SIMULATION OF THE PRODUCTION LINE IN SOFTWARE TOOL ARENA
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ABSTRACT
The project deals with the definition of simulation in the area of industrial engineering, its practical usage and benefits for industrial companies. There is described an example of practical realization of the project focused on simulation of the series production line. The project was realized in the software tool ARENA. In the paper there are mentioned analytical works, creation of the model as well as creation of GUIs. There are also described examples of the experiments which were realized, mentioned the overview of obtained outputs and possibilities of their interpretation and usage for the further work. At the end of the paper there are summarized the benefits of the project and mentioned recommendations for the company.

KEYWORDS
Simulation, production line, series production, manufacturing system.

INTRODUCTION
Today’s society can be characterized as an “information society”. Their competitive advantages are increased by ability of corporations to utilize, correctly exploit and control invisible assets (information which enable right managing of corporation). Information in all of its forms represents very important and valuable enterprise resource. Simulation is entirely specific area of modern information technologies, which involves representation or emulation of system properties and behaviour. Currently the computer simulation can be found in many practical applications; for example in logistic systems, quantitative analysis, on-line simulators, creation and examination of virtual worlds (i.e. crash simulators), in software prototyping or simply in popular simulation games. Simulation is generally a widespread used tool for predicting and verifying. It is also exploited as a support for decision making. Concrete examples of simulation practical application represent production systems models applications. After modifying input parameters, realization of simulation execution and output-data evaluation, user receives information about behaviour of the system (the reaction of concrete system’s settings). In this way user can easily examine characteristics of the system influenced by input settings and constraints (capacity of the system, amount of resources, time periods, etc.). The results obtained from simulation experiments can be used as a support for decision making, managing or controlling production system processes.

For computer simulation is very important large knowledge database, which contain a huge number of theories, principles or simulation attitudes. This is a reason for explain the term simulation in our meaning and short describe basic principles of our work. In the main part of the paper is described an example of real project, which was solved at the Department of industrial engineering and management. The project represents simulation of the modern production line where are produced two types of product. In the paper are briefly described analytical works connected with model creation as well as model logic (created in the SW toll ARENA), description of the created interfaces, mentioned form and summary of output reports as well as results of the simulation experiments. In the document are also described input data, which were used for model creation as well as realized experiments (the main aim of whole project). At the end of the paper are mentioned recommendations which result from realized experiments.

THEORETICAL BACKGROUND
At the beginning of the paper it is important to explain the definition of the term simulation. We talk about simulation when there is such system which represents the behaviour of another system over time. A computer simulation is that kind of simulation where the emulation is done by a computer program. Generally said there are two basic types of computer simulation. The first one type uses continuous models where the state changes continuously across time. Another one is based on discrete models and the state of the system changes only at discrete time instants. In this group of simulation models are differentiated two subsets:

- Event driven
- Time-stepped models.
The difference between these two attitudes is shown on the following picture:

**Figure 1: The difference between tie stepped and event stepped simulation**

For this work are more important event-driven-simulation models where states change occur at discrete time instants represented by events (coming requirement, etc.). Software tool, which enables creation of such models and which is available at the Department of Industrial engineering and management, is ARENA, product of the company Rockwell Software. This SW tool was also used for realization of the real project – simulation of the production line. There is briefly description of this software tool characteristic in the following chapter.

**SOFTWARE TOOL ARENA**

At the Department of Industrial Engineering and management are available two software products which enable creation and simulation run of manufacturing systems models: ARENA and QUEST. Both software tools enable simulation of relatively large and complex models; enable verification of the simulated system (e.g. satisfactory of capacities), set of the production flow or usage of available resources. For my work was chosen SW tool ARENA, which enables easier model creation. Generally, ARENA 9.0 is a product of the firm Rockwell Software and enables creation of very large models (not only of manufacturing systems). ARENA is very intuitive tool with user-friendly GUI and is also compatible with MS Office – enables data input or output in .xls and .txt data format. Output reports are very transparent and detailed.

The working worktop of ARENA can be divided into three parts:

- Panel of modules – where are available libraries of modules for a user
- Working part – where is the model created by user
- Data part – where user can modify parameters of resources and entities.

Appearance of the working worktop is shown in the following figure:

**Figure 2: Worktop of ARENA SW tool**
ARENA also enables economical analysis of the simulated system due to implemented ABC costing methodology. But this additional function is not important for our project realization.

**DESCRIPTION OF SOLVED PROJECT**

Project deals with the simulation of production line with two types of product. For each product there is defined a different operating sequence (time of machining – maximum/minimum/average value, order of workplaces).

The manufacturing system consists from 13 workplaces with 5 workers (one of them cooperates on 2 workplaces). For each machine are defined time of machining (according to operating sequence), level of scraps and number of workers. Movement of the product within the scope can be decomposed in the following way:

![Diagram showing movements](image)

*Figure 3: Decomposition of the movements*

In the figure 3 are shown elementary positions within each workplace. Work place consists of a “waiting point” (position a in the Fig.3) and a “working point” (position b in the Fig.3). At the waiting point product waits for a resource, in case the resource is already released by another product. As soon as the resource is available, product seize the resource and moves from the waiting point to the working part (and the manufacturing process starts). After finishing the process of machining, product leaves a working point and the resource is again released. In the same time the product moves from the working point to the position b... The track between positions a and b represents loading and from the system point of the view it is wasted time (without any value added). Transport between workplaces (as well as within the workplace) is ensured by conveyor (accumulating type) with defined length of particular segments and speed.

Due to this basic movement decomposition, I defined 5 states for resources (all of the resources are inhere in one of following states):

- Busy (the resource is seized and working)
- Idle (the resource is “empty”, waiting for some work)
- Blocked (the resource is seized, machining has been already finished but the product can not leave working point because following conveyor segment is full)
- Loading (the resource is seized, but product is moving from the position a to b)
- Hand work (the resource is seized and the type of machining is hand work).

These states and their recording enables to user entirely explore all possible settings of the system and their influence on usage and resource utilization as well as explore entity life in a system (it will be explained later).

**DETAILED CHARACTERISTIC OF THE SIMULATED SYSTEM – INPUT RECORDS**

As it was mentioned in the chapter below, the simulated manufacturing system consists of 13 workplaces with 13 machines and 5 workers. Worker number 1 is an operating staff of two machines – for the workplaces number 1 and 13. For some machines are defined machining times of deviation (+-, for example:

<table>
<thead>
<tr>
<th>Working place</th>
<th>Time of machining [min]</th>
<th>Deviation [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>0.5628</td>
<td>0.1</td>
</tr>
<tr>
<td>No.2</td>
<td>0.35</td>
<td>0</td>
</tr>
<tr>
<td>No.3</td>
<td>0.6333</td>
<td>0.15</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*Table 1: Example of the input data*

For the system is defined level of the scraps, which is redistributed to particular machines due to ratio stresses and correction coefficient. The particular stress is constant, but the total level of the scraps in system can variant due to variable correction coefficient. Example of the recounted value of scraps for particular workplaces is shown in the following table:
Correction coefficient 0.6

<table>
<thead>
<tr>
<th>Working place</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine No.1</td>
<td>0</td>
</tr>
<tr>
<td>Machine No.2</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td><strong>Total scrap of the system</strong></td>
<td><strong>8%</strong></td>
</tr>
</tbody>
</table>

Table 2: Definition of scraps in the system

The interoperable transport is ensured by accumulating conveyor with constant speed of movement. Whole track is divided into several segments (each segment connects two workplaces) with different length, different capacity (that mean with different number of pallets which can be transported in the same time) but the same speed. Transporting system of the production line is enclosed (never ending loop). Product is not laid directly on the conveyor, but is situated on the cart. At the last station are product removed from the cart and send to another working line. Carts are released, send to the workplace number 1 and used for transport of another product (seized with a new one). Layout of the production line is shown in the following picture:

![Layout of the production line](image)

Figure 4: Layout of the production line

**MODEL CREATION, GUI**

Model of the simulated system was created in the SW tool ARENA, which is available at the Department of Industrial engineering and management. As it was mentioned in the chapter below ARENA is a product of the firm Rockwell Software and enables simulation of large and complex manufacturing systems in details. ARENA supports use of VBA – Visual Basic for Applications for more complex models. ARENA also supports possibility to include its Type Library for Visual Studio (Arena.Interop.dll) projects, which includes objects, their properties, methods, events and constants. Visual Basic was used for creation of input interface for modifying and entering data. User can very easily controls data inputs, changes their values and parameters, opens the model or starts the simulation run. The examples of created user interface are shown in the following pictures:
Due to created GUI user can change values of these attributes:

- Correction coefficient for recounting scrap levels of particular machines
- Machining time (and its variables)
- Type of the product
- Number of pallets in system
- Limit (number of pallets) for transfer of worker number 1 between the workplaces No.1 and No. 13
- Length of replication
- Length of warm up period

All of these settings (created by user) are displayed and automatically saved into output reports. These reports consist of several parts and inform about obtained values, results of experiments and input settings. They are also replenished with graphs and tables which make the obtained results clear. An example of the output data is shown in the following picture:

In the figure 6 are shown results of the experiments which characterize (for each resource individually) per centual share of particular states. Sum of these small "parts" represents whole dispensable time capacity of particular resource. The output report, which is automatically generated during the simulation run, consists of several output data. The most important are:

- Data about model settings (overview of the input data)
- General data about production
- Detailed analysis of the resource usage (overview of states, times periods, capacity, and so on)
- Analysis from the point of view of product (states, and so on)
- Information about pallets.

Analysis of these output data can serve as basis for decision making, optimization of the system, product planning or decisions about preventative measures (after finding the bottleneck).
EXPERIMENT, RECOMMENDATIONS
After model creation and preparation input/output GUIs were realised several experiments. There were 12 basic variant of input setting – maximum, minimum, average time value of machining (i.e. 3) and their mixture (another 3 combinations) for each type of product (there are 2 types). These 12 variants were explored with different level of scrap (12% / 8%), different number of pallets in system (20/25/30), different length of replication run (8/16/80 hours) or diverse interval of passing the worker 1 between workplaces 1 and 13 (5/6). There were realised more than 90 experiments. After analysing output data it is possible to recommend and determine:

- The bottlenecks of the system
- Number of pallets in system which ensures continuous material flow but does not involve needless “locked-up” capital
- Interval of passing worker number one between workplaces 1 and 13
- Number of products which are produced during particular time period, the structure of production:
  - Number of good products
  - Number of wastrel products
- Usage of resources, percentage of different working states.

According these results I could characterize optimal setting of the system, define the bottlenecks and other requirements for continuous production (with no unwilling errors). User can also examine different solutions, different settings of manufacturing system with no (or minimum) financial risk.