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A HANDBOOK FOR INTEGRATING DISCRETE EVENT SIMULATION AS AN AID IN CONCEPTUAL DESIGN OF MANUFACTURING SYSTEMS

Mats Jägstam

University of Skövde
Center for Intelligent Automation
Department of Engineering Science
Skövde SE-54128, SWEDEN

Pär Klingstam

Volvo Car Corporation
Manufacturing Simulation
Dept 81960, PVOS 31
Gothenburg SE-40531, SWEDEN

ABSTRACT

Despite significant cost savings and the stride towards developing and implementing the Virtual Factory, few companies have managed to fully integrate simulation as a daily tool in their engineering processes. The objective of the paper is to explore the pre-requisites for this integration, using Discrete Event Simulation as an aid for high quality decision making in early phases (conceptual design and pre-study). The paper looks at three aspects of the pre-requisites: *technological, operational, and organizational* and summarizes the main challenges connected to each one of the aspects. The main result presented in the paper is a proposal for a *simulation handbook*, to be used when integrating simulation into the engineering process. The strength of the handbook is the focus on operational and organizational issues, reflecting different roles with connection to simulation. Future work aims at validating the impact of the handbook.

1 INTRODUCTION

Rapid and cost effective design of flexible productions and manufacturing facilities is one focused area for gaining a competitive advantage in today's fierce business environment. In the light of the requirements being placed on the product and process development, the philosophy of concurrent engineering has been widely adopted. One important step in the direction towards concurrent engineering is the use of methods and tools for virtual development e.g. digital mock-ups and simulations. Industry has presented significant savings from adopting this approach.

However, few companies have managed to fully integrate this technology into their engineering processes. Williams (1996) states, that few companies have managed to make simulation a "corporate norm" to achieve the ongoing, long-term benefits with using the technique. Apart from technological reasons, many companies experience difficulties in integrating this "new" technology with their company specific, well proved and established method of work. This often is a result of different focus of the team members. To succeed requires extensive efforts on the development of the technological, the operational, and the organizational aspects.

At Volvo Cars, *Discrete Event Simulation* (DES) has mainly been used in late project phases to verify an already decided alternative solution or to influence improvements on an existing system. The reasons for this way of working are many, e.g. lack of people with simulation experience and knowledge and limited integration of the technique into the projects, due to absence of well-defined simulation strategies and working procedures. However, lately DES has got a lot of attention from management at development departments as well as in the assembly and power train plants, due to the challenge of developing concepts for and implementing the Virtual Factory in the company. To reach the Virtual Factory requires putting a lot of effort into modeling and simulation in early project phases and to continuously improve and update models that have the purpose of being a "living" model.

1.1 Objectives

The objective of this paper is to explore the pre-requisites for using DES as an aid for high quality decision making in early phases (conceptual design and pre-study). The paper looks at these pre-requisites from three aspects: *technological, operational, and organizational* and outlines a roadmap for implementing the technology in an integrated manner, through the use of a *simulation handbook*.

2 DES IN CONCEPT AND PRE-STUDY PHASE

The aim of the concept and pre-study phase is to evaluate different concepts for process design, production processes and feature benefits. It leads to a design selection together with the identification and elimination of project uncertainties in pre-development activities.

The focus of a simulation, irrespective of what phase in lifecycle we consider, should always be on the decision that the simulation should support, see Figure 1. In the early phases, like the concept and pre-study phase, it is not always necessarily to make simulation models that will survive after management has taken the decision. Focus is often to get at support for the decision as fast as possible without disregarding the quality of the simulation. This sometimes even implies a non-simulation approach using simple analytical methods and tools.

The remainder of this section will look at some of the challenges for succeeding with implementing the technology; in an integrated manner in early phases.

2.1 Technological Challenges

Speaking with colleagues about simulation, you are often asked about which tool you use? The reason for this question is that it is relatively easy to understand the answer for a colleague, a piece of hard fact. This may be the reason why the technology is so often in focus when speaking about simulation, it is easy to get facts.

However, when looking at the technological challenges in early project phases, there are a few things worth mentioning.

Firstly, the difficulty of using simulation for decision making support is often the lack of simulation data. The challenge here is the development of an IT solution that can support structuring of historic data (reference data) as well as the knowledge transfer back to the on-going projects. An example of such information is availability figures for a number of reference stations e.g. a station with four spot welding robots.

Secondly, it is not obvious that simulation is the best tool for solving the task. By the authors' experience, it is often a problem to choose the right tool for the job in early phases. The technological challenge lies in the development of a "toolbox" for the DES engineer. There is a vast amount of methods and tools with relevance to DES, e.g., Six Sigma, process mapping, statistical analysis, and layout. The challenge is how the different methods and tools should work together and at what time in the project?

2.2 Operational Challenges

As clear as it is to speak of the technological challenges, as difficult it is to consider the operational challenges. Here we are considering changing the well-proved and established method of work to something new. Doing concurrent work, frontloading the development process, and working with virtual testing instead of physical, has "reset" the well-known development process. We have to learn how to work in a new environment and we need to describe what this new process looks like. A small example of how Volvo Cars is working with this challenge is provided in the subsequent sections.

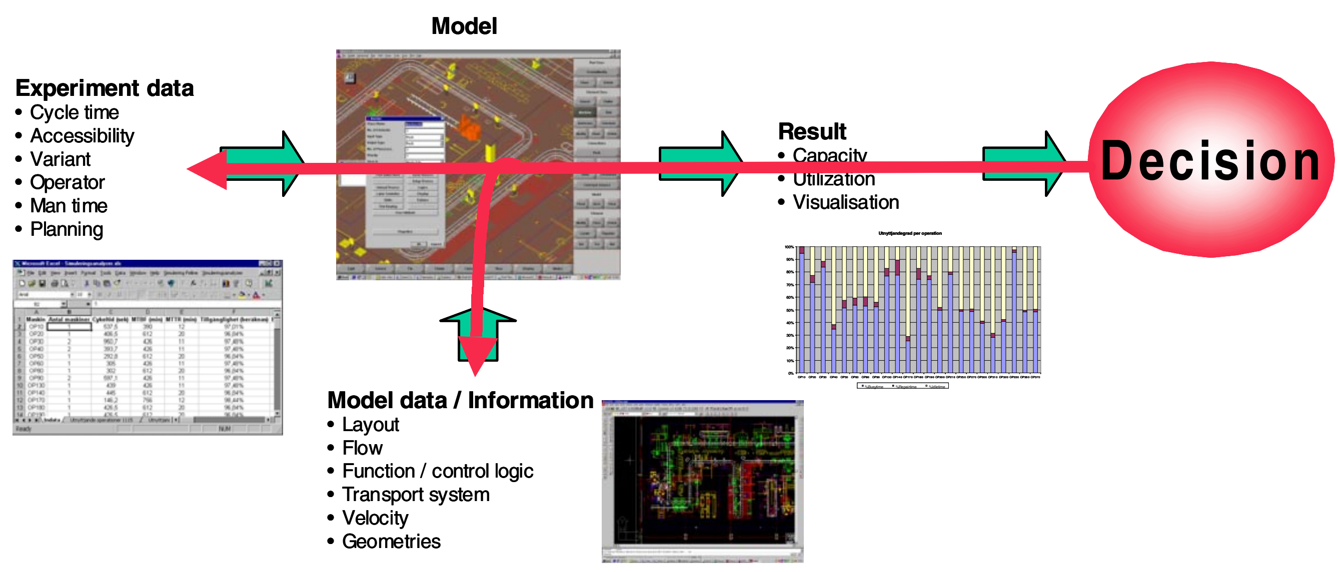

Figure 1: Model over Simulation Work with Focus on the Decision that the Simulation will Support

2.2.1 Lessons Learned at Volvo Cars

At Volvo Cars, operational development is seen as a necessity to be able to stay in the forefront in the development of premium cars. A lot of effort is put on realizing the Virtual Factory. Operational development activities have some common components, which are important:

- *Process mapping*: A description of the activities included in each life cycle phase.
- *Instructions*: A description of how the activity is to be carried out. Step by step guide.
- *Templates*: A description of what the deliverable should look like and the parameters to document.
- *Roles*: A description of the roles connected to each activity.

A recent operational development project focused on mapping of the concept phase. The lessons learned from this project can be briefly summarized as follows.

- It is important to keep the focus on the *deliverables* to the gate system (Project Navigation System).
- It is important to describe the deliverables with templates that guides the engineers.
- It is important to involve all concerned parties. To develop new ways of working is a waste of time if the users do not accept the changes.
- Do not neglect the organizational part of the work, i.e. the education and broad implementation. It takes time.

2.2.2 Operational Challenges in Simulation

Simulation is often seen as a tool only, but the true strength is that it provides a structured approach through simulation methodology. However, it is sometimes forgotten that it must be connected to the development process as well. It is a real challenge to do this mapping and there are few good examples of such a simulation strategy in literature to date. Additionally, we must take care of the recent "news" in the simulation world as well:

Applications – from traditional to enterprise wide: According to Jain (1999), the use of simulation will extend from the traditional applications in manufacturing and logistics to business processes and interactive simulation applications in training and sales.

Scope – from design focus to continuous use in the life cycle: Traditionally, simulation has been used as a tool to model complex systems in detail. The high level of detail requires thorough understanding of the system and mature input data. Recent developments show that simulation is expanding its scope to include the full life cycle of a project as well as being used continuously as system designs evolve (Kosturiac and Gregor 1999).

Users – from experts to executives: According to Pegden, trained experts have mainly used simulation to model complex and expensive systems. However, this situation is likely to change in the future, where analysts throughout the enterprise will routinely use the technology. To support this new class of users, the tools will become easier to buy, learn, and apply (Banks 1998).

2.3 Organizational Challenges

To be able to change the ways of working, the technological and operational challenges must be handled first, i.e. the development of methods and tools. However, to really make an impact in an organization, the implementation and integration of the ways of working must be handled right.

To spread the word in the organization requires large efforts when it comes to education and training. Once the new working procedures have been verified through some pilot studies, it is time to roll it out to a larger audience. This is a grand challenge because of today's lack of people with simulation experience and knowledge. To gain acceptance requires a lot of time and a structured educational program.

3 OUTLINING THE SOLUTION

As mentioned in earlier sections there are a lot of challenges to take care of before we really can reap the fruits of the Virtual Factory. Therefore the solution is not unambiguous. At Volvo Cars, the work with implementing DES, into becoming a daily used tool, has involved every participating role in the company from managers, strategic planners, project leaders, pre-production engineers to flow analysts. This has resulted in the development of a handbook for integrating DES, outlining a simulation strategy and working procedures.

A handbook, be it paper or computer based, is an interface between practitioners in the field and the research literature or experts. This means that research has been done in i.e. enterprise reference architectures like GERAM (IFIP-IFAC 1999) and project management has to be taken into account (Kerzner 1998, Jägstam et al. 2001).

3.1 Development of the Handbook

The involvement of every anticipated practitioner that may be affected of the handbook is very important. Lessons can be learned from different surrounding fields. Vicente et al. (1998) states that industry practitioners need to be involved in the requirements setting and ongoing development of a handbook.

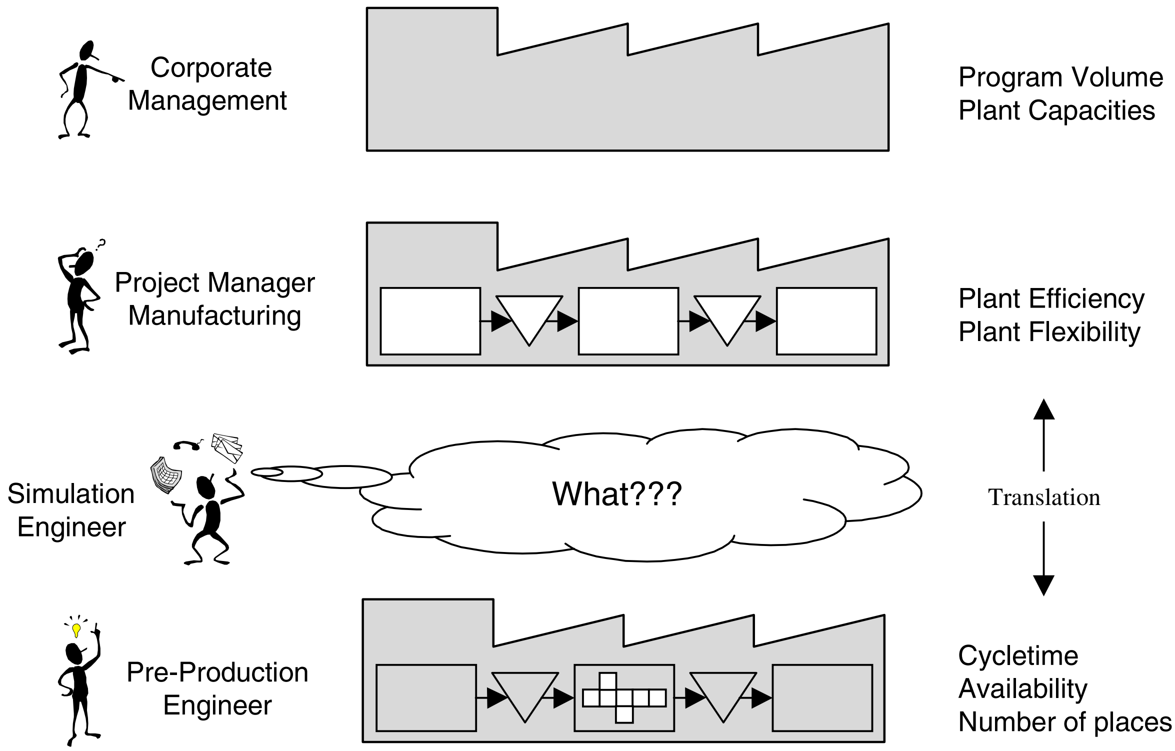

Figure 2: Communication of "Flow" Information Between Different Roles and Corporate Levels

The results of the process mapping (including development of process maps, instructions, templates, and role descriptions), that involves everybody in the process that is being mapped, underlies the development of the handbook. It is recommended that frequent meetings and educational seminaries are hold during the developing process. These activities motivate, educate personnel. It also creates the base for the handbook. It also vouches for a good reception of the book.

3.2 Structure of the Handbook

The structure and design of a handbook is crucial to the effectiveness, use and impact of a handbook. Three different roles have been identified for successful integration of DES:

- *Manger, strategic planer*: responsible for integrating and developing new methodologies.
- *Project manager*: responsible for ordering/buying a simulation. Normally this person is a well-qualified production engineer.
- *Simulation engineer*: responsible for the actual building of the simulation model.

The handbook is divided into these different roles and different phases of the lifecycle. This division is made to keep the focus on the goal for the different roles. It also makes it faster and easier for the user to find the guidelines for their specific role. The activities in every phase are decomposed into, *inter alia, purpose, description, an checklist* and *output*.

3.2.1 Communication

To understand how the roles communicate between different corporate levels is a grand challenge. The following briefly explains how information concerning the "flow" can be communicated and refined between different roles and corporate levels, see overview in Figure 2.

- *Corporate level*: Corporate management decides program volumes and strategies for respective plant volumes are elaborated.
- *Factory level*: The *project manager* (PM) for manufacturing development specify requirements for plant efficiency (capacity, availability, throughput time) and plant flexibility (volume, variant), which both are crucial for "knowing your flow".
- *Area level*: The *pre-production engineers* (PPE) works with a specific area and analyses the impact from changes posed by the project e.g. a product change. The impact on the flow is shown by consequences on e.g. cycle time/line speed, availability, and number of places/line meters.

There is often a gap between the factory and the area level, which, to a large extent, depends on disparate views of the PM and the PPE. The PM works with a holistic view of the whole factory, which is often difficult to translate to the more down to earth elements of the real world at the area level.

The simulation engineer (or flow analyst) has a vital role to communicate or translate the abstract requirements to a more hands-on approach, understandable of the PPE. The simulation engineer should also communicate with the PM and support him/her in making a summary of the efficiency and flexibility consequences.

3.3 Usage of the Handbook

The activities in the handbook are quite generic to suit different plants within the company. The structure of the handbook makes it easy to use and eliminates uncertainties between the different roles in the development of new manufacturing systems. The handbook could also be used as a support between the buyer of a simulation and the simulation consultants when there is a need to buy external competence. One important activity in every lifecycle phase is the feedback of results, knowledge and experience to the rest of organization. The usage of the handbook is also an iterative development of the handbook and the ways of working.

4 CONCLUSION

This paper clearly indicates some identified problem with the work of integrating DES into a company. There is a need for a structured way of implementing simulation tools into the company specific models for developing manufacturing systems. However, this should not be treated as a "once-in-a-lifetime" activity but should be seen as a continuous development process in order to adapt to ever changing circumstances.

The main contribution of the paper is a proposal for an easily understood solution to the identified problems, through the use of a *simulation handbook*. The strength of the handbook is the focus on operational and organizational issues (simulation strategy and working procedures), reflecting different roles with connection to simulation. Future work aims at validating the impact of the handbook.

REFERENCES

Banks, J. 1998. The Future of Simulation Software: A Panel Discussion. In *Proceedings of the Winter Simulation Conference 1998*. eds. D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan. 1681-1687.

IFIP-IFAC, Task Force, 1999. *GERAM Generalized Enterprise Reference Architecture and Methodology, Version 1.6.3.*

Jain, S. 1999. Simulation in the Next Millennium. In *Proceedings of the Winter Simulation Conference 1999*. eds. P. A. Farrington, H. B. Nembhard, D. T. Sturrock, and G. W. Evans. 1478-1483.

Jägstam, De Vin, Moore, 2001. Working Methods and Project Management in Manufacturing System Design. In *Proceedings of the International Manufacturing Conference 18*. 383-390.

Kerzner, H., 1998. *In Search of Excellence in Project Management, Successful Practices in High Performance Organizations*. Van Nostrand Reinhold.

Kosturiac, J. and M., Gregor. 1999. Simulation in Production System Life Cycle. *Computers in Industry* 38. 159-172.

Vicente, K. J. et al. 1998. Better handbooks, better design. *Ergonomics in Design* 6 (2). April 21-27.

Williams, E. 1996. Making Simulation a Corporate Norm. In *Proceedings of the 1996 Summer Computer Simulation Conference*. eds. W., Ingalls, J., Cynamon, and A., Saylor. 627-632.

AUTHOR BIOGRAPHIES

MATS JÄGSTAM is a Ph.D. candidate at the Center for Intelligent Automation, University of Skövde. He received his MSc from University of Skövde. His main focus area is DES in logistics and production and system development methodologies. He is currently working within the research project dAISy to improve the integration of DES at inter alia Volvo Cars Powertrain in Skövde. His e-mail address is <mats.jagstam@ite.his.se>

PÄR KLINGSTAM Ph.D. employed by Volvo Car Corporation for the development and implementation of new working methods for Operational Analysis and Discrete Event Simulation. He received his Ph.D. from the Department of Production Engineering at Chalmers University of Technology. His main interests include DES in logistics and production and system development methodologies. His e-mail address is <pklingst@volvocars.com>