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Evaluation and Ranking of Discrete Simulation Tools

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ABSTRACT

In studying through simulation, choosing an appropriate tool/language would be a difficult task because many of them are available. On the other hand, few research works focus on evaluation of simulation tools/languages and their comparison. This paper makes a couple of evaluations and ranks more than fifty simulation tools that are currently available. The first evaluation and ranking is in the approach of Analytic Hierarchy Process and the second one is in the Feature Analysis and Weighted Average Sum. The evaluations and rankings are based on thirteen indicators included in simulation tools, which are the general features, visual aspects, coding aspects, efficiency, modeling assistance, testability, software compatibility, input/output, experimental features, statistical facilities, user support, financial and technical features as well as pedigree. These evaluations and rankings provide significant information for any decision-maker to choose favorite simulation tools.

1. Introduction

Huge budgets have been devoted on simulation studies so that simulation has become a popular methodology to study a broad range of applications in recent years. In classical thinking, there are three types of approaches for simulation studies: Continuous, Discrete Event and Monte Carlo. These approaches and their differences are described in [1]. Among those, discrete event simulation softwares attract more attentions because they are a popular means of decision support and because of their ability to model complex systems with relative ease [2]. According to above mentioned items, many software tools have been developed for modeling problems, systems and solutions. The growing number and quality of simulation softwares, the development costs of models, the set-up cost and the running cost require expertise for their evaluation. Moreover, the fact is that the complexity of simulation tools requires a great deal of expertise and plays a vital issue to simulation practitioners to select an appropriate simulation tool for specific studies.

This paper follows the research which has been done in [3] and focuses on evaluation and ranking of the most important simulation softwares. The structure of the remaining sections is as follows: Section 2 presents the related works over evaluation of simulation tools. Section 3 describes the indicators provided for the evaluation and ranking. Section 4 evaluates the software tools, based on the indicators in a couple of approaches, the approach of Analytic Hierarchy Process (AHP) and the approach of the Feature Analysis and Weighted Average Sum (FSWAS). Finally, section 5 is considered for conclusion.

2. Related Works

With the large number of discrete event simulation tools available, the user needs to make careful criteria for selecting most suitable tools. The major works on taxonomy of simulation tools were performed by Overstreet0[4], Derrick et al. [5], Nance [6], Schruben and Roeder [7], Overstreet and Nance0[8], Roeder [2] and Sulistio et al. [9], Wang et al. [10] and Suliza et al.

[11] and Rashidi [3]. Several works have focused on evaluation of discrete event simulation in recent years. In this section, the related works over indicators for evaluation of software simulation tools are reviewed.

Mackulak and Savory did a survey on the most important simulation software features [12]. The authors identified the most important features include a consistent and user friendly for user interface, database storage capabilities for input data, an interactive debugger for error checking, interaction via mouse, a troubleshooting section in the documentation, storage capabilities for simulation models and results, a library of reusable modules of simulation code and a graphical display of input and output.

Page, in his thesis [13], developed a framework for next generation of simulation modeling. At the time of the research done, computing and information technology was making great pace, so that simulation was affecting particularly in distributed interactive and parallel discrete event simulation. This research lead to address two questions: "(a) can the existing theories of modeling methodology contribute to these new types of simulation? and (b) how, if at all, should directions of modeling methodological research be redefined to support the needs of advancing technology?" This research presents a series of criteria for evaluating simulation tools, which are quantifiable.

Banks and Gibson presented an overview of how to select simulation software tools [7]. In their overview, they provided guidelines to make a general evaluation of discrete simulation tools. These guidelines can be categorized into five groups: input, processing, output, environment, vendor and cost. They also highlighted three important points: (a) the appropriate features for user situation in applications must be considered; (b) the judgments on the basis of 'yes' and 'no', in overview check boxes would not be helpful; (c) sometimes, user may not need special features. The researchers also presented some qualitative features to evaluate discrete simulation tools.

Hlupic, Irani and Paul did a substantial research on simulation tools and presented a checklist to compare discrete simulation softwares [14]. The checklists are comprehensive, but some weaknesses are involved such as, (a) there are somewhere repetitive feature; (b) the checklist on the basis of answering 'yes' and 'no' questions, would not be helpful. An example of this deals with the user interface. The user interface related items pertaining to mouse support exist in efficiency, modeling assistance and input/output. In overall, the research was cumbersome and the analysis was not quantifiable.

Hlupic and Paul presented several criteria for the evaluation and comparison of simulation tools in the manufacturing domain together with their levels of importance for using in the particular purpose [15]. The authors indicated which criteria are more important than the other ones, according to the purpose of software use.

Tewoldeberhan et al. proposed an approach of two-phase evaluation and selection methodology for simulation softwares [16]. In their approach, simulation software vendors participated in both phases. The phase one reduces the long-list to a short-list of tools and phase two matches the requirements of the company with the features of the simulation tool in detail. They also used different methods for a detailed evaluation of each tool.

Seila et al. presented a framework to choose simulation software and evaluated 20 software tools [17]. Their proposed framework first tries to identify the project objective. It is also prudent to define long-term expectations. Other important questions deal with model dissemination across the organization for the others to use, model builders and model users, type of process (assembly lines, counter operations, material handling) the models will be focused, range of systems represented by the models, etc.

Ahmed, Hall and Wernick described a rational for formal evaluation criteria in simulation softwares [5] and provided more guidelines for development. They presented the background for developing a formal set of criteria and summarized the previous work. In their research, they reviewed the work done by Boehm [18], Lindland et al. [19] and Kitchenham et al. [20] in developing their proposed framework. Their work proposes five main criteria for evaluation of discrete simulation tools: syntactic quality, semantic quality, pragmatic quality, test quality and maintainability. They also considered the value of the simulation in their framework as a separate evaluation. Their work is fairly detailed, but the framework is not analytical and subjective. Their work is a refinement over the previous work, mainly in [21], by including enhancement of semantic quality and the addition of maintainability.

Jadhava and Sonar reported a systematic review of papers published in journals and conference proceedings [22]. Their review investigates methodologies for selecting software tools, software evaluation techniques, software evaluation criteria, and systems that support decision makers in evaluating software tools. The key findings of their review are: (a) analytic hierarchy process has been widely used for evaluation of the software tools; (b) there is a lack of a common list of generic software evaluation criteria and its meaning and (c) need to develop a framework comprising of software selection methodology, evaluation technique, evaluation criteria and system to assist decision makers in software selection.

Albrecht and AZ followed evaluation of simulation tools [1], based on the works done by Banks and Gibson [7] and that of Page [13] and drew a procedure. Their procedure covers seven major areas: (a) modeling environment; (b) model documentation and structure; (c) verification and validation; (d) experimentation facilities; (e) statistical facilities; (f) user support and (g) financial and technical features. Taking the above factors into account, a quantitative method of comparing four Simulation Modeling Tool (SMT) tools (Arena, Extend, Sigma and Ptolemy II) was evaluated. Their research concluded that: (a) among the four SMT tools, Ptolemy II is the most flexible, true open-source and offers the most features. However, since it is primarily a test bed, it has few standard features and it has the ability to extend some features; (b) Arena and Extend, as commercial tools, offer the most comprehensive tools ready to use; (c) Sigma is the least simulation tool developed of the four and offers a compromise between true open-source and closed one.

Gupta et al. illustrated and assessed the role of the Analytic Hierarchy Process (AHP) in simulation software evaluation [23]. The authors ranked four widely used manufacturing simulators: NX-IDEAS, Star-CD, Micro Saint Sharp and ProModel. Their evaluation was based on 12 main groups of features and having more than 200 features. From their calculation and ranking, ProModel had the highest ranking and was the best software according to the user's requirements.

The Institute for Operations Research and the Management Sciences (OR/MS) made another evaluation on simulation tools in [24], as a survey. The information in the survey was provided by the vendors in response to the questionnaire that developed. The research considered typical applications of the software, primary markets for which the software is applied, system requirements including RAM, operating systems, model building including graphical model construction (icon or drag-and-drop), model building using programming/ access to programmed modules, run time debug, input distribution fitting (specify), output analysis support (specify) have been considered. Batch run or experimental design (specify), optimization (specify), code reuse (e.g., objects, templates), model packaging (e.g., can completed model be shared with others who might lack the software to develop their own model?), tools to support packaging (specify), does this feature cost extra?, cost allocation/costing, mixed discrete/continuous modeling (levels, flows, etc.), Animation: Animation, real-time viewing, export animation, compatible animation software, 3D animation, import CAD drawings, support/training: user support/hotline, user group or discussion area, training courses, onsite training, consulting available, Price: standard, student version as well as major new features (since 2007). Their survey should not be considered as comprehensive, but rather as a representation of the available simulation tools. The questionnaires were sent to simulation vendors drawn from the previous survey participants, the OR/MS today database and other sources. It includes the products of those vendors who responded by the deadline.

Jadrić et al. did one comparison of discrete event simulation tools in an academic environment[25]. The authors made a model consists of three categories: modeling and simulation capabilities of the explored tools and tools' input/output analysis possibilities, all with respective sub-criteria. Then the model is run on a couple of tools, Arena and ExtendSim, to determine which one is suitable for the students. Their results indicate that ExtendSim is well preferred comparing to Arena concerning subjective indicators while the objective indicators are better for Arena.

Gupta designed and implemented Smart Sim Selector [26] which is a software developed for the purpose of providing support for users when selecting simulation software. This selector consists of a database that is linked to an interface developed using Visual Basic 6.0. This tool queries a database and finds a simulation package suitable to the user, based on requirements specified by the users.

Damje et al. did a ranking of business process simulation software tools with DEX/QQ hierarchical decision model. They proposed a new hierarchical decision support model [27] for ranking of Business Process Simulations Software (BPSS) based on their technical characteristics by employing DEX and Qualitative to quantitative (QQ) methodology. Their proposed hierarchical model has three advantages: (a) it is easily extendible for adding new criteria in the hierarchical structure; (b) it is an operational decision support system tool that implements the proposed hierarchical model. The effectiveness of their proposed hierarchical model is assessed by comparing the resulting rankings of BPSS with respect to currently available results.

Fowler et al. compared discrete-event simulation approaches for complex manufacturing systems and healthcare systems [28]. Their aim is to explore differences in simulation of complex manufacturing systems and healthcare systems as the first step to improve simulation of healthcare systems. They focused on applications of discrete-event simulation to mainly address operational questions and described the manufacturing and healthcare domains.

Their findings were that the composition of services in healthcare is quite different from the more static product structure and route definition in complex manufacturing systems. The simulation models in healthcare are often smaller in size and need more details compared to the large-scale simulation models in complex manufacturing.

Rashidi made a survey on taxonomies of discrete simulation tools and then presented five taxonomies of them [3]. The first taxonomy is in different approaches for world-views, which include event scheduling, activity scanning, three-phase and process interaction. The second one is based on how the tools handle entities and the third one is to have simulation tools with (without) some programming capabilities. The fourth taxonomy is based on how discrete simulation tools aid in the construction of user's applications and the fifth one is related to executing the model. Afterwards, more than sixty simulation softwares are evaluated in the taxonomies provided.

3. THE INDICATORS USED FOR THE EVALUATION AND RANKING

In this section, we put together indicators that used in the works of Page [13]; Banks and Gibson [7]; Hlupic, Irani and Paul [14] and Ahmed, Hall and Wernick [5]. These indicators are in the general features, visual aspects, coding aspects, efficiency, modeling assistance, testability, software compatibility, input/output, experimental features, statistical facilities, user support, as well as financial and technical features. The structure of these indicators that are given in [29] had some overlaps. Here, we rearrange the structure of each indicator so that the overlaps between them are minimized. These indicators are described below.

A. General Features

The first step in simulation study is system modelling. A well designed simulation modelling tool needs to consider some general features related to model’s logic, presentation of the model, entity name and the unit of measurements. In this evaluation, the considered items are: (a) Terminology used in general and specific applications; (b) Representativeness of models; (c) Ease of conceptualization of simulation logic; (d) Modelling transparency; (e) Hierarchical model building; (f) Run-time applications; (g) Conceptual model generator; (h) The length of entity name; (i) Entity name; (j) Experience required for software use; (k) Formal education in simulation required for software use; (l) User friendliness; (m) Ease of learning and using; (n) Initialization; (o) Specification of time units; (p) Integration of operations: data gathering, simulation model development, output data analysis; (q) Real-time simulation models; (r) Distributed simulation on network environment; (s) Specification of length measures and(t) Number of elements in the model.

B. Technical and Financial Features

Simulation modeling tools should consider hardware/system requirements, educational needs, the cost of simulation tool, how easy to install it and what it will cost to maintain the simulation tool. In this evaluation, the following items are considered: (a) Formal logic required; (b) Portability and file conversion; (c) Ease of installation and hardware requirements; (d) Availability of tool on standard platform (operating systems and hardware-CPU); (e) Versions of software for different operating systems and for network; (f) Conversion of numbers: real vs. integer; (g) Security device; (h) Frequency and comprehensiveness of update; (i) Free technical support; (j) Types of contracts available; (k) Educational discount; (l) Consultancy fees; (m) Price and price of training course; (n) Installation costs and life cycle maintenance costs; (o) Free software trials; and (p) Quantity discount.

C. Efficiency

Efficiency is one of the important indicators for evaluation of any computing software/tool. Efficiency in simulation’s computing refers to algorithmic efficiency (optimizing the speed and memory requirements of a simulation tool), storage efficiency (effectiveness of computer data storage) and other factors in interactions. It is often used with the specific purpose of relaying the capability of a specific model to produce a specific outcome effectively with a minimum amount or quantity of waste, expense or unnecessary effort. In this evaluation, the following items are considered: (a) Robustness; (b)Level of detail; (c) Model reusability; (d) Model status saving; (e) Automatic saving; (f) Interaction; (g) Adaptability to model changes; (h) Multitasking: performing several tasks at the same time; (i) Model chaining: linking outputs from different models; (j) Exit to the operating system within the tool; (k) Compilation time; (l) Model execution time; (m) Case sensitivity; (n) Various queuing policies; (o) Number of queuing policies; (p) Time scale for model building; (q) Reliability; (r) Pre-existing generic models; (s) Merging of models; (t) Editing partially developed models; (u) Automatic model building; (v) Ease of model editing; (w) Interactive handling of parameters during experimentation; (x) Specification of part flow by a mouse; and(y) Virtual memory facility.

D. Testability

Software testability is the degree to which a model built supports testing in a given test context.

Testability is not an intrinsic property of a software model and cannot be measured directly by some parameters such as size. For a system to be properly testable, it must be possible to control each component's internal state and inputs and then to observe its outputs. In fact, testability is an extrinsic property which results from interdependency of the software model to be tested, test goals, test methods used and test resources such as test context and test case. In this evaluation, the following items are considered: (a) Logic checks; (b) Interactive error messages and its quality; (c) Moment of error diagnosis: model entry, compilation, model execution, combination; (d) Ease of debugging; (e) Display function values, variables, element's state, attributes and their accessibility, workflow path and events on the screen as well as part position within element; (f) Dynamic display of capacity; (g) Facility for immediate user actions; (h) Flow analysis; (i) List files: list of model entities and parameters; (j) Trace files: showing events and entity status; (k) Explode function: showing a state of an element/entity; (l) Step function: event to event jumping; (m) List of used elements; (n) Echo and interactive debugger; (o) Display of parts flow tracking record collected during simulation run; (p) Backward clock and (q) Audible alarms.

E. Modeling Assistance

A well designed simulation modelling tool must provide some facilities in system modelling. In this evaluation, the following items are considered: (a) Prompting and its quality; (b) Objects and considering modularity; (c) Defined elements, model and data separation; (d) Facility to design reusable user; (e) Libraries and templates of simulation; (f) Warning messages for operations effect on the model file including overwriting and closing file not saved as well as model currently developed; (g) context sensitive prompt to facilitate model development; (h) Undo/redo commands; (i) Automatic connection between elements and automatic editing of data; (j) Concurrently with model development; (k) Use of mouse; (l) One-line help and its quality; (m) Search facilities within help;(n) Help on system messages; (o) Printing help text; (p) Documentation notes to insert comments; (q) Quality of facilities for documentation notes and (r) Text editor as integral part of the simulation tool.

F. Experimentation Facilities

In evaluation of simulation tools, another indicator is facilities to help running experiments. Once a simulation model is created and verified, it needs to be used and executed often many times for different conditions. For experimentation, facilities like automatic batch runs, allowance for a warm-up period and independent replications of experiments with re-initialization between runs without totally restarting the model are good features to have. Other desirable features include re-start from non-empty state, breakpoints and online speed adjustment. If the discrete simulation tool can provide experimental design capability with accuracy checking and automatic determination of run length they also are premiums. In this evaluation, the following items are considered: (a) Automatic batch run; (b) Warm-up period; (c) Independent replications of experiments; (d) Re-initialization; (e) Re-start from non-empty state; (f) Breakpoints; (g) Speed adjustment; (h) Experimental design capability; (i) Quality of experimental design facility; (j) Accuracy check; and (k) Automatic determination of run length.

G. Statistical Facilities

Today, simulation modelling tools needs to include some statistical distributions and even user-defined distributions to model different conditions in the systems. These abilities are very important facility for stochastic system modelling. To offer these facilities, the simulation tools must manage large volumes of random number generators, and if possible several random number streams. Each of the random number streams should be allowed for user-specified seeds or at least several separate seeds. To improve variance reduction the ability to handle antithetic sampling and distribution fitting are needed. Standard experiment analysis functions such as goodness-of-fit tests and output data analysis are advantageous. Moreover, quality of data analysis facilities and the capability to analyse confidence intervals are important. In this evaluation, the following items are considered: (a) Theoretical statistical distributions; (b) Number of theoretical statistical distributions; (c) User-defined distributions; (d) Random number streams; (e) Number of different random number streams; (f) User-specified seeds of random number streams; (g) Antithetic sampling; (h) Distribution fitting; (i) Goodness-of-fit tests; (j) Output data analysis; (k) Quality of data analysis facility; (l) Confidence and (m) Interval.

***H.** Input/output Issues*

A well designed simulation modelling tool must provide some facilities for inputting the model and data as well as outing the results during the execution time and at the end. In this evaluation, the following items are considered: (a) Menu driven interface; (b) Pull down menus; (c) Type of menu selection; (d) Selection buttons; (e) Dialogue boxes; (f) Multiple inputs; (g) Model input; (h) Database maintenance for input/output; (i) Multiple outputs; (j) General output reports; (k) Static graphical output; (l) Dynamic graphical output; (m) Types of graphical display: bar graphs, histograms, level graphs, pie charts, line graphs, scatter diagrams, time series, area graphs; (n) User defined output; (o) Automatic rescaling of histograms and time series; (p) Quality of output reports; (q) Understand ability of output reports; (r) Periodic output of simulation results; (s) Availability of results before end of simulation; (t) Input data reading from files; (u) Writing reports to files; (v) Writing reports to printer; (w) Writing reports to plotter; (x) Snapshot reports; (y) Summary reports for multiple runs.

I. Coding Aspects

In making a model and its programming, one of the important aspects is to code the model; that is organizing the elements in the model particularly in simulation programming tool. In this evaluation, the following items are considered: (a) Programming flexibility; (b) Program generator; (c) Access to source code; (d) Readability of source code and (e) Readability, self-documentation and precision of added code; (f) Comprehensiveness of added code; (g) Link to a lower language; (h) Data storage, retrieval and manipulation facilities; (i) Quality of data storage, retrieval and manipulation facilities; (j)Built-in functions; (k) User functions; (l) Global variables; (m) Names of functions, variables and attributes: defined by; (n) Writing comments for logical elements; (o) Type of time variable; (p) Type of translation: compilation/ interpretation; (q) Text/code manipulation; (r) Length of the lines in coding editor; (s) Support of programming concepts; (t) Quality of the support for programming concepts; (u) Interface to user written programs and (v) Object oriented programming.

J. Software Compatibility

Software compatibility can refer to the compatibility that a particular software model has running on a particular platform (CPU and operating system) and integrated with other software tools. In this evaluation, the following items are considered: (a) Integration with spreadsheet tools, statistical tools, word processors, computer-aided design softwares, database management system and expert systems; and (b) Integration with manufacturing requirements planning and scheduling softwares.

K. Visual Aspects

Visual aspects refer to provide some facilities in animation, numerous screens and graphics elements during the execution of a model and its output. In this evaluation, the following items are considered: (a) Animation in different types: concurrent animation, post-processed animation; (b) Timing of animation; (c) Animation with visual clock and playback mode; (d) Animation layout development in concurrent with model development, before model development and after model development; (e) Type of graphical display and 3D graphics; (f) Integrity of graphics; (g) Multiple screen layout; (h) Facility for customizing the view of the model; (i) Importing graphics and multimedia elements; (j) Screen and icon editor; (k) Ease of icon development and using screen editor; (l) Types of icons: bit mapped/ pixel based; (m) Icon library; (n) Merging icon files; (o) Resizing and rotating icons; (p) Changing the colour of the icons; (q) Zoom function; (r) Panning; (s) Switching on/off the graphic; (t) Switching between screens; (u) Switching between character and icon graphics; (v) Print screen facility; (w) Virtual screen; (x) Indication of the element status; (y) Changing the colour of the element status display; (z) Limitation on the number of displayed icons; (aa) Number of icons stored in the icon library; (bb) Change of icons during simulation; (cc) Icons with multiple colours; (dd) Virtual reality features; (ee) Easy copying of icons and (ff) Rejection of illegal inputs.

L. User Support

In the simulation tools, user support tools are important, unless the user develops their own simulation-modelling tool. The level of documentation provided in the tools and the quality of the documentation is highly important. Good technical and promotional information into, such as e-mails, chats and internet discussion groups, can assist in learning simulation modelling tool, as a training course (such as introductory, basic and advanced), tutorials and demonstration models. If simulation modelling tools are developed for educational use, the provision of a lecturer's guide is necessary. General support functions such as providing tool maintenance facilities are also critical. In this evaluation, the following items are considered: (a) Documentation and quality of documentation as well as manuals for users; (b) Reference card and glossary; (c) Technical and promotional information material in forms of e-mail, newsletter and bulletin board; (d) Discussion groups on the Internet; (e) Lecturer's guide for educational licenses; (f) Demo disks, tutorial and demo models; (g) Training course in both basic and advanced levels; (h) Custom tailored training course; (i) Duration of training courses; (j) Frequency of training courses; (k) Help-line; (l) User group meetings; (m) Frequency of user group meetings; (n) Tool maintenance and (o) Consultancy.

M. Pedigree

Pedigree refers to the lineage or genealogical descent of the simulation tools, whether documented or not, whether purebred or not. In this evaluation, the following items are considered: (a) Age and genealogy; (b) spread and success; (c) Availability of software maturity references; (d) Reputation of supplier and (e) Sources of information.

4. Evaluation of the Indicators and Ranking of the Simulation Tools

In this section, the evaluations on the simulation tools are performed by a couple of approaches. The first approach is to evaluate the indicators and ranking the simulation tools in the Analytical Hierarchical Process. Since the AHP is a technique to solve multi-criteria decision-making problems using pair-wise comparison and expert's judgment, we employ that. The second approach is to evaluate the indicators and ranking the simulation tools in the feature analysis and weighted average sum procedure. These approaches are described in the following sub-sections. In this paper, more than fifty simulation tools are evaluated and ranked. The data processes, here, are based on the information provided in [24] searching in the vendor sites on the Internet and discussions. In the discussion, a team of seven graduate students, in statistics and computer science subjects, are assigned to do the task as a project. Each member in the team had significant background in the simulation.

A. The Analytic Hierarchy Process and Simulation Software Ranking

The approach, here, is very similar to that was used in [23]. The Analytic Hierarchy Process (AHP) approach separates the evaluation decision into hierarchy levels and attempts to reduce the inconsistencies in judgments. It was originally used for socioeconomic and political situations but of late it has proved useful for judgmental decision making in other areas, such as the selection of equipment for ice breakers, the selection of materials handling equipment and perhaps more relevant, the selection of manufacturing software [4] and scheduling software. Further applications along with a good exposure of AHP, are given by Partovi et al. [30] and Zahedi[31].

In using the AHP technique, all the criteria are compared in a pair-wise way, using Saaty's intensities of importance [32], in order to establish which criteria are more important than others. The values are then placed in a matrix and the normalized principal eigenvector is found to provide the weighting factors which provide a measure of relative importance for the decision maker. The next step is to make pair-wise comparisons of all alternatives with respect to each criterion. Final rankings of the alternatives are made by multiplying the critical weights of the alternatives by the critical weights of the criteria. The alternatives with the highest scores are then deemed to be the preferred choice.

In this approach, the following steps are performed:

Step-1: In this step, the weight factor (importance) of each group of indicator, desired by the participant, is calculated. Depending upon the priority requirement of the participant of one group of indicator over another, the matrix shown in Table 3 for the general features is filled. The entries are filled as per Saaty's intensities of importance. All diagonal elements in the matrix will be one. We have to fill only the upper triangular matrix and the lower triangular matrix will contain the reciprocal entries. Once the matrix has been filled, the next step is to divide each element by the corresponding sum of the column (see the numbers given in the Pare thesis). Then the average of each row is calculated that gives us the score for each indicator (see the last column of the Table 3). For other twelve indicators a table like Table 3 is made[1].

Step-2: In this step, Table 4 is made and the score for each indicator is transferred to the corresponding element.

Step-3: In this step, the total score for each simulation tool is calculated by the following equation:

$$TotalScore = MaximumValue \times \sum_{i=1}^{13} W_i \times S_i (1)$$

The total score is in the last column of Table 3. For example, see how the value 0.245 (the second row, last column) is calculated for the software tool @RISK. In the above equation, the maximum value is five and the weights are according to [32].

According to the result provided in the Table 4, we derive several observations as follows:

- **Observation-1:** The top-six simulation tools in the total scores are ***Stat.:Fit, QMS, LABSAG (Spanish & Portuguese), LABAMS (English), Project Simulator, CSIM for Java*** and ***CSIM20***respectively.
- **Observation-2:** Table 1 shows the sum of scores for each indicator in the simulation tools (see the last row of the Table 4). As we can see in the Table 1, the *Experimental Facilities*, Visual *Aspects, Efficiency, Modelling Assistance,* and *Financial & Technical Features* are five indicators that got the highest score respectively.
- **Observation-3:** Among the indicators, *Statistical Facilities*, *Software Compatibility*, *Testability, General Features and User Support* are five indicators that obtained the lowest scores respectively. According to this result, these indicators are specific challenges for the future of the simulation softwares.

[1]A copy of the information for other indicators can be obtained from the author by mailing at zrashi@gmail.com.

TABLE 1
THE RESULT OF THE AHP FOR TOTAL SCORE OF THE INDICATORS IN THE SIMULATION TOOLS

Indicators	Value
General Features	5.24
Visual Aspects	12.21
Coding Aspects	5.859
Efficiency	8.553
Modeling Assistance	6.443
Testability	4.255
Software Compatibility	3.935
Input/output	4.634
Experimental Facilities	33.2
Statistical Facilities	3.818
User Support	4.496
Financial & Technical Features	6.321
Pedigree	5.301

B. The Feature Analysis and Weighted Average Sum (FAWAS) and Simulation Software Ranking

The approach, here, is based on combing the techniques of the Feature Analysis and Weighted Average Sum (FAWAS) (See [22] and [1] for detail on these techniques). In this approach, each member of the analysis team must have specified a score for the indicators mentioned in the section 3. In the evaluation, we consider score = zero to five, with zero means the indicator is not in the software or not available and five means the indicator is completely available. In conditions where it is a comparative ranking (e.g. Price) the most desirable score would be five and the least desirable score would be zero. After specifying the scores, an average was calculated to make a final score for each of the indicators. The result of this approach is illustrated in Table 6.

According to the information provided, we derive several observations as follows:

- **Observation-4:** The top-five simulation tools in the total scores are *Arena Simulation Software, ExtendSim Suite, AnyLogic, ExtendSim AT, ExtendSim OR* and *Micro Saint Sharp* respectively.
- **Observation-5:** The simulation tools that got the highest scores in each indicator are given in Table 5. The highest score in each column of the cells in Table 6 are highlighted as bold.
- **Observation-6:** Figure 1 shows the average scores for each indicator in the simulation tools. As we can see in the Figure 1, the *User Support, Pedigree, Efficiency, Financial & Technical Features* and *Statistical Facilities* are 5 indicators that got the highest average respectively. Among the indicators, the *Modelling Assistance, Testability, Coding Aspects, Visual Aspects* and *Experimental Facilities* are five indicators that obtained the lowest average scores respectively.
- **Observation-7:** As we can see in the Figure 1, the indicators of the ***Visual Aspects, Coding Aspects, Modelling Assistance, Testability*** and ***Experimental Facilities*** got a score less than the average (2.5). According to this result, these indicators are specific challenges for the future of simulation softwares.

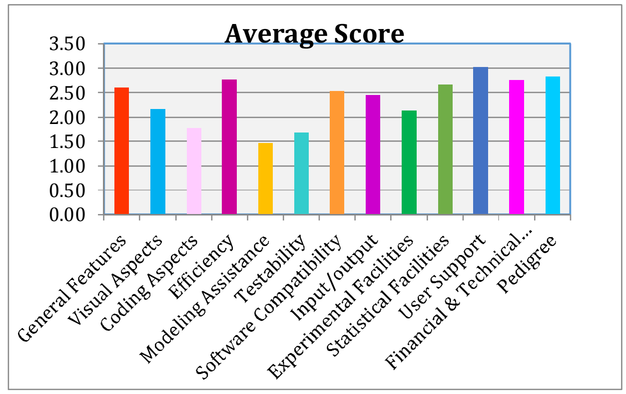

Figure 1: The result of FAWAS for the average score of the simulation tools.

5. CONCLUTION

This paper reviewed the recent approaches for evaluation of the software simulation tools. Then, it evaluated thirteen indicators in the current simulation tools and ranked them in two approaches. The first approach is Analytic Hierarchy Process and the second one is the Feature Analysis and Weighted Average Sum. The results of these couple of ranking the simulation tools are too different and there are few similarities in ranking scores of the indicators. The first similarity is that *Efficiency* as well as *Financial and Technical Features* are in the higher-scores among the thirteen indicators. The second similarity is that *Testability* was the lowest among the five lower-scores indicators.

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TABLE 2
THE SOFTWARES WITH THE HIGHEST SCORE IN EACH INDICATOR IN THE ANALYTICAL HIERARCHICAL PROCESS

Row	Indicators	Software (s) in The Highest Score	
1	General Features	Stat.:Fit CSIM for Java Proof 5	Clinical Trials Simulator Proof 3D
2	Visual Aspects	LABSAG (Spanish & Portuguese) LABAMS (English) Project Simulator	Emergency Department Simulator Stat.:Fit
3	Coding Aspects	Emergency Department Simulator XLSim 3.0 Clinical Trials Simulator	Stat.:Fit QMS
4	Efficiency	CSIM for Java QMS WebGPSS	Stat.:Fit Blues Simulation System (Bluesss)
5	Modeling Assistance	QMS Stat.:Fit Enterprise Portfolio Simulator	Portfolio Simulator CSIM for Java
6	Testability	Enterprise Portfolio Simulator Portfolio Simulator Clinical Trials Simulator	CSIM for Java Analytica 4.2
7	Software Compatibility	Stat.:Fit PSM++ CSIM for Java	LABSAG (Spanish & Portuguese) , LABAMS (English) Blues Simulation System (Bluesss)
8	Input/output issues	CSIM20 CSIM for Java SLX	Proof 5 Proof 3D
9	Experimental Facilities	XLSim 3.0 QMS Stat.:Fit	Proof 5 Proof 3D
10	Statistical Facilities	CSIM for Java Proof 5 Proof 3D	CSIM20 SLX
11	User Support	CSIM for Java CSIM20 Stat.:Fit	SLX Proof 5
12	Financial & Technical Features	Flexsim CT Emergency Department Simulator Vanguard System	Service Model Optimization Suite Flexsim
13	Pedigree	SLIM Flexsim CT Flexsim HC	ForeTell-DSS XLSim 3.0

TABLE 3
A PART OF CALCULATION OF THE SCORE FOR THE GENERAL FEATURES (SCOREGF)

Software	@RISK	@RISK 5.5	Analytica 4.2	AnyLogic	Arena Simulation Software	Blues Simulation System (Bluesss)	Clinical Trials Simulator	...	$Score_{gf}$
@RISK	1.00(0.02)	1.00(0.02)	1.23(0.02)	1.28(0.02)	1.44(0.02)	0.64(0.01)	0.44(0.01)	...	0.017
@RISK 5.5	1.00(0.02)	1.00(0.02)	1.23(0.02)	1.28(0.02)	1.44(0.02)	0.64(0.01)	0.44(0.01)	...	0.017
Analytica 4.2	0.81(0.01)	0.81(0.01)	1.00(0.02)	1.04(0.02)	1.17(0.02)	0.52(0.01)	0.35(0.01)	...	0.014
AnyLogic	0.78(0.01)	0.78(0.01)	0.96(0.02)	1.00(0.02)	1.12(0.02)	0.50(0.01)	0.34(0.01)	...	0.014
Arena Simulation Software	0.70(0.01)	0.70(0.01)	0.86(0.01)	0.89(0.01)	1.00(0.02)	0.45(0.01)	0.30(0.00)	...	0.012
Blues Simulation System (Bluesss)	1.56(0.03)	1.56(0.03)	1.93(0.03)	2.00(0.03)	2.25(0.04)	1.00(0.02)	0.68(0.01)	...	0.027
Clinical Trials Simulator	2.29(0.04)	2.29(0.04)	2.83(0.05)	2.93(0.05)	3.29(0.05)	1.47(0.02)	1.00(0.02)	...	0.040
CSIM for Java	2.65(0.04)	2.65(0.04)	3.26(0.05)	3.38(0.06)	3.80(0.06)	1.69(0.03)	1.15(0.02)	...	0.046
CSIM20	1.64(0.03)	1.64(0.03)	2.02(0.03)	2.10(0.03)	2.35(0.04)	1.05(0.02)	0.71(0.01)	...	0.029
DecisionTools Suite	0.72(0.01)	0.72(0.01)	0.88(0.01)	0.92(0.02)	1.03(0.02)	0.46(0.01)	0.31(0.01)	...	0.012
Emergency Department Simulator	1.32(0.02)	1.32(0.02)	1.63(0.03)	1.69(0.03)	1.90(0.03)	0.85(0.01)	0.58(0.01)	...	0.023
Enterprise Portfolio Simulator	1.43(0.02)	1.43(0.02)	1.77(0.03)	1.83(0.03)	2.06(0.03)	0.92(0.02)	0.63(0.01)	...	0.025
ExtendSim AT	0.65(0.01)	0.65(0.01)	0.80(0.01)	0.83(0.01)	0.94(0.02)	0.42(0.01)	0.28(0.00)	...	0.011
ExtendSim OR	0.68(0.01)	0.68(0.01)	0.83(0.01)	0.87(0.01)	0.97(0.02)	0.43(0.01)	0.30(0.00)	...	0.012
ExtendSim Suite	0.68(0.01)	0.68(0.01)	0.84(0.01)	0.87(0.01)	0.98(0.02)	0.44(0.01)	0.30(0.00)	...	0.012
Flexsim	0.65(0.01)	0.65(0.01)	0.80(0.01)	0.83(0.01)	0.93(0.02)	0.42(0.01)	0.28(0.00)	...	0.011
Flexsim CT	0.93(0.02)	0.93(0.02)	1.15(0.02)	1.19(0.02)	1.34(0.02)	0.59(0.01)	0.41(0.01)	...	0.016
Flexsim HC	1.21(0.02)	1.21(0.02)	1.49(0.02)	1.55(0.03)	1.74(0.03)	0.77(0.01)	0.53(0.01)	...	0.021
ForeTell-DSS	0.68(0.01)	0.68(0.01)	0.84(0.01)	0.87(0.01)	0.98(0.02)	0.44(0.01)	0.30(0.00)	...	0.012
GoldSim	0.83(0.01)	0.83(0.01)	1.02(0.02)	1.06(0.02)	1.19(0.02)	0.53(0.01)	0.36(0.01)	...	0.014
Integrated Performance Modelling Environment (IPME)	1.43(0.02)	1.43(0.02)	1.77(0.03)	1.83(0.03)	2.06(0.03)	0.92(0.02)	0.63(0.01)	...	0.025
LABSAG (Spanish & Portuguese) , LABAMS (English)	2.07(0.03)	2.07(0.03)	2.55(0.04)	2.65(0.04)	2.98(0.05)	1.33(0.02)	0.90(0.01)	...	0.036
MedModel Optimization Suite	0.82(0.01)	0.82(0.01)	1.01(0.02)	1.05(0.02)	1.18(0.02)	0.52(0.01)	0.36(0.01)	...	0.014
Micro Saint Sharp	1.09(0.02)	1.09(0.02)	1.34(0.02)	1.39(0.02)	1.56(0.03)	0.70(0.01)	0.47(0.01)	...	0.019
Portfolio Simulator	1.54(0.03)	1.54(0.03)	1.89(0.03)	1.96(0.03)	2.21(0.04)	0.98(0.02)	0.67(0.01)	...	0.026
Process Simulator	0.81(0.01)	0.81(0.01)	1.00(0.02)	1.04(0.02)	1.17(0.02)	0.52(0.01)	0.35(0.01)	...	0.014
Project Simulator	1.54(0.03)	1.54(0.03)	1.89(0.03)	1.96(0.03)	2.21(0.04)	0.98(0.02)	0.67(0.01)	...	0.026
ProModel Optimization Suite	0.66(0.01)	0.66(0.01)	0.81(0.01)	0.84(0.01)	0.94(0.02)	0.42(0.01)	0.29(0.00)	...	0.011
Proof 3D	2.39(0.04)	2.39(0.04)	2.94(0.05)	3.06(0.05)	3.43(0.06)	1.53(0.03)	1.04(0.02)	...	0.041
Proof 5	2.46(0.04)	2.46(0.04)	3.03(0.05)	3.14(0.05)	3.53(0.06)	1.57(0.03)	1.07(0.02)	...	0.042
PSM++	1.38(0.02)	1.38(0.02)	1.70(0.03)	1.76(0.03)	1.98(0.03)	0.88(0.01)	0.60(0.01)	...	0.024
QMS	1.81(0.03)	1.81(0.03)	2.23(0.04)	2.32(0.04)	2.60(0.04)	1.16(0.02)	0.79(0.01)	...	0.031
REACT	1.19(0.02)	1.19(0.02)	1.46(0.02)	1.52(0.02)	1.70(0.03)	0.76(0.01)	0.52(0.01)	...	0.020
Renque	1.06(0.02)	1.06(0.02)	1.31(0.02)	1.36(0.02)	1.52(0.03)	0.68(0.01)	0.46(0.01)	...	0.018
Risk Solver	0.76(0.01)	0.76(0.01)	0.94(0.02)	0.98(0.02)	1.10(0.02)	0.49(0.01)	0.33(0.01)	...	0.013
Risk Solver Platform	0.64(0.01)	0.64(0.01)	0.79(0.01)	0.81(0.01)	0.91(0.02)	0.41(0.01)	0.28(0.00)	...	0.011
Risk Solver Premium	0.75(0.01)	0.75(0.01)	0.92(0.02)	0.96(0.02)	1.07(0.02)	0.48(0.01)	0.33(0.01)	...	0.013
ServiceModel Optimization Suite	0.63(0.01)	0.63(0.01)	0.78(0.01)	0.81(0.01)	0.91(0.01)	0.40(0.01)	0.28(0.00)	...	0.011
ShowFlow	0.77(0.01)	0.77(0.01)	0.95(0.02)	0.99(0.02)	1.11(0.02)	0.49(0.01)	0.34(0.01)	...	0.013
Simcad Pro-Patented Dynamic Process Simulator	0.67(0.01)	0.67(0.01)	0.83(0.01)	0.86(0.01)	0.97(0.02)	0.43(0.01)	0.29(0.00)	...	0.012
Simio	0.78(0.01)	0.78(0.01)	0.96(0.02)	1.00(0.02)	1.12(0.02)	0.50(0.01)	0.34(0.01)	...	0.013
SIMUL8 Professional	0.66(0.01)	0.66(0.01)	0.81(0.01)	0.84(0.01)	0.94(0.02)	0.42(0.01)	0.29(0.00)	...	0.011
SIMUL8 Standard	0.70(0.01)	0.70(0.01)	0.86(0.01)	0.89(0.01)	1.00(0.02)	0.45(0.01)	0.30(0.00)	...	0.012
SIMUL8 Web	0.73(0.01)	0.73(0.01)	0.89(0.01)	0.93(0.02)	1.04(0.02)	0.46(0.01)	0.32(0.01)	...	0.012
SLX	1.43(0.02)	1.43(0.02)	1.77(0.03)	1.83(0.03)	2.06(0.03)	0.92(0.02)	0.63(0.01)	...	0.025
Stat::Fit	2.87(0.05)	2.87(0.05)	3.53(0.06)	3.67(0.06)	4.12(0.07)	1.83(0.03)	1.25(0.02)	...	0.049
Tecnomatix Plant Simulation	0.76(0.01)	0.76(0.01)	0.93(0.02)	0.97(0.02)	1.09(0.02)	0.48(0.01)	0.33(0.01)	...	0.013
Vanguard Business Analytics Suite	0.66(0.01)	0.66(0.01)	0.81(0.01)	0.84(0.01)	0.94(0.02)	0.42(0.01)	0.29(0.00)	...	0.011
Vanguard Strategic Forecasting Suite	0.63(0.01)	0.63(0.01)	0.78(0.01)	0.81(0.01)	0.91(0.01)	0.40(0.01)	0.28(0.00)	...	0.011
Vanguard System	0.66(0.01)	0.66(0.01)	0.81(0.01)	0.84(0.01)	0.94(0.02)	0.42(0.01)	0.29(0.00)	...	0.011
WebGPSS	1.15(0.02)	1.15(0.02)	1.41(0.02)	1.47(0.02)	1.65(0.03)	0.73(0.01)	0.50(0.01)	...	0.020
XLSim 3.0	2.29(0.04)	2.29(0.04)	2.83(0.05)	2.93(0.05)	3.29(0.05)	1.47(0.02)	1.00(0.02)	...	0.039
SUM	60.97	60.97	75.14	77.98	87.55	38.99	26.58	...	1.05

TABLE 4
CALCULATION OF THE TOTAL SCORES OF THE SIMULATION TOOLS IN THE AHP APPROACH

Indicator (Weight) / Software	General Features (0.038)	Visual Aspects (0.98)	Coding Aspects (0.244)	Efficiency (0.13)	Modeling Assistance (0.04)	Testability (0.071)	Software Compatibility (0.042)	Input/output (0.051)	Experimental Facilities (0.049)	Statistical Facilities (0.046)	User Support (0.017)	Financial & Technical Features (0.25)	Pedigree (0.125)	Total Score
@RISK	0.017	0.009	0.016	0.039	0.028	0.007	0.006	0.009	0.423	0.008	0.011	0.019	0.015	0.245
@RISK 5.5	0.017	0.008	0.016	0.029	0.026	0.014	0.007	0.010	0.099	0.009	0.011	0.015	0.015	0.149
Analytica 4.2	0.014	0.042	0.013	0.022	0.020	0.039	0.006	0.012	0.085	0.008	0.011	0.018	0.015	0.317
AnyLogic	0.014	0.004	0.012	0.014	0.014	0.006	0.006	0.008	0.032	0.009	0.010	0.022	0.021	0.104
Arena Simulation Software	0.012	0.004	0.012	0.015	0.017	0.006	0.007	0.008	0.040	0.008	0.011	0.014	0.015	0.095
Blues Simulation System (Bluesss)	0.027	0.008	0.012	0.047	0.032	0.013	0.027	0.014	0.047	0.026	0.011	0.014	0.026	0.161
Clinical Trials Simulator	0.040	0.048	0.034	0.021	0.037	0.079	0.006	0.009	0.053	0.007	0.011	0.013	0.012	0.378
CSIM for Java	0.046	0.048	0.016	0.117	0.037	0.039	0.046	0.144	0.376	0.050	0.251	0.017	0.018	0.567
CSIM20	0.029	0.065	0.012	0.029	0.022	0.009	0.010	0.180	0.423	0.042	0.036	0.017	0.016	0.559
DecisionTools Suite	0.012	0.016	0.022	0.028	0.025	0.006	0.006	0.008	0.099	0.007	0.011	0.021	0.015	0.199
Emergency Department Simulator	0.023	0.074	0.035	0.030	0.028	0.009	0.006	0.007	0.041	0.006	0.011	0.035	0.013	0.506
Enterprise Portfolio Simulator	0.025	0.048	0.019	0.031	0.037	0.098	0.006	0.008	0.054	0.007	0.010	0.017	0.011	0.373
ExtendSim AT	0.011	0.004	0.013	0.023	0.017	0.006	0.005	0.008	0.038	0.008	0.010	0.016	0.015	0.102
ExtendSim OR	0.012	0.004	0.014	0.023	0.019	0.006	0.005	0.008	0.036	0.009	0.011	0.016	0.015	0.102
ExtendSim Suite	0.012	0.003	0.014	0.023	0.018	0.006	0.005	0.008	0.036	0.009	0.010	0.018	0.015	0.100
Flexsim	0.011	0.003	0.015	0.020	0.025	0.006	0.006	0.009	0.049	0.009	0.010	0.029	0.014	0.119
Flexsim CT	0.016	0.003	0.015	0.018	0.019	0.006	0.006	0.009	0.048	0.009	0.010	0.039	0.035	0.141
Flexsim HC	0.021	0.003	0.015	0.022	0.025	0.006	0.007	0.009	0.051	0.011	0.010	0.026	0.033	0.131
ForeTell-DSS	0.012	0.014	0.016	0.031	0.019	0.006	0.027	0.009	0.049	0.009	0.011	0.016	0.033	0.179
GoldSim	0.014	0.034	0.015	0.019	0.020	0.033	0.005	0.014	0.049	0.020	0.010	0.020	0.009	0.270
Integrated Performance Modelling Environment (IPME)	0.025	0.009	0.021	0.021	0.024	0.006	0.023	0.014	0.049	0.016	0.010	0.022	0.018	0.158
LABSAG (Spanish & Portuguese) , LABAMS (English)	0.036	0.096	0.016	0.044	0.032	0.039	0.042	0.019	0.058	0.014	0.017	0.021	0.014	0.614
MedModel Optimization Suite	0.014	0.004	0.015	0.020	0.025	0.006	0.006	0.008	0.039	0.011	0.010	0.019	0.011	0.108
Micro Saint Sharp	0.019	0.004	0.017	0.017	0.009	0.006	0.005	0.014	0.032	0.012	0.010	0.014	0.014	0.100
Portfolio Simulator	0.026	0.064	0.023	0.021	0.037	0.098	0.005	0.009	0.058	0.009	0.010	0.027	0.011	0.465
Process Simulator	0.014	0.054	0.019	0.021	0.025	0.009	0.006	0.009	0.039	0.008	0.014	0.017	0.011	0.354
Project Simulator	0.026	0.096	0.022	0.021	0.032	0.009	0.007	0.009	0.054	0.007	0.011	0.014	0.011	0.571
ProModel Optimization Suite	0.011	0.004	0.019	0.021	0.025	0.006	0.005	0.008	0.040	0.008	0.010	0.020	0.011	0.114

TABLE 4 (CONTINUED)
CALCULATION OF THE TOTAL SCORES OF THE SIMULATION TOOLS IN THE AHP APPROACH

Indicator (Weight) / Software	General Features (0.038)	Visual Aspects (0.98)	Coding Aspects (0.244)	Efficiency (0.13)	Modeling Assistance (0.04)	Testability (0.071)	Software Compatibility (0.042)	Input/output (0.051)	Experimental Facilities (0.049)	Statistical Facilities (0.046)	User Support (0.017)	Financial & Technical Features (0.25)	Pedigree (0.125)	Total Score
Proof 3D	0.041	0.003	0.025	0.022	0.022	0.007	0.017	0.026	0.559	0.043	0.022	0.015	0.020	0.266
Proof 5	0.042	0.003	0.026	0.022	0.022	0.007	0.017	0.027	0.559	0.049	0.022	0.013	0.021	0.268
PSM++	0.024	0.007	0.021	0.047	0.028	0.012	0.090	0.015	0.047	0.020	0.013	0.012	0.026	0.178
QMS	0.031	0.064	0.026	0.104	0.037	0.016	0.011	0.011	0.838	0.009	0.017	0.025	0.026	0.695
REACT	0.020	0.003	0.016	0.047	0.025	0.006	0.009	0.009	0.060	0.011	0.013	0.019	0.026	0.139
Renque	0.018	0.010	0.016	0.022	0.025	0.009	0.020	0.014	0.060	0.015	0.010	0.016	0.020	0.156
Risk Solver	0.013	0.074	0.014	0.023	0.014	0.009	0.023	0.010	0.099	0.011	0.011	0.018	0.012	0.468
Risk Solver Platform	0.011	0.074	0.015	0.028	0.013	0.009	0.005	0.010	0.084	0.011	0.011	0.025	0.012	0.474
Risk Solver Premium	0.013	0.074	0.014	0.028	0.012	0.009	0.005	0.011	0.099	0.011	0.011	0.023	0.012	0.474
ServiceModel Optimization Suite	0.011	0.004	0.015	0.022	0.025	0.006	0.006	0.008	0.040	0.008	0.011	0.030	0.011	0.124
ShowFlow	0.013	0.004	0.014	0.017	0.013	0.006	0.006	0.011	0.032	0.010	0.010	0.014	0.022	0.100
Simcad Pro-Patented Dynamic Process Simulator	0.012	0.003	0.013	0.019	0.016	0.006	0.005	0.008	0.032	0.013	0.011	0.016	0.020	0.098
Simio	0.013	0.003	0.017	0.021	0.025	0.006	0.012	0.009	0.044	0.014	0.010	0.021	0.010	0.112
SIMUL8 Professional	0.011	0.003	0.012	0.020	0.025	0.006	0.006	0.009	0.031	0.010	0.011	0.015	0.020	0.099
SIMUL8 Standard	0.012	0.004	0.026	0.041	0.025	0.008	0.008	0.008	0.031	0.010	0.010	0.014	0.020	0.132
SIMUL8 Web	0.012	0.005	0.023	0.021	0.032	0.009	0.012	0.009	0.048	0.010	0.010	0.017	0.020	0.134
SLIM	0.017	0.003	0.016	0.035	0.024	0.006	0.008	0.009	0.060	0.012	0.013	0.019	0.053	0.146
SLX	0.025	0.003	0.017	0.022	0.017	0.016	0.010	0.029	0.239	0.035	0.024	0.021	0.021	0.181
Stat::Fit	0.049	0.074	0.032	0.059	0.037	0.009	0.135	0.011	0.838	0.008	0.025	0.016	0.013	0.730
Tecnomatix Plant Simulation	0.013	0.003	0.016	0.018	0.025	0.008	0.005	0.009	0.039	0.010	0.010	0.021	0.015	0.106
Vanguard Business Analytics Suite	0.011	0.074	0.015	0.018	0.019	0.007	0.006	0.008	0.055	0.008	0.010	0.017	0.020	0.455
Vanguard Strategic Forecasting Suite	0.011	0.074	0.015	0.018	0.019	0.008	0.006	0.008	0.056	0.008	0.010	0.017	0.020	0.455
Vanguard System	0.011	0.074	0.016	0.018	0.025	0.008	0.006	0.007	0.052	0.008	0.010	0.032	0.020	0.476
WebGPSS	0.020	0.042	0.020	0.104	0.025	0.007	0.009	0.015	0.093	0.017	0.011	0.024	0.009	0.378
XLSim 3.0	0.039	0.015	0.035	0.028	0.035	0.015	0.015	0.015	0.838	0.024	0.014	0.016	0.033	0.415
Total Scores	5.24	12.21	5.86	8.55	6.44	4.25	3.93	4.63	33.20	3.89	4.50	6.32	5.30	81.04

TABLE 5
THE SOFTWARE WITH THE HIGHEST SCORE IN EACH INDICATOR FOR FAWAS

Row	*Indicators*	Software(s) in the Highest Score	
1	General Features	ServiceModel Optimization Suite Vanguard Strategic Forecasting Suite Risk Solver Platform	Flexsim ExtendSim AT
2	Visual Aspects	Tecnomatix Plant Simulation Flexsim CT SLX	ExtendSim Suite Flexsim HC
3	Coding Aspects	AnyLogic SIMUL8 Professional Arena Simulation Software	Blues Simulation System (Bluesss) CSIM20
4	Efficiency	AnyLogic Arena Simulation Software Micro Saint Sharp	ShowFlow Vanguard Strategic Forecasting Suite
5	Modeling Assistance	Micro Saint Sharp Risk Solver Premium Risk Solver Platform	ShowFlow Risk Solver
6	Testability	AnyLogic Micro Saint Sharp Flexsim HC	ForeTell-DSS ShowFlow
7	Software Compatibility	Tecnomatix Plant Simulation ExtendSim AT Simcad Pro-Patented Dynamic Process Simulator	Micro Saint Sharp ExtendSim OR
8	Input/output issues	Emergency Department Simulator AnyLogic Vanguard System	ExtendSim AT ExtendSim OR
9	Experimental Facilities	SIMUL8 Standard SIMUL8 Professional Simcad Pro-Patented Dynamic Process Simulator	AnyLogic ShowFlow
10	Statistical Facilities	Emergency Department Simulator DecisionTools Suite Enterprise Portfolio Simulator	Clinical Trials Simulator Project Simulator
11	User Support	Flexsim HC Integrated Performance Modelling Environment (IPME) Vanguard Business Analytics Suite	Simio Enterprise Portfolio Simulator
12	Financial & Technical Features	PSM++ Clinical Trials Simulator Proof 5	SIMUL8 Standard Project Simulator
13	Pedigree	GoldSim WebGPSS Simio	MedModel Optimization Suite Project Simulator

TABLE 6
EVALUATION OF THE INDICATORS IN THE SIMULATION SOFTWARES IN THE FAWAS APPROACH

Row	Software	General Features	Visual Aspects	Coding Aspects	Efficiency	Modeling Assistance	Testability	Software Compatibility	Input/output	Experimental Facilities	Statistical Facilities	User Support	Financial and technical Feature	Pedigree	Total Scores	Average Score
1	@RISK	2.46	1.46	1.86	1.71	1.14	2.10	3.29	2.72	0.29	3.51	3.36	2.68	2.93	29.50	2.27
2	@RISK 5.5	2.46	1.79	1.89	2.29	1.21	1.00	2.91	2.53	1.21	3.34	3.34	3.21	3.00	30.19	2.32
3	Analytica 4.2	3.03	0.33	2.29	3.10	1.57	0.36	3.21	2.17	1.43	3.54	3.36	2.74	3.07	30.20	2.32
4	AnyLogic	3.14	3.81	2.50	4.69	2.21	2.50	3.17	3.43	3.76	3.20	3.47	2.25	2.14	40.28	3.10
5	Arena Simulation Software	3.53	3.41	2.43	4.36	1.86	2.29	2.90	3.14	3.00	3.41	3.36	3.64	3.07	40.40	3.11
6	Blues Simulation System (Bluesss)	1.57	1.80	2.43	1.43	1.00	1.07	0.71	1.89	2.57	1.11	3.21	3.50	1.71	24.01	1.85
7	Clinical Trials Simulator	1.07	0.29	0.86	3.21	0.86	0.18	3.33	2.91	2.29	4.14	3.34	3.86	3.79	30.12	2.32
8	CSIM for Java	0.93	0.29	1.86	0.57	0.86	0.36	0.43	0.18	0.32	0.57	0.14	2.90	2.57	11.97	0.92
9	CSIM20	1.50	0.21	2.43	2.31	1.43	1.57	1.93	0.14	0.29	0.68	0.99	2.91	2.86	19.25	1.48
10	DecisionTools Suite	3.43	0.86	1.36	2.43	1.29	2.29	3.43	3.17	1.21	4.19	3.36	2.34	3.00	32.34	2.49
11	Emergency Department Simulator	1.86	0.19	0.86	2.21	1.14	1.57	3.00	3.59	2.93	4.36	3.21	1.43	3.43	29.77	2.29
12	Enterprise Portfolio Simulator	1.71	0.29	1.60	2.14	0.86	0.14	3.14	3.07	2.23	4.17	3.50	3.00	3.93	29.79	2.29
13	ExtendSim AT	3.77	3.57	2.21	2.96	1.93	2.29	3.89	3.29	3.14	3.53	3.43	3.06	3.07	40.14	3.09
14	ExtendSim OR	3.63	3.67	2.14	2.93	1.71	2.29	3.74	3.29	3.29	3.24	3.34	3.21	3.07	39.56	3.04
15	ExtendSim Suite	3.60	4.93	2.14	2.93	1.79	2.21	3.74	3.14	3.29	3.24	3.50	2.74	3.07	40.33	3.10
16	Flexsim	3.79	4.46	1.99	3.29	1.29	2.29	3.04	2.74	2.43	3.06	3.50	1.74	3.14	36.74	2.83
17	Flexsim CT	2.64	5.00	2.00	3.71	1.71	2.29	3.32	2.84	2.49	2.94	3.49	1.29	1.29	35.01	2.69
18	Flexsim HC	2.03	4.81	1.93	3.07	1.29	2.43	2.90	2.77	2.36	2.44	3.64	1.91	1.36	32.94	2.53
19	ForeTell-DSS	3.60	1.00	1.86	2.14	1.71	2.31	0.71	2.86	2.43	3.14	3.21	3.14	1.36	29.49	2.27
20	GoldSim	2.96	0.40	2.00	3.50	1.57	0.43	3.59	1.81	2.43	1.40	3.43	2.54	4.79	30.84	2.37
21	Integrated Performance Modelling Environment (IPME)	1.71	1.51	1.43	3.21	1.36	2.29	0.86	1.86	2.43	1.70	3.64	2.29	2.57	26.86	2.07
22	LABSAG (Spanish & Portuguese) , LABAMS (English)	1.19	0.14	1.86	1.54	1.00	0.36	0.46	1.36	2.07	1.94	2.11	2.40	3.14	19.57	1.51
23	MedModel Optimization Suite	3.00	3.47	2.00	3.29	1.29	2.29	3.33	3.20	3.07	2.53	3.43	2.63	4.00	37.51	2.89
24	Micro Saint Sharp	2.26	3.79	1.71	4.04	3.43	2.43	3.74	1.83	3.71	2.40	3.50	3.57	3.14	39.56	3.04
25	Portfolio Simulator	1.60	0.21	1.29	3.21	0.86	0.14	3.57	2.69	2.07	3.11	3.50	1.86	3.93	28.04	2.16
26	Process Simulator	3.03	0.26	1.57	3.14	1.29	1.64	3.00	2.71	3.07	3.69	2.50	2.94	3.93	32.77	2.52
27	Project Simulator	1.60	0.14	1.36	3.21	1.00	1.50	2.96	2.71	2.21	3.76	3.36	3.66	3.93	31.40	2.42

TABLE 6 (CONTINUED)
EVALUATION OF THE INDICATORS IN THE SIMULATION SOFTWARES IN THE FAWAS APPROACH

Row	Software	General Features	Visual Aspects	Coding Aspects	Efficiency	Modeling Assistance	Testability	Software Compatibility	Input/output	Experimental Facilities	Statistical Facilities	User Support	Financial and technical Feature	Pedigree	Total Scores	Average Score
28	ProModel Optimization Suite	3.74	3.31	1.57	3.20	1.29	2.29	3.54	3.29	3.00	3.40	3.50	2.54	3.93	38.60	2.97
29	Proof 3D	1.03	4.11	1.21	3.07	1.43	2.07	1.14	0.96	0.21	0.64	1.63	3.33	2.21	23.06	1.77
30	Proof 5	1.00	4.04	1.14	3.07	1.43	2.07	1.14	0.93	0.21	0.57	1.63	3.76	2.14	23.14	1.78
31	PSM++	1.79	1.87	1.43	1.43	1.14	1.21	0.21	1.66	2.57	1.37	2.71	4.11	1.71	23.23	1.79
32	QMS	1.36	0.21	1.14	0.64	0.86	0.86	1.71	2.23	0.14	3.24	2.06	2.01	1.71	18.18	1.40
33	REACT	2.07	4.63	1.86	1.43	1.29	2.29	2.07	2.86	2.00	2.54	2.79	2.57	1.71	30.10	2.32
34	Renque	2.31	1.31	1.86	3.00	1.29	1.57	0.99	1.77	2.00	1.81	3.50	3.14	2.21	26.77	2.06
35	Risk Solver	3.21	0.19	2.14	2.93	2.32	1.57	0.86	2.41	1.21	2.64	3.36	2.74	3.86	29.45	2.27
36	Risk Solver Platform	3.86	0.19	2.00	2.36	2.50	1.57	3.71	2.41	1.43	2.47	3.29	1.99	3.86	31.63	2.43
37	Risk Solver Premium	3.29	0.19	2.14	2.36	2.57	1.57	3.57	2.34	1.21	2.61	3.07	2.20	3.86	30.99	2.38
38	ServiceModel Optimization Suite	3.89	3.10	2.00	3.00	1.29	2.29	3.14	3.14	3.00	3.50	3.36	1.69	3.93	37.31	2.87
39	ShowFlow	3.19	3.74	2.14	3.93	2.43	2.29	3.01	2.24	3.74	2.74	3.46	3.54	2.07	38.53	2.96
40	Simcad Pro-Patented Dynamic Process Simulator	3.64	4.36	2.21	3.54	2.00	2.24	3.76	3.13	3.79	2.20	3.16	3.20	2.29	39.51	3.04
41	Simio	3.14	4.21	1.71	3.14	1.29	2.29	1.57	2.81	2.71	1.94	3.57	2.43	4.71	35.54	2.73
42	SIMUL8 Professional	3.74	4.29	2.43	3.36	1.29	2.29	3.21	2.66	3.86	2.81	3.21	3.29	2.21	38.64	2.97
43	SIMUL8 Standard	3.53	3.50	1.14	1.64	1.29	1.71	2.29	3.03	3.86	2.69	3.43	3.69	2.21	34.00	2.62
44	SIMUL8 Web	3.39	2.54	1.29	3.20	1.00	1.64	1.57	2.71	2.50	2.67	3.50	3.00	2.21	31.23	2.40
45	SLIM	2.50	4.70	1.86	1.93	1.36	2.29	2.29	2.70	2.00	2.40	2.63	2.57	0.86	30.07	2.31
46	SLX	1.71	5.00	1.71	3.00	1.86	0.86	1.93	0.86	0.50	0.79	1.50	2.33	2.14	24.19	1.86
47	Stat::Fit	0.86	0.19	0.93	1.14	0.86	1.50	0.14	2.36	0.14	3.47	1.42	3.04	3.43	19.48	1.50
48	Tecnomatix Plant Simulation	3.24	5.00	1.89	3.79	1.29	1.71	4.24	2.73	3.07	2.79	3.50	2.43	3.07	38.74	2.98
49	Vanguard Business Analytics Suite	3.74	0.19	2.00	3.81	1.71	1.96	3.29	3.16	2.19	3.44	3.57	2.86	2.21	34.13	2.63
50	Vanguard Strategic Forecasting Suite	3.89	0.19	2.00	3.81	1.71	1.71	3.21	3.10	2.14	3.37	3.50	3.01	2.21	33.87	2.61
51	Vanguard System	3.74	0.19	1.86	3.71	1.29	1.71	3.29	3.37	2.29	3.44	3.50	1.57	2.21	32.17	2.47
52	WebGPSS	2.14	0.33	1.50	0.64	1.29	1.93	2.11	1.66	1.29	1.67	3.14	2.09	4.79	24.57	1.89
53	XLSim 3.0	1.07	0.90	0.86	2.43	0.93	0.93	1.29	1.64	0.14	1.17	2.59	3.16	1.36	18.46	1.42
Total Scores		138.16	114.56	93.86	146.21	77.61	89.01	133.61	130.20	113.22	140.78	160.80	145.74	150.43	1634.18	125.71
Average Score		2.61	2.16	1.77	2.76	1.46	1.68	2.52	2.46	2.14	2.66	3.03	2.75	2.84	30.83	2.37

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