Evaluation framework for defense simulation packages

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Simulation tools of various systems are very important in civil and defense sectors because the actual systems are expensive, complex, sensitive and could be a threat to human lives and property if used incorrectly or lack of expertise. Therefore, such tools are used commonly in different organizations as an alternative to the actual systems. Various simulation tools are available for defense systems but the question arises is which tool is best and meets user's demands. This problem can be solved with a suitable selection of a simulation tool. How to select a suitable tool? This is another issue which is the subject of this thesis and where this research work is focusing. To solve this issue, an evaluation framework is proposed for defense simulation tools. The proposed framework is developed based on the characteristics of the defense simulation tools, the expert's opinions, and the existing evaluation methods in the literature. This framework consists of three levels: the first level indicates the main criteria, the second level describes the sub criteria while the third level defines the simulation tools. Further, a comparative analysis is made to existing works which shows an improvement in evaluations mechanisms.

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1. Introduction

Due to various benefits of using the simulation packages such as; cost efficiency, time, risk mitigation, greater insights and user friendliness of systems. It has been extensively used in many application domains such as defense, airports, manufacturing, engineering, and healthcare [1]. It provides easy way to solve complex real world problems. Presently, a wide range of simulation software packages are available in the market. Such packages have varying properties such as quality, features, modeling approaches, strategies deployed, and cost efficiency and so on. Due to this, selecting a suitable simulation package is becoming a challenging issue. Users lack expertise or the know-how to decide which package will be suitable for their applications [2]. Using an evaluation method/technique to select suitable simulation package is inevitable. Researchers have made efforts to solve simulation packages evaluation and selection problem. They proposed different methods and techniques to evaluate various purpose simulation packages[2]–[6], [7]–[11]. This paper discusses a proposed model to evaluate defense simulation packages.

The remainder of the paper is structured as following: Section 2 discusses methodology which provides a detailed explanation of the approach applied to develop the. Section 3 includes proposed model to evaluate defense simulation packages. Section 4 concludes the paper and pointing to the future works in the area of simulation packages evaluation and selection.

2. Methodology

The framework developed in this research work addresses the assessment needs of defense simulation tools. It aides the comparison of different tools in order to narrow down and deduce the one which nearly has all the essential features to build a scenario and customize it easily, flexibly and ensure its quality. The development of the framework is spread across three stages which are described here.

2.1 Review of defense simulation tools

The purpose of this review is to do a detailed background check of the simulation tools and their characteristics. In this stage, several companies' websites such as VT MAK [53], C4i Consultants [54], Northrop Grumman [55] and Nexter [56] were accessed and the information pertaining to their respective simulation tools was collected. Based on the data collected several parameters were agreed upon to assess the characteristics of the simulation tools that may impact the simulation models' building process. The parameters can be described as follows, validation & verification, multiple-run, dynamic display features, breakpoints, input, model building, icons, running and integrity with other tools.

2.2 Survey of existing evaluation methods and techniques

A variety of simulation packages have been developed for different purposes. Such packages differ on the parameters of quality, features, cost and complexity [1]. Therefore, picking a suitable simulation software package is relatively a critical issue.

One of the most common methods to evaluate simulation packages using criteria is discussed. Researchers have made efforts to build various classifications of criteria. The criteria were created and classified into groups and sub-groups. In[13]six groups of criteria were classified by Law and Haider. This classification has been obtained based on vendor survey of 23 simulation packages. In [14] Law held on work on this research with McComas and developed a wide range of criteria. In[15]Holder gave a description for a group of six features with simple questions like: are the graphics of a high or a low quality. In[16] Mackulaket al. introduced eight main groups of features based on a questionnaire survey involves 54 features. Banks [17]depended on five main groups of features to evaluate four simulation packages. Davis and Williams [4]utilized a collection of criteria to define a list of eight criteria. The defined list considered the issues that demand to be considered while selection of a simulation software. Moreover, they suggested Analytic Hierarchy Process (AHP) to assist in deciding between five simulation packages. Furthermore, Banks [18]listed a set of 24 features and classified them into three main groups.

In[19]six main groups of criteria were used to test six simulators. It is worth mentioning that "on-line user assistance" was considered as main criteria unlike previous researchers. Hlupic [20]classified criteria into eleven main groups. He also developed a software called "SimSelect" to evaluate simulation software. SimSelect includes 40 different features. Nikoukaran et al. [2]defined a hierarchal framework that includes seven main groups of criteria. Harrington and Tumay[21]defined eight main criteria with explanation of each criterion. They advised that the users should understand what they need, first, and then find the method on how to do it. In addition, Hlupicet al. [22] provided 230 evaluation criteria classified into several main groups the user can select from. They also suggested a set of factors should be considered before selecting criteria. In addition, they provided guidelines of the desirable properties of the simulation packages. In [23]46 criteria were classified into five main groups by Banks et.al. In addition, they provided a brief description for these criteria. Finally, Arisha [24] split the evaluation criteria into two main groups: Business criteria and Technical criteria. In addition, they provided a checklist that involves sub-groups of criteria and related features to simplify the evaluation process of simulation software packages.

MCDM refers to "making decisions in the presence of multiple, usually conflicting criteria"[25]. It is "the process of finding the best candidate and involves the evaluation and selection among a finite number of potential candidates to solve real-life complex decision problems" [26]. MCDM methods [27] are considered as a valuable decision support tool; it ensures the users' focus is on what is important, logical and easy to apply.

In the literature, many MCDM methods available such as Analytic Network Process (ANP), Analytic Hierarchy process(AHP), Fuzzy Analytical Hierarchy Process (FAHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Selection Index (PSI) and others as mentioned in [28]. Such methods have a significant impact on different application areas[29]. In the context of simulation packages evaluation and selection, a number of MCDM methods were applied including AHP, FAHP, TOPSIS and PSI [4]–[6]. A brief description for such methods and works who have adopted it is provided below.

AHP is one of the most popular approaches of MCDM. It was introduced by Thomas L. Saaty in 1970s. Saaty defined AHP as *"A theory of measurement through pair wise comparisons and relies on the judgments of experts to derive priority scales"*. AHP was used for many areas such as political strategy, planning [29], forecasting, business process re-engineering and total quality management [30]. AHP has many advantages such as simplicity, ease of use, data cursory and scalability, since hierarchy structure is flexible to cope with different sized problems. However, interdependence among criteria and alternatives in the hierarchy may lead to issues such as inconsistency among judgment and ranking criteria[29].In the context of simulation software selection and evaluation, five (5) simulation packages were evaluated using AHP. The evaluation was based on eight criteria: *Cost, Ease of use, Training, Comprehensive of the system, Integration with other systems, Hardware &Installation, Confidence related-issues and Documentation*. The results reflect that AHP was greatly effective to facilitate the selection process[4].

Because Analytic Hierarchy Process (AHP) is not applicable for uncertainty data, Zadeh introduced fuzzy sets theory [5]. Based on Balmat, Fuzzy sets theory "allows solving a lot of problems related to dealing the imprecise and uncertain data"[29]. After introducing Fuzzy set theory, many researchers have integrated fuzzy theory with AHP to get Fuzzy Analytic Hierarchy Process (FAHP). FAHP was originally proposed by VanLaarhoven and Pedrycz in 1983[31]. It was utilized in multiple research works for decision making, for example: evaluating a vendor in a supply chain, choosing facility layout, appraising naval missile systems and choosing the best system of computer aided manufacturing [5]. FAHP takes the advantages of AHP and fuzzy set theory such as considering imprecise input and scalability. However, this technique is disadvantageous when it comes to sorting of alternatives which will be affected by the method of defuzzying the fuzzy number [29], [32], [33]. Azadeh and Shirkouhi have used FAHP to evaluate the simulation software packages. In their research, six simulation packages were evaluated based on a set of criteria such as*user, testing &efficiency, vendor, model and input*. This work contributed invariably to reduce the ambiguities and uncertainties relevant to criteria of selection [5].

Moreover, another decision-making methodology based on FAHP was proposed [34]. It consists of several steps to solve simulation software selection problems. This methodology uses a hierarchal structure to evaluate six simulation packages: *Automod, Arena, Promodel, Simul8, Witness and Visual Slam*. These packages were evaluated on the basis of application and type of simulation they support. Fuzzy AHP was used for the evaluation and ranking these packages based on a number of criteria for example: *user, vendor, efficiency, model &input, output and execution*. These criteria in turn were split into sub-criteria. This methodology was compared with a set of former studies based on a number of features including flexibility on the basis of assigning weights, criteria, evaluation technique, methodology, handling crisp data, treating uncertainty & ambiguities, ranking & experimentation capability and handling non-crisp data. Moreover, it was compared with other robust and standard methods like Data Envelopment Analysis and Numerical Taxonomy. The methodology has proven its superiority and it has the ability to resolve complex decision-making problems with high flexibility. It provided an efficient framework for solving simulation software selection problems.

Hwang and Yoon originally evolved the TOPSIS method in 1981. The said method has been applied in various application areas such as supply chain management & logistics, design, engineering and manufacturing system [29]. In their research, Hwang and Yoon explained TOPSIS technique as*"the best alternative would be the one that is nearest to the positive-ideal solution and farthest from the negative ideal solution. The positive ideal solution is a solution that maximizes the benefit attribute and minimizes the cost attribute, whereas the negative ideal solution maximizes the cost attribute and minimizes the benefit attribute"* [6] .

The TOPSIS method has several features and is a simple process, easy to use and programmable. It consists of the same steps regardless of the number of attributes. However, TOPSIS has some limitations such as the use of Euclidean Distance without observing the attributes correlation, difficulty to weight attributes and save the consistency of judgment [29]. In context of simulation packages selection and evaluation, TOPSIS was used along with entropy weight method in [6] to evaluate three simulation software based on four criteria. Resultantly, TOPSIS improved the decision making process.

Preference Selection Index (PSI) method was developed by Maniya and Bhatt in 2010 [28]. This method takes all criteria simultaneously and gives a complete evaluation to the simulation software. In addition, it provides ranking for simulation packages according to a given application. In [6] PSI was used to evaluate three simulation software with regards to four selected criteria. The result of the evaluation illustrated the effectiveness of this method. It improved the decision making process vividly. PSI is relatively simple method. It accommodates any number of qualitative and quantitative criteria at the same time. It can be used for any type of decision-making situation.

Another contribution to facilitate simulation packages evaluation and selection is described in [2]. It is the hierarchical framework developed for simulation packages evaluation and selection. It comprises of a collection of criteria that can be used to evaluate the simulation software. It includes seven (7) main criteria: *user, vendor and software* criterion that was divided into five main groups: *model& input, output, execution, testing & efficiency and animation*. Such criteria were classified as critical to be considered in the software evaluation process. Moreover, each of these seven criteria consists of a group of sub-criteria. For instance: the *vendor* criterion includes a group of related sub-criteria like *pedigree*, *documentation, support* and *pre-purchase*. The sub-criteria in turn include ther sub-criteria in a hierarchical fashion. It is unnecessary to use all criteria in the framework to evaluate the simulation software. One can select criteria based on the purpose of simulation packages. Such framework aide in choosing appropriate criteria for analyzing and understanding the simulation software. Further, the hierarchical structure is flexible enough to accommodate more criteria without re-organizing it. The framework is also unallocated for a particular area. It can be applied for several application areas. However, the framework lacks a suitable evaluation technique like Analytic Hierarchy Process (AHP) to decide which software is a suitable for a given mission or scenario.

SimSelect is a software to facilitate the simulation packages evaluation and selection. It was developed by Hlupic et.al [7]. The said software consists of a database created forusing Access Engine in Visual Basic 3.0 and initialized by Access 1.1. The database represents the "engine-room" of the software. It contains various information about 20 simulation packages like purpose of simulation, the type of package, price and name of the package. Such packages were evaluated using 40 criteria taken from [35]. The main interface of the software includes requirements, process, help and exit options. The software enables user to select and prioritize his requirements from a list of choices offered on the SimSelect interface. Based on the user selection SimSelect will display a suitable package to the user. If the required software matching the requirements is not found, it provides recommendations to alternative packages instead. SimSelect does not provide comments insertion facility. In addition, further details of requirements should be provided to acquire accurate results**.**

Another program called Smart Sim Selector was developed to address simulation packages selection issue regarding automobile environment [8]. Smart Sim Selector comprises of a database related to the interface. The database contains data about 11 simulation packages. These packages were evaluated using 210 criteria from Verma et.al[36]. It can be maintained and modified easily. In addition, Smart Sim Selector offers three techniques to evaluate simulation packages: Analytic Hierarchy Process (AHP), Weighted Score Method and Technique of Order Preference by Similarity to Ideal Solution (TOPSIS). Similar to SimSelect, this software enables user to select and prioritize its requirements from a list of choices offered on the screen. Based on the user selection the software will display a suitable package to the user. Smart Sim Selector stores few number of simulation packages. Besides that, it doesn't allow to insert comments. However, it represents step forward to improve the simulation software evaluation and selection mechanisms.

Moniz defined the scenario as *"a policy analysis tool that describes a possible set of future conditions"*[37]. It can be used in different situations for example: analyze the complex problems, the situations where past or present is ineligible to predict the future or events that are likely to face serious changes [38]. Scenario can be considered as a method to evaluate simulation packages like the one mentioned in[9]. Two simulation software: Extended Air Defense Simulation (EADSIM) and Wargame 2000(WG2K) were evaluated using the scenario method. A defense against ballistic missile attack scenario was implemented in both software. The results were analyzed using three techniques including graphical analysis, statistical analysis (i.e. bootstrap approach) and six measures of effectiveness. Unfortunately, WG2K doesn't support playback feature as EADSIM thus they couldn't get accurate results of the scenario implementation. Tewoldeberhanet et. al, proposed a methodology for discrete-event simulation packages evaluation and selection [10]. It consists of two main phases. Phase one, aimed to reduce the long-list of simulation packages into short-list. Phase two matches the company/organization requirements with the features of the simulation packages. These two phases include a number of steps to be accomplished (Fig. 1). Such methodology was applied by the Accenture, one of the world's leading management and technology organization. Accenture's team applied the proposed methodology to obtain discrete-event simulation package. In the first phase, more than 50 simulation packages were reduced into five packages. In the second phase, the five packages were evaluated. Two simulation packages were out of the evaluation process because the vendors refused to participate in the evaluation process. In addition, two criteria were not evaluated because they required months of recursive and continual tests. Throughout the event, the methodology proved to be effective, objective, reliable and can be applied in variant application domains. Researchers have proposed guidelines to select the suitable simulation software for example: in [39] Banks proposed a group of guidelines to choose the appropriate simulation package. He indicated that selecting simulation package depends on the problem scenario to be addressed by simulation and the properties of simulation software, in [11]Hlupic and Paul provided guidelines to select manufacturing simulation software. He also tested these guidelines through several case studies and lastly, a group of seven steps to select simulation software was proposed in [40].

2.2.1. Comparative analysis of evaluation methods

A summary of evaluation methods and techniques are provided in Table 1. The summary shows that most of the tools dealt with simulation packages other than defense simulation packages. Therefore, an evaluation method for defense simulation packages is very necessary due to their specific requirements [1].

2.3 Expert opinions

The last step before the actual development of the framework is communicating with the experts to investigate the feedback about the industry standards solutions including VR-Forces [53], EDMSIM [54], C2PC [55] and FINDERS C2 [56]. In this step surveys were created which consist of a number of multiple-choices questions about various characteristics of these simulation tools.

3. Proposed model

The proposed model for defense simulation packages evaluation and selection consists of three levels. Most of the criteria adopted in this framework are identified based on Nikoukaran et al. work [17]. The first level includes the main criteria, the second level describes the sub criteria and the third level includes the tools that will be evaluated. The hierarchical structure of the developed framework is shown in Figure 1.

3.1 Level 1: main Criteria

The first level of the framework indicates the main criteria that can be used to evaluate defense simulation tools. Mainly, the framework comprises of nine (9) main criteria such as *user, testing & efficiency, vendor, model & input, output, execution, animation, usability and interoperability*. The supra mentioned criteria allows assessing the solutions from different aspects.

Table 1. Summary of simulation packages evaluation methods and techniques.

S.No	Method/Technique	Description
1	Evaluation criteria[2], [4], [13]–[22], [24]	A set of criteria are defined, classified and used to fulfill simulation packages evaluation and selection.
2	Analytic Hierarchy Process (AHP)[4]	Technique to solve multi-criteria decision making problems using pairwise comparison and expert's judgments.
3	Fuzzy Analytic Hierarchy Process (FAHP)[5], [34]	It integrates the fuzzy set characteristics and AHP to address fuzziness problems.
4	Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)[6]	It states that the best decision will be closer to the positive-ideal solution and outmost from the negative ideal solution.
5	Preference Selection Index (PSI)[6]	It takes all criteria simultaneously and gives renders a complete evaluation to the simulation software.
6	Hierarchical framework[2]	It consists of a collection of criteria and sub-criteria organized in a hierarchical fashion.
7	SimSelect[7]	A software stores information about 20 simulation packages the user can select from. These packages evaluated based on 40 criteria.
8	Smart Sim Selector[8]	A software stores information of about 11 simulation packages that the user can select from. These packages are evaluated based on 210 criteria.
9	Scenario[9]	Scenario can be implemented in a simulation package to measure its effectiveness.
10	Two-phase methodology[10]	It consists of two main phases to solve discrete- event simulation packages selection and evaluation problem. Additionally, each main phase involves a set of steps to be performed.
11	Guidelines[11], [39], [40]	A set of guidelines that user can follow to select the suitable simulation software.

1. *User*

   The *user* is the person who will acquire and use the simulation tool [2]. His/her role cannot be ignored during the development of the evaluation framework. Therefore, the user criterion has been identified in the proposed framework to evaluate specific considerations that the user may be concerned with to use a simulation tool such as the platforms that the tool can run on, the cost of the simulation tool and the application domain of the simulation tool.

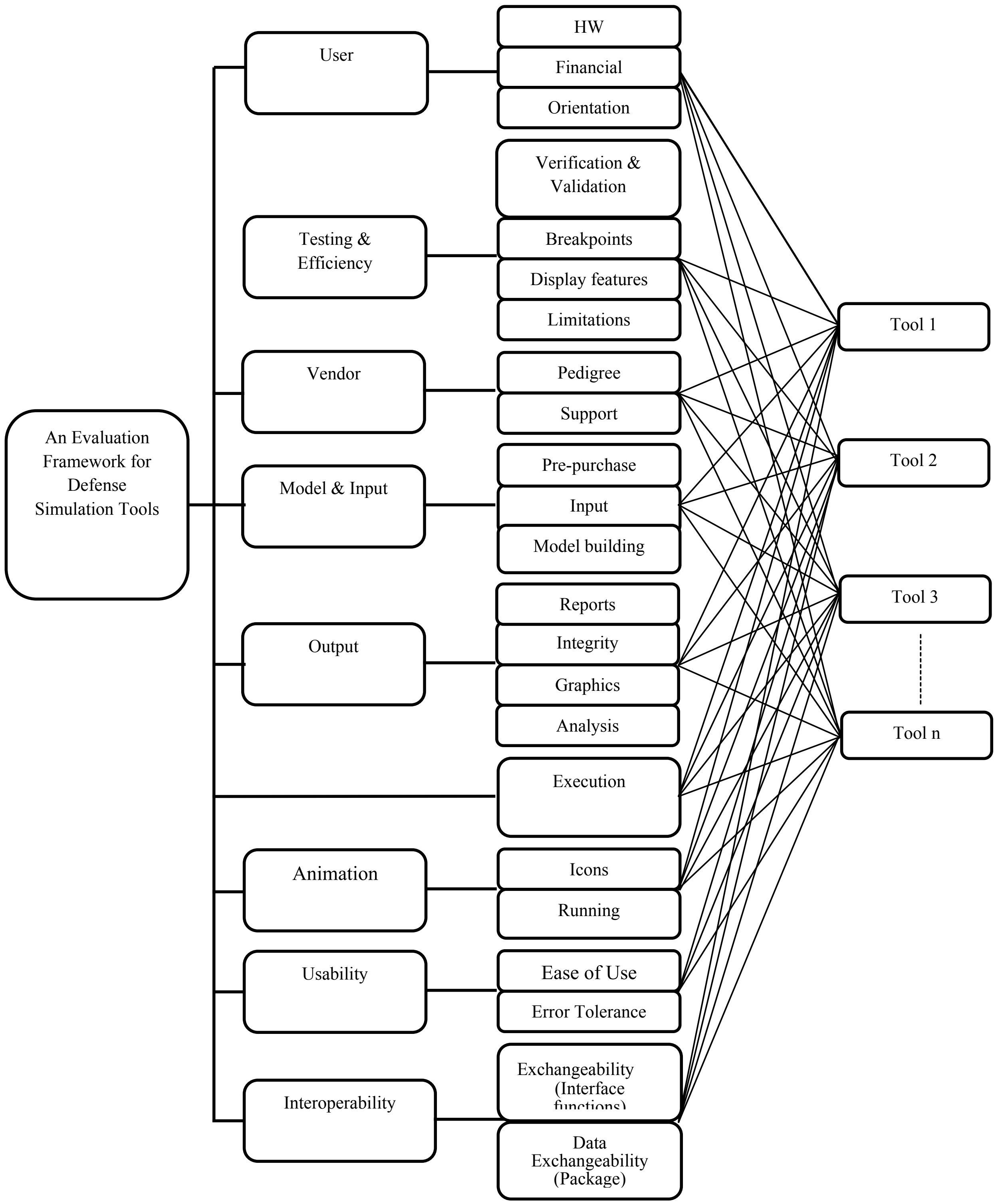

Fig. 1.The framework hierarchy.

Table 2. Criteria and sub criteria.

Criteria	Sub-criteria	Description
User	Hardware	The tool runs on various platforms including PCs, workstations and high performance computers.
	Financial	Relating to the cost of purchasing the tool.
	Orientation	Whether the software is designed for general purposes or is developed for specific purposes.
Testing and efficiency	Validation and verification	The tool offers validation and verification means such as on-line help, on-line error message, logical error checks and handling.
	Display features	The tool supports dynamic display methods which mean the values relating to an entity changes automatically without user intervention in response to specific action.
	Breakpoints	The tool supports breakpoints feature which helps the user to stop and start actions at some point of time.
	Limitations	The tool doesn't have limitations.
Vendor	Pedigree	Relating to software and vendor history.
	Support	The vendor provides support for the user such as user manual, training courses or package maintenance and updates.
Model and input	Pre-purchase	The vendor provides on-site demonstration demos or 1 month trial version for the user before purchasing the tool.
	Input	The tool supports different processing methods such as interactive and batch processing.
	Model building	The user builds a model using different facilities such as mouse, keyboard, scanner or trace ball.
Output	Reports	The tool supports reports such as standard reports and user-defined reports.
	Integrity	The tool can be integrated with other packages.
	Graphics	The tool provides a graphical representation of the results.
	Analysis	The tool provides statistical analysis of the model execution results.
Execution		The tool can run the model multiple times and is able to change the random number generator seed every time.
Animation	Icons	The tool provides or supports a set of icons to facilitate model building.
	Running	The animation feature impacts the model run speed.
Usability	Error tolerance	The tool performs infallibly even in the event of failure of some of its components.
	Ease of use	The tool can be learned and used easily.
Interoperability	Exchangeability (interface functions)	The interface functions can be exchanged easily.
	Data exchangeability (package)	The data can be transferred among the tool and other packages successfully.

2. *Testing and efficiency*
Simulation has a fundamental role in the defense environment For several reasons including allowing validation of new notions and technologies, enabling repetition and management of low-cost training as compared to using real means [41]. Therefore, it is necessary to provide the means that may increase the efficiency of simulation tools to be able to achieve its missions. Testing and efficiency criterion has been identified in the proposed framework to examine which facilities the model testing feature provided by the simulation tool.

3. *Vendor*
   Vendor can be a person, company or organization that provides the simulation tools to the user. Vendor has a significant role in providing the simulation tool. Therefore, vendor criterion has been identified to assess how reliable the tool and the vendor can be and the support means which are provided to encourage users to acquire the simulation tools [2].
4. *Model & Input*
   Defense simulation tools are usually used to support the defense tactical situations and training exercises. It can execute various scalable scenarios under different environment conditions [42]. Accordingly, there is an urgent need for better means to build efficient scenarios. Thus, the model & input criterion has been identified to evaluate model-building means feature in the simulation tool.
5. *Output*
   Defense simulation tools provide a testbed for critical tasks and operations in the defense environment [43]. Therefore, it makes sense to care about how the simulation results will be presented by these tools. The output criterion has been identified in the proposed framework to evaluate the output presentation methods or facilities supported by the tool.
6. *Execution*
   During scenario execution, one of the effective analysis methods is running the scenario multiple times. It allows capturing the data and sampling scenario scenes based on either the simulation time or event occurrences [44]. Multiple-run is essential feature to obtain accurate results, which is highly required in case of simulation tasks in the defense environment. Therefore, the execution criterion has been identified in the proposed framework to verify the existence of multiple run features in the simulation tool.
7. *Animation*
   Animation can be defined as the process of giving the illusion of movement to models, entities or inanimate objects [45]. It enhances the modeling and simulation process by presenting exactly what is happening in the real environment and makes the models more understandable, believable and realistic. It is a useful tool in the defense environment for showing the movement of entities such as vehicles, aircrafts, friends or adversary forces and presenting the interaction among different objects especially in the complex defense scenarios [46]. Accordingly, the animation criterion has been identified in the proposed framework to evaluate the tool in terms of icons that can be used to create animation and assess the impact of animation on the running of the simulation model.
8. *Usability*
   The Department of Defense (DoD) strongly depends on the modeling and simulation to plan the future operations and simplify decision making [47]. Therefore, it is essential to measure the usability of the tools that executes the modeling and simulation tasks. Usability criterion has been identified in the proposed framework to measure the extent to which the simulation tool can be used to achieve specified goals with effectiveness and efficiency [48].
9. *Interoperability*
   Interoperability criterion describes the ability of two or more solutions to exchange information and use the information that has been exchanged or synchronized [48]. Usually, one simulation tool may be insufficient to address all defense modeling and simulation needs because the defense entities, their procedures and systems are evolving continually [49]. Therefore, interoperability criterion has been identified to evaluate the tool's ability to interact with other tools to fulfill the changing user needs during scenario implementation process.

These criteria are selected to allow assessing the defense simulation tool from different aspects and give an overall evaluation of some characteristics of these tools.

3.2 Level 2: sub criteria

The second level describes the sub criteria correlating to the main criteria. Hardware, orientation and financial are sub criteria of the User criterion. "Hardware" sub criterion specifies the types of platform that the simulation tool can functionalize on such as PCs, workstations and High Performance Computers [5]."Financial" captures the cost of purchasing the simulation tool [3]. "Orientation" verifies whether the simulation tool is developed to facilitate an individual purpose such as military, communications and emergency disasters or serves multiple purposes (i.e. a general purposes tool) [2]. Testing & efficiency criterion is further sub-categorized into validation & verification, display features, breakpoints and limitations sub criteria. "Validation & verification" can be conducted during the development of simulation and aims to produce an accurate and credible model. There are various validation and verification means [2] such as on-line help which enables the user to retrieve the required information via built-in search option, on-line error message which presents a message about the error occurred during building the simulation model, logical error check and handling along with the errors caused when the simulation tool operates incorrectly. "Display features" sub criterion verifies if the tool supports the dynamic display of the entities which shows how the entity values, attributes, functions or state of the events can be changed dynamically [5]. "Breakpoints" verifies whether the tool supports the breakpoint feature, breakpoints feature allows starting and stopping the simulation model at specific point of time. This feature is usually put in simulation model for debugging purposes [24]. "Limitations" sub criterion verifies the disadvantages or shortcomings that may limit the capabilities of the simulation tool to build efficient models. Vendor criterion is divided into pedigree and support sub criteria.

"Pedigree" sub criterion assesses the history of the vendor and his simulation tool [3]. "Support" sub criterion verifies the support facilities that vendor may provide to the end user such as user manual, training courses and tool maintenance & update. User manual document describes how to use the simulation tool and its functional procedures and it may include description of the rights and responsibilities of the user, the owner and the supplier of the tool [48]. Training courses help user to learn and understand the tool faster and tool maintenance & update possibility to motivate the user purchasing the simulation tool. Pre-purchase, input and model building are sub criteria of the Model & input criterion. "Pre-purchase" sub criterion verifies whether the simulation tool provides assistant means to learn the models development techniques including on-site demonstration which describes the tool features that may be used to develop training exercises and one-month trial version to explore the tool capabilities in developing models [5]. "Input" sub criterion assesses the types of data processing that the simulation tool supports such as the batch processing which allows to execute only one task or a series of tasks without manual intervention and interactive processing which enables the user to input data or commands [50]. "Model building" sub criterion assesses the model developmental means supported by the simulation tool such as mouse, keyboard, traceball or scanner [2]. Output criterion is divided into reports, integration, graphics and analysis sub criteria. "Reports" sub criterion evaluates the types of reports the simulation tool may provide for the user. Examples of such reporting tools can be standard reports and user defined reports [51]. Standard reports provide specific data such as average time in queue, average number in queue and utilization rates while user-defined reports represent the output data in a layout specified by the user. "Integration" sub criterion measures the possibility of integrating the tool either with another simulation tool or with different packages such as spreadsheet, word processors, Database Management systems (DBMS) and so on, in order to improve the output presentations forms [2], [48]. The graphical representation such as histogram, bar charts, pie charts and line graphs helps to present the results in a more expressive form. It allows to understand the overall findings in a glance and draw conclusion from these findings [52]. "Graphics" sub criterion verifies if the simulation tool provides a graphical representation of the results. "Analysis" sub criterion verifies whether the tool presents the simulation results in the form of statistics such as means, variance and confidence intervals [3].

Animation criterion is divided into icons and running sub criteria. "Icons" sub criterion assesses whether the tool provides or supports different classifications of icons. "Running" sub criterion evaluates the impact of the animation on the speed running of the model in case that the animation is running concurrently within the model [2]. Error tolerance and ease of use are sub criteria of the Usability criterion. "Error tolerance" measures the ability of the simulation tool to operate continuously despite the occurrences of errors in its components [48]. "Ease of use" sub criterion measures how easy is it to learn and use the simulation tool [12]. Finally, Interoperability criterion is broken into exchangeability (interface functions) and data exchangeability (package) sub criteria. "Exchangeability (interface functions)" sub criterion measures how easy is it to exchange the interfaces functions within the simulation tool and hence support the interoperability with other interfaces. "Data exchangeability (package)" sub criterion measures the ability of the target simulation tool to exchange information with other packages.

3.3 Level 3: defense Simulation tools

The third level of the framework defines the defense simulation tools that should be evaluated based on the main and sub criteria. Table 2 presents the framework criteria, sub criteria as well as a brief description for each sub criterion. Table 3 shows a Comparison with the Existing Works as mentioned in section 2.

Table 3. Comparison with the Existing Works

Method/Technique	**Focus**
Evaluation criteria	• Unallocated for specific application domain
Multi Criteria Decision Making (MCDM) methods	• Originally, it is developed to solve the selection problem in different application domains and not simulation tools selection and evaluation • Mostly depends on the mathematics equations (complexity)
Hierarchical framework	• Unallocated for specific application domain • The user needs a long processing time if used all the criteria in the framework to evaluate the simulation tool • The user needs to determine the objectives in case

Method/Technique	Focus
	of selection of a group of criteria from this framework
SimSelect	• Restricted for specific number of packages and criteria
Smart Sim Selector	• Restricted for specific number of packages, criteria and evaluation techniques
Scenario	• Scenario – based evaluation approach • Doesn't return reliable results • Ignores the tools' characteristics
Two-phase methodology	• Complex method
Guidelines	• Generic • Cannot be relied upon because it is not applied practically
The Proposed framework	• Customized for defense & civil area • Simple, organized and clear • Adjustable with other methods • Flexible in use and extendable

4. Conclusion

The wide use of simulation packages in many areas has resulted in a wide adoption, requirement and elevation in the development of such tools. Consequently, Choosing amongst this vast amount of available packages is a critical decision. This paper proposed an evaluation framework for defense simulation packages. The framework was developed with respect to the characteristics of various defense simulation tools, evaluation methods and techniques found in the literature and expert's opinions of the domain related to the tools. Development process has three levels: the first level includes the main criteria which can be used to evaluate tools such as user, testing & efficiency, vendor, model & input, output, execution, animation, usability and interoperability. The second level divides the main criteria into sub criteria such as hardware, financial, orientation, validation & verification, display features, breakpoints, limitations, pedigree, support, pre-purchase, input, model building, reports, integration, graphics, analysis, icons, running, error tolerance, ease of use, exchangeability (interface functions) and data exchangeability (package). Finally, the third level indicates to the simulation tools that should be evaluated. This study aims to provide an evaluation framework for defense simulation software. Said framework is an additional contribution in the area of simulation packages evaluation and selection. In future, this framework will be improved and tested using the Analytic Hierarchy Process and with few other methodologies.

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