

# COMMERCIAL SIMULATION PACKAGES: A COMPARATIVE STUDY

EVON M. O. ABU-TAIEH and ASIM ABDEL RAHMAN EL SHEIKH

*Faculty of Computer Information, The Arab Academy for Banking and Financial Sciences,  
P O Box 13190, Amman 11942, JORDAN.  
Email: eabutaieh@aabfs.org, a.elsheikh@aabfs.org*

**Abstract:** This paper attempts to identify answers for numerous logically raised and thought out questions that are stumbled upon when using any given simulations package whether that may be commercially in the market or in the academic arena. For this purpose, the researchers have investigated 56 packages, with the aim of tackling not only the trends that simulation packages are pursuing, but also to address the issues denoting technology prevail. Accordingly, the surveyors identified a set of questions to be answered tackling the following issues: use of spreadsheets as reporting tools, 3D vs. 2D animation, simulation approaches, and object oriented. The manner in which the paper has been articulated was a systematic well thought methodology, with scientifically proofed findings recapitulates in the summary part of this paper.

*Keywords:* simulation, simulation approaches, simulation applications, animation, object oriented,

## 1 INTRODUCTION

The aim of this paper is to give an overview of the simulation packages available commercially in the market and in the academic arena. The researcher tried to answer questions like: *What simulation modeling approach did the package use from the available approaches: process interaction, event scheduling, activity scanning, and three-phase, What reporting tool did the package use i.e. Spreadsheets or propriety reporting tool, What programming language was used*, which will give an indication whether the package is object oriented or algorithmic based, and whether the package uses animation and if the animation used is 2D or 3D animation. In addition, the time handling (discrete, continuous, hybrid) issue was of curiosity to the researcher, in view that the time handling is essential, particularly since four commercial packages only can handle the hybrid, as shall be seen in the next sections.

Throughout this paper, a review of 56 simulation packages takes place. Accordingly, each package has been studied by investigating the simulation package website, as well as, the available literature from various published sources (Survey, 2003) and (Rizzoli, 2003). After thorough investigation, it has been noted that a number of the aforementioned points of comparison had been concealed, which can be due to information disclosure policies abided by those software companies; particularly the programming language and the simulation method adopted by software companies in order to develop their respective packages.

## 2 CRITERIA REVIEW AND JUSTIFICATION

Comparing commercial simulation packages is an important matter, (Oren, 2005), (Banks, 2005), (Survey, 2003) and (Rizzoli, 2003) tried to devise criteria of comparison through building Body of Knowledge for simulation. In fact, the comparison stems from different sources: the modeler, the user of the simulation package, the programmer, and the application. This research came to complement the work of others.

As such, the researchers tried to answer questions like:

*What simulation modeling approach did the package use from the available approaches?* There are four well-known simulation-modeling approaches: process interaction, event scheduling, activity scanning, and three-phase (Pidd, 1998). Each approach has advantages and disadvantages, inherently the advantages/ disadvantages of the approach will haunt the commercial simulation package.

The second question the paper tries to answer is *What reporting tool did the package use?* i.e. Spreadsheets or propriety reporting tool. Since spreadsheets are important to commercial simulation packages, some even pride by saying “we start where spreadsheets left off.”

The third question asked is: *What programming language was used*, which will give an indication whether the package is object oriented or algorithmic based. In addition, such question is important to any developer to know if the developer

can add to the package or intervene in the simulated model in the code level or not.

The fourth aspect is: *Whether the package uses animation and if the animation used is 2D or 3D animation.* Simulation does not mean animation. Many will think that animation is part of simulation that is not always true. As shall be seen in later sections, 3D animation is very important aspect of the simulation because it gives better perspective, yet sometimes 2D is better.

In addition, *the time handling (discrete, continuous, hybrid)* (Pidd, 1998) issue was of curiosity to the researcher, in view that the time handling is essential, particularly since four commercial packages only can handle the hybrid, as shall be seen in the next sections.

The sixth comparison criterion is the *Applications of simulation packages.* This is a criterion from the perspective of the user of the simulation package. Since Simulation & modeling is used in a multitude of applications. Many researchers attempted to classify and categorize the simulation applications (Oren, 2005), (Banks, 2005) to name a few. In addition, such study gives a perspective regarding the use of the package.

### 3 FINDINGS

The packages, which have been reviewed in the context of this paper, are: Analytica, AnyLogic 5.0, Arena, AutoMod, AweSim, Berkeley Madonna™, BuildSim, Crystal Ball Standard Edition & Professional Edition, DecisionPro, DecisionScript, Design II simulation Package, Dymola, Ecosim Pro, eM-Plant, Enterprise Dynamics, ExpertFit, Extend, Factory Explorer, FirstSTEP Designer, Flexsim, GAUSS, GoldSim, GPSS World for Windows, MAST, MICROSINT, MyStartegy, ModelMaker, NAG SMP Library, NAG C Library, Optsim (Artifex), PASON Simulation System, MJC2, SLIM, Process Industry Manufacturing Scheduling System (PIMSS), ProModel-ProcessModel, Proplanner Manufacturing Process Management Software, ProVision, PowerSim, QX3D, Resource Manager, SAAM II, SansGUI Modeling and Simulation Environment, SAS Software, ShowFlow, SIGMA, SimCreator, SimCAD Pro, SIMPROCESS, SIMUL8, STELLA / ithink, STARDIS, Supply Chain Builder, VisSim, Visual Simulation Environment, WebGPSS (micro-GPSS) and Witness.

#### 3.1 Simulation Approaches

There are four main renowned simulation approaches: *Event-Scheduling method, Activity Scanning, Process- Interaction, and Three-Phase* approach, in comparison, the following can be noted:

The *Event-Scheduling method* is simpler and only has two phases so there is no Cs and Bs, this allow the program to run faster since there are no scanning for the conditional events. All these advantages also tells us something about the disadvantages of the method since there are only two phase then all events are mixed (no Bs and Cs) then the method is not parsimony, which means it is very hard to enhance (Pidd,1998).

The *Activity Scanning* approach is also simpler than the Three-Phase method since it has no calendar, and it support the parsimonious modeling. However this approach is much slower than Three-Phase since it treats all activities are treated as conditional. On the other hand, the executive has two phases. Usually this approach is confused with the Three-Phase method (Pidd, 1998).

The *Process- Interaction* “share two common advantages first; they avoid programs that are slow to run. Second, they avoid the need to think through all possible logical consequences of an event” (Pidd, 1998). Yet, as (Pidd, 1998) claims this approach suffers from DEADLOCK problem, but this approach is very attractive for novice modelers. Although, (Schriber et al, 2003). Says “process interaction was understood only by an elite group of individuals and was beyond the reach of ordinary programmers”. In fact (Schriber et al, 2003).adds “.Multi- threaded applications were talked about in computer science classes, but rarely used in the broader community”. Which indicates that the implementation of Process-Interaction was very difficult to implement. The obvious contradiction, in the previous quote is due to the mix up between the *Process Interaction* approach and the *Transaction-flow approach*.

To see the complete idea of the origins of Transaction-Flow best stated by (Schriber et al, 2003):

*This was the primordial soup out of which the Gordon Simulator arose. Gordon’s transaction flow world-view was a cleverly disguised form of process interaction that put the process interaction approach within the grasp of ordinary users. . Gordon did one of the great packaging jobs of all time. He devised a set of building blocks that could be put together to build a flowchart that graphically depicted the operation of a system. Under this modeling paradigm, the flow of elements through a system was readily visible, because that was the focus of the whole approach.*

The *Three-Phase* approach allows to “simulate parallelism, whilst avoiding deadlock” (Pidd and Cassel, 1998). Yet, Three-Phase has to scan through the schedule for bound activities, and then scans through all conditional activities which slow it down. Yet many forgo the time spent in return for solving the deadlock problem. In fact, Three-Phase

is used in distributed systems weather talking about operating systems, databases, etc, under different names among them Three-Phase commit see (Tanenbaum and Steen, 2002).

In regards to the simulation approaches, only 22 packages mentioned the simulation approach used in the package, while 34 packages refrained from mentioning their simulation approaches. Noting that among the 22 packages, almost 18 claimed the Event Based Approach, whereas, two simulation packages claimed the Activity Based Approach (*FirstSTEP Designer*, *SIMPROCESS*) and two claimed the Process Interaction Simulation Approach (*AutoMod* and *ProModel-ProcessModel*), as seen in Figure 1.

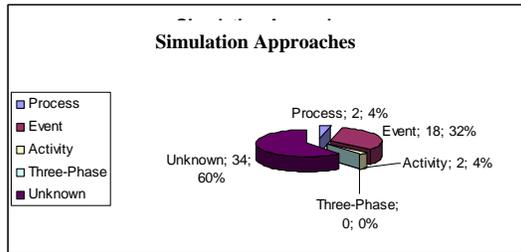


Figure 1: Simulation approaches

Within this context, *FirstSTEP Designer* used Activity Based approach (Interfacing Web), which is "much slower than Three-Phase approach since all activities are treated as conditional" (Pidd, 1998). Additionally, *Factory Explorer* used Event Based simulation approach (WWK Web). In the Event Based simulation approach "there are only two phase then all events are mixed then the method is not parsimony, which means it is very hard to enhance" (Pidd, 1998). In the same token, *GoldSim* which is only for dynamic systems and uses Event-Based Simulation Approach (GoldSim Web). Likewise, *ShowFlow* is based on Event Based Simulation Approach (ShowFlow Web) and *MyStartegy* can only deal with Dynamic systems (MyStartegy Web).

On another note, *ProModel* Family of software is based on Process-Interaction Simulation Approach (ProModel Web) yet (Pidd, 1998) claims that this approach suffers from DEADLOCK problem, while *Resource Manager* claims that it interacts with Microsoft Excel (UserSolutions Web) although it is not obvious how.

Succinctly, as regards to simulation approaches, none of the researched packages, of declared simulation approach, used the Three-Phase Approach, nonetheless, almost 34 packages never declared their simulation approach, as seen in Figure 3, which only magnifies that such idea could only be attributed to trade secret.

### 3.2 Use of Spreadsheets

There are 15 packages, almost 27%, that made referral to using the spreadsheet or Microsoft Excel as reporting tool, and they are: *Analytica*, *Crystal*

*Ball*, *Design II*, *Factory Explorer*, *First step Designer*, *FlexSim*, *GoldSim*, *MyStartegy*, *Nag SMP*, *Library*, *Nag C Library*, *ProModel*, *Recourses Manger*, *SimCAD*, and *ShowFlow*.

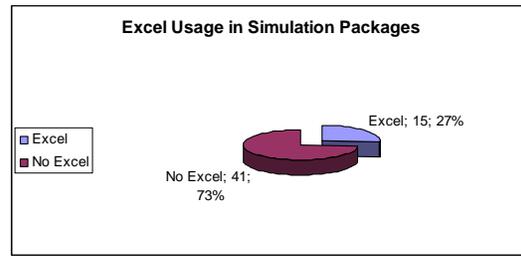


Figure 2: Excel usage in simulation packages

However, certain packages, like *Analytica*, use Excel as a reporting tool but not as platform (Lumina Web), which insinuates that the environment, where the model is built, is done on the *Analytica* specifically developed program. Likewise, *DESIGN II*, which is a simulator kernel that can be called from any Visual Basic, Visual C++ program (WinSim Web), as well as *Flexsim*, which can import & export to Microsoft Excel, and *SimCAD*, which is built on *AutoCAD* software (Flexsim Web).

The aforementioned facts emphasize the significance of using spreadsheets, like Microsoft Excel, in respect to the simulation packages, as seen in Figure 2. In fact, some packages claim that they pick up where spreadsheets left off, "Spreadsheets alone are inadequate for assessing the probability of an event because they lack the ability to generate and analyze alternative scenarios in a sophisticated way."(Goldman, 2002).

### 3.3 Object Oriented

Regarding the question on object oriented, almost 14 simulation packages claimed that they are object oriented or use Java as development language, which is a great indicator that simulation packages are converting to object oriented.

The fourteen commercial packages are: *Berkeley Madonna*<sup>TM</sup>, *Ecosim Pro*, *eM-Plant*, *Enterprise Dynamics*, *Flexsim*, *GAUSS*, *GoldSim*, *MJC2*, *PASION Simulation System*, *SansGUI Modeling and Simulation Environment*, *SIMPROCESS*, *SIMUL8*, *STARDIS*, *WebGPSS (micro-GPSS)*.

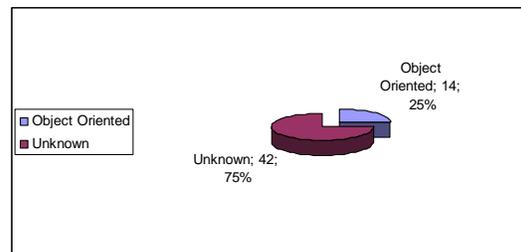


Figure 3: Object oriented languages use

Furthermore, it is worth mentioning the following findings in regards to this criterion:

*Berkeley Madonna*<sup>TM</sup> and *PASION Simulation System* both use the dynamic approach while the second package uses 2D animation the first package does not use any animation. Rather *Berkeley Madonna*<sup>TM</sup> uses graphs to show the results only.

In addition, *Ecosim Pro* is one of the 5 packages that uses both discrete and dynamic approaches. On the other hand, *GAUSS*, *SIMUL8*, *STARDIS* and *WebGPSS (micro-GPSS)* all use the discrete approach.

In regards to the 2D and 3D animation, 5 packages fell in each category. While *Ecosim Pro*, *eM-Plant*, *Enterprise Dynamics*, *Flexsim* and *SIMPROCESS* used 3D animation. On the other hand *GoldSim*, *PASION Simulation System*, *SIMUL8*, and *STARDIS* used 2D animation. Furthermore, *Enterprise Dynamics* used both 2D and 3D.

In regards to the use of spreadsheets as platform for reporting *Flexsim* and *GoldSim* used the spreadsheets as reporting tool

### 3.4 2D Vs. 3D

The notion whether to use 3D or 2D animation is significant, indeed as the model running in 3D (see Figure 4 ) gives better perspective of things in the model. Noting that making a simulation package that is capable of 3D animation is not easy, 3D idea is best represented in Figure 4 that was developed by *QX3D*; nevertheless, the 2D animation is also wanted in certain applications.

Of the 56 reviewed simulation packages, 25 simulation packages used animation for the model, which accounts to 44% of all reviewed packages, while 25% used 3D animation as seen in Figure 5, and 11 simulation packages used 2D animation. This observation signifies not only the importance of animation to simulation, but also the growing use and importance of 3D animation in the simulation world, noting that *FlexSim* is famous for the 3D animation.

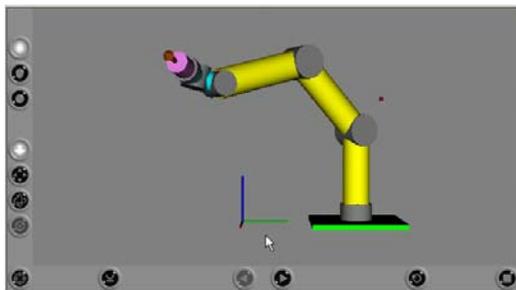


Figure 4: Building a robotic arm based on a stick figure using QX3D (QX3D Web)

The commercial simulation packages that used 2D animation are: *AnyLogic 5.0*, *Enterprise Dynamics*,

*Extend*, *FirstSTEP Designer*, *GoldSim*, *ModelMaker*, *PASION Simulation System*, *ProModel-ProcessModel*, *SimCAD Pro*, *SIMUL8*, *STARDIS*.

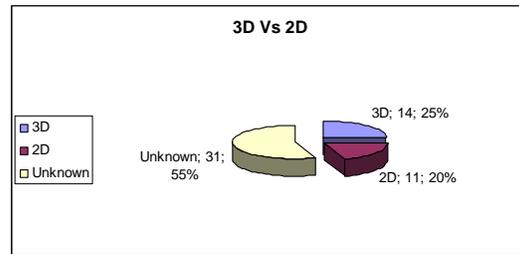


Figure 5: 3D vs. 2D animation

While the commercial simulation packages using 3D animation are: *AutoMod*, *Enterprise Dynamics*, *Dymola*, *Ecosim Pro*, *eM-Plant*, *Factory Explorer*, *Flexsim*, *Micro Saint*, *NAG SMP Library*, *ShowFlow*, *SimCreator*, *SIMPROCESS*, *Visual Simulation Environment*, *Witness*.

### 3.5 Time Handling

In regards to the time handling of simulation in the reviewed packages; 25% of the packages are based on discrete approach, while 16% of the simulation packages are based on the dynamic approach, however, only five packages used both discrete and continuous approaches, namely: *AnyLogic*, *Ecosim Pro*, *Extend*, *ModelMaker* and *Optisim (Artifex)* as seen in Figure 6.

The Discrete based commercial simulation packages are: *AutoMod*, *Arena*, *Factory Explorer*, *Micro Saint*, *Visual Simulation Environment*, *Witness*, *FirstSTEP Designer*, *SIMUL8*, *STARDIS*, *GAUSS*, *GPSS World for Windows*, *SAAM II*, *SIGMA*, *Supply Chain Builder*, *WebGPSS (micro-GPSS)*.

It is worth noting here that although using discrete simulation approach still the following has the capability of 3D animation: *AutoMod*, *Factory Explorer*, *Micro Saint*, *Visual Simulation Environment*, and *Witness*. Also *Factory Explorer* and *FirstSTEP Designer* both use Microsoft Excel as platform of reporting. On the other hand, *FirstSTEP Designer*, *SIMUL8* and *STARDIS* use 2D animation.

The simulation packages based on the dynamic approach are: *Berkeley Madonna*<sup>TM</sup>, *BuildSim*, *Design II simulation Package*, *Dymola*, *Mystrategy*, *SimCreator*, *PASION Simulation System*, *QX3D*, *STELLA / ithink*. Also, it is worth noting that *Dymola* and *SimCreator* both use 3D animation while *PASION Simulation System* uses 2D animation; further more *Design II simulation Package* and *Mystrategy* both use Spreadsheets as reporting tools.

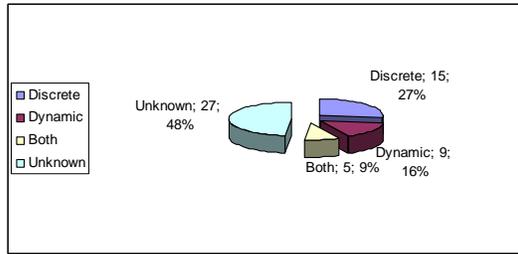


Figure 6: Simulation types

### 3.6 Monte Carlo

On another note, of the 56 reviewed packages, only four packages used Monte Carlo, which "can be loosely described as statistical simulation methods" (CSEP Web, 1995), namely; *Crystal Ball*, *BuildSim*, and *Decision Script & Pro*. It is worthwhile to note that *Crystal Ball* simulation package utilize Microsoft Excel & Visual basic (CrystalBall Web). Although *BuildSim* uses Dynamic approach and Generates, the code of the simulation model, yet no animation is available for this commercial simulation package.

### 3.7 Simulation Packages Applications

Simulation & modeling is used in a multitude of applications. Many researchers attempted to classify and categorize the simulation applications (Oren, 2005), (Banks, 2005), (Survey, 2003) and (Rizzoli, 2003) to name a few. While researching the simulation packages the researcher found 22 applications shared among the simulation packages. Some applications were more popular than others were as Figure 7: *Simulation packages applications*

suggests.

The 22 applications are listed in **Error! Reference source not found.**

#### *Air traffic control and space systems*

Air traffic control is ground-based service that advises pilot regarding maneuvering the plane into safety, the service provided on ground and in air using radar and visual contact. The service is divided into airport services, low and high airspace (en-route). The goal of the service is to control traffic. The commercial simulation package *Visual Simulation Environment (VSE)* provides such application among many other. *VSE* time handling method is discrete and uses event-scheduling approach.

### *Business process reengineering and workflows*

Business process reengineering is "Analysis and radical redesign of business processes using objective, quantitative methods and tools and management systems to accomplish change or performance improvement" (Grant, 2002). Some of the tools used in this application is commercial simulation packages like: *Analytica*, *Arena*, *Crystal Ball Standard Edition & Professional Edition*, *DecisionPro*, *DecisionScript*, *ExpertFit*, *MyStartegy*, *ProModel-ProcessModel*, *ProVision*, *SimCAD Pro*, *STELLA / ithink*, *Visual Simulation Environment* and *WebGPSS (micro-GPSS)*.

### *Complex System Design Evaluation*

Complex phenomena, through modeling, can only allow pattern predictions, compared with the precise predictions that can be made out of non-complex phenomena, as notably explained by Hayek (Popper 2002). In this regard, Hayek believed that economics and the sciences of complex phenomena in general, which, in his view, included biology, psychology, and so on, could not be modeled after the sciences that deal with essentially simple phenomena like physics.

Noting that research topics covered by Complex Systems span over a diverse array of fields including mathematics, physics, computer science, and biology, as such, there are many definitions of complexity. Additionally, and in view that many natural, artificial and abstract objects or networks can be considered Complex Systems, thereby to study these topics under complexity science is highly interdisciplinary. Considered radical contribution to early complexity theory, Hayek made distinction between the human capacity to predict the behavior of simple systems and its capacity to predict the behavior of complex systems through modeling.

Understanding that Complex Systems include various examples, such as: ant-hills, ants themselves, human economies, climate, nervous systems, cells and living things, including human beings, as well as modern energy or telecommunication infrastructure. In this context, not only are all the foregoing things considered networks of some kind, and they are complex, but apparently, they may also have little in common, hence the term "complex system" is vacuous. However, noting that all complex systems have behavioral and structural features in common, which at least unites them relatively as phenomena. In addition, they are united theoretically. Since all these systems may, in principle, be modeled with varying degrees of success by a certain kind of mathematics, it is therefore possible to state clearly what it is that these systems are supposed to have in common with each other, in relatively formal terms.

Table 1: Commercial simulation packages applications

|   |                                      |
|---|--------------------------------------|
| 1. Air traffic control and space systems          | 2. Supply chain management           |
| 3. Business process reengineering and workflows   | 4. Transportation systems            |
| 5. Complex system design evaluation               | 6. Aerospace                         |
| 7. Computer and communication networks            | 8. Oil & Gas                         |
| 9. Computer performance evaluation                | 10. Construction                     |
| 11. Education and training                        | 12. Financial modeling               |
| 13. Health care systems                           | 14. Parcels & parcel handling(queue) |
| 15. Manufacturing systems                         | 16. De-bottlenecking                 |
| 17. Military / combat systems                     | 18. What if scenarios                |
| 19. Satellite and wireless communications systems | 20. Robotic and mechanical systems   |
| 21. Service systems                               | 22. Decision and risk analysis       |

The Features of complex systems in nature are:

*Relationships are non-linear:* In practical terms, this means a small perturbation may cause a large effect (butterfly effect), a proportional effect, or even no effect at all. In linear systems, effect is always directly proportional to cause.

*Relationships contain feedback loops:* Both negative (damping) and positive (amplifying) feedback are often found in complex systems. The effects of an element's behavior are fed back to in such a way that the element itself is altered.

*Complex systems are open:* Complex systems in nature are usually open systems — that is, they exist in a thermodynamic gradient and dissipate energy. In other words, complex systems are usually far from energetic equilibrium: but despite this flux, there may be pattern stability.

Complex systems have a memory: The history of a complex system may be important. Because complex systems are dynamical systems they change over time, and prior states may have an influence on present states. More formally, complex systems often exhibit hysteresis.

Complex systems may be nested: The components of a complex system may themselves be complex systems. For example, an economy is made up of organizations, which are made up of people, which are made up of cells - all of which are complex systems.

*Boundaries are difficult to determine:* It can be difficult to determine the boundaries of a complex system. The decision is ultimately made by the observer.

*Dynamic network of multiplicity:* As well as coupling rules, the dynamic network of a complex system is important. Small-world or scale-free networks which have many local interactions and a smaller number of inter-area connections are often employed. Natural complex systems often exhibit such topologies. In the human cortex for example, we see dense local connectivity and a few very long

axon projections between regions inside the cortex and to other brain regions.

*May produce emergent phenomena:* Complex systems may exhibit behaviors that are emergent, which is to say that while the results may be deterministic, they may have properties that can only be studied at a higher level. For example, the termites in a mound have physiology, biochemistry and biological development that are at one level of analysis, but their social behavior and mound building is a property that emerges from the collection of termites and needs to be analyzed at a different level.

Simulation packages that claimed Complex system design evaluation are : *AnyLogic 5.0, Arena, AutoMod, NAG SMP Library, SIGMA* and *Visual Simulation Environment*.

#### **Computer and Communication Networks**

Computer and communication networks are another application where simulation is very useful; in view that communication network cannot be built and tested by the same individual, while taking into consideration that beforehand testing of the communication network is essential; however, experimentations in real life situation are nearly impossible. As such, a number of simulation packages offer such service: *AnyLogic 5.0, AweSim, ExpertFit, GPSS World for Windows, Optsim (Artifex), SAS Software, SLIM, VisSim, Visual Simulation Environment*.

#### **Computer Performance Evaluation**

Understanding that computers are made of many components, and each component has many different attributes from different manufacturer, accordingly, computer performance evaluation is another application where simulation would be of paramount significance. Particularly since experimenting with all the possible scenarios is nearly impossible. As such, the commercial simulation packages caught on this fact and two packages offered this application namely: *AnyLogic 5.0, Visual Simulation Environment*.

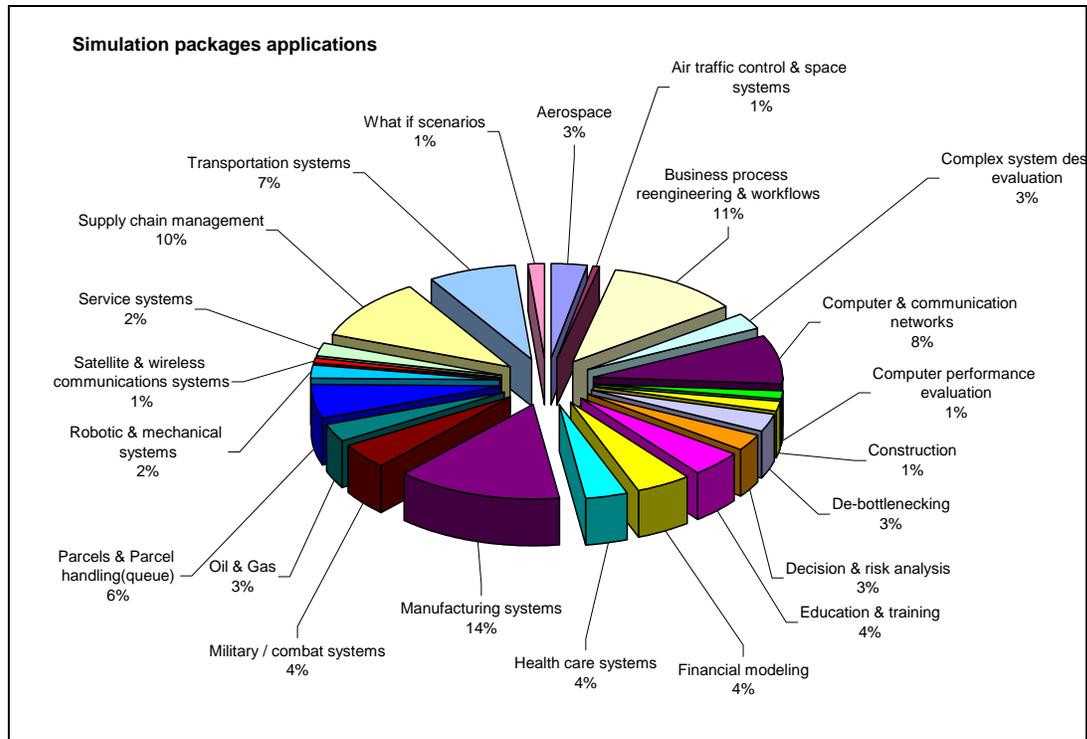


Figure 7: Simulation packages applications

### **Education and Training**

Education and training is one of the pillars of simulation. The application ranges from teaching about chemical molecules and chemical reaction to training a pilot on a new plane. In fact most applications stems from this application. Many packages stated this application by name. Some of the packages that stated such application are *AnyLogic 5.0*, *NAG SMP Library*, *PASION Simulation System*, *STELLA / itink*, *Visual Simulation Environment* and *WebGPSS (micro-GPSS)*.

### **Health Care Systems**

Health and care systems also another application that ranges from simulating emergency rooms cases and ambulance requests to analyzing the finances of the health care systems. Under this application many simulation packages signed their capabilities: *AutoMod*, *ExpertFit*, *MICROSAINT*, *NAG SMP Library*, *SIGMA*, *Visual Simulation Environment*

### **Manufacturing Systems**

Manufacturing is the application of tools and a processing medium to the transformation of raw materials into finished goods for sale. *Manufacturing systems is claimed by: Analytica, AutoMod, ExpertFit, Factory Explorer, Flexsim, GoldSim, GPSS World for Windows, MAST, MICROSAINT, NAG SMP Library, Process Industry Manufacturing Scheduling System (PIMSS), Proplanner Manufacturing Process Management*

*Software, Resource Manager, SIGMA, SimCAD Pro and Visual Simulation Environment.*

### **Military / Combat Systems**

Military / combat systems are applications that cover many topics in research. Such application deals with moving groups of people to deployment of armies to simulating a battlefield. The packages, claimed this application, are: *AnyLogic 5.0*, *ExpertFit*, *MICROSAINT*, *NAG SMP Library*, *STARDIS* and *Visual Simulation Environment*. The last package claims being used in the gulf war.

### **Satellite and Wireless Communications Systems**

Satellite and wireless communication systems are systems that are impossible to experiment with without simulation. The only package that offered such application is *Visual Simulation Environment*.

### **Service Systems**

*Service systems* range from an individual person equipped with tools of the trade (e.g., architect, entrepreneur) to a portion of a government agency or business (e.g., branch office of a post office or bank) to complete multinational corporations and their information systems (e.g. Domino's Pizza, Federal Express). Hospitals, universities, cities, and national governments are designed service systems. The language, norms, attitudes, and beliefs of the people that make up a service system may evolve over time, as people adjust to new circumstances. In this sense, service systems are a type of complex system that is partially designed and partially evolving. Service

systems are designed to deliver or provision services, but they often consume services as well. Packages that claim this application are: *Arena*, *ExpertFit*, *SIGMA* and *Visual Simulation Environment*.

### **Supply Chain Management**

This application is very broad, as it includes *inter alia*: Supply chain decisions support, inventory management, supply process optimization, internal logistics, company spreading etc. Supply chain management is an application that cares for efficiency and effectiveness and ranges from setting up policies to operative decisions. Many simulation packages stake a claim to this application: *AnyLogic 5.0*, *Arena*, *Flexsim*, *MAST*, *Process Industry Manufacturing Scheduling System (PIMSS)*, *SAS Software*, *SLIM*, *Supply Chain Builder* and *Visual Simulation Environment*.

### **Transportation Systems**

Transportation systems are expansive, as it ranges from simulating traffic light and intersections to roads closing and diversions. Many simulation packages claim this application i.e. *AnyLogic 5.0*, *AutoMod*, *Berkeley Madonna™*, *ExpertFit*, *NAG SMP Library*, *SLIM*, *VisSim*, *Visual Simulation Environment* and *Witness*.

### **Aerospace**

Aerospace comprises the atmosphere of Earth and surrounding space. Typically, the term is used to refer to the industry that researches, designs, manufactures, operates, and maintains vehicles moving through this air and space. Aerospace is a very diverse field, with a multitude of commercial, industrial and military applications. Aerospace is not the same as airspace, which is a term, used to describe the physical air space directly above a location on the ground. Four commercial simulation packages claimed this application namely: *Analytica*, *AutoMod*, *NAG C Library* and *QX3D*.

### **Oil and Gas**

This application pertains to Petroleum and well logging software for the oil and gas professional. In addition, this application covers many aspects yet four packages claimed it: *Analytica*, *Design II simulation Package*, *NAG SMP Library* and *Witness*.

### **Construction**

*Construction* is a series of carefully planned events, since construction technology uses materials, work, processes, and equipment to build a structure on a site, as such, the Construction application simulation

packages are: *Analytica* and *Design II simulation Package*.

### **Financial Modeling**

Financial modeling is broad application; it ranges from mixing a financial portfolio of stocks to decisions regarding best financial decision of buy/sell. Five simulation packages claimed this application, namely: *Analytica*, *DecisionPro*, *DecisionScript*, *GAUSS* and *NAG SMP Library*.

### **Parcels & Parcel Handling (queue)**

Parcel and parcel handling application is best seen in a post office arena. Each parcel has an destination address and certain attributes like size and fragility etc. Switching this scenario to production line in a factory that produces a product that needs packaging is still the same. Six simulation packages claimed this application: *AutoMod*, *Enterprise Dynamics*, *ExpertFit*, *Extend*, *SAS Software* and *SimCAD Pro*.

### **De-bottlenecking**

Bottlenecks appear when many compete for one resource. Whether the resource is a server on a computer network, a loan officer in a bank or production machine in a factory. Four simulation packages claimed this application namely: *eM-Plant*, *Factory Explorer*, *ShowFlow*, and *SIMUL8*.

### **What if... scenarios**

As the name of this application suggests, this application is a corner stone in the simulation arena. Yet only four packages mentioned this application by name. The packages are *Arena*, *Resource Manager* and *SIMUL8*.

### **Robotic and Mechanical Systems**

Simulating Robotic and mechanical systems is much cheaper than building the system and testing it. Packages like: *Dymola*, *QX3D* and *SimCAD Pro* claimed such application.

### **Decision and Risk Analysis**

Making Decisions and risk analysis always come hand in hand. Simulating the decisions and measuring the risk that comes with each decision is an application that comes with any arena of work from project management, to financial analysis. Many simulation packages like *Analytica*, *Crystal Ball Standard Edition & Professional Edition*, *DecisionPro*, and *SIMPROCESS* claimed such application.

Figure 8: Simulation Application packages gives more details tree-like taxonomy, each application categories and leafs reflect the packages that fall under such application.

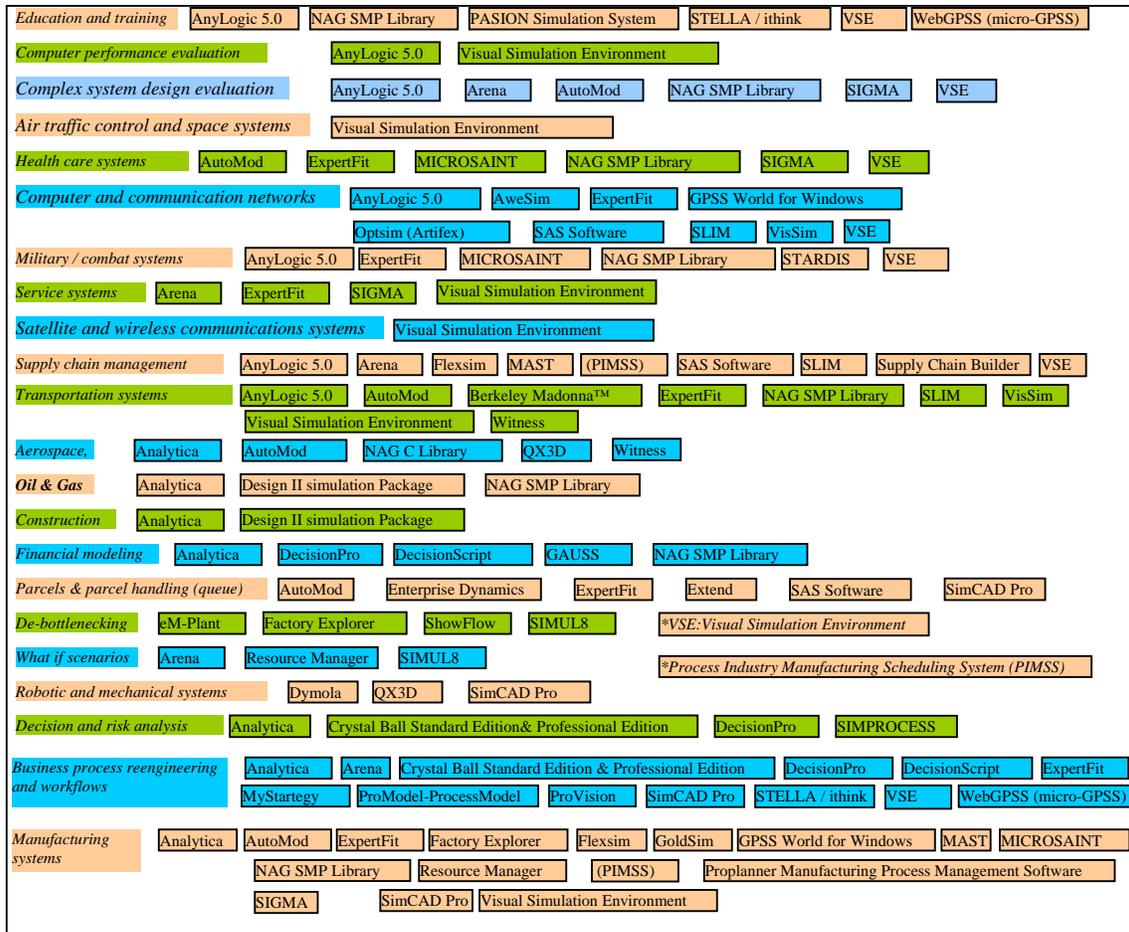


Figure 8: Simulation applications-packages tree

4 SUMMARY

This paper investigated 56 packages to answer the following set of comprehensive questions:

- What simulation modeling approach did the package use from the available approaches?
- What reporting tool did the package use?
- What programming language was used? (Which gives an indication whether the package is object oriented or algorithmic based).
- Whether the package uses animation and if the animation used is 2D or 3D animation?
- What time handling methodology is used (discrete, continuous, hybrid)
- What type of application are the packages capable of serving?

Although these questions targeted the trends that simulation packages are taking, nevertheless, the findings of the aforementioned questions are indicators, to which technology is prevailing.

Pithily, the research identified 26% of the 56 packages to use spreadsheets as reporting tools.

Table 2 : Review of the simulation packages

| Comparison Item  | Count | Percentage of 56 |
|--|-------|------------------|
| Total of packages where reviewed   | 56    | 100%             |
| Uses Microsoft Excel either as reporting tool or to export data to the spreadsheet | 15    | 26%              |
| Uses 3D animation  | 14    | 25%              |
| Use 2D animation   | 11    | 19.6%            |
| Discrete   | 15    | 26%              |
| Continuous   | 9     | 16%              |
| packages use both discrete and continuous (Hybrid)                                 | 5     | 7%               |
| Declared Simulation approach   | 22    | 39%              |
| Event-Scheduling method  | 18    | 32%              |
| Activity scanning method   | 2     | 3.5%             |
| Process-Interaction method   | 2     | 3.5%             |
| Object Oriented or Java Use  | 14    | 25%              |
| Use of Monte Carlo approach  | 4     | 7%               |

Additionally, 25% of the reviewed simulation packages pride themselves with 3D animation, while 19.6% use 2D animation.

In the same token, 26% of the reviewed packages are based on discrete approach, whereas 16% are based on continuous approaches, and only five packages can handle both discrete and continuous. In regards to the simulation approaches 36 of the simulation packages did not disclose their simulation approach, however, 32% used Event-Scheduling method, 3.5% used Activity scanning method, and 3.5% used Process-Interaction method, highlighting that none of the packages declared the usage of the famous Three-Phase simulation approach. As for the object oriented questions, 25% used object oriented or Java. Finally, the Famous Monte Carlo approach was used only by four packages. The findings and a summery of the numbers are laid in the Table 2.

## REFERENCES

- AnyLogic 4.5, user manual, pg 1. [www.xjtek.com/](http://www.xjtek.com/) (Accessed 1-4 -2004)
- [www.aptech.com/](http://www.aptech.com/) (Accessed 1-4 -2004)
- [www.arenasimulation.com/](http://www.arenasimulation.com/) (Accessed 1-9-2003)
- [www.automod.com/](http://www.automod.com/) (Accessed 1-9-2003)
- [www.automode.com/](http://www.automode.com/) (Accessed 1-4 -2004)
- Banks J. 1999. Introduction To Simulation. In *Proceedings of the 1999 Winter Simulation Conference*, ed. P. A. Farrington, H. B. Nembhard, D. T. Sturrock, and G. W. Evans., 7-13, December 5 – 8, Phoenix, Arizona, United States. Publisher: ACM Press New York, NY, USA
- Banks J. 2000. Introduction To Simulation. In *Proceedings of the 2000 Winter Simulation Conference*, ed. J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, 510-517, December 10-13 , Orlando, Florida, United States. Publisher: Society for Computer Simulation International, San Diego, CA, USA.
- [www.berkeleymadonna.com/flowchart.html/](http://www.berkeleymadonna.com/flowchart.html/) (Accessed 1-9-2003)
- Booch, G., Rumbaugh, J., Jacobson, I. 1999. The Unified Modeling Language User Guide. Addison-Wesley, Reading, MA, 1999.
- [www.tritera.com/products/web\\_buildsim/](http://www.tritera.com/products/web_buildsim/) (Accessed 1-9-2003)
- Caldwell, Bruce J. (2002). Popper and Hayek: Who influenced whom? (in English). Karl Popper 2002 Centenary Congress. Retrieved on 2007-05-04.
- [www.cse.fau.edu/~maria/COURSES/CEN4010-SE/C10/10-7.html/](http://www.cse.fau.edu/~maria/COURSES/CEN4010-SE/C10/10-7.html/) (Accessed 1-4 -2004)
- [www.cmsres.com/](http://www.cmsres.com/) (Accessed 1-9-2003)
- [www.createasoft.com/](http://www.createasoft.com/) (Accessed 1-9-2003)
- [www.crystalball.com/](http://www.crystalball.com/) (Accessed 15-10-2003)
- Introduction to Monte Carlo Methods* (electronic Book), 1995, [www.phy.ornl.gov/csep/CSEP/BMAP.html/](http://www.phy.ornl.gov/csep/CSEP/BMAP.html/) (Accessed 1-4 -2004)
- [www.dynasim.se/](http://www.dynasim.se/) (Accessed 1-9-2003)
- [www.ecosimpro.com/](http://www.ecosimpro.com/) (Accessed 1-9-2003)
- [www.enterprisedynamics.com/](http://www.enterprisedynamics.com/) (Accessed 1-9-2003)
- [www.Flexsim.com/](http://www.Flexsim.com/) accessed 1-9-2003
- Goldman L. 2002. Crystal Ball Professional Introductory Tutorial. In *Proceedings of the 2002 Winter Simulation Conference*, ed. E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, 1539-1545, December 8-11, San Diego, California, United States. Publisher: Winter Simulation Conference
- [www.goldsim.com/](http://www.goldsim.com/) (Accessed 1-9-2003)
- Grant, Delvin. 2002. A Wider View of Business Process Reengineering. COMMUNICATIONS OF THE ACM February 2002/Vol. 45, No. 2
- Hayek, Friedrich (1978). "The Results of Human Action but Not of Human Design", *New Studies in Philosophy, Politics, Economics* (Chicago: University of Chicago Press, 1978), pp. 96-105.
- [www.imaginthatinc.com/](http://www.imaginthatinc.com/) (Accessed 1-9-2003)
- [www.interfacing.com/](http://www.interfacing.com/) (Accessed 1-9-2003)
- [www.iseesystems.com/](http://www.iseesystems.com/) (Accessed 1-9-2003)
- [www.j-sim.org/](http://www.j-sim.org/) (Accessed 10-April-2004)
- [www.lanner.com/corporate/](http://www.lanner.com/corporate/) (Accessed 1-9-2003)
- [www.lumina.com/](http://www.lumina.com/) (Accessed 1-9-2003)
- [www.maad.com/](http://www.maad.com/) (Accessed 13-9-2003)
- McKim , C. J. 2000. Object Oriented Concepts. Rensselaer, 2000., Rensselaer at Hartford Lecture notes-[www.rh.edu/~jcm/concepts.pdf/](http://www.rh.edu/~jcm/concepts.pdf/) (Accessed on 20-6-2004)
- [www.mjc2.com/](http://www.mjc2.com/) (Accessed 1-9-2003)
- [www.modelkinetix.com/](http://www.modelkinetix.com/) (Accessed 1-9-2003)
- [www.strategydynamics.com/](http://www.strategydynamics.com/) (Accessed 1-3-2004)
- [www.nag.com/](http://www.nag.com/) (Accessed 1-9-2003)
- [www.OrcaComputer.com/](http://www.OrcaComputer.com/) (Accessed 1-9-2003)
- Pidd, M. 1998. Computer simulation in Management Science, 4<sup>th</sup> Ed., John Wiley & Sons, Chichester, England.
- [www.powersim.com/](http://www.powersim.com/) (Accessed 1-9-2003)
- [www.processmodel.us/booklet.pdf/](http://www.processmodel.us/booklet.pdf/) (Accessed 1-9-2003)
- [www.protodesign-inc.com/](http://www.protodesign-inc.com/) (Accessed 1-9-2003)

[www.concurrent-dynamics.com/qx3d/](http://www.concurrent-dynamics.com/qx3d/)(Accessed 1-9-2003)

[www.raczynski.com/pn/pn.htm/](http://www.raczynski.com/pn/pn.htm/)(Accessed 1-6-2004)

Redman S.,Law S. 2002. An Examination Of Implementation In EXTEND, ARENA, AND SILK. In *Proceedings of the 2002 Winter Simulation Conference* ed. E. Yücesan, C-H. Chen, J. L. Snowdon, and J. M. Charnes, 550-556, December 8-11, San Diego, California, United States. Publisher: Winter Simulation Conference.

Rizzoli A, [www.idsia.ch/~andrea/](http://www.idsia.ch/~andrea/) (Accessed 1-9-2003)

[www.rsoftdesign.com/](http://www.rsoftdesign.com/)(Accessed 1-9-2003)

[www.saam.com/software/saam2/saam2software.htm/](http://www.saam.com/software/saam2/saam2software.htm/)(Accessed 1-9-2003)

[www.showflow.co.uk/](http://www.showflow.co.uk/)(Accessed 1-9-2003)

[www.simcreator.com/index.php/](http://www.simcreator.com/index.php/)(Accessed 1-9-2003)

[www.simprocess.com/](http://www.simprocess.com/)(Accessed 1-9-2003)

[www.simul8.com/](http://www.simul8.com/)(Accessed 16-5-2003)

[www.stardis.com/](http://www.stardis.com/)(Accessed 1-9-2003)

[www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html](http://www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html) (Accessed 1-9-2003) OR/MS Today, August 2003

[www.tecnomatix.com/](http://www.tecnomatix.com/)(Accessed 1-9-2003)

[www.usersolutions.com/](http://www.usersolutions.com/)(Accessed 1-9-2003)

[www.vanguardsw.com/](http://www.vanguardsw.com/)(Accessed 1-9-2003)

[www.vissim.com/](http://www.vissim.com/)(Accessed 1-9-2003)

[www.webgpss.com/](http://www.webgpss.com/)(Accessed 1-9-2003)

[www.winsim.com/](http://www.winsim.com/)(Accessed 1-9-2003)

[www.wwk.com/](http://www.wwk.com/)(Accessed 1-9-2003)

#### AUTHORS' BIOGRAPHIES:

**EVON M. O. ABU-TAIEH** is a Ph.D. holder and assistant professor in the Arab Academy for Banking and Financial Sciences (AABFS). She is also Assistant Dean in the Information Systems College and Director of the London School of Economics program in the AABFS.

She earned her PhD from AABFS in 2005 in simulation. She received her masters in computer science from Pacific Lutheran University, and her B.Sc. from St. Martin's College both in Washington Stat, USA.

She published many research papers in many topics: GIS, RSA, Neural Networks, simulation, Data mining in airline reservations. She was appointed in many conferences as reviewer, track chair and track co-chair

**ABU-TAIEH** worked in the field of computers for almost 17 years as system analyst, software engineer, and head of IT department in many organizations: Mutah University, Ministry of Transport, Baccalaureate school.

Her current research interests are software engineering, databases, simulation and modeling, AI, and ciphering algorithms.

**ASIM ABDEL RAHMAN EL SHEIKH** was awarded his masters degree in Operational Research from London School of Economics & Political Science, University of London, London, England. Later he was awarded his PhD in simulation and modeling.

Currently he is Dean of Faculty of Information Systems & Technology, The Arab Academy for Banking & Financial Sciences, Jordan. Author of two books and more than 35 papers. Research interest areas: Software piracy, Software outsourcing, Simulation modeling, SW engineering.