ANALYSIS AND OPTIMIZATION OF COMPLEX SMALL-LOT PRODUCTION IN NEW MANUFACTURING FACILITIES BASED ON DISCRETE SIMULATION

Doc. Václav Votava, CSc.[(a)], Ing. Zdeněk Ulrych, Ph.D.[(b)], Ing. Milan Edl, Ph.D.[(c)], Ing. Michal Korecký, Ph.D.[(d)], Ing. Václav Trkovský, CSc.[(e)]

[(a) - (c)] Department of Industrial Engineering and Management, University of West Bohemia in Pilsen, Univerzitni 8, Pilsen, Czech Republic
[(d) - (e)] SKODA HOLDING a.s., Tylova 57, Pilsen, Czech Republic

[(a)]votava@kpv.zcu.cz, [(b)]ulrychz@kpv.zcu.cz, [(c)] edl@kpv.zcu.cz
[(d)] michal.korecky@skoda.cz, [(e)] vaclav.trkovsky@skoda.cz

ABSTRACT
This paper focuses on simulation study of small-lot production of complicated products with a long technological time. The paper describes a possible procedure for generating simulation models based on incomplete data from EIS. This simulation model must flexibly react to changes in complicated technological steps. This paper describes one possible solution to this problem.

Keywords: small-lot production, discrete simulation, simulation system ARENA

1. INTRODUCTION
All companies now use Information Systems (IS) for planning and controlling their businesses. Basic information saved in an IS is used to support the controlling of manufacturing processes in companies for each type of product. When a company wants to transfer production to a new manufacturing space with new manufacturing facilities, it is appropriate to verify project documentation, new technology and all static capacity calculations by dynamic calculation – simulation. On the basis of the experiments which were carried out, it is possible to undertake organizational precautions which are essential before starting new production.

This paper focuses on the creation of a simulation model. This simulation model must flexibly react to changes in complicated technological steps. The method used must preferably be simple and fast. This paper describes one possible solution to this problem. The solution deals with a simulation study of small-lot production of complicated products with a long technological time for the company ŠKODA TRANSPORTATION. The verified products include:

- Production of locomotives,
- Production of trams,
- Renovation of metro wagons,
- etc.

A simulation model is created which enables very simple adaptations to various types of products with various manufacturing plans.

2. METHODOLOGY
This section describes the methodology used in the simulation study. The whole approach is illustrated in Figure 1.

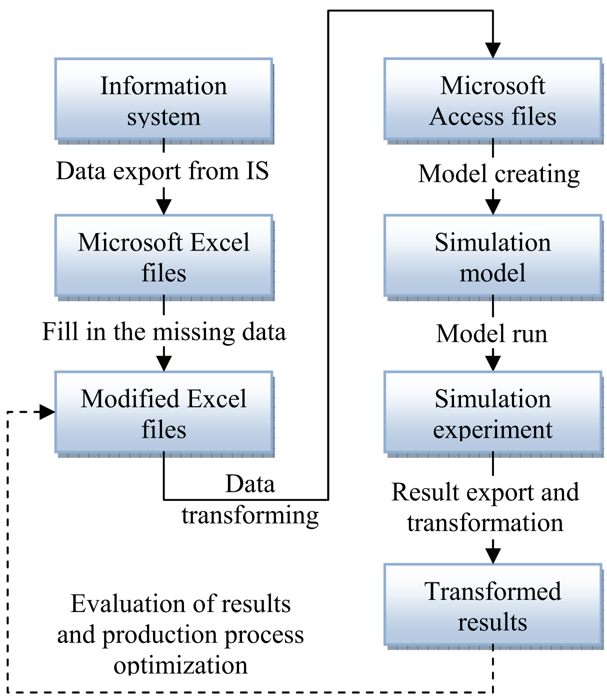


Figure 1 Methodology of the presented simulation study

From Figure 1 we can see that the whole process of the simulation study is divided into several basic steps. These steps are:

- Data export from IS into MS Excel Files,

- Filling in the missing data (e.g. transport between workplaces),
- Data transformation to MS Access files suitable for simulation model,
- Simulation model creating,
- Model run,
- Simulation results export and transformation into MS Excel or MS Project Files
- Evaluation of results and production process optimization.

The above mentioned steps are using the components in boxes in Figure 1:

- Information system,
- Microsoft Excel files,
- Modified Excel files,
- Microsoft Access files,
- Simulation model,
- Simulation experiment,
- Transformed simulation results.

2.1. Information system

An information system is the fundamental data resource for a simulation model. From the information system we obtain the following basic information about each product:

- sequence of production operations,
- technological time of each operation.

2.2. Microsoft Excel files

The ability of many information systems to export data from IS to Microsoft Excel files in a structured form is used here. Data structures have to be the same all the time. This is important for following automatic input data processing.

From Figure 1 we can see that MS Excel files are used as a transfer step between the information system and the database which uses the simulation model. This step is important for data retrieval for the simulation model. The simulation model verifies products which have not yet been produced, therefore some products do not yet have a final technological operation described. For this reason we chose MS Excel, because Excel very simply allows modification and filling in of missing input data (estimated or existing). Excel allows very simple and independent preparation of input data for individual experiments.

2.3. Modified Excel files

An information system does not usually contain all the necessary input data for a simulation model. Missing input data must be manually entered in this step. In this step we also reduce the technological process so that outputs from the simulation model are not misrepresented and the simulation runs well and faster. All inputs for the model are saved to several Microsoft Excel files. Individual files contain the following information:

- technological sequence of each product (including hierarchical structure (components) of product) – technological sequence of one product can be divided into more files
- system information
  - list of resources – including basic information about resources
  - list of components - including basic information about components
  - list of transport equipment – including basic information about transport equipment
  - list of workplaces – including basic information about workplaces
- calendar – list of shifts and definition of these shifts. Shifts are defined for all resources, transport equipment and workplaces used
- production plan – this file creates a schedule of the production plan for each product in the simulated time period

The structure of records in the files must have clear rules. These rules are important for following the automated processing of input data.

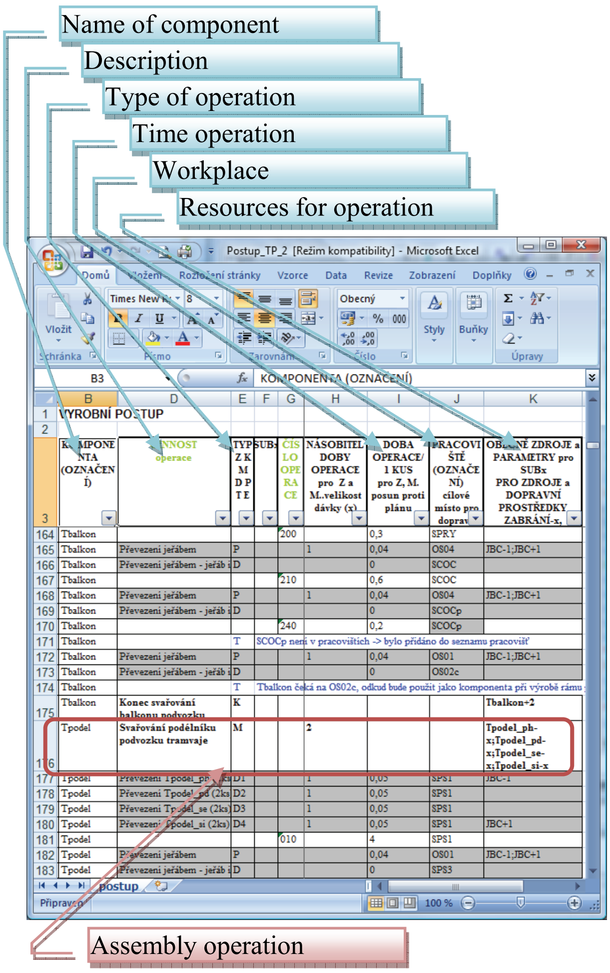


Figure 1 File example - Manufacturing sequence

For example, in Figure 2 is shown an MS Excel file, which describes the production process of one product. This file describes basic information about a production process:

- sequence of production operations
- required resources for production operations
- workplace for production operations
- hierarchical structure of product

In this step we change data by hand, which may result in some errors in the data. This step is followed by formal data control by special software created for this purpose. An example of this control software is shown in Figure 3.

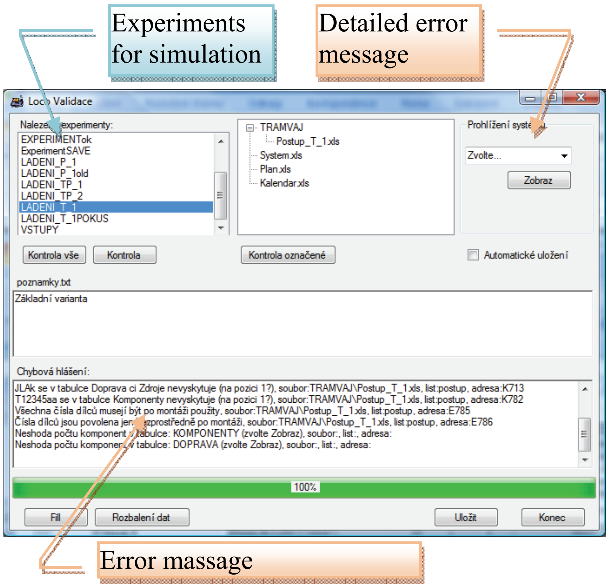


Figure 2 GUI Application LocoValid

2.4. Microsoft Access files

Missing information was added to all Excel files in the previous step. Input data must now be transferred from Microsoft Excel files to Microsoft Access files in order to automatically generate the simulation model. This transfer is important to accelerate the work in the simulation model. MS Access is simply supported both by MS Excel and the ARENA simulation system.

2.5. Simulation model

A simulation model is created in the Rockwell Software simulation system, ARENA v. 11. The model contains a variable part and a fixed part.

2.6. Fixed part of model

The fixed part of the model is not modified during any simulation experiments. This part of the model describes the typical behaviour of all workplaces. Simple animation also belongs to this part of the model and shows the position of separate workplaces and transport between workplaces.

The fixed part of the model is permanently prepared beforehand.

2.7. Variable part of model

This part of the model depends on the production process of each product, on setting resources and a production schedule. This means we cannot create this part of the model before we simulate a concrete situation.

The simulation model is created so that part of the model is generated automatically during the initialization of the simulation model on the basis of the input data. The behaviour of the model is managed by data saved in the MS Access database.

Parts of the simulation model generated on the basis of input data:

- list of resources used,
- list of transport equipment used,
- list of product components,
- shift models for resources,
- capacity of resources,
- capacity of workplaces,
- animation of resource utilization,
- animation of workplace utilization.

Model behaviour managed by input data:

- arrival time for component to production,
- technological information for production:
  - operation time,
  - transport time,
  - resources used,
  - transport equipment used,
  - workplace for technological step,
  - storage position of finished product for assembly (storage workplace or manufacturing workplace),
  - request for assembly,
  - transport of all requested components for assembly to target workplace
  - finalizing production of whole product,
  - etc.

The variable part of the model is generated automatically during the initialization of the simulation model. Visual Basic Application (VBA) is used to generate this. Data for generation is loaded from MS ACCESS database. Data is automatically transferred to modules used in the ARENA simulation system.

2.8. Simulation experiment

Simulation run is started after the variable part of the model has been automatically generated. An animation of the part manufacturing workshops can be seen in the following figure.

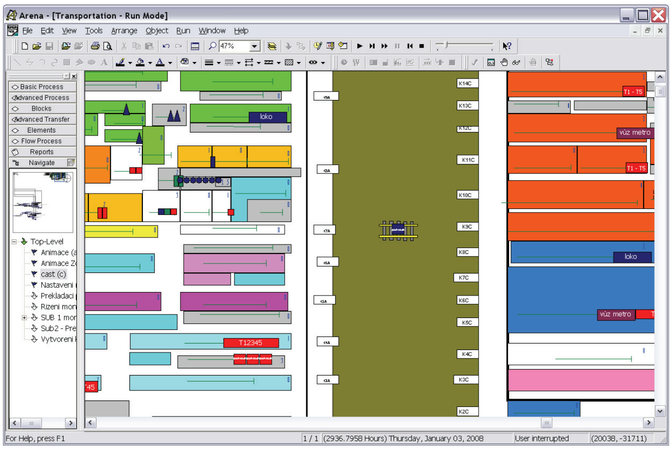


Figure 3 Animation of manufacturing workshops

Animation of workplace in detail is shown in Figure 5. During animation the following information is shown:

- current number of components,
- name of workplace,
- icon of component.

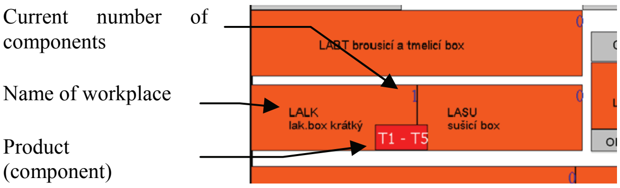


Figure 4 Workplace animation

2.9. Transformed results

After each simulation run an evaluation of the results must be performed. All results are automatically converted into MS Excel tables and graphs and MS Project.

Types of result are:

- production process,
- statistics,
- resources,
- products.

On the basis of the results it is necessary to experimentally optimize the system. Changes for further experiments are saved to modified Excel files. Further steps are the same as in the first experiment (Figure 1).

2.9.1. Production process

The following outputs are included in this group of statistics:

- start time and end time of each operation according to outputs from simulation model
- start time and end time of each hierarchical component of product (Figure 6)

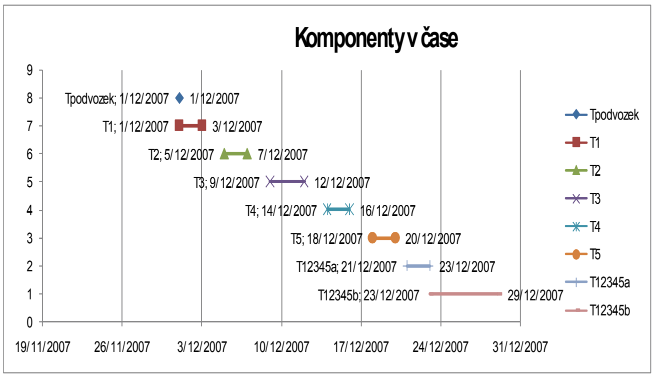


Figure 5 Start time and end time of each hierarchical component

2.9.2. Statistics

In this group of outputs are included simulation outputs, which describe the simulated system from a more global point of view.

We can find the following outputs:

- statistics about utilization of individual resources,
- the number of products waiting in various queues at workplaces,
- etc.

2.9.3. Resources

This group of outputs shows a detailed view of each resource usage over time. In this group of statistics we can see resource usage over time.

2.9.4. Products

This file contains information about the components of each product. Information is about the start time and end time of each hierarchical component and each product. An example of output is shown in Figure 7.

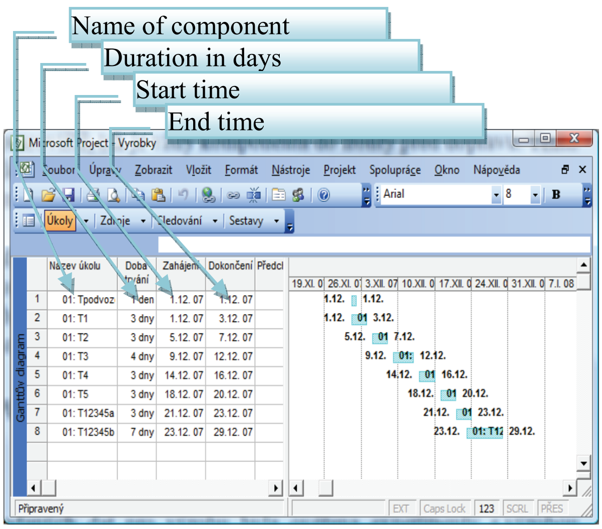


Figure 6 Outputs about time of components

3. OPTIMIZATION OF SYSTEM

During the verification of the whole system, the following optimization of manufacturing system was also performed.

In Figure 8 we can see how much selected storage space was used in one workplace during 3 experiments (v5, v6, v7). From the figure it is evident how organization and management decisions step by step decrease the demand for storage space in the selected workplace.

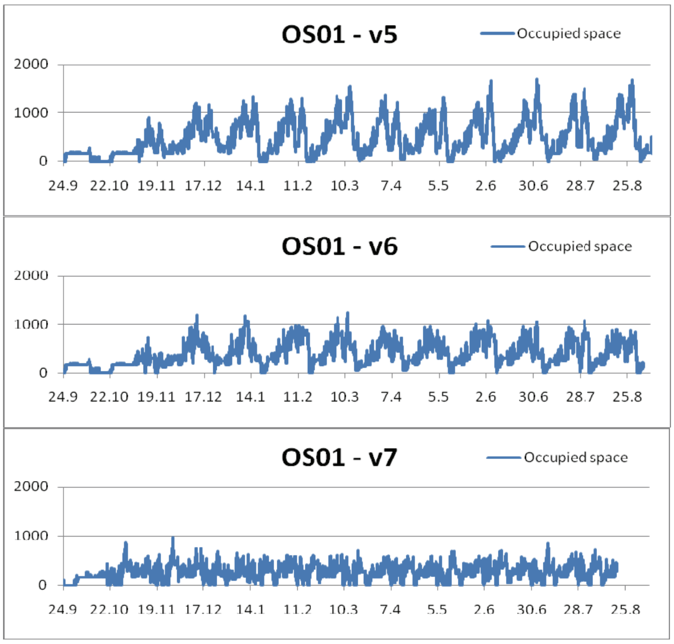
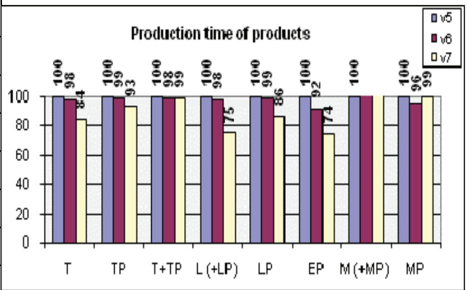


Figure 7 Occupation of selected storage place in experiments

In Figure 9 shows how total times of separate, basic types of products are shortened in individual experiments. For some products we can see that the total time is about 26% shorter between experiments.

	v5	v6	v7
T	100	98	84
TP	100	99	93
T+TP	100	98	99
L (+LP)	100	98	75
LP	100	99	86
EP	100	92	74
M (+MP)	100	101	101
MP	100	96	99



v5	basic experiment
v6	increasing number of grinding workplaces
v7	changing of arrival time for component to production

Figure 8 Total time of products

4. CONCLUSION

The simulation project verifies the group of variants for various capacity utilizations of a production hall and for various production plans. The experiment located bottlenecks, which were eliminated in various ways:

- Some workplaces were moved
- Capacity in some workplaces was increased
- Some handling space and storage space was increased
- Some technological steps were changed

This simulation project enabled many potential problems to be dealt with before real production started. In the future a simulation model will enable verification of throughput of production for various production outputs and for a defined combination of products.

Outputs from this project are used to assist in TOP management decision-making in the company ŠKODA TRANSPORTATION.

REFERENCES

Banks, J., Carson, J.S., Nelson, B.L., Nicol, B.N., 2001. *Discrete-Event System Simulation*. Upper Saddle River: Prentice Hall.

Ulrych, Z., 2006. Generation of simulation models based on data from EIS. *MITIP 2006*. pp. 397-408. September 11-12, Budapest (Hungary).

Bradlay A., 2006., *ARENA documentation*. Rockwell Software Inc.

AUTHOR’S BIOGRAPHY

Vaclav Votava had worked as a researcher at SKODA company in Pilsen (since 1964 in the field of the automatic control, measurements, information systems, software development). From 1991 he has been Associate Professor in the Department of Industrial Engineering and Management at the University of West Bohemia in Plzen. Current activities are focused on education (present and on-line form), simulation of the discrete systems, information systems analysis, multimedia approach, internet information systems.

Zdenek Ulrych works as a lecturer and research worker in the Department of Industrial Engineering and Management at the University of West Bohemia in Plzen (Czech Republic). He holds M.Sc. and Ph.D. in Mechanical Engineering at the same university. His research interests are oriented towards the design and development of eLearning support software and discrete simulation.

Milan Edl works like senior lecturer and research worker at the Department of Industrial Engineering and Management at the University of West Bohemia in Plzen (Czech Republic). He holds M.Sc. and Ph.D. in Mechanical Engineering at the same university. His research interests are oriented to the design and development of multimedia educational software and distributed simulation and their visualization.

Michal Korecky is the Vicechairman of the Board and Development Director of the company SKODA HOLDING a.s. and Chief Operating Officer and Executive of its daughter company SKODA

TRANSPORTATION s.r.o. in Pilsen. He holds M.Sc. in Foreign Trade at the University of Economics in Prague and Ph.D. in Industrial Engineering and Management at the University of West Bohemia. His professional interests are oriented towards business strategy, R&D management, production management and project risk management.

Vaclav Trkovsky works in Development Department of SKODA HOLDING a.s., he is responsible for evaluation of development and investment projects and manages particular projects. He holds M.Sc. in Electronic Computers at the University of West Bohemia and Ph.D. in Technical Cybernetics at the Czech Technical University in Prague. His professional interests are oriented towards project evaluation and management and production process analysis and optimization.