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An Architecture of Procedures in Modeling for Manufacturing Logistics

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Abstract – The concepts of Modeling and Simulation (M&S) are gradually becoming a fundamental sector which attracts the attention of researchers in the modern age. Operational systems in Small and Medium-sized Enterprises (SMEs) have to be investigated using these concepts to achieve quality results. Until now, many scholastic contributions have been published regarding the various perspectives and aspects of M&S. However, there are gaps in the discussion of the complete cycle of modeling and simulation which incorporates the verification and development of an architecture that can be used in manufacturing logistics for Product Development Schemes (PDS). In that case, this paper presents the Simulation Procedures (SP) and architecture can be used to comprehend the systems for product development. This contribution focusses on the validation and verification of the architecture as well. As such, this contribution fills the prevailing gap between the architectural design/development and the validation/verification of modeling and simulation procedures. These are the fundamentals in the application of the M&S approach to comprehend the systems of product development in SMEs.

Keywords – Modeling and Simulation (M&S); Small and Medium-sized Enterprises (SMEs); Simulation Procedures (SP); Product Development Schemes (PDS).

1. Introduction

The field of Modeling and Simulation (M&S) over the past few decades is transformed due to the advancement in technology. Since M&S is constantly receiving information about the behavior of a phenomenon without actually applying it in real life, it is a fundamental concept that has to be evaluated by researchers. Simulation allows manufacturers and producers to determine the behavior of the products even before its application since computer simulation technology can be involved to determine the same. M&S makes use of models to accept data concerning the behavior of something and it incorporates the relevant simulators, prototypes and emulators which are incorporated over time or statistically to create information essential for making informed technical and managerial decisions. 'Simulation' and 'Modeling' are terms used interchangeably based on a specific scenario being addressed. The application of concepts within the engineering sector is considerably recognized.

For simulation technologies represent a toolset of engineering applications and domains which is incorporated within the segment of knowledge management. M&S has fundamentally enabled engineers to reduce costs, enhance the quality of systems and products also apply knowledge management skills. The concept represents a domain of disciplines that amounts to the ideology that M&S is a complete application which is applicable in product development systems. For engineers and product developers to ensure the simulation results that have been applied in the actual-world, it is essential to comprehend the implementation, conceptualization and assumption constraints in their field of production.

M&S approaches are applicable in operational and organizational systems adding to their successful application in physical system improvement, analysis, manufacturing and designing. M&S include the procedures of formulating and designing models for the projected real-world systems such as design concepts. After that, it is fundamental to conduct the experiments with models to comprehend the performance of systems under various operating conditions, assessing alternative management approaches and the processes of making decisions. The concepts are increasingly viewed as a scientific research approach adding to traditional deductive and inductive techniques. Many research analysts have added to M&S initiatives.

Researchers in [1] have provided an explanation of the predictive and simulation modeling. The Discrete Event Simulations (DES) has been proposed following the Agent-Centered Simulations (ABS). There are evident merits and demerits between ABS and DEC. Researchers in [2] have evaluated various techniques for the simulation of architectural validation and verification. Researchers in [3] have reported various M&S applications of business systems and presented an analysis of the ABS model development. The various Researchers in [4] operate on M&S applications, strategies, procedures and methods in various scholastic research segments. Nonetheless, there are little scholastic assumptions covering a complete cycle of M&S which incorporate the development/design and architecture validation/verification for application in SMEs product development models. As such, it is challenging for business practitioners to tell of the validity of a particular model which means that reliability of simulation experiments is assured.

The scholastic researches in [5] demonstrated that various simulation approaches could be used for various educational aims. DES is capable of mitigating operational issues whereby strategic problems are incorporated in model dynamics. ABS is considered as a versatile framework since agent approaches are object-based and flexible for evaluating the anatomy of more complex systems created by multiple business actors. Industrial logistics signify a more complex socio-technical framework featured by interlinked components with non-rational management operations. The agent-centered simulation can possibly model the interactions between the various components of the product development system hence facilitating the comprehension of the general performance under dynamics and uncertainty.

Participatory and game simulation are certainly fundamental for training at a considerably tactical dimension due to the fact that game enables the identification of counterproductive and productive human factors and actions [6]. The capacity of the agent-centered approach is the analysis and modeling of the human habits. The manufacturing logistics are widely featured by non-rational operative decisions made by business practitioners regarding the needs of consumers. By properly modeling the SMEs decisions at more agent level, business practitioners and developer of products can obtain insight into the reasoning procedure of decisions being executed. By allowing the operational professionals to be in the simulation process, it is possible to assess the process perception and the product development operations. This provides more insight at a considerable abstraction level compared to technical-based discrete event simulation.

Concerning the training objectives, agent-centered simulations and games are applicable in coordination, negotiation and training in manufacturing logistics. In this training process, discrete-event simulations and the framework dynamics can be applied to eliminate the uncertainty processes of making informed decisions which also incorporates the process of adding model details. Participatory simulation is considered fundamental and valuable when it comes to the validation of different simulators which model the more complex systems. The merit of the sharing simulation corresponds to the delivery system of the assessed system, as manufacturing logistics can be based on collaborative efforts where various skills, knowledge and professionals have been placed to operate together.

The discrete-event simulation has minimal requirements of technological preparedness and it is considered fundamental to support all fields of the product development process. The framework dynamics and the agent-centered simulation might necessitate formal approaches and mathematical assumptions regarding the system architecture, i.e., differential equation, game-based techniques and the decision theories. This research presents the procedure which covers a complete cycle of M&S and incorporate both the model development, model validation and verification for application in SMEs product development procedures. The remaining section of the paper is organized as follows: Section II is the background analysis part. Section III provides critical literature review of the paper. In Section IV, M&S procedures, verification and validation are discussed. Lastly, Section V concludes the paper and provides future research directions.

2. Background Analysis

M&S Concepts

In this paper, two definitions of the concepts: Modeling and Simulation have been considered in composing this research paper. M&S is considered as a procedure of driving systems with the essential inputs and evaluating the outputs that are corresponding. The concepts can also be defined as a procedure of designing the model of the conceptual framework and utilizing it to form experiments, to comprehend the performance of framework and assess the alternative management approaches and developing proper decision-making techniques using the results of simulation. The main objective of M&S incorporates the performance evaluation, education, entertainment, training, discover, prediction and proof. The simulation methods are applicable in different research segments which incorporate environmental systems, government systems, business organizations, societal frameworks, manufacturing approaches and computer systems. M&S approaches have to be applied in the various research fields like design frameworks and the mechanisms of decision-making, management of incorporated product teams, novel product enhancement processes and organizational management framework. The application of M&S techniques to comprehend the performances of social and technical frameworks is gradually attracting the attention of researchers.

M&S Domains

In manufacturing logistics, M&S approaches are applied in two different forms of model i.e., physical technique whose performance evaluation is based on the protocols and guidelines of process-centered models and physics. Process-centered models are controlled by organizations, groups and determined by human behaviors.

Mechanism simulations represents the simulation process of physical frameworks where movements, velocities, component stress and degree of freedom are analyzed and simulated for the complete optimization process of machines. The spatial-linkage mechanism incorporates various mechanical segments. As such, the simulation process will evaluate whether the mechanism can possibly produce three various spatial dimensions of freedom to make the strength of products and materials to be enough whenever external forces are applied.

The system and process simulation connects to the simulation of various operational and organizational models which incorporate the manufacturing framework, business service frameworks, industrial production procedures, complex issue-solving procedures, social, technical frameworks and human models. Simulation models can be established to mimic novel processes of product enhancement which incorporate four teams: service, manufacturing, detailed designing and preliminary designing. The aim of the simulation was to comprehend the operational procedures and finding out the teams that used more resources in designing iteration over various

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stages in the procedure with the notion to identify enhanced management strategies with a general ambition to minimize the timeframe for product development and also enhance the performance of time-to-market [7]. The concentration of the remaining segment of the paper is the procedures, framework M&S.

M&S Techniques

The commonly used simulation techniques for product development systems in SMEs incorporate DES and ABS. The techniques are applied in relation to the other simulation approaches such as Monte Carlo simulation and the mathematical simulation.

1) Agent-Based Simulations (ABS)

Agent-Based Simulations (ABS) represents a fast-advancing M&S approach which can be utilized to simulate model complex scientific models and manufacturing processes. ABS adds up its framework using the bottom-up model. This concept incorporates a series of autonomous agents which interact and act with each other in accordance to standardized simulation protocols in simulation. The major features of ABS simulation are shown below.

- Bottom-up modeling system.
- Concentration in modeling personal interaction and agents between them.
- Decentralized simulation framework model i.e., every agent has its control thread.
- The modeling of the system evaluation is not based on the simulation framework but from the autonomous actions of the agents, decision-making processes and iteration processes.
- Queueing problems are not explained.
- Modeling input are centered on the theories and subjective information on the behaviors of agents.
- Personal agents can utilize their initiatives and create proper decision which affect the status of the overall architecture.

In the ABS models, the autonomous agent interacts and acts complying with the standardized simulation protocols in the segment of simulation. The micro-leveled personal agent's behaviors and actions determine and affect the micro-level framework performance that can analyze and observe with the assistance of the users simulation framework. ABS is gradually becoming a fundamental issue-solving technique for many conditions in SMEs where the general framework behavior is based on the behaviors of micro-levels. There are many ABS software models and are well matched to certain forms of application. ABS frameworks incorporate Anylogic, Mathematica, Matlab, Swarm, Starlogo, Repast, Spread sheet and NetLogo.

2) Discrete-Events Simulations (DES)

DES is a considerably mature approach of simulation compared to ABS. DES is a way to structure frameworks in a top-down system and to evaluate the time-centered habits of the model. Formal approaches have been structured to make DES systems and ensure the credibility of these systems. There are various features of DES and these include:

- Focusing on the model general procedural approaches.
- Top-down model method.
- The centralized simulation model i.e., a particular simulation that has a single control thread.
- Modeling system performances have a single control thread.
- The modeling framework performance is connected to the model procedures.
- The queue identification is a fundamental aspect in the model's overall performance.
- Modeling inputs are centered on the objective information such as the data collected from the framework which has been modeled. SMEs, in the simulation system include the process steps connected to other fundamental steps but have no capability to operate independently. As such, the performance of the general system is depending on the connection between the various steps of the process.

3. Literature Review

DES is applicable to analyse and model the various aspects of logistics in the manufacturing sector. Particularly, the management of product flow and the planning of the workforce requirements are fundamental applications of the simulation initiatives. The profiling of the literature assumption is according to the past research about simulation application in the manufacturing logistics. DES is considered as a fundamental tool that can possibly enhance the flow of products, scheduling and tracking the usage of resources. Researchers in [8] have addressed the impact of manufacturing capacity in SMEs based on the evaluation of production size and evaluated the applicability of supporting owners of SMEs to handle various operational tasks.

Researchers in [9] have also formulated the decision-support framework based on discrete event simulation for strategic evaluation of the product capacity. Past researches have also evaluated the scheduling rules for products to be evaluated using the canning machines. As such, DES is developed to evaluate the duration it will take for manufacturers to receive products from the resource management sector. Researchers in [10] have evaluated the inner logistics in the industrial sector and assess the implication of various management control framework concerning the wait time for accessing the product samples. The simulation paradigm is applicable for realistic representation of procedures in the manufacturing logistics for evaluating the performance of the logistical framework.

Researchers in [11] have evaluated the system dynamics applicable in business simulations. This paradigm is considered as a mechanism-enhanced tool that

allows SMEs to make proper decisions for the resources and services from a global viewpoint. The framework dynamics and simulations have been presented to evaluate the blocking of products in the manufacturing sector. This was the case to evaluate the rules for handling production delays and envisaging the unintended and counterproductive effects of the novel rules. The system dynamics are used in simulating the flow of products to assess the system-wide bottleneck. Based on the simulation, researchers in [12] have argued that the daily variations of the utilized resources may not be balanced by enhancing the capacity of production; thus, the optimum design of flows has to be the basis of operational technologies. Past Researches have assessed the logistical outsourcing and applied the system dynamics simulations based on sensitive evaluation for analysis and evaluation of the economic performance and sustainability. The holders of content can utilize system dynamics simulations to envisage the complexities and evaluate the risks and opportunities of rules and the management controls projected.

ABS may be viewed as an approach of soft computing in the manufacturing logistics. ABS gives the gateway for comprehending the conditions of the connected and distributed providers of services. The connected analysis and modeling is capable of dealing with issues in engineering systems even in systems that are more complex. Researchers confirm that this paradigm has been introduced to mitigate the issue of collaboration and coordination for producers in the manufacturing sector. The positive impact of the coordination initiative was denoted by these modeling considerations. The standardized decision protocols for producers were fundamental for operative decision-making approaches based on the effective provision of products. Structuring decisions created by suppliers and distributers in the manufacturing sector have been evaluated by Researchers. The presentation of the multi-site system was also simulated using the pre-chosen indicators which incorporates the various released products, consolidation degree and the asset returns. The multi-agent framework was not just effective for the modeling flows of the providers of service in other SMEs sectors; as such these could also be applied in manufacturing logistics. With reference to the multi-agent language, the relationships and properties of the actors can be validated and simulated for certain social and technical ecosystems.

According to research evaluations by Researchers in [13], the participatory and games simulation incorporates the life-like media which allows SMEs to establish experimental learning. The application of these media allows the development of non-technical connected skills. The past literature works have evaluated the pedagogical organizational games which simulated the supply of products in the supply chains. These major participants in this simulation practice were motivated to propose various remedies, evaluating the costs, assessing time-efficiency and analysing the stock level of products. Based on the quality of services in the manufacturing logistics, the web-centred business simulation was structured and deployed to SMEs for training and testing. The findings from this simulation indicated that the application of data is connected to the perceptions of data sources. The game gave significant insight into the application of future technological basis on logistical works. Concerning the practical setting of two SMEs, the application of wearable technological initiates was based on roleplay. This may also be relevant for analysis in the working ecosystems in manufacturing logistics.

Researchers in [14] have evaluated the hybrid logistics as an effective connection of different modeling approaches. Many hybrid modeling incorporates DES and the system dynamics. In this simulation, two different case evaluations with reference to regional and control social care framework engineering have been evaluated, this combined DES and system dynamics. The significant merit of hybrid modeling is its capacity to incorporate various simulation methods and the empirical information from various sources.

4. M&S Procedures, Verification and Validation

M&S procedures help controlling activities which incorporate the formulation of issue statement, conceptual model enhancement, simulation model creation and model validation/verification. Certain procedures utilized to simulate actual-world issues may vary for many reasons such as the variations in problem statement simulation, purpose experiments, testing preference and the demerits of simulation initiated.

M&S Procedures

Researchers on the M&S process enhancement incorporate the application of fundamental steps as shown in Figure 1 below.

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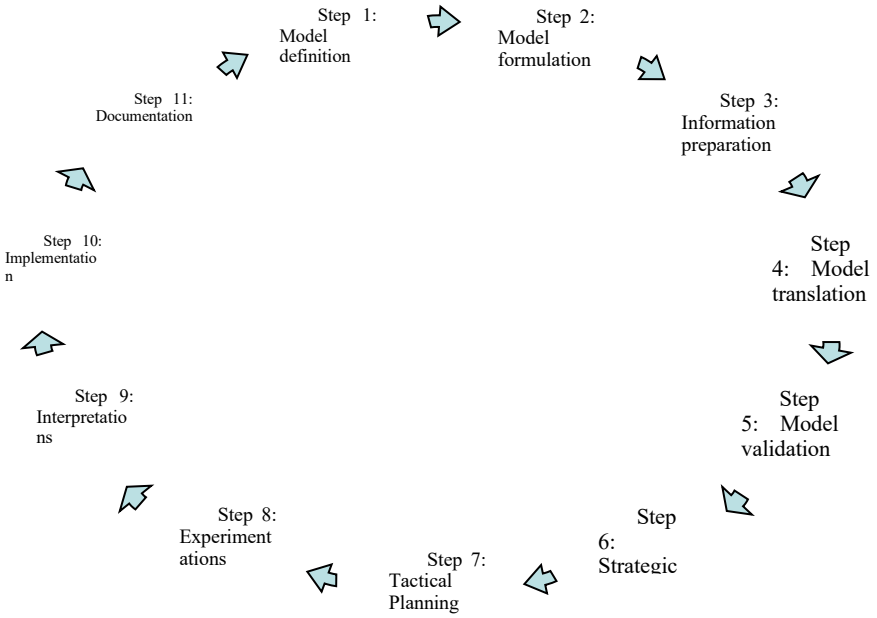

Fig 1. M&S process enhancement foundational steps

There are other processes for M&S and one of them include 13 steps as shown in Figure 2.

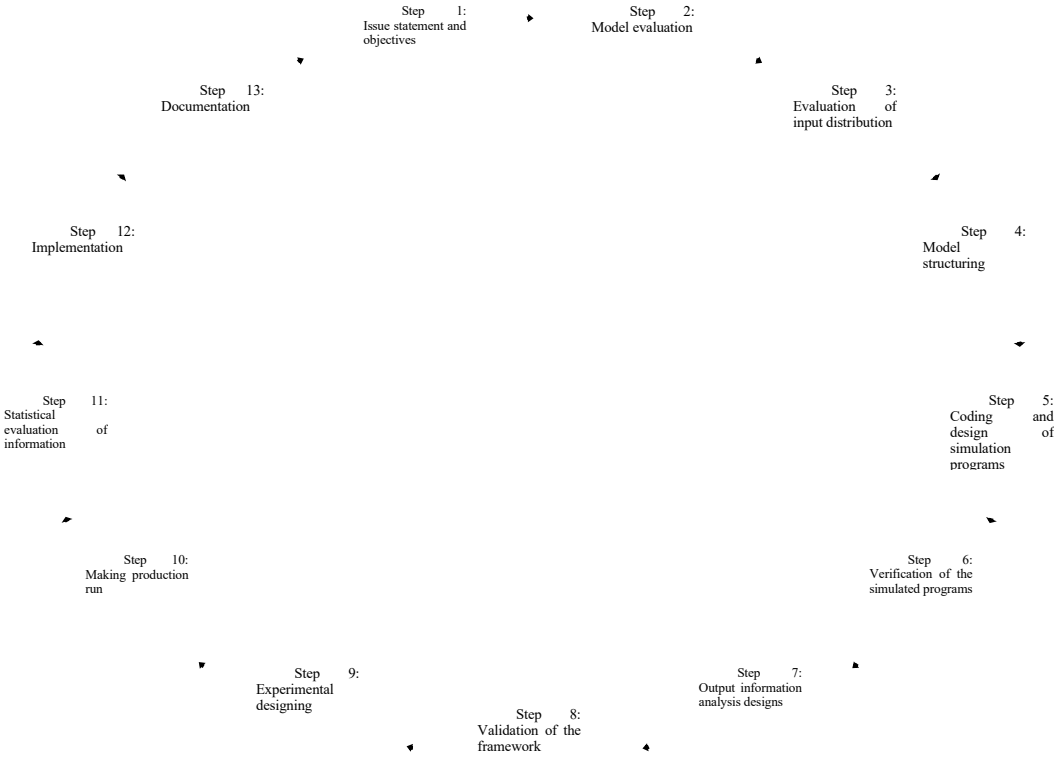

Fig 2. 13-step M&S procedure of simulation

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The M&S procedure indicated in Figure 2 is a critical basis that guides authors in research experiments and activities in actual-world mitigation of issues. The procedures were assessed based on the application of the relevant case studies to explore the actual-time performance of the novel product enhancement process based on the perception to identify the time resource utilized by the work teams in the process and recommending enhanced management approaches which could minimize the product enhancement cycle time. The part below provides a description of the 13-step procedure of simulation.

Step 1: Issue Statement and Objectives
This step provides an analysis of the research problem and research interests based on the case evaluation where SMEs owners are elaborated as well. The actual-world issues are assessed, and the expectation of the study results are acknowledged.

Step 2: Model Evaluation
This step specifies the purpose of simulation experiments where objectives and aims are specified.

Step 3: Evaluation of Input Distribution
The third step includes the collection of essential information and data for the explanation of both the simulation and conceptual models which are used as input data for simulation experiments. It is fundamental to note that this is normally based on iterative negation procedure between the study team and the case study owners since the essential data has to exist in the efficient forms that can be accessible by the enterprise. If this is not the case, the owners can collaborate with the team of study to formulate the synthetic sets of data.

Step 4: Model Structuring
This step incorporates structuring a conceptual framework which is built and defined based on certain research purposes using information and data collected to signify the relationship which is fundamental to solve the study issues.

Coding and Design of Simulation Programs
The M&S approach is chosen to signify the defined study issue. The choosing of the simulation approach incorporates the consideration of both feasibility and suitability.

Step 6: Verification of the Simulated Programs
To verify the simulated programs, it is fundamental to select the best simulation tool which is a software that allows the consideration of both model adaptability and availability.

Step 7: Output Information Analysis Designs
This is based on the development of the simulation system. The computer-centered simulation system as a conceptual model is formed using the chosen simulation tools and method.

Step 8: Validation of the Framework
To validate the framework, the verification experiments are completed using the simulation models to concentrate on determining if the simulation framework provides the anticipated and reliable output for particular inputs in cases where owners are known.

Step 9: Experimental Designing
In this step, the results of the simulation from the verification experiment are analyzed. The model of simulation and the results are analyzed and verified over certain indicators and methods. If there is need step 3 to 8 is repeated. With reference to comments which have to be provided suggestions and feedbacks from various perspectives enable the simulation model to be upgraded and improved to the following step.

Step 10: Making Production Run
In this step, the validation experiments are done using revised models of simulation. The validation experiments are then evaluated to determine if the simulation framework has the required accuracy to address and represent the research issue based on certain research purposes.
Step 11: Statistical Evaluation of Information
The findings from the validation experiments are evaluated and validated based on the application of the specific validation indictors and techniques. If there is need, the initial steps are repeated.

Step 12: Implementation
The simulation experiments are done to effectively simulate the actual-life cases. The results of simulation are discussed and analyzed. The potential management remedies are considered to focus on particular research issues.

Step 13: Documentation
The documents and instructions that support the model and experiments of the simulation are developed. For instance, owners should preserve the documents on how to work with the models of simulation and how to set input information values and how to evaluate the results of the model. Thus, this step is essential for other clients and users to comprehend, improve and modify the simulation models when the need to do so arises. This also enhances the confidence level among the users that apply this model to mitigate actual-life issues. As for the case scenario utilized to assess this process, the user manual for implementing the simulation model was written.

Model Validation/Verification
The aim of model validation and verification is to structure the model of simulation that is essential and applicable to

actual-life context. For this purpose, M&S processes incorporate the mathematical assumptions and simulation requirements connected to the mode. The verification process makes sure that the model is as correct and complete as required to provide fundamental representation of actual-world situations. In this manner, the validation of the model ensures that the simulation framework is fundamental to solve real-life problems. The model validation procedures are meant to assure the accuracy of the model based on comparison of the simulation results to operational and experimental results in real-life case. The contributors to the domain of verification of model and validation of skills have to comprehend the architecture proposed in this paper.

Validation and Verification Architecture

Figure 3 below represents the validation and verification architecture which signifies the representation of the essential activities.

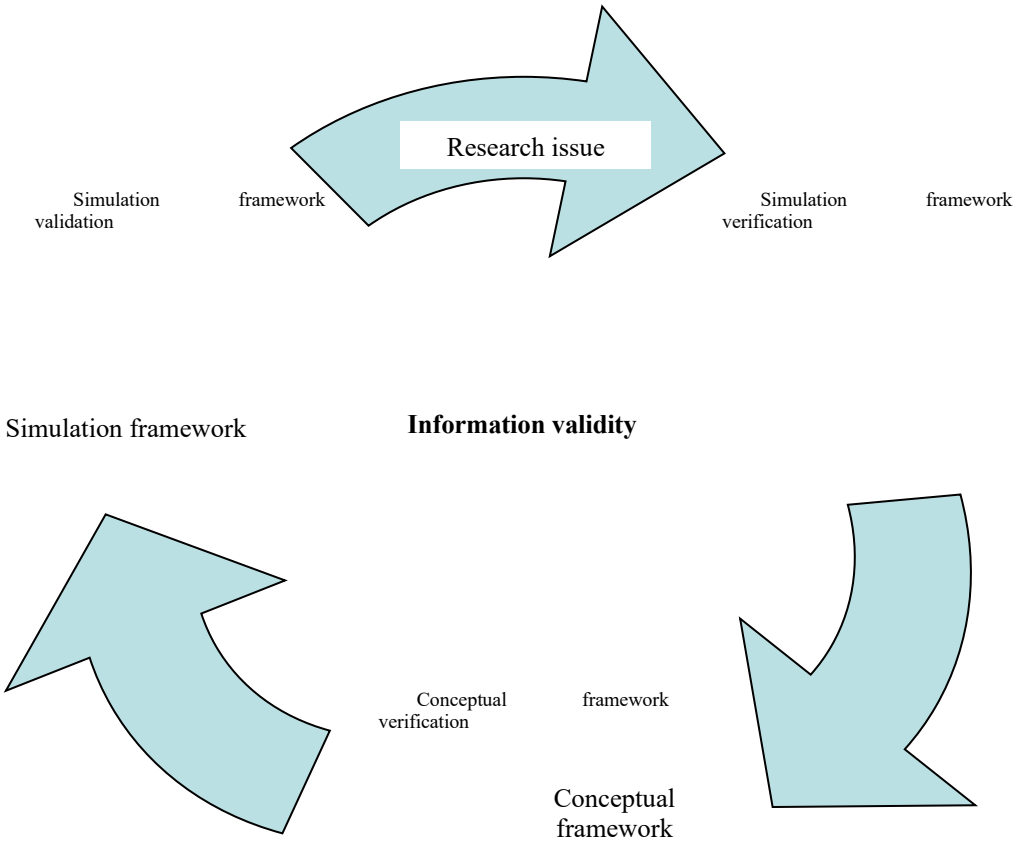

Fig 3. Validation and verification architecture

Three validation and verification activities are required. Firstly, the conceptual framework verification makes sure that the conceptual model is an effective representation of the study issue in actual-world case. Secondly, the simulation framework verification makes sure that the computer-centered simulation framework is a sufficiently precise implementation of the conceptual framework. Thirdly, the simulation model validation does a series of simulation experiments that concentrates on evaluating the efficiency of the model and accuracy based on certain research aims and objectives. All the data utilized in the model development, design, model validation and verification require validation.

Model Validation and Verification Approaches

There are various model validation and verification approaches which have been evaluated in the past researches and their experiences in research and manufacturing logistics discussed. Four major approaches utilized to validate and verift siulation models incorproate:

- *Individual-validation:*The model enhancement and group of the simulations make informed

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decisions concerning if the simulation framework is valid or not.

- *Co-validation:*The group of simulation incoporate the users of the model within the model enahncement process; where the process of validation is incorporated within the framework development process.
- *Independent validation:*This approach represents independent parties that decide if the model of simulation are valid or not.
- *The scoring validation:*The scoring framework is utilized to evaluate if the model of simulation is valid or not.

Every approach has different features that implies various approach which are effective for various real-life cases, simulation aims and objectives.

Model Validation and Verification Techniques

There are various validation and verification techniques structured for certain simulation scenarios. The contributions to the framework validation and verification techniques incorporates the methods such as animation validations, model-to-model validation, event validations, extreme situation validations, face validations, historical information validation, operational graphical validation, sensitivity evaluation validations, predictiv validations, traces validation, turing test validation and game validation.

Various model validation and verification techniques have their merits and demerits. This implies that the various techniques are suitable for various actual-life issues and study purposes. Concerning the model validation and verification technique selection, more data can be found according to research evaluations by Researchers.

5. Conclusion and Future Direction

In conclusion, M&S methods are becoming a fundamental study avenue for evaluation of operational and business models. The present research efforts focus on various aspects and views of M&S methods with specific interests; however, there is less research done on the complete vision of M&S in a process suitable for engineering designing application. This paper bridges the prevailing gap between model development and design, model validation and verification by presenting M&S procedures. The M&S process was shown with reference to actual-world problem-solving case studies. The procedures accommodate the various model validation and development processes, methods, domains and concepts. Two common M&S approaches are evaluated i.e., DES and ABS. It is believed that DES is rapidly advancing to be an effective decision-support framework both in knowledge economy and global manufacturing. This attracts researchers to further invest in research and development efforts to venture in new avenues of DES such as simulation-centered education and business intelligence (BI) systems. Future research should also focus on the development of a novel generation of DES by considering the transformation in the application ecosystem of SMEs.

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