INTRODUCTION OF SIMULATION METHOD AND POSSIBILITIES OF STANDARDISATION

József Perger[(a)], János Jósvai[(b)], András Pfeiffer[(c)], Botond Kádár[(c)]

[(a)] Audi Hungaria Motor Kft.
[(b)] Széchenyi István University, Professorship for Material Sciences and Automobile Production
[(c)] Computer and Automation Research Institute, Hungarian Academy of Sciences

[(a)] jozsef.perger@audi.hu, [(b)] josvai@sze.hu, [(c)] pfeiffer@sztaki.hu, [(c)] kadar@sztaki.hu

ABSTRACT
The paper focuses on the applicability of simulation technology in several hierarchical levels of a production oriented industrial firm. The topic of the paper addresses the discrete event simulation technology which is used to model the material flow and the manufacturing processes in the company. This paper would like to show some practice experience about the industrial introduction steps of manufacturing simulation, as well as our recent research result in the field of standardized simulation model building and data handling procedure.

Keywords: discrete event simulation, industrial management, standardization, PLM.

1. INTRODUCTION

In today's economy, product life cycle has been shortened. There is a new challenge for manufacturers: high quality products are to be produced, the introduction time is very short and the costs must be as low as possible. PLM is an engineering solution to address this challenge. It allows for users to analyze and manage products through the whole product lifecycle. One efficient tool and method is the modelling and simulation the manufacturing processes of the products.

Because of its great versatility, flexibility, and power, simulation is one of the most widely used evaluations and decision-support techniques (Law and Kelton 2001). While simulation, in theory, has great potential to assist in the understanding and efficient operation of manufacturing systems, several studies shows that there is a low usage of discrete event simulation by industry (Banks 1998).

The introduction of simulation into the manufacturing field of industry has its first steps. The different manufacturing areas have as well different data needs, and data gathering possibilities. The very first step of an industrial introduction is the harmonization of data handling, identification and gathering processes. Then the model elements could be defined for reuse, the elements have the ability to be configured for special behaviours, this is valid for equipment as well. The standardization of simulation modelling in the industrial field continuous with working and control methods, these logical systems are difficult to describe in standards, especially if there are many changes in the real logics and resource using methods.

The paper focuses on the possibilities of simulation standardization in the automotive industry, which is a recent issue in today's customer oriented production, as well as a methodology is presented regarding the introduction of simulation methods in the “every day use” in the same environment. The topic of the paper addresses the discrete event simulation technology which is used to model the material flow and the manufacturing processes in the company. The CAD/CAM related simulation e.g. finite element analysis and robotic simulation is out of the scope of this paper.

2. STATE OF THE ART

An extensive study of the penetration and use of discrete event simulation in the UK manufacturing industry identified only 11% of sites out of sample of 431 which were currently utilizing simulation as a decision support tool. This view of the penetration of simulation into industry is also supported by more recent surveys (Eriksson 1999, Hirschberg and Heitmann 1997, McLean et al 2003, McLean and Shao 2003). The literature on manufacturing systems simulation reinforces our conviction that simulation is a technique that still has a lot of underexploited potentialities.

When conducting a simulation study it is recommended that a structured systematic approach be carefully planned and rigidly adhere to. The 40-20-40 rule is a widely quoted rule in simulation related papers. The rule states that, in developing a model, an analyst's time should be divided as follows:

1. 40% to requirements gathering such as problem definition, project planning, system definition, conceptual model formulation, preliminary experiment design and input data preparation;
2. 20% to model translation
3. 40% to experimentation such as model validation and verification, final experimental

design, experimentation, analysis, interpretation, implementation and documentation.

The previous principle is confirmed in (Tecnomatix 2006), where the authors point out that collecting and preparing the data in order to use in the simulation study is one of the most important tasks, as it takes up about 35% of the project time. Creating the model takes up another huge amount of time (25%), while validating and correcting needs 15%, running the experiments 10%, finally analyzing and evaluating 15% of the project time (Pfeiffer 2007).

The key requirements of simulation influence the needs and expenditures of the realization process of a simulation. We specify the requirements, based on the challenges formulated above, and highlight the main directions to be followed in order to be able to fulfil the requirements. Thus, key requirements can be listed as follows.

- Data acquisition, preparation and modelling capability are key elements, while during the other phases, regarding a production simulation study the reduction of the expenditures is fairly not as promising as by the others.
- Consequently, improving model building techniques, applying reusable model elements, through modular software architecture and object oriented modelling.
- Integration to ERP, MES systems might results in a reasonable data acquisition platform.
- Reuse model components for different purposes in different life-cycle phases of the system modelled.

Regarding the national perspective, we think that there must be a solid base for industrial application in Hungary, regarding the numerous multinational, high-tech manufacturing enterprises. These companies often “import” their knowledge due to applying solutions and processes which are – so called – company-wide standards. Despite to this advantageous situation, conducting simulation studies, moreover, continuous use of simulation is nowadays not a key issue in Hungarian companies, and thus, the important simulation-related knowledge has not been transferred and transmitted until now in the industrial practice (Pfeiffer 2007).

A manufacturing system has usually a large investment, it consist mostly of capital equipment and software to operate them. The integration of these separate systems is time-consuming, and means high costs. To establish an efficient manufacturing system design the dynamic model of the organizations is useful. It makes possible to perform “what-if” analysis, but it needs experts in construction and also in analysis of results. The most of the industrial simulation models are addressed to a defined set of industrial issues. This means, the models are used for special tasks, reuse of models is difficult or only with large modifications possible. In our opinion these drawbacks could be reduced or even eliminated with the proper usage of simulation standards.

In the following space we will give a short overview about the standards and standardization activities which influence the simulation models and their implementation processes in an industrial firm.

2.1. Simulation related standards

2.1.1. NIST

National Institute of Standards and Technology (NIST) was founded in 1901 and is a non-regulatory federal agency within the U.S. Commerce Department's Technology Administration. NIST's mission is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life. From automated teller machines and atomic clocks to mammograms and semiconductors, innumerable products and services rely in some way on technology, measurement, and standards provided by the National Institute of Standards and Technology.

Within NIST, the Manufacturing Simulation and Visualization (MS&V) efforts are focused on accelerating the development of simulation standards. The Manufacturing Systems Integration Program has a subproject called Simulation- based Manufacturing Interoperability Standards and Testing. This subproject contains several main fields, these are Frameworks and Architectures, Data Models and Standards (see below) CMSDIM, Simulation Prototypes and Testing Systems.

2.1.2. Core Manufacturing Simulation Data Information Model (CMSDIM)

The CMSD Information Model defines a data specification for efficient exchange of manufacturing data in a manufacturing simulation environment. The specification provides a neutral data format for integrating manufacturing application and simulation. The purpose of the CMSD Information Model is to:

- Enable data exchange between manufacturing simulation systems, other software applications, and databases.
- Support the construction of manufacturing simulators.
- Support testing and evaluation of manufacturing software.
- Support manufacturing software application interoperability.

This product defines a data interface specification for efficient exchange of manufacturing life cycle data in a simulation environment. The specification provides neutral data interfaces for integrating manufacturing software applications with simulation systems. The initial effort is focusing on machine shop data definitions. The plan of the authors is to extend the data specification to include supply chain, aerospace assembly operations, automotive vehicle assembly operations, plant layout, and other relevant manufacturing and simulation information.

A NIST analysis shows, that several standards exist, but comparing these standards it can be stated that there are huge differences even in naming of conception. The analysis shows how much information discrete-event simulation requires, as well. Functionality of units must be described, such as: logical elements, product elements, process plan. Application objects are for example: arrival, breakdown, path, processor, schedule, etc. These attributes show how complex this area is, and the standardization of simulation tasks has lot of different influence types (NIST 2004.)

2.1.3. VDA Standard

This statement serves as an execution application and technology cross policy for internal and external simulation projects. It serves as the basis for the acceptance and performance including:

- the definition of general, organizational and computer technical guidelines,
- the standard procedure for simulation projects, and guidelines for implementation,
- the requirements for quality and its management,
- the global, non-project specific input data and requirements,
- the requirement for the data and its management and validation,
- the requirements for simulation models and their validation,
- the principles of modelling and programming,
- the requirements for experimental design and analysis. (VDA 2008)

Well-defined project structure and recommendations are given in this standard with specific points regarding areas and rules how to manage the development of a simulation model (Figure 1). On the base of the VDA the full simulation project can be controlled in structural way and this standard offers guidelines for this procedure. VDA also offers recommendations for model structure, verification and validation, documentation and evaluation. Furthermore it contains a description part for Plant Simulation, where software specific recommendations are assembled, such as use of class library, data handling, naming conventions, meanings of different colours, program head. There are some specific areas in the automation industry (e.g. chassis, surface handling, assembly, logistics and factory simulation), which are handled by VDA separately, giving exceptions for the modelling of these fields.

2.1.4. ANSI/ISA 95

ISA-95 is the international standard for the integration of enterprise and control systems and it consists of models and terminology. The information in the standard is structured in UML models, which are the basis for the development of standard interfaces between ERP and MES systems (Bradl 2008). The ISA-95 standard can be used to determine which information, has to be exchanged between business logistics systems and manufacturing operations systems. Another objective of the ISA 95 is to provide standardized models of activities in manufacturing operating systems.

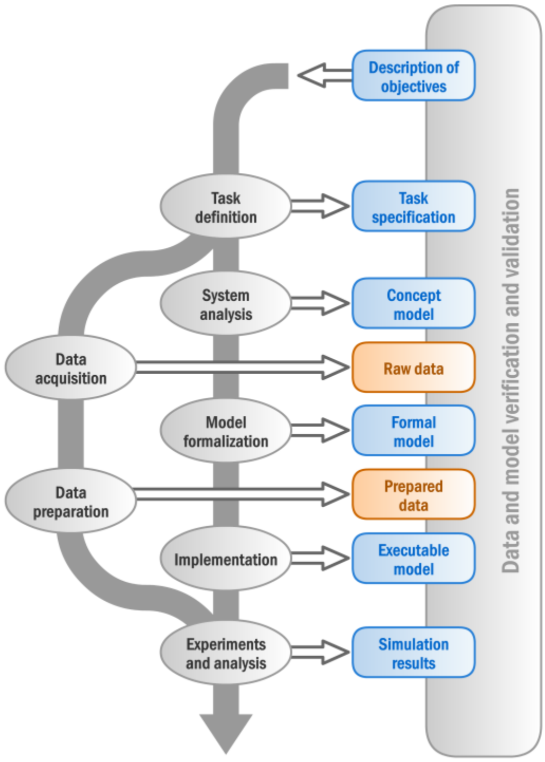

Figure 1: Process Model ASIM (2007)

There are no direct references for simulation in the ANSI/ISA 95 standard, however, the operational manufacturing activities and the functional components of the Manufacturing Execution Systems (MES) are given in detail and as a model of these material and informational systems, and the simulation models can follow the ANSI/ISA 95 models.

3. ENTERPRISE SIMULATION CUBES

In this section we introduce a new classification model called *Enterprise Simulation Cubes* in which, from the targeted simulation model point of view, we consider the enterprise decision hierarchy, stage of the modelled system in its own life-cycle and the functional divisions of the system in the enterprise. The dimensions above form a framework and according to these classification groups several different simulation cubes can be identified, each of which represents a specific sub-cube in the overall framework (Figure 2).

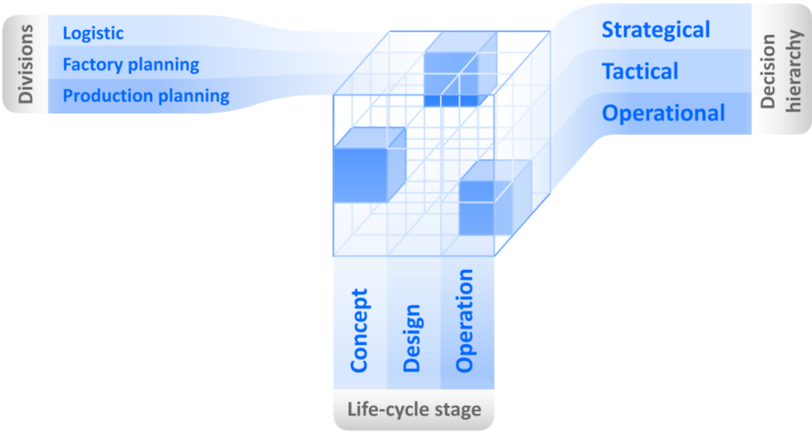

Figure 2: The concept of Enterprise Simulation Cubes

From the *decision hierarchy* point of view we consider the well-known

- Strategic,
- Tactical and
- Operational levels.

The Life-cycle projection includes the

- Conceptual,
- Design and
- Operational stages.

Last but not least we consider the functional divisions in the enterprise like:

- Logistics,
- Factory Planning,
- Production Planning, etc.

If a sub-cube is taken from above framework, which takes one specific value from each of the above categorizations, specific requirements, questions, the level of model's detail, the simulation time horizon, etc. can be considered.

The requirements in a sub-cube define the depth or resolution of the model. At one extreme, an entire production system can be modelled as a single "black box" operation with a random activity time (ProModel 2003). This solution is more relevant in conceptual life-cycle stages and/or during strategic decisions. At the other extreme, every detailed motion of a machine could be modelled with a one-to-one correspondence depicting the entire machine operation. This is more relevant in lower hierarchical levels e.g. design or operation life-cycle of the system in operational decisions.

Determining the appropriate level of detail is an important decision. Considerable high detail makes it difficult and time consuming to develop a valid model. Excessively low-level of detail makes the model unrealistic by excluding critical variables. Figure 3: illustrates how the time to develop a model is affected by the level of detail. The importance of including proper detail to meet the objectives of the study is also highlighted.

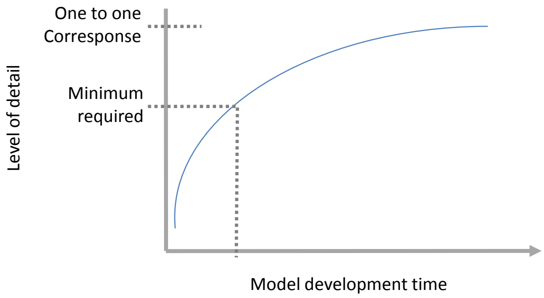

Figure 3: Effect of level of modelling detail on model development time (from ProModel 2003)

As for different life-cycle stages (orange arrow in Figure 4) the granularity of the simulation models differ. In the *conception phase* the simulation might be used for marketing a project to the management. The modeller should realize the simulation meta-model following the principle that the first-phase models usually do not require model components which are too detailed, i.e., the system itself to be modelled is very complex ((Pfeiffer 2007.), see Figure 4). At this work-phase simulation is not connected usually to the company information systems. Another constraint in this phase is to provide data mainly regarding investment cost and capacity, moreover, these results must be interpreted to managerial personnel, which usually mean high level graphical representation of the system modelled.

In the *design phase* simulation is used to find the best solution from a set of potential designs. The focus in this phase is the overall operating strategy. From the modelling point of view, the model-structure created in the preceding phase, is expanded with the *static* data gathered from the DE, i.e., an interface to the company database has to be realised.

During the *operational phase* – where usually subsystem of the production system are built, delivered, and installed – the simulation is connected to the real control software to test the software implementation. The controllers use the emulation (refined simulation) model as a replacement for the physical equipment. In this way the control logic can be tested for the entire facility. If changes of the system are required the simulation model can be applied for improving the installed system or testing suggested modifications before implementing the changes.

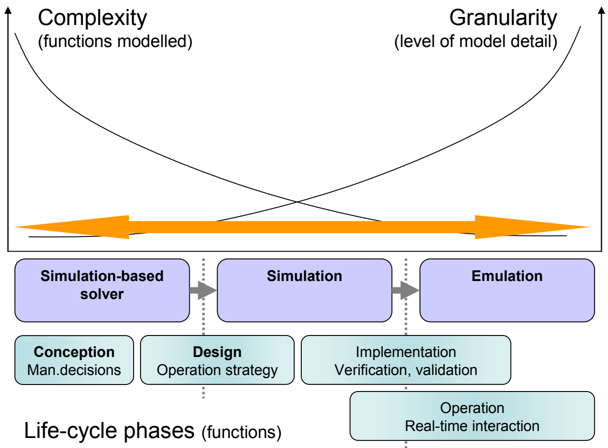

Figure 4: Proposed extension of simulation to different life-cycle phases of a production system

The complexity of model building should never be underestimated and it is always better to begin simple and add complexity rather than create an entire complex model at once (see different modelling details at the different phases in Figure 5). Building a model in phases (or stages) enables failures to be more readily identified and corrected as well. It is also easier to add detail to a model than it is to remove from it, furthermore, a model with excessive detail may be too expensive to program and to execute.

Our hypothesis is that if the level of modelling detail increases, the features and functions modelled must be reduced, also required by the limited computational efforts available.

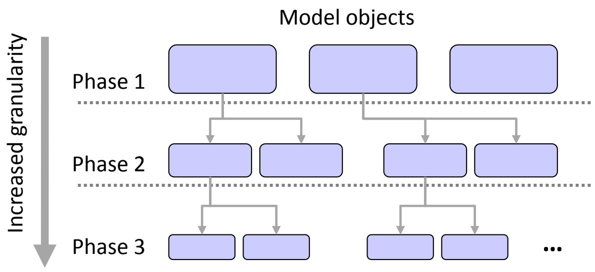

Figure 5: Granularity of the model objects at the different phases of the simulation models

The introduced new approach reflects a new conceptual view in simulation modelling of productions systems and may support better integrity to manufacturing ICT systems. The necessity and actuality of applying this new technique is proven through a literature review, furthermore, the proof of the concept is reinforced by two case-studies in the coming space.

4. CASE STUDIES

In this section we briefly introduce two case studies referring to separate sub-cubes of the framework presented in the previous section.

4.1. Tactical decision making at the design phase – case-study

The first case-study was carried out with the factory planning division of an industrial enterprise and mid-term tactical decision making was supported by a simulation model in the design of a new factory section. Before the real implementation of a budgeted project, with the static design and paper-based calculation in hand, a simulation model was created to test and validate the dynamic behaviour of the envisaged system.

Adhering to the Enterprise Simulation Cube, the target of the simulation model was to answer the question whether the static design is capable to offer the calculated throughput, but the model should integrate the supporting function of other divisions which was not possible to be included in the static design. During the simulation analysis, the main focus was given to a new unload station ("Unload 3" in Figure 6) at the end point of the main roller track system.

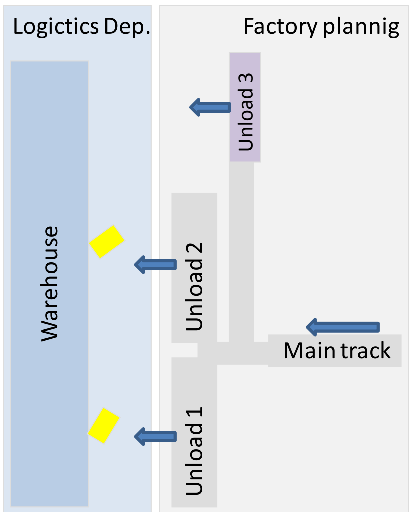

Figure 6: The layout and the main material flow of the selected section to be modelled

With the help of the standard, company wide modelling object libraries, the simulation model has been developed in Plant Simulation v8.1 and comprises the object classes as follows:

- MU: Product, pallet, elevator, logistics pallet, and forklift;
- RB: roller track component (consist of the track and the low level control system);
- Operator: operator of the system at the unload stations, driver of the forklift, etc.;
- Warehouse: store in and out the products;
- Control: control of the input and output data, the operators activity as well as the elevator;
- DataIF: data interface for easy data exchange;
- Statistics library and GUI.

Two main areas had to be analyzed in details with the resulted simulation models:

1. Define the sorting and mixing logic of the main elevator, i.e., in which order should the pallets be loaded onto the elevator.
2. Define the minimum cycle time for the forklifts necessary for the undisturbed operation of the unload station (the forklifts served as interfaces between the unload stations and the main warehouse).

In Figure 7 the results of different simulation scenarios are presented where the effect of the incoming product mix at the elevator is analyzed. In this dynamic analysis the simulation runs statistically and demonstrated the right-left-right logic RLR of the product mix dominate the other scenarios. The final control system, which is working today, applies this mixing rule.

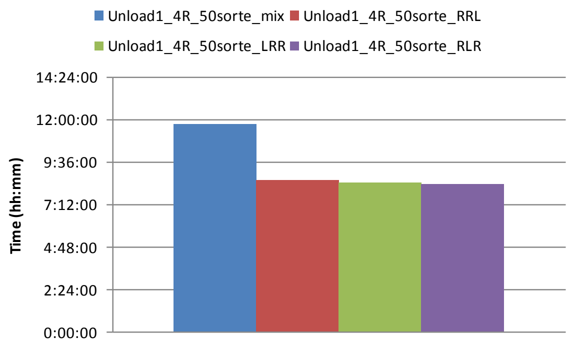

Figure 7: Time total required for unloading 1800 pallets by applying different mixing logics in front of the main elevator at the unload station 3

Figure 8 shows the results of the analysis that was carried out in order to identify the effect of the forklift's service time on the throughput of the system. According to the simulation runs we can state the forklift's service time effect comes out if and only if this service time is higher the 1 minute. From this point if the service time is higher the throughput of the system decreases linearly.

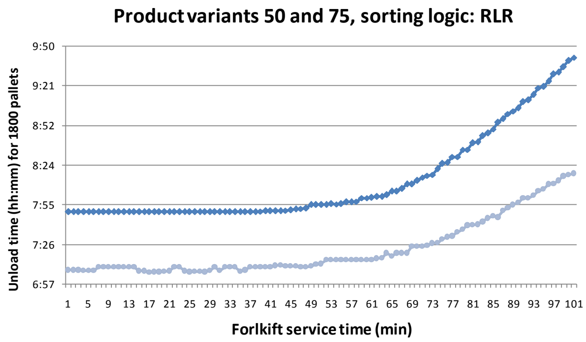

Figure 8: The total time required for unloading 1800 pallets at unload station 3, as the function of the forklift service cycle time

4.2. Operational decision making at the operation phase – case-study

The second case-study was carried out with the manufacturing planning division of an industrial enterprise. The simulation model developed in this case-study aimed at supporting the short-term production scheduling decisions of a manufacturing line.

The main target of this simulation model (Figure 9) was to answer the questions, how the production schedule and the line balancing affect the behaviour of the production line. As such, the main goals of the study were as follows:

- Determination of optimal production plan
- Balancing the utilization of workstations
- Stock reduction within the assembly cell

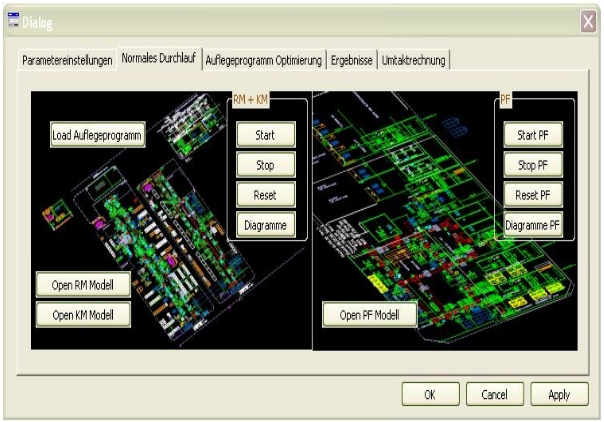

Figure 9: User interface of the production scheduling case-study model

The standard graphical analysis tools in the simulation model support the decision making, moreover, these diagrams are changing dynamically during the on-line simulation time strengthening both the verification and the real-time decision process (Figure 10).

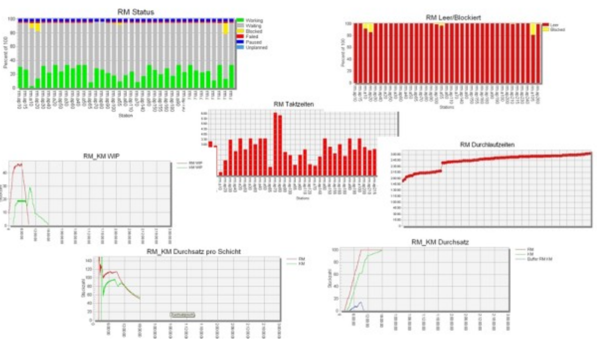

Figure 10: Graphical evaluation diagrams for operational decision making

The simulation model of the second case-study was further complemented with a Genetic Algorithm (GA) based optimizer. The same simulation model which was implemented for the analysis of the production line is also applied as the fitness function of the GA optimizer. The results of the genetic-based solution can be exported and used in outer application for further operations (see GUI of the GA-based optimizer in Figure 11).

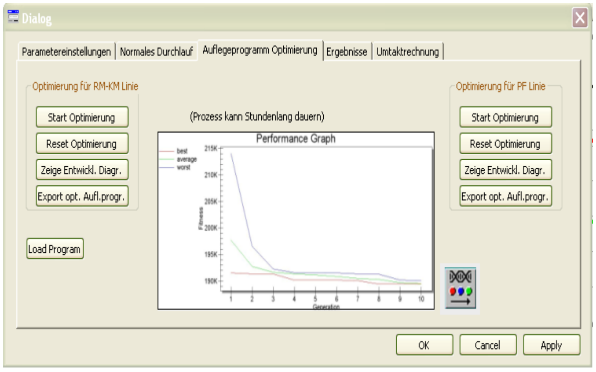

Figure 11: User interface of the GA-based optimizer

This operational production scheduling tool supports the decision making by applying real production data. In order to identify the aims of the model and the data gathering needs, as well as the definition of the level of detail, it was obvious to apply the Enterprise Simulation Cube. By this way the different areas of the life-cycle stages, the different decision hierarchy and divisions of the plant involved could be easily identified.

5. CONCLUSIONS

The paper focuses on the applicability of simulation technology in several hierarchical levels of a production oriented firm, furthermore on the possibilities of simulation standardization in the automotive industry, which is a recent issue in today's customer oriented production, as well as a methodology is presented regarding the introduction of simulation methods in the "every day use" in the same environment.

The paper discusses several process models designed for simulation steps, these models have the handling area from data gathering to experiment analysis. A new concept – Enterprise Simulation Cube - has been established to identify and classify simulation model views, aspects for detail level and model complexity.

Two case-studies were presented highlighting how to use the Enterprise Simulation Cube, and the practical advantage of it. One case-study concentrated on a tactical-level decision support for a factory design project while the second one demonstrated how the simulation tool can be used on the operational level in the daily shop-floor production planning process.

REFERENCES

Eriksson, U., 1999, Production Engineering, Chalmers University of Technology, Göteborg, Sweden. Working paper.

Banks, J., 1998, Handbook of simulation, Principles, Methodology, Advances, Application and Practice. JohnWiley & Sons Inc., ISBN 0-471-13403-1

Hirschberg, A.G., Heitmann, K., 1997, Simulation in German industry – a survey, in W. Hahn & A. Lehmann, eds, Simulation in Industry, -9th European Simulation Symposium, 1997, Passau, Germany, Society for Computer Simulation International, pp.: 429–433.

Law, A., Kelton, D.: Simulation modeling and analysis, McGraw-Hill, 2000.

Manufacturing Systems Engineering Group, Manufacturing Engineering Laboratory, Manufacturing Systems Integration Division, 2004. Production Systems Engineering: Requirements Analysis for Discrete-Event Simulation. Gaithersburg: National Institute of Standards and Technology.

Pfeiffer, A., 2007. Novel Methods for Decision Support in Production Planning and Control, Thesis (PhD). Budapest University of Technology and Economics.

Tecnomatix Technologies Ltd., 2006. Tecnomatix Plant Simulation Help.

McLean, C., Leong, S., Harrell, C., Zimmerman, P. M., Lu, R. F., 2003, Simulation standards: current status, needs, future directions, panel: simulation standards: current status, needs, and future directions, Proceedings of the 35th conference on Winter simulation: driving innovation, December 07-10, 2003, New Orleans, Louisiana, pp: 2019-2026.

ISA. http://www.isa.org/

ISA-95. http://www.isa-95.com/

SYSOSTDS http://www.sisostds.org/index.php?tg=articles&idx=More&topics=20&article=42

CMSD Product Development Group, Simulation Interoperability Standards Organization, Core Manufacturing Simulation Data Information Model (CMSDIM), PART 1: UML Model http://www.sisostds.org/index.php?tg=fileman&id

x=get&id=49&gr=Y&path=Specifications&file=CMSD2006-9-13.pdf
Bradl, D. What is ISA-95? Industrial Best Practices of Manufacturing Information 2008-05-19, http://www.sesam-world.dk/_pdf/_m80/What%20is%20ISA%2095.pdf
VDA, Ausführungsanweisung Ablaufsimulation in der Automobil- und Automobilzulieferindustrie, V. 2.0, 2008.11.06.
McLean, C., Riddick, F.: PC Modeling and Simulation Guidelines, Volume 1 – overwiev, NIST, 2004.
NIST. http://www.nist.gov/
MEL-NIST. http://www.mel.nist.gov/proj/msv.htm
McLean, C., Shao, G., 2003, Generic case studies for manufacturing simulation applications, in Proceedings of the 2003 Winter Simulation Conference, 2003.
ProModel User's Guide, 2003.

AUTHORS BIOGRAPHY

József Perger has been working for the Audi Hungaria Motor Kft since 1995. He has degrees from mechanical engineering, logistics and economy. Today he is working in the field of production planning. He is a PhD candidate now and he is doing research in the system of the local and regional conditions in order to improve the company. Also he would like to analyze the expenditures of the manufacturing process, using a digital manufacturing planning program.

János Jósvai is working at the Széchenyi István University, Győr, Hungary. He is a PhD candidate, his field is manufacturing planning and simulation methods. He has several year experiences in material flow simulation of manufacturing systems and in production process planning. In the field of research and development he spent significant time aboard with international cooperation in matter of digital factory.

András Pfeiffer, earned his PhD in 2008 at the Budapest University of Technology and Economics. Currently he is a senior research fellow at the Engineering and Management Intelligence Laboratory of the Computer and Automation Research Institute, Hungarian Academy of Sciences (SZTAKI). His current interest includes decision support in production planning and control, as well as the simulation and emulation modeling of complex production systems, self-building simulation systems.

Botond Kádár is a senior researcher at the Engineering and Management Intelligence Laboratory of the Computer and Automation Institute of the Hungarian Academy of Sciences (SZTAKI). He obtained his MSc and Ph.D. degrees at the Budapest University of Technology and Economics, Hungary, in 1993 and 2002, respectively. His current interest includes production control, simulation and multiagent approaches for production engineering and manufacturing systems and he is involved in several research and development projects from these fields. Dr. Botond Kádár is author or co-author of 70 publications with over 120 citations.

ISBN 978-84-692-5417-2