Verification and Validation in GERAM Framework for Modeling of Information Systems

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Verification and Validation in GERAM Framework for Modeling of Information Systems

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Abstract - The main aim of this article is to propose a methodology for using verification and validation tools in a framework for modeling of an Industrial Enterprise Information Systems. The first part of this paper introduces the Generalized Enterprise Reference Architecture and Methodology (GERAM) framework and its parts that are used for modeling of industrial enterprise information systems. The second part introduces the verification and validation concepts and tools. The third part of this article proposes the use of the verification and validation tools in GERAM framework to improve the coherency, correctness, error-free, qualitative aspects and efficiency of an enterprise information system.

Index Terms - Information Systems, Enterprise modeling, Verification, Validation, Industrial Enterprise, ISO 15704, GERAM

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1 Introduction

THE Intricacies of models, their results and effect on their environment as well as the reaction of the stakeholders to the modeled system before its implementation can be observed with modeling techniques. Models are the representation of reality of each system. The complexities of the existing information systems in industrial and manufacturing enterprises do not allow modelers to do modeling without regard to verification and validation of these designed models. Nowadays, there are many frameworks available providing a road map for the modeling of the information systems, but, many of these frameworks does not consider verification and validation approach of these models. The complexity and importance of modeling of the information systems in today's competitive and global businee which is continually changing require modeling of information systems to be highly adaptive to changes in the market. For this reason, the application of verification and validation tools for the framework governing these models is critical. As a standard and comprehensive framework, the GERAM framework which is considered as an ISO 15704 does not consider the use of verification and validation tools in modeling.

2 Enterprise and Modeling Framework

2.1 Enterprise architecture

Enterprise architecture was developed by John Zachman while with IBM in the 1980s [1].

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Architecture is the integrated structural design of an enterprise, the elements and components of it and the relationships among them which are related to the requirements of the enterprise [2]. In this definition, ''an enterprise may be a company, an institution, or a department within a company'' [3].

2.2 Information Systems Architecture

The architecture for an information system is the abstract plan that includes the corresponding designed processes of the system's structure suitable to the goals of the system based on design principles and a methodological framework [2].

2.3 ISO15704 (Annex A: GERAM)

IFIP-IFAC Task Force developed the Generalized Enterprise Reference Architecture and Methodology (GERAM) [4-6], and adopted it as an Appendix of ISO15704:2000 [7, 8].

This framework started from the evaluation of existing enterprise integration architecture (CIMOSA, GRAI/GIM and PERA). GERAM is about methods, models and tools which are needed to build and maintain the integrated enterprise [7].

The structure of GERAM reflects its envisaged purpose of assessing candidate architectures for a given enterprise architecture task type and thus enabling users to make an informed decision on the combination of architecture frameworks (or architecture framework elements) to be used so that all necessary aspects are covered [9].

3 Verification and Validation (V&V)

V&V Challenges

The challenges of Verification and validation as stated in Pace [10] are:

• The first motivation of V&V is for modeling and simulation for risk reduction, i.e., to ensure that the simulation can achieve its user favorable objectives.

• Effective communication is a problem because of continuing differences in the details about concepts, terminology, and V&V paradigms among various modeling and simulation communities; excessive use of acronyms makes it difficult to communicate easily across different communities.

• Advances in modeling and simulation framework/theory can improve the V&V capabilities and is necessary to increase automated V&V techniques.

• Limitations in items required for effective V&V data and detailed characterization of uncertainties and errors, simulation/software artifacts, etc. They have to be addressed, with a lot of the management processes to cope with them.

• Cost and resource requirements for modeling and simulation V&V are not as well understood as they need to be because meaningful information about such is not widely shared within modeling and simulation communities, and much more information about cost and resource requirements needs to be collected and made available to facilitate development of more reliable estimation processes. The modeling and simulation V&V community is faced with two very different kinds of challenges. One set relates to modeling and simulation management (or implementation): how to do what we know how to do in a proper manner consistently. The other challenges have a research flavor: areas that we need to understand better in order to find viable technical solutions [10].

How choose the technique of V&V?

The model manager and V&V agent must be familiar with and select the techniques and approaches to use to maximize confidence in each model by considering such constraints/factors as:

- Cost
- Time
- Model's intended use
- Model's users
- Data availability
- Required level of verification & validation
- Development approach
- Model maturity [11]

The Fig.2 shows the V&V flowchart.

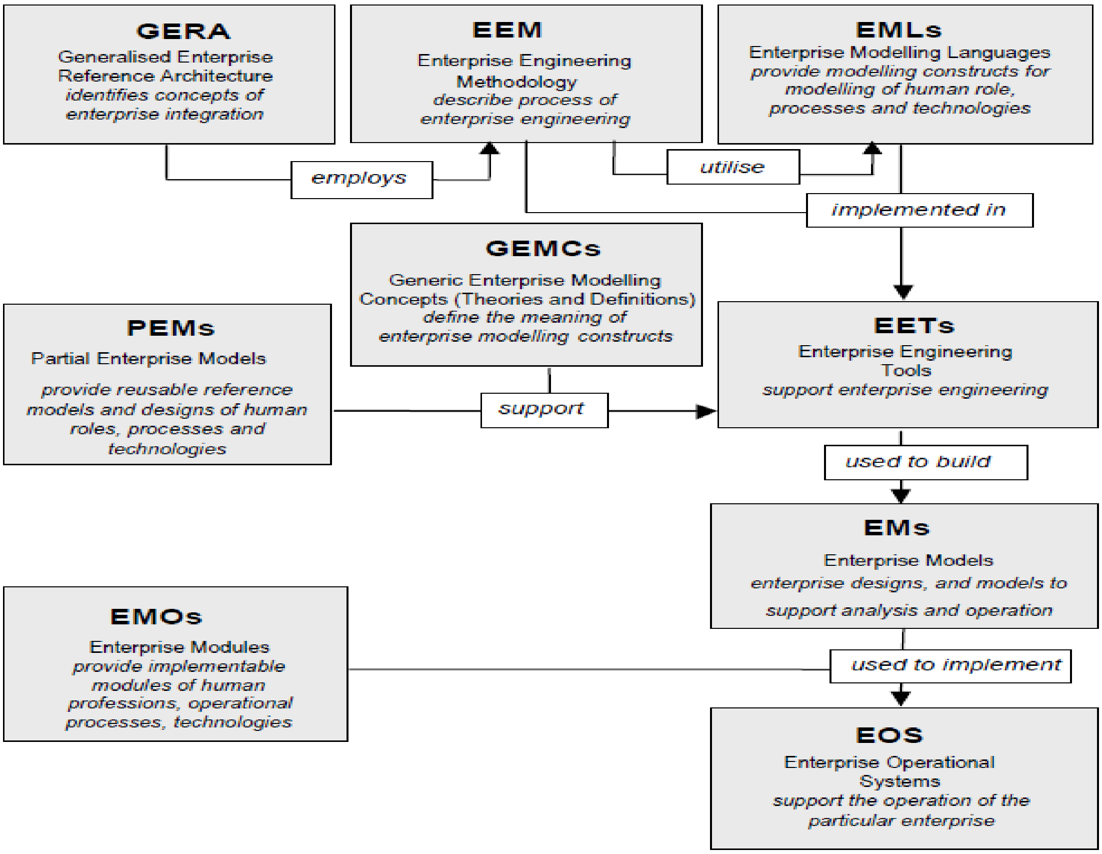

Fig. 1 - GERAM framework components [7]

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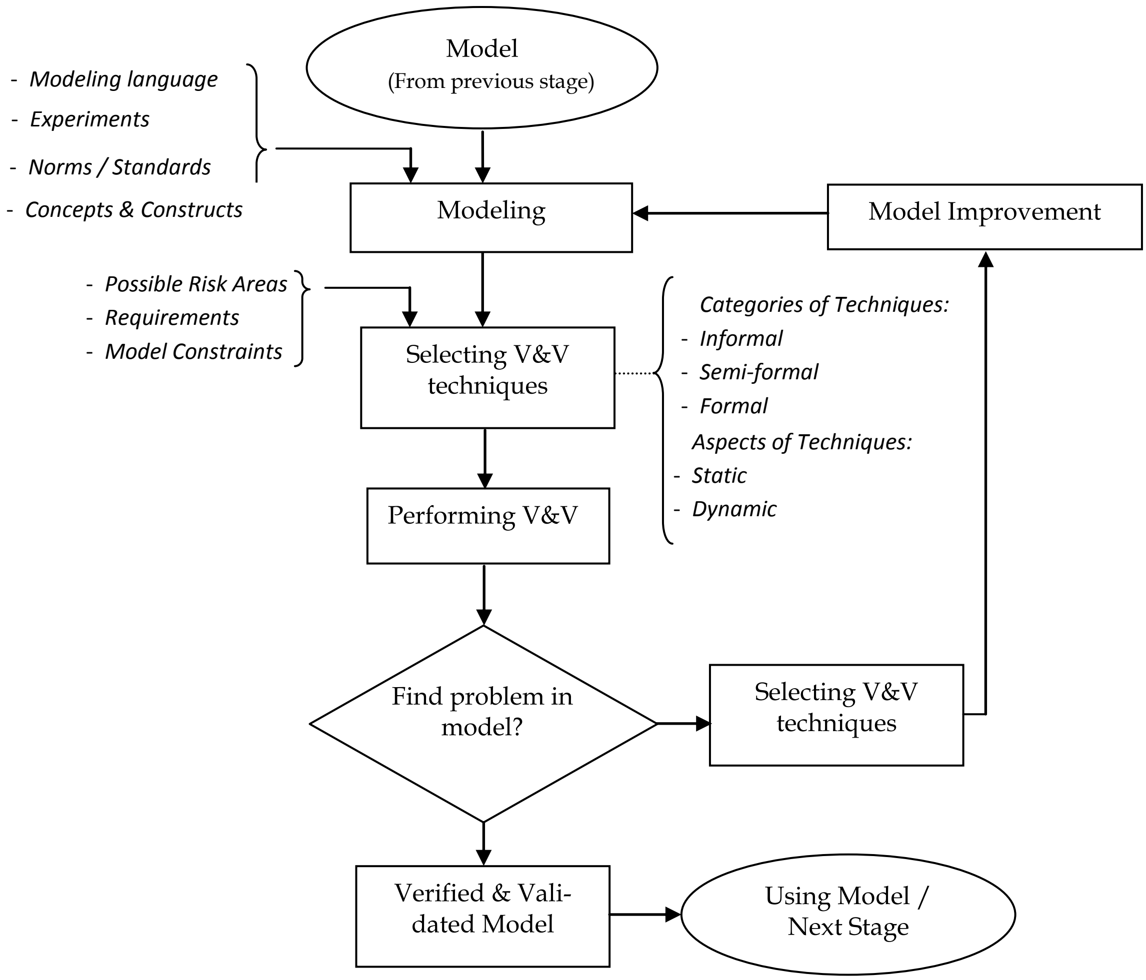

Fig. 2 – Basic flowchart of V&V in modeling [12-14]

3.1 V&V techniques

Several techniques can support the V&V tasks (Table. 1). These techniques classified in three main categories: Informal, Semi-formal, and Formal Also, they are divided into two main aspects view: Static aspects, and Dynamic aspects.

The model can be analyzed with the use of the static aspects without the requiring execution of the model. This approach enables the detection of syntactic anomalies or semantic problems and, more generally, can check that systems or models comply with construction standards. These techniques can be used during the verification or validation tasks [13].

Next, is the dynamic technique which may require the execution of a model to evaluate its operational semantic. This aspect includes the assessment and monitoring of the behavioral errors in the model. The requirement of this aspect is first to model the system using the formal modeling language and then to analyze the input and study the output, evaluate the model for coherence of different views, deadlocks and the performance level of the modeled system. For this type of analysis, the techniques used can be based on simulation, emulation or testing [13].

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TABLE 1
Overview of Techniques [13]

Focus on (Information, Resource, Organisation, Behaviour)

Techniques	Static aspect	Dynamic aspect
Informal	Reference models and reference architectures utilization, Audit, human expertise, Face Validation. Reviews(models, project).Walkthroughs, Desk Checking, Inspections, Turing Test, Automated documentation generation, Models comparison(by human expert)	
semi-formal	Cause-Effect Graphing Data Analysis(data dependency, dataflow) Interface Analysis (model interface, user interface) Structure Analysis syntax Analysis Control Analysis (calling structure, concurrent process, control flow, state transition) Fault/failure Analysis Semantic Analysis Symbolic Evaluation Traceability Assessment Automated documentation generation	Acceptance Testing, Assertion Checking, Bottom-Up Testing Compliance Testing (authorization, performance, security standards) Execution Testing(morning, profiling, tracing, reporting) Field Testing, Graphical Comparisons, Object-Flow Testing predictive Validation, Regression Testing, Statistical Techniques Structural testing(White-Box), Functional testing (Black-Box) Testing(Branch, condition, data and controls flow, loop, path, path condition, statement,) Debugging (symbolic, classic), Comparison Testing Fault/Failure Insertion Testing, Interface Testing (data, model, user) Partition Testing, Product Testing, Sensitivity Analysis Special Input Testing (boundary value, equivalence partitioning, extreme input, invalid input, real-time input, self-driven input, stress, trace-driven input) Sub-model/Module Testing. Top-Down Testing. Visualization/Animation
formal	Formal methods utilization (B,Z,VDM, other) and associated tools Induction, deduction, abduction, model checking, theorem proving, Inference, Inductive Assertions, Proof (correctness, completeness, consistence), Properties proof, Model mapping, Predicate transformations, Predicate Calculus, Logic (temporal, propositional, first order, etc). Algebra (linear, process algebra, dedicated algebras). Lambda calculus Simulation (when based on formal behavioral rules and models). Bi simulation	

In brief, these three categories of techniques study two aspects/views of the systems and each one includes the following items:

- Static :
  1. Interface Accuracy: Checking the interaction between user and model
  2. Structural Accuracy:
     a. How to operate
     b. Structural: correctness, completeness, consistency, traceability

- Dynamic: Behavioral error detection
  a. How well to operate
  b. Behavior
  c. Input
  d. Output [13-15]

The V&V techniques can be briefed in:

- Informal techniques: these are essentially qualitative in nature and are based on human expertise and do not require such a high level of formalization of the model.

- Semi-formal techniques: these techniques are essentially based on model execution. They require the formalization of a single and unambiguous operational semantic which is fundamentally defined by a set of formal execution rules, temporal hypotheses and initialization rules for the model. This technique enables effective execution of the model and a high level of confidence in the execution results. In addition, it frequently requires the development of dedicated and often specific models known as simulation models, and the definition of scenarios defined a priori, thus excluding objectively or subjectively 'forgotten' behaviors that it would, however, be interesting to analyze.

Formal techniques: such techniques are strongly related to formal methods. They require a high level of formalization of the modeling language. In other words, the modeling language used must be equipped with an adequate mathematical semantic based on interpretation rules which guarantees the absence of ambiguity in the descriptions produced and deduction rules which make

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it possible to reason about the required specifications in order to discover potential errors, mistakes or inconsistencies by proving properties [13].

3.2 Verification

Verification is about answering such fundamental questions as: did I build the model right? Have the models been built so that they fully satisfy the developer's intent (as indicated in the specifications)? Verification has two aspects: design (all specifications and nothing else are included in the model or simulation design) and implementation (all specifications and nothing else are included in the model or simulation as built) as shown in Figure 3.

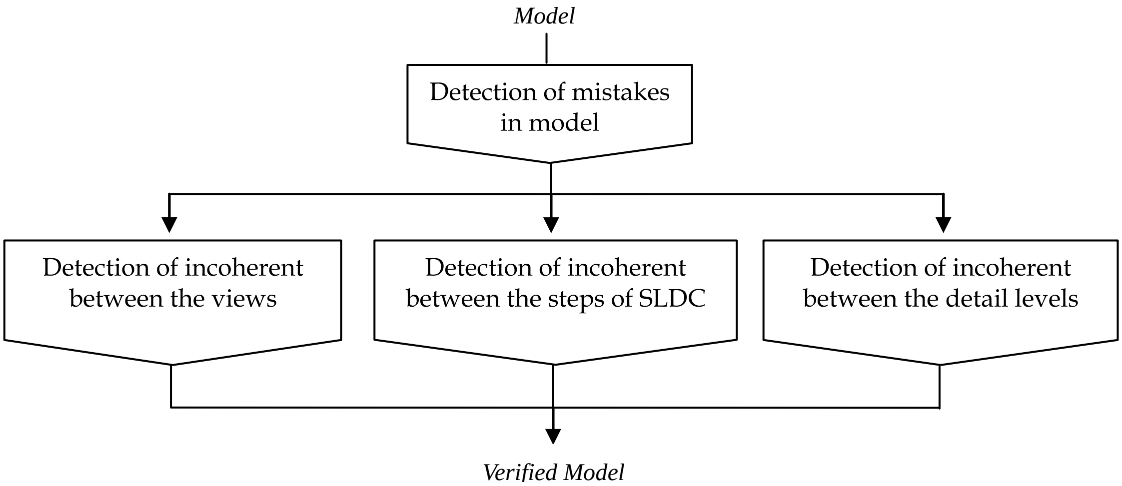

Fig. 3 - Basic flowchart of Verification

3.3 Validation

Validation is about answering questions such as: did I build the right thing? Will the model or simulation be able to adequately support its intended use? Is its fidelity appropriate for that which is built? Validation has two aspects: conceptual validation (when the anticipated fidelity of conceptual model is assessed) and results vali dation (when the results from the implemented model are compared with an appropriate referent to demonstrate that the model can in fact support the intended use). There have been many paradigms of the relationships among V&V activities and model or simulation development and what is represented in the model or simulation as shown in Figure 4.

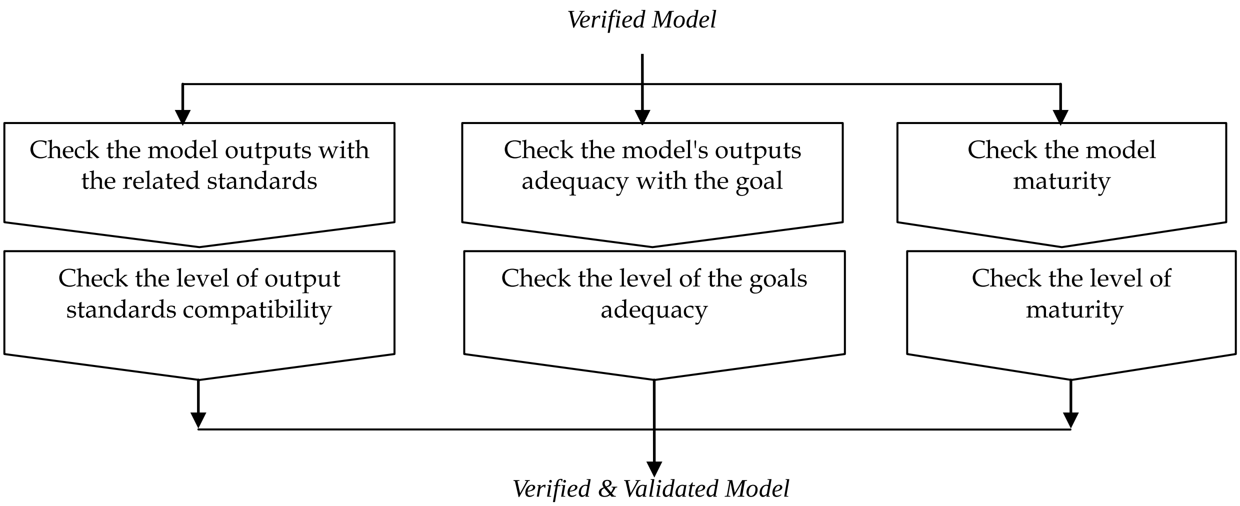

Fig. 4 - Basic flowchart of Validation

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3.4 V&V in GERAM framework

3.4.1 V&V for GERA architecture modeling

GERA modeling framework:
GERA (Generalized Enterprise Reference Architecture) is one component that defines several important ingredients of architectures for any enterprise entity, including the information system [2].

Verification and Validation must be considered for three dimensions of the GERA architecture as depicted in Figure 5. They include:

- V&V of life-cycle dimension that controls and defines the stages of the modeling process of the enterprise.
- V&V of genericity dimension provides the satisfaction of particularization of the modeling process from generic and partial to particular.
- V&V of view dimension provides the satisfaction of necessary views (Function, Information, Resource, and Organization) in different stages.

In addition the above mentioned V&V requirements, the V&V should be capable to obtaining the V&V in the following items:

- Coherence between the different views of model in framework
- Coherence between the different genericity degree of model in framework
- Coherence between the different steps of life cycle in framework
- Coherence between the different levels of model in framework

V&V in different life cycles of GERA:

Identification:

The objects involved in the system. The set of activities which identify the contents of the particular entities of the system under consideration is defined in this stage.

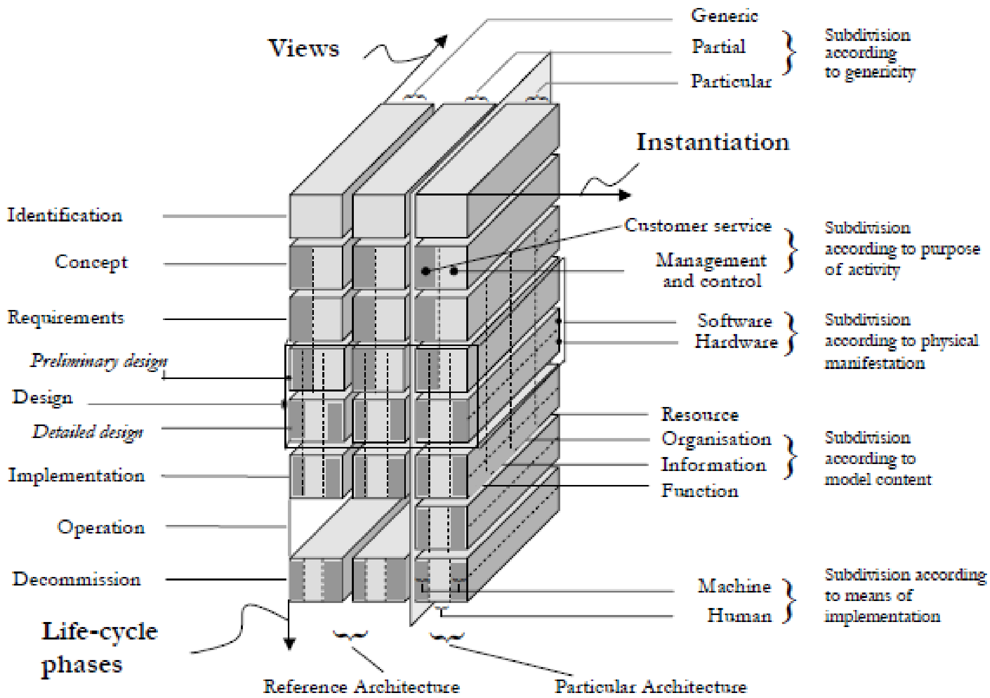

Fig. 5 – GERA Modeling Framework with Modeling Views [7]

The environment of the system and the internal and external entities and their relationships with the environment are defined, described and documented. Some typical entities of the systems are: departments, teams, staffs, products, tools. Because this stage is the first stage in life cycle of GERA, the use of V&V is very important and should be done carefully. Figure 6 shows the proposed flowchart. As it is shown in Figure 6, the identification stage will be divided in three instantiation details: Generic, Partial, and Particular. The V&V should include all of these detailed categorizations. It seems that the informal and semiformal-static aspects' tools can be more usable for this purpose.

Concept:

The concept part includes the definition of the entities such as mission, vision, values, strategies, objectives, operational concepts, policies, strategies, tactics, business plans. With consideration of the goal of the system and the stakeholders' exception from the system, the V&V

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tools should achieve the targeted verification and validation of the system. The method of choosing the favorite tool can be done according to the flowchart shown in Figure 2. In addition to the subdivision of genericity for the V&V for concept stage, further subdivisions based on the purpose of the activity such as the "customer service", and "management and control" approaches of the system validation and verification should also be considered.

Requirements:
During this stage, the operational requirements of each entities of the system are described and their various features like functional, behavioral, informational, and capability needs are built. In addition of the genericity, and purpose of activity subdivisions, the subdivision according to model content should be done and implemented with their validation and verification. This subdivision includes resource, organization, information, and function. The V&V of each individual subdivision as well as the coherence and interoperation of them should be implemented with the use of the V&V tools. The static and dynamic aspects of this stage and its subdivisions should be considered during the implementation of V&V.

Preliminary Design:
In this stage, the activities that support the entities to fulfill the requirements of the system are designed. The scope of the design includes overall specifications of the system that are necessary to achieve the estimation of the cost, risk and other parameters of the project. In addition to the genericity dimension, the purpose of activity and model content subdivisions as well as other subdivisions according to the means of implementation is added to this stage. Proper V&V tools should be employed to implement V&V for different static and dynamic aspects of the system. In the latest subdivision, the human and machine tasks are defined. However, tasks' details are done in next stage: detailed design.

Detailed Design:
The major and detailed designs of the system are defined at this stage. The human and machine tasks, their relationships with the organization, function, information and resources as well as their activity purpose (customer service, and management and control) are specified. In addition to the above mentioned aspects of the system, the subdivision of physical manifestation, including hardware and software divisions are also defined. For all aforementioned detailed design articles, V&V tools are used to certify the error-free, coherence, and the integrity of the system's detailed design.
In addition, different aspects of the system such as cost, time, and coherence should be determined and verified.
The V&V tools are used to study the static and dynamic aspects of the designed system. If the V&V is done well, the implemented system can be a very suitable system. Some V&V tools like simulation can evaluate the system's performance before implementation. The purpose of this evaluation is to reduce the time and cost of the system and to deliver an end system with required level of validation.

Implementation:
All tasks and activities that should be carried out to build and deliver the required designed system are done in this stage. All subdivisions mentioned in the previous stage (detailed design) are considered in this stage as well. With the use of V&V tools, component and system testing as well as integration testing are done. Both static and dynamic aspects of the system should be tested carefully to ensure successful implementation.

Operation:
Operation refers to be those activities that are carried out to produce the intended products or services of the implemented system. These activities include, operating, monitoring, controlling, and evaluation of the system. As it is shown in Figure 6, the operation is a particular subdivision of genericity. The V&V paradigm is used to produce more efficient and productive system outputs.

Decommission:
At the end of the system's life cycle in GERA, the whole or part of the system can be remissioned, recycled, redesigned, retrained, disassembled or disposed. Usually, the information system should be redesigned or remissioned in order to be well suited for the user satisfaction requirement of the system. Both the static and dynamic aspects of V&V are very important for the identification and correction of the weak points of the current system. They are also used to improve the design or revision of future systems to fulfill stakeholders' requirements (see Figure 6).

3.5 V&V for other component of GERAM

EEMs- Enterprise Engineering Methodologies:
This part of the framework describes the process of enterprise engineering and will guide the user in the engineering tasks related to enterprise modeling. Verification and validation should be considered in this approach. The modeling methodology is a methodology with the aim to help the users or developers to use a language or a set of languages to describe the method of using and validating these tasks in the model used for the system.

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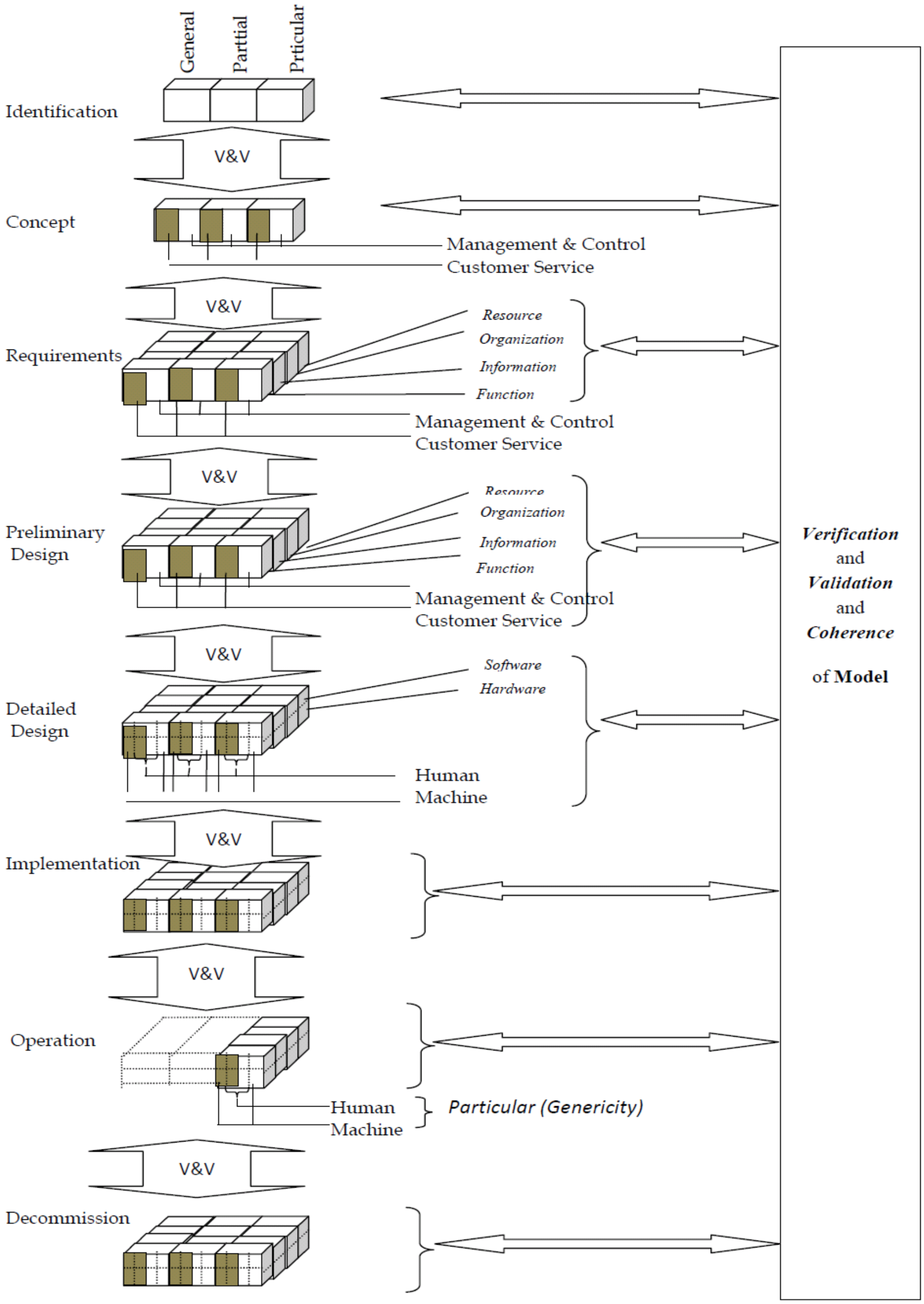

Fig. 6 – Verification and Validation in GERA framework

The V&V requirement for this item of framework is divided into two categories: static and dynamic. The static part is related to the choice of the favorite and suitable modeling languages and describes the methods of their applications. In addition, the static part provides assurance for the coherences and interoperability of different parts of the modeled system.

The dynamic requirement includes all aspects of the human factor and its relationship with machines and the organization. This aspect of V&V can be done with the

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dynamic tools of V&V mentioned in Table 1. The interfaces (users and machines) will check with V&V tools before the use of the modeling languages and tools and prior to the system implementation.

Economic aspects and feasibility of the framework for modeling of the system should be considered as well. These aspects include: cost, time, favorite performance of the system, favorite verification and validity of the model and system.

EMLs – Enterprise Modeling Languages:

In general, when modeling a complex system is undertaken often more than one modeling language is needed. Therefore, the compatibility and coherence of these modeling languages should have a favorite end system that is suitable for the users and other stakeholders of the system.

Appropriate tools maybe used for modeling different aspects of each viewpoint. For example, when the function view is modeled, the static approaches of the functions can be considered and then the dynamic approaches of these functions can be examined and subsequently their behavior should be modeled. In other word, the static, dynamic and behavior parts are done in sequence. These modeling approaches should use different V&V tools as deemed necessary in a given situation and with regard to the method represented in Figure 2.

PEMs - Partial Enterprise Models:

PEMs are used to improve the efficiency of modeling process, these partial models can be used to test the components that will be used in Enterprise Models (EMs).

With regard to the V&V of PEMs, it seems the best way is to use V&V on partial models of Human Role, Process, Technology, and IT Systems. The V&V of these models should be done first separately and then together to study their coherence and different views and aspects. The informal V&V tools can be useful for this goal.

In Partial Human Role Models, the skills, capabilities, socio-technical aspects, authorities and other human related aspects must be included in modeling.

In Partial Process Models, V&V tools and especially the semi-formal dynamic ones can be used to assess the verification and validation of the business process model. With the use of the V&V, the efficiency of the enterprise modeling can be significantly improved.

In Partial Technology Models, some informal models can help the modelers to confirm the V&V of factors such as: common description of resources, components and their operational rules.

In Partial Models of IT systems, the V&V must verify and validate all components that are needed in communication and information processing. The static and dynamic aspects of the components should be considered. The static aspect of V&V can be done by some tools like: Data Analysis, Structural Analysis, Interface Analysis, Syntax Analysis, Control Analysis, etc. The dynamic aspect of V&V can use tools such as: Execution Testing, Graphical Comparisons, Structural Testing, and Debugging. The integration of these aspects of modeling is very important, thus during the V&V operation special attention should be paid to the integration component of modeling.

EETs – Enterprise Engineering Tools:

These tools should be used to support the EMLs, EEMs, and especially EMs. Therefore, addition of the V&V tools to each category can be very useful and help to develop an efficient, error-free, cost and time effective system models.

EOSs – Enterprise Operational Systems:

EOSs consist of the enterprise requirements, operations and implementation method to achieve the desired enterprise goals and objectives. EOSs are used in the implementation stage of the life cycle to design necessary models and implement them to provide the system specifications.

4 Conclusion and future works

The main objective of this research is to propose the use of verification and validation techniques during the implementation of the industrial information systems using ISO15704:2000 Annex. A (GERAM Framework). We are also showed, how the application of the verification and validation concepts can be useful during the modeling of complex systems.

In this article, at first we presented the development of tools to support and provide guidance for modeling of systems with the use of the GERAM framework. We were discussed about importance of the analysis of functional and behavioral coherency, interoperation as well as verification and validation of them.

Second step was the development of simulation tools with regard to the said framework, we also mentioned about the importance of using V&V to improve the quality of the system designed and reducing the risk factors. Finally, we used the concept of ISO15704 to improve the model in order to have a comprehensive framework for modeling of the industrial information systems.

References

[1]. C. Finkelestein, *Enterprise Architecture for Integration: Rapid Delivery Methods and Technologies*, Artech House Publishers, 2006.

[2]. P. Bernus, G. Schmidt, *Architectures of Information Systems,* in: P. Bernus, K. Mertins , G. Schmidt (Eds.), Handbook on Architecture of Information Systems (2nd Ed.), Springer Verlag, Heidelberg, pp. 1–9, 2006.

[3]. L. Guijarro, "Interoperability frameworks and enterprise architectures in e-government initiatives in Europe and the United States," *Government Information Quarterly,* Vol. 24, pp. 89–10, 2007.

[4]. IFIP-IFAC Task Force, "IFIP-IFAC task force on architectures for integrating manufacturing activities and enterprises," IFIP newsletter/IFAC newsletter, 1993.

[5]. IFIP-IFAC Task Force, *GERAM: The Generalized Enterprise Refer-*

ISSN 2229-5518

ence Architecture and Methodology, in: P. Bernus, L. Nemes, G. Schmidt (Eds.), Handbook of Enterprise Architecture, Springer Verlag, Heidelberg, pp. 40–82, 2003.

[6]. T.J. Williams, P. Bernus, J. Brosvic, D. Chen, G. Doumeingts, L. Nemes, J.L. Nevins, B. Vallespir, J. Vlietstra, D. Zoetekouw, "Architectures for integrating manufacturing activities and enterprises," *Computers in Industry*, Vol. 24, No. 2–3, pp. 109–110, 1994.

[7]. ISO/TC184/SC5/WG1, Annex A: GERAM. ISO/IS 15704-2000: industrial auto- mation systems—Requirements for enterprise - reference architectures and methodologies, 2000.

[8]. ISO/TC184/SC5/WG1, ISO/IS 15704: Industrial automation systems—Requirements for enterprise—reference architectures and methodologies, 2000.

[9]. O. Noran, "A systematic evaluation of the C4ISR AF using ISO15704 Annex a (GERAM)," *Computers in Industry*, Vol. 56, pp. 407–427, 2005.

[10]. D.K. Pace, "Modeling and Simulation Verification and Validation Challenges," *John Hopkins Apl Technical Digest*, Vol. 25, No. 2. pp. 163-172, 2004.

[11]. O. Balci, "Validation, Verification, and Testing Techniques Throughout the Life Cycle of a Simulation Study, *Annuals of Operations Research*, Vol. 53, pp. 121-173, 1994.

[12]. V. Chapurlat, B. Kamsu-Foguem, F. Prunet, "Enterprise model verification and validation: an approach," *Annual Reviews in Control*, Vol. 27, pp. 185–197, 2003.

[13]. V. Chapurlat, C. Braesch, "Verification, validation, qualification and certification of enterprise models: Statements and opportunities," *Computers in Industry*, Vol. 59, pp. 711–721, 2008.

[14]. O.O. Molyer, "A Methodology for Verification and Validation of Models and Simulations: Acquirers' View Point," Paper presented at *the RTO NMSG Conference on Future Modelling and Simulation Challenges*, held in Breda, Netherlands, 12-14 November 2001.

[15]. G. Love and G. Back, "Model Verification and Validation for Rapidly Developed Simulation Models: Balancing Cost and Theory," *Proceedings of the 18th International Conference of the System Dynamics Society*, held in Bergen, Norway, on August 6-10, 2000.