Computer Simulation Using Excel without Programming

Evon M. O. Abu-Taieh
Computer Simulation Using Excel without Programming

Evon Mohammed Odeh Abu-Taieh

Submitted in Partial fulfillment of the Requirements for the Degree of Doctor of Philosophy in Computer Information Systems
College of Banking and Financial Sciences
The Arab Academy for Banking and Financial Science
To Mother & Father
To my Teachers, Family and Friends
ACKNOWLEDGMENTS

I am particularly indebted to my supervisor Dr. Asim El-Sheik. I am deeply grateful to his support, advice and encouragement. Furthermore, I am deeply grateful to the appointed committee: Dr. Ahmad Mashhour, Dr. Raed Abu-Zitar, and Abid Thyab Al-Ajeeli.

Also, deeply grateful for my teachers of Dr. Jalal El-Outom, Dr. Walid Slamah, Dr. Ala’a Abu-Samaha, Dr Munib Qutishat, and Dr. Sattar Jabbar Aboud.

I am also grateful for Dr. Jeihan Abu-Tayeh for her penmanship and editing style.

I would like to thank DR. Fawaz Abu-Tayeh, Dr. Alia Abu-Tayeh, Eng. Akef Abu-Tayeh and Sultaneh Abu-Tayeh for their financial support throughout my study, also for the technical advice and constant encouragement.

I would like to extend my deep gratitude to H.E. Minister of Transport Saoud Nsairat and H.E. Secretary General Eng. Alaa Batayneh, not discounting the role of my colleagues at the Ministry of Transport Eng. Osama Al-Karadsheh, Murad Al-Haroun, Ahamad Masud, Firas Shawar, and Anas Abd Al-Rahman.

Last, not least, my friend Eng. Maha El-Maheid, and my family for their encouragement and moral support.
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.
CHAPTER 4

SIMULATION PACKAGES REVIEW

INTRODUCTION .................................................................................................................. 84
SURVEY REVIEW ............................................................................................................... 84
APPLICATIONS .................................................................................................................. 87
  Analytica ......................................................................................................................... 87
  AnyLogic 5.0 .................................................................................................................. 89
  Arena .............................................................................................................................. 90
  AutoMod ......................................................................................................................... 91
  AweSim .......................................................................................................................... 92
  Berkeley Madonna™ .................................................................................................... 94
  BuildSim ......................................................................................................................... 96
  Crystal Ball Standard Edition & Professional Edition .................................................. 97
  DecisionPro .................................................................................................................... 98
  DecisionScript .............................................................................................................. 98
  Design II simulation Package ...................................................................................... 99
  Dymola .......................................................................................................................... 100
  Ecosim Pro .................................................................................................................. 102
  eM-Plant ......................................................................................................................... 103
  Enterprise Dynamics ................................................................................................... 103
  ExpertFit ....................................................................................................................... 105
  Extend ............................................................................................................................ 105
  Factory Explorer ......................................................................................................... 107
  FirstSTEP Designer ...................................................................................................... 109
  Flexsim .......................................................................................................................... 111
  GAUSS ........................................................................................................................... 113
  GoldSim ........................................................................................................................ 114
  GPSS World for Windows ............................................................................................ 115
  MAST ............................................................................................................................ 115
  MICROSAIN T .............................................................................................................. 117
  MyStartegy ................................................................................................................... 118
  ModelMaker ............................................................................................................... 119
  NAG SMP Library ...................................................................................................... 121
  NAG C Library ............................................................................................................ 122
  Optsim (Artifex) ......................................................................................................... 122
  PASION Simulation System ....................................................................................... 124
  MJC ............................................................................................................................... 124
  SLIM ............................................................................................................................. 125
  Process Industry Manufacturing Scheduling System (PIMSS) ..................................... 127
  ProModel-ProcessModel ......................................................................................... 128
  Proplanner Manufacturing Process Management Software ....................................... 129
  ProVision .................................................................................................................... 130
  PowerSim .................................................................................................................... 131
  QX3D ............................................................................................................................ 132
  Resource Manager ..................................................................................................... 132
  SAAM II ....................................................................................................................... 133
  SansGUI Modeling and Simulation Environment ...................................................... 135
  SAS Software ............................................................................................................. 135
  ShowFlow .................................................................................................................... 136
  SIGMA ......................................................................................................................... 137
CHAPTER 5

COMPUTER SIMULATION WITH ENHANCED THREE PHASES MODELLING USING ACTIVITY CYCLE DIAGRAM: E3P-SIM

E3P-SIM ........................................................................................................................................ 155
Tools bar .................................................................................................................. 156
ENTITY ..................................................................................................................... 157
ACTIVITY CYCLE DIAGRAM ......................................................................................... 159
Queue .................................................................................................................. 159
Activity ........................................................................................................ 161
Split Activity .................................................................................................. 162
Line/connector .................................................................................................. 162
DATA TO KEEP TRACK OF FOR SCHEDULING ................................................................. 163
ASSUMPTIONS ........................................................................................................ 164
SAVING AND DOCUMENTING THE RESULTS ................................................................. 165
Port Example ........................................................................................................ 166
Creating the model .............................................................................................. 167
Results & documentation ...................................................................................... 168
Supermarket ......................................................................................................... 170
Creating the model .............................................................................................. 170
Restaurant ............................................................................................................ 171
Creating the model .............................................................................................. 172
Clinic Example ...................................................................................................... 172
Creating the model .............................................................................................. 173
Pub example .......................................................................................................... 173
Creating the model .............................................................................................. 174
Call Center Example .............................................................................................. 174
Creating the model .............................................................................................. 175
Airport Passenger ................................................................................................ 175
Creating the model .............................................................................................. 176
MANUAL RUN AND TRACING ......................................................................................... 177
CASE STUDY ANALYSIS ............................................................................................ 186
System Generated Data ......................................................................................... 187
Results Comparison .............................................................................................. 190
CODE SIMPLIFICATION DESCRIPTION ....................................................................... 193
Code Description .................................................................................................. 195
Advantages and Limitations of E3P-Sim ................................................................. 198
Advantages .......................................................................................................... 199
Limitations ........................................................................................................ 201

CHAPTER 6

SUMMARY, CONCLUSIONS AND FUTURE RESEARCH ......................................................... 202

SUMMARY ........................................................................................................ 203
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCLUSION</td>
<td>204</td>
</tr>
<tr>
<td>FUTURE RESEARCH</td>
<td>207</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>208</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>211</td>
</tr>
<tr>
<td>THE ORIGINAL CODE</td>
<td>211</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>247</td>
</tr>
<tr>
<td>TRANSPARENT FORMS</td>
<td>247</td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>252</td>
</tr>
<tr>
<td>FORMS CODE</td>
<td>252</td>
</tr>
<tr>
<td>APPENDIX D</td>
<td>272</td>
</tr>
<tr>
<td>SAMPLE RUNS</td>
<td>272</td>
</tr>
<tr>
<td>APPENDIX E</td>
<td>314</td>
</tr>
<tr>
<td>MANUAL RUNS</td>
<td>314</td>
</tr>
</tbody>
</table>
Figures

Figure 1: A process-Interaction Executive [Pidd, 1998].......................................................... 34
Figure 2: An Event-Scheduling Executive [Pidd, 1998] ...................................................... 36
Figure 3: An Activity-Scanning Executive [Pidd, 1998].......................................................... 37
Figure 4: A Three-Phase Executive [Pidd, 1998].................................................................. 38
Figure 5: Symbols for Activity Cycle Diagrams [Pidd, 1998] ............................................. 40
Figure 6: Generic Activity Cycle Diagram ............................................................................ 41
Figure 7: Life Cycles of each Entity in PUB Example........................................................... 41
Figure 8: Life Cycles of each Entity in PUB Example Completed Using ACD. ............... 42
Figure 9: The X-ACD Symbol Set (Adapted from Pooley and Hughes 1991) [Odhabi, et al 1997]. ........................................................................................................................ 43
Figure 10: The H-ACD Symbol Set (Adapted from Kienbaum and Paul 1994a) .............. 46
Figure 11: An Illustration of the Four-Phase Method [Odhabi, et al 1998].......................... 50
Figure 12: Modeling Elements of Classical Petri Nets [Sawhney et al., 1999]................... 53
Figure 13: Enhanced Petri Nets Modeling Symbols [Sawhney et al., 1999]....................... 54
Figure 14: A Taxonomy for Input Models [Leemis, 2000, 15].......................................... 59
Figure 15: Remote S&A Data Transfer [Lorenz et al., 1997]........................................... 65
Figure 16: Client-Site Simulation with Loaded Applets [Lorenz et al., 1997]...................... 65
Figure 17: Remote Simulation and Local Visualization [Lorenz et al., 1997]..................... 66
Figure 18: Graphical Modeling Using Silk-Based JavaBeans [Healy and Kilgore, 1997].................. 68
Figure 19: The proposed simulation life cycle [El Sheikh, Abu-Taieh, Eldabi, 2005] ....... 76
Figure 20: Analytica Overview [Lumina Web]................................................................ 88
Figure 21: Analytica Model Development Window [Lumina Web]..................................... 88
Figure 22: Analytica Output Analysis [Lumina Web].......................................................... 88
Figure 23: Development Window [AnyLogic Web]............................................................ 89
Figure 24: Running Example [AnyLogic Web]................................................................. 90
Figure 25: Development Window [ArenaSimulation Web].............................................. 91
Figure 26: Some Examples in 3D [AutoMod Web]............................................................ 92
Figure 27: The AweSim Executive [O’Reilly, 2002]........................................................ 92
Figure 28: Multi Model Window [O’Reilly, 2002].............................................................. 93
Figure 29: Multi Report Window [O’Reilly, 2002].............................................................. 93
Figure 30: Phase Plane (X-Y) Plots [BerkeleyMadonna Web]........................................ 94
Figure 31: Controlling the Model [BerkeleyMadonna Web]............................................. 95
Figure 32: Oscilloscope Plots [BerkeleyMadonna Web].................................................... 95
Figure 33: Oscilloscope plot vs. Time [BerkeleyMadonna Web]....................................... 95
Figure 34: Runs Comparison [BerkeleyMadonna Web].................................................... 95
Figure 35: BuildSim Data Analysis [BuildSim Web].......................................................... 96
Figure 36: Crystal Ball Tool Bar [Goldman, 2002]............................................................ 97
Figure 37: Sample Output Analysis [Goldman, 2002]..................................................... 98
Figure 38: EDoctor Decision Script Example [vanguardsw Web].................................... 99
Figure 39: Refinery Example [WinSim Web]................................................................. 100
Figure 40: Robotic Arm [DynaSim Web]........................................................................ 101
Figure 41: Development Environment [DynaSim Web]................................................... 101
Figure 42: European Space Agency ESA space [EcoSimPro Web]................................... 102
Figure 43: Ecosim Pro Development Environment [EcoSimPro Web]........................... 102
Figure 44: eM-plant at Work [TecnoMatix Web]............................................................ 103
Tables

Table 1: X-ACD & H-ACD symbols Comparison ........................................................... 49
Table 2: Comparison Between Web Features and Simulation [Kuljis and Paul, 2000] .... 70
Table 3: Table of Simulation Sources Based on the Work of [Rizzoli, 2003] ............... 86
Table 4: Review of the Simulation Packages .............................................................. 151
Table 5: Buttons Descriptions .................................................................................... 157
Table 6: Items Attributes for the Port Example .......................................................... 168
Table 7: Items Attributes for the Supermarket Example .............................................. 170
Table 8: Restaurant Items .......................................................................................... 172
Table 9: Clinic Items .................................................................................................. 173
Table 10: Pub Example Items ...................................................................................... 174
Table 11: Call Center Sample ITEMS ....................................................................... 175
Table 12: Items of Airport Example .......................................................................... 177
Table 13: Initial Conditions ....................................................................................... 177
Table 14: Running Cycle 1 ....................................................................................... 178
Table 15: Running Cycle 2 ....................................................................................... 178
Table 16: Running Cycle 3 ....................................................................................... 178
Table 17: Running Cycle 4 ....................................................................................... 178
Table 18: Running Cycle 5 ....................................................................................... 179
Table 19: Running Cycle 6 ....................................................................................... 179
Table 20: Running Cycle 7 ....................................................................................... 179
Table 21: Running Cycle 8 ....................................................................................... 179
Table 22: Running Cycle 9 ....................................................................................... 180
Table 23: Running Cycle 10 ..................................................................................... 180
Table 24: Running Cycle 11 ..................................................................................... 180
Table 25: Running Cycle 12 ..................................................................................... 181
Table 26: Running Cycle 13 ..................................................................................... 181
Table 27: Running Cycle 14 ..................................................................................... 181
Table 28: Running Cycle 15 ..................................................................................... 181
Table 29: Running Cycle 16 ..................................................................................... 182
Table 30: Running Cycle 17 ..................................................................................... 182
Table 31: Running Cycle 18 ..................................................................................... 182
Table 32: Running Cycle 19 ..................................................................................... 182
Table 33: Running Cycle 20 ..................................................................................... 183
Table 34: Running Cycle 21 ..................................................................................... 183
Table 35: Running Cycle 22 ..................................................................................... 183
Table 36: Running Cycle 23 ..................................................................................... 183
Table 37: Running Cycle 24 ..................................................................................... 183
Table 38: Running Cycle 25 ..................................................................................... 184
Table 39: Running Cycle 26 ..................................................................................... 184
Table 40: Running Cycle 27 ..................................................................................... 184
Table 41: Items activity Statistics ............................................................................. 185
Table 42: E3P-Sim queues snap shots ...................................................................... 186
Table 43: Items/Activities statistics ......................................................................... 187
Table 44: Continuum of Items/Activities statistics ................................................... 188
Table 45: Jobs arrivals in three different runs ............................................................. 190
Table 46: Arrival frequency ................................................................. 190
Table 47: Statistical comparisons ...................................................... 192
Table 48: Data Storage structure in sheet 5. ........................................ 198
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]:

\[
\frac{\text{Functionality} \times \text{Ease-of-Use}}{\text{Cost} \times \text{Complexity}}
\]

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 \textit{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 \textit{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 \textit{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 Variety of operating policies. Thus the most desirable policy may be selected [Paul & Balmer, 1998].