

Integrating Manufacturing System Simulation Development A Methodological Framework

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Abstract: Today, discrete-event simulation (DES) use in the manufacturing industry has become widespread, but far from all companies use this technology. Often simulation is used on a 'one-shot' basis only, or as a standalone tool, reflecting a low level of integration. At the same time, a majority of companies do not use simulation at all. It is argued here that these companies lack methodologies for adopting and integrating simulation into their manufacturing system development process. Also, simulation research on integration aspects often deals with specific functional, or data-level issues, such as integrating and connecting simulation to other systems and tools, rather than structural, hierarchical, and procedural integration aspects as part of a methodological approach. Furthermore, simulation use seems to lack strategic focus. Based on industrial experience, this paper presents the framework of a methodology for integrating discrete-event simulation into manufacturing system development.

Keywords: Manufacturing system development, Discrete-event simulation, Integration.

1 Introduction

Today, DES can be applied to a wide range of manufacturing system development activities. However, DES use is in many respects still modest. Often it is used on a 'one-shot' basis only, troubleshooting specific problems such as bottlenecks, or as a standalone tool, both of which reflects a low level of integration. On the other hand, a majority of companies do not use simulation at all [RHB00].

These companies seem to lack clear guidelines for adopting simulation and increasing their level of simulation integration in their manufacturing system development process. At the same time, research on integration aspects often deals with specific functional or data-level issues, such as developing various tools for integrating and connecting simulation to other systems, rather than general structural, hierarchical, and procedural integration aspects as part of a methodological approach. Conversely, research that takes a holistic and systemic view on simulation integration into manufacturing system development is scarce, or researchers only implicitly report on how simulation in practice should be integrated.

2 Problem

The few empirical studies that exist seem to indicate that discrete-event simulation use is still modest in the manufacturing industry, particularly outside the U.S., or as [Bu00] states, .it seems as if the optimistic forecasts by renowned companies and research institutes at the beginning of the 90s did not come true. Even companies that report on successful and continuous use of simulation have not reached their current level of integration and acceptance overnight. At the same time, many organizations cannot devote the necessary resources, competence, and organizational support over enough time to reap the benefits of simulation integration. Certainly, a fundamental problem is that DES of manufacturing systems is a highly complex activity, touching upon several operational and strategic issues. At the same time, attention is drawn to several other means of improving the system development process other than simulation. More importantly, however, the simulation activities that do receive the attention of managers and other employees often send distorted signals about costs, benefits, and required resources.

When looking at reasons for this limited use of simulation, albeit with a less than satisfactory empirical base, a few common factors can be identified. First, there is still a low level of simulation knowledge and competence in industry, which results in poor commitment to simulation projects, or even worse, no simulation at all. In particular, there seems to be a focus on *costs* rather than benefits.

3 Objectives and Scope

The objective of this paper is to outline a methodological framework for integrating simulation into manufacturing system development. The paper focuses on discrete-event simulation of production flows, and presents a structured approach for integration based on experience from Libyan Oil industry, mainly two simulation projects that spanned two years and were carried out at *BT Products AB* in Zwetaina, Libya, a world leading manufacturer of electrical warehouse trucks.

4 Simulation Integration

According to [Ve96] .integration means putting together heterogeneous components to form a synergistic whole. In this case, the goal is to make DES integral to the PRP by putting together all relevant components of DES with those of the manufacturing system development process. Based on the above, and the systemic aspects defined by [Hi96] simulation integration can be defined as: Simulation integration is the integration of simulation from functional, structural, hierarchical, and procedural aspects into the manufacturing system development process, where development refers to the planning, design, redesign, development, reconfiguration, etc. of manufacturing systems. Although integration seems to have become something of a general buzz-word in industry, much remains to be done when it comes to integration of modeling and simulation of manufacturing systems into the development process.

As mentioned in the introduction, DES is often used on a 'one-shot' basis, troubleshooting specific problems such as bottlenecks, and as a stand-alone tool, not integrated with other applications and systems. Regarding for instance models used in FMS design, report that these models present a unique common characteristic they were developed as "stand-alone" models, in which the emphasis is on the application of the model to solve isolated problems. This isolated use shows in the form of poor documentation and a virtual "shut-down" of all simulation activities in between the solving of these isolated problems. The present situation regarding simulation integration is illustrated in Figure 1.

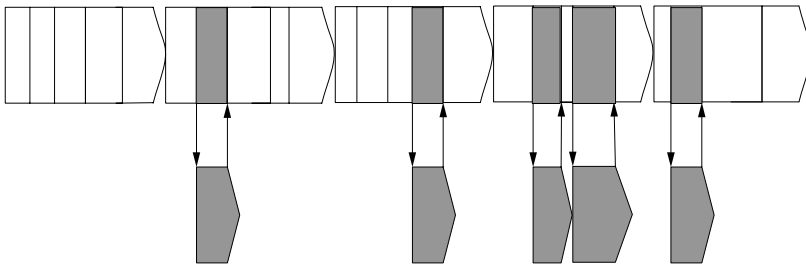


Figure 1 A schematic view of the low level of simulation integration common in today's manufacturing enterprises

Figure 2 attempts to show some of the issues in overcoming these problems, i.e. reaching higher levels of simulation integration: deciding what kind of data and information that needs to be shared and exchanged between the manufacturing system development process and the simulation/flow analysis; establishing who should be involved, i.e. resolving organizational issues; determining when, i.e. at what phases of the process that simulation should be employed; and agreeing on how simulation/flow analysis should be made a continuous process instead of a set of separate projects.

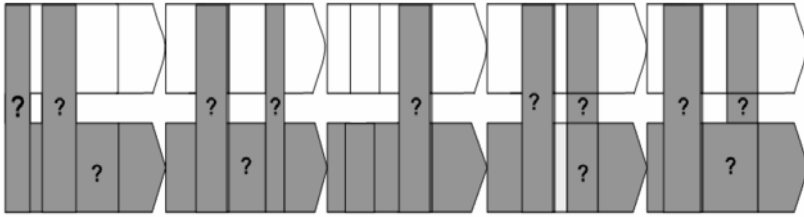


Figure 2 A schematic view of the research issues to reach simulation integration.

As for manufacturing system development in general, the need for simulation integration has been implicitly brought up by several researchers, e.g. [KI99]. Altogether, however, few researchers have focused on methodologies for reaching that integration, which based on concepts and theory, not just the ready availability of data and information. It should be noted, however, that with the large number of DES application areas and emerging integration capabilities mentioned above, the problem of simulation integration has become very complex, thus necessitating a holistic and well-structured approach to the problem. At the same time, in the manufacturing industry several factors work together to make the adoption and use of DES more time-consuming, more inefficient, less accepted, less accurate and less likely to succeed than would be necessary. In other words, problems connected to discrete-event simulation projects are present in several areas and at different strategic and operational levels. The cause of these problems, and hence the potential to successfully integrate simulation into the development process, can be found in those building blocks of the manufacturing environment that form the prerequisites for simulation integration. Thus, from a simulation perspective, these building blocks have been classified into four domains: data, organization, strategy, and enablers (DOSE), as proposed by [Ho01].

The methodology, which aims at integrating simulation with the manufacturing system development process, should present benefits within both these areas. As stated by [KI99], there are basically two fields of knowledge related to simulation: *simulation* knowledge, and *process* knowledge.

From these two perspectives, integration should lead to the following benefits on the process side:

- reduced overlapping of activities,
- Shorter lead times,
- Better correspondence between planned and real outcome of strategic and operational objectives, and
- Better informed decisions; and on the simulation side:
- Strengthened managerial support,
- Increased relevance of cost and benefit analysis,
- Fewer resources consumed in simulation projects, more realistic expectations on simulation, and
- Support for continuous use of simulation.

The simulation and process views could be further divided into process, content, problem, and project aspects, where process in this context relates to the manner in which a study is planned, conducted, and completed [Pi98].

5 Outline of the Methodological Framework

To paraphrase [Ki94], what we need is a holistic methodology with supporting tools, which will allow us to deal with all aspects of discrete-event simulation, the interrelationships and the difficult process of planning and managing change. Basically, a methodology is a set of instructions provided through methods, models, tools and guidelines that are to be used in a structured way. In this case, the methodological basis can be described as a set of questions that need to be addressed and answered: Why? What? Who? When? Where? and How?

The objective of the methodology is to help companies manage adoption and integration of DES (simulation) into their manufacturing system development process (process), and ultimately to answer the above questions. The methodology will thus provide:

- A coherent and holistic view on the scope of simulation integration
- Practical guidelines for adoption and integration

A number of requirements on the methodology have been defined based on theoretical findings and industrial experience. The methodology should:

- Assess, inform and guide decisions regarding adoption and integration of simulation into manufacturing system development,
- Increase the relevance of requirements and trade-off
- Analysis of adoption and integration of simulation,
- Establish by quantitative and qualitative means the worth of simulation to the organization,
- Provide practical guidelines for adoption and integration of simulation, and
- Be well-documented and simple to use.

Methodology Components

This section will briefly outline the following methodological components:

- The DOSE domains,
- The DOSE-FIRO matrix,
- Activity-based simulation management (ABSIM), and
- Time analysis.

The DOSE domains

DOSE provides the underlying structure for the methodology as well as a theoretical description of how the different components of the integration process fit together. It is

argued here that all issues connected to simulation integration can and should be classified into either one of these four domains. Future research should then aim at further decomposing each domain.

The DOSE-FIRO matrix

The purpose of the DOSE-FIRO matrix is to link the DOSE constructs to a description of the manufacturing system development process, which is conceptually illustrated in Figure 3.

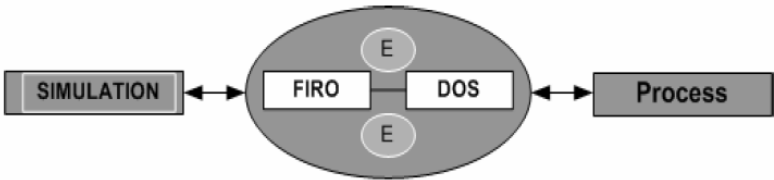


Figure 3 A conceptual illustration of the DOSE-FIRO matrix.

In practice, this process should be guided by answering four of the questions outlined in Section 5: Why, What, Who, and When, which is done in the Mapping phase, see Figure 4. One of the challenges for future development of the methodology is to detail the design and procedural aspects of using this matrix.

Activity-Based Simulation Management

In short, ABSIM can be described as a model to communicate cost and benefits of discrete-event simulation projects. In this sense it fills a theoretical and practical gap. It applies the fundamental principles of ABM to simulation as a process, and is based on the one hand on activities, resources, and their related activity and process drivers, and on the other hand on qualitative and quantitative benefits, see Figure 5.

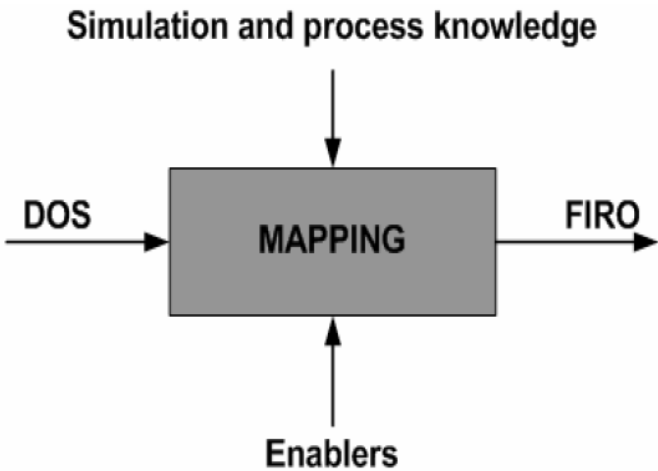


Figure 4 An IDEF0 view of the mapping phase.

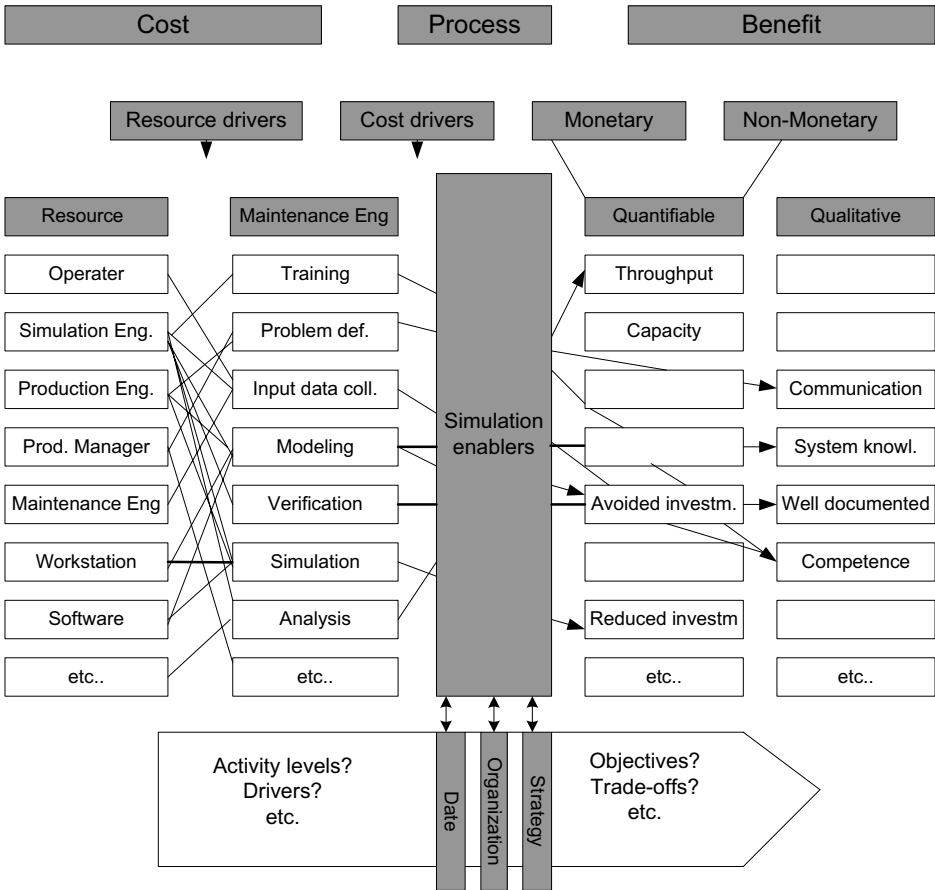


Figure 5 The ABSIM framework (Note: content in white boxes are examples only and should not be seen as fixed components of the framework).

6 Discussion

The authors believe that the methodological approach outlined here, although only briefly summarized, has presented a holistic view on the complexity and diversity of issues related to adopting and integrating simulation into the manufacturing system development process. While a structured approach to deal with these issues has been suggested, there is a need for further research.

First, more explicit links to related standards in this area should be made, such as [En90] and work carried out under ISO/TC 184. While not directly applicable, certain

components and models of these could be useful. Secondly, the general methodology phases need to be further decomposed in order to provide for more specific guidelines. Furthermore, it has been suggested here that the choice of in source vs. outsource simulation strategy has different implications on a number of parameters over the short- and long-term. These need to be carefully examined and weighted against each other. Also, what needs to be considered is how a higher level of simulation integration and more integrated use of flow analysis changes the way manufacturing systems are developed, as well as the interaction between product and process developers, i.e. concurrent engineering aspects.

7 Conclusions

Successful results from the simulation projects carried out at BT Products show that there are several benefits to adopting simulation as an integrated part of the manufacturing system development process. The structured approach and the underlying view on integration presented here constitutes an important basis for a framework that will result in a more detailed and comprehensive methodology for adopting and raising the levels of simulation integration.

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