self-explanatory and reliable results that can be manipulated using the Microsoft Excel tools. Furthermore, the researcher chose to try out the efficiency, validity and liability of this system, using the "Convenience Sample" (Mason and Gunst and Huss, 1989, p15) through examining this package against well known published simulation problems that amounted to approximately seven published problems, comprising different service delivery institutions that include; PUB, Port, Supermarket, clinic, restaurant, call center, and airport.

Third, the result of studying 56 commercial and non-commercial simulation packages is given in chapter 4. The packages are thoroughly studied either by conducting experiments using them, or studying what was available about them over the internet. This chapter provides the researcher with the two faces of one coin theory and its implementation, likewise, this chapter sheds the light on the fact that *E3P-Sim* is not like any other package in the market place and the only one that uses Three-Phase approach, ACD, Microsoft Excel, and Visual Basic.

In conclusion, chapter 5 introduces the proposed system, which is named *E3P-Sim*; moreover, the chapter explains how the system works from both technical and user points of view. In addition, the chapter lists a number of examples, which illustrate how the system

provides solution to various prominent problems in the simulation arena. Furthermore, the code and the philosophy behind it are thoroughly discussed, as well as the advantages and limitations of the system.

Finally, chapter 6 summarizes the research that has been carried out, in order to achieve this thesis. In addition, the chapter states the conclusion, through which the product of this research has been realized and named *E3P-Sim*, highlighting the fact that *E3P-Sim* has been thoroughly tested through its examination against well known published simulation problems that amounted to approximately ten published problems, comprising different service delivery institutions. Moreover, the chapter suggests, as well as thoroughly investigates future research prospects.

Chapter 2

BACKGROUND OF SIMULATION

Introduction

The aim of this chapter is to serve as a comprehensive explanatory platform of simulation. It is imperative to define simulation, in order to set boundaries for the research. As such, the chapter comprises of five main sections: an overview of simulation modeling approaches, modeling notations, Petri Nets, sampling methods or input methods, and WEB Based simulation and Object Oriented simulation.

The chapter starts with a review of simulation definitions, forms of models, the need for simulation, simulation approaches and modeling notations. Next, the chapter discusses forms of models: scale model of the real system, or discrete and continuous models. Furthermore, the question "*why simulate?*" is addressed, through discussing a number of reasons by different authors in this section. Modeling approaches are discussed next with general considerations. Simulation modeling approaches are analyzed, emphasizing especially on the discrete types; namely: process-interaction, event scheduling, and activity scanning, with a minuscule comparison between the different approaches. Moreover, the chapter discusses the different modeling notations Activity Cycle Diagram (ACD) with different versions of the ACD: Extended Activity Cycle Diagrams (X-ACD) and Hierarchy Activity Cycle Diagrams (H-ACD).

Bearing in mind that Petri Nets handles concurrent discrete events dynamic systems simulation, which is outside the scope of this thesis, nonetheless, various simulation packages that are discussed in chapter 4, namely Optsim (Artifex), have used Petri Nets. Therefore, it has been reasoned to be imperative to further discuss Petri Nets in the second section of this chapter. Particularly that the idea of Petri Nets was developed to answer the question of concurrency, which naturally arises constantly when discussing simulation. The Petri Nets will be discussed by interpreting the formal definition of Petri Nets, describing the classical Petri Nets and the different classifications of Petri Nets. However, the section does not include the parallel discrete-event simulation languages (PDES); although some papers, such as [Low et al., 1999] are available for concerned to read.

Given the significance to identify with all or most of the sampling methods that exist, in order to evaluate simulation packages, particularly with regards to the taxonomy of the input

method, therefore, the third section of this chapter aims to identify and categorize the sampling methods available in the simulation and statistical world, as many simulation packages, discussed in chapter 4, pride themselves about the number of sampling function available to the user. It is worth noting, however, that the taxonomy will enable the prospective user to know if the input method suitable for Time-independent Models or Stochastic Processes. For example, if a simulation package claims that it uses Markov Chain in Time-independent Univariate Discrete Models; then evaluator of the simulation package will have to reconsider the package viability.

Furthermore, the fourth section tackles three interrelated topics: sampling method and their taxonomy is the first. Second, Monte Carlo simulation, which represents part of the sampling methods taxonomy, noting that Monte Carlo is particularly important, since four simulation packages have used it (see chapter 4); namely: *Crystal Ball, BuildSim*, and *Decision Script* and *Pro*. And finally, Neural network, which is regarded as a sampling method, since many simulation packages use the idea of neural network as fitter functions.

Finally, the fifth section of this chapter reviews web based simulation, along with all three different types of simulation and modeling. In addition to the different programming languages and environments, through which simulation can be done using object oriented perspective. Then, the idea of object oriented simulation is discussed in comparison to algorithms perspective. As such, modeling principles and aims, from an object oriented perspective, is introduced as a reminder to the reader. Considering that WEB Based simulation and Object Oriented is to give an overview of the object oriented simulation perspective, consequently discussing object oriented perspective entails discussing the web based technology, particularly, since the effect of object oriented is visibly seen on the web based technology.

Simulation Definitions

In their book, Paul & Balmer have quoted Pidd defining simulation as

> Analyst builds a model of the system of interest, writes computer program which embody the model and uses a computer to initiate the system's behavior when subject to a Varity of operating policies. Thus the most desirable policy may be selected [Paul & Balmer, 1998].