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Marcin ZEMCZAK*

Institute of Engineering Processes Automation and Integrated Manufacturing Systems,
Faculty of Mechanical Engineering, Silesian University of Technology, Gliwice, Poland
*marcin.zemczak@polsl.pl

COMPUTER AIDED SIMULATION OF A MIXED-MODEL PRODUCTION SYSTEM

Abstract: The paper presents the issue of computer aided simulation application in a mixed-model production systems. Computer simulation is a very powerful tool for building, testing and rebuilding production systems, especially as an aid in the decision making process. Different methods of computer simulation with the basic characterization and their main advantages and disadvantages are presented. Basing on the key features of presented simulation types, a method most proper for simulating a mixed-model production system is proposed. Simulation of a production system in Flexsim simulation software environment is presented. Conclusions on the advantages of use of computer aided simulation are given.

1. Computer aided simulation

Computer aided simulation is a powerful tool, that has for many years improved the process of decision making in the context of design and operation of different types of manufacturing systems. The biggest advantage of virtual simulation is that it is far less time and money consuming than building and testing a real system, which by the way is sometimes just inaccessible. The designer is able to run different scenarios and improve the system by redesigning it before the implementation of a real system. Exemplary use of the simulation can be found in [1,2], especially in the context of the operation of manufacturing systems [3]. It is also found in other aspects of the operation of modern companies as supply chain management [4] or scheduling [5].

Since modern computers have a high computing power, even big systems, that are quite computationally complex are easy to simulate within a desired level of detail. In the paper three main simulation methods have been described, in order to decide which one is the most adequate to simulate an exemplary mixed-model production system. Also Flexsim simulation environment has been briefly described to give the reader a closer look into computer aided simulation software possibilities.

2. Mixed model production system

The desire of successful companies is to ensure a short realisation time of the product and the quick response to rapidly emerging demand for a variety of products in various types.

Moreover, it is really a big issue for each company to maximize the utilization of production capacity at its disposal, as it determines the cost of production, and therefore the competitive position on the market.

An example of such activities can be widely observed in mixed-model production systems, mainly specific to the automotive industry, where at the same resources multiple options are possible in the system (e.g. for car manufacturing):

- few different models,
- multiple engines,
- multiple colours of interior,
- multiple additional equipment components,
- special and limited versions,
- etc.

One of the problems that arise in such systems is the appropriate utilization of the stations equipment and employees on the assembly line. Level of production and the types of products are hardly predictive, thus the production plan may be constantly changing (also as a result to distortions connected with parts availability in JIT systems). This type of environment requires a specific management, as such a system is supposed to achieve few different goals at the same time. They are:

- minimization of completion time of a specific set of tasks,
- ensuring adequate saturation of assembly line,
- ensuring adequate utilization of human resources.

Conducting experiments on an operating system while manufacturing orders for customers is inacceptable due to high cost of assembly line stoppages and poor utilization factors of machines and human resources. That's the main reason to consider computer aided simulation as a tool in system optimization or even its redesign. Because with the use of computers there is no need to work on a real system, the company would not have to bear the costs of experiments, and what is more it would be possible to run multiple scenarios and redesign system at any moment. The question is which simulation method to use in case of such system.

3. Simulation methods

Simulation is used as a tool aiding decision making processes in manufacturing systems. Creating a virtual system and conducting experiments on it is much cheaper and less time consuming than working with a real system [6]. What is more, in the case of systems that are designed but not yet built it is the only possible way to check the correctness of the system behaviour and its parameters (e.g. efficiency, flexibility) before implementing the physical system. Simulation can be conducted with the use of one of three available methods (Fig. 1):

1) System dynamics,
2) Agent-based simulation,
3) Discrete event simulation.

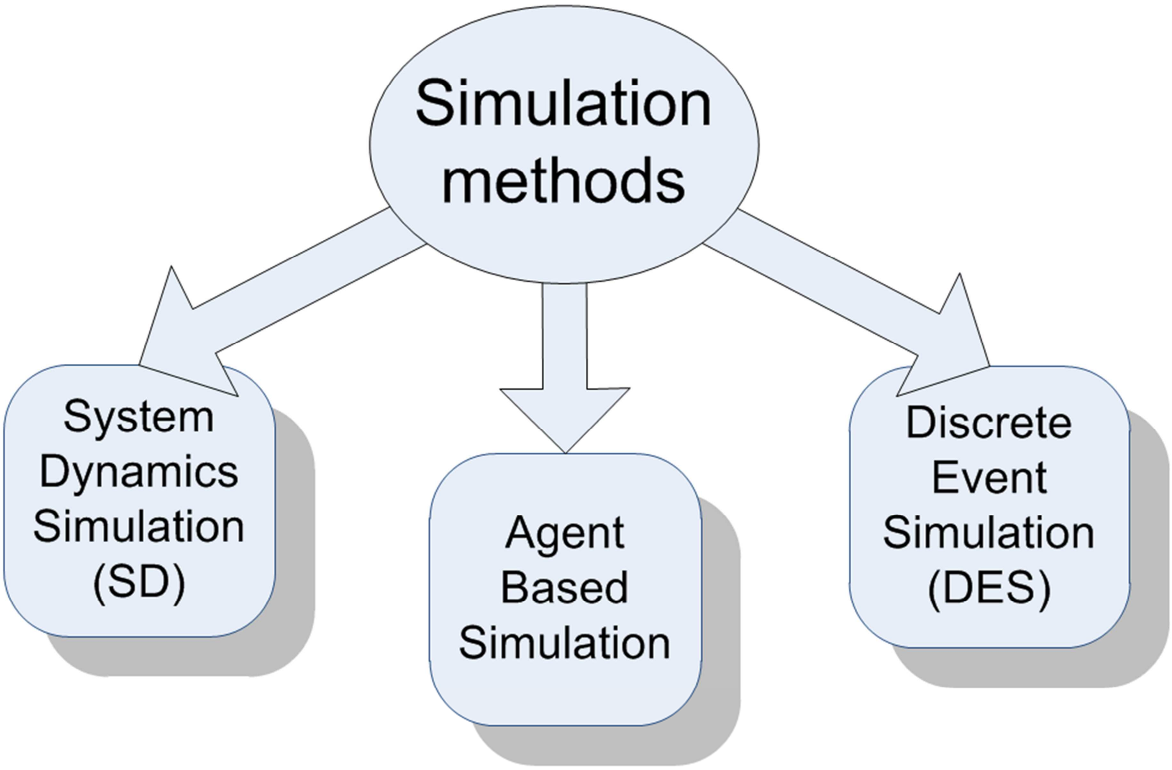

Figure 1 Simulation methods for manufacturing systems

3.1. System dynamics simulation

System Dynamics (SD) is the oldest method, its principles were developed by Forrester under the name of Industrial Dynamics [7]. The first computer simulator SIMPLE (Simulation of Industrial Management Problems with Lots of Equations) was developed in 1958 [8]. In SD method, the system is described in terms of deterministic mathematical equations, it has the shape of causal loops, with positive and negative feedback diagrams of stock and flow. However, in real systems not everything is deterministic, some operations are stochastic or even do not follow any mathematical or analytical model. Such problem arises in mixed-model production systems, therefore the use of SD method would not be effective in case of such systems.

3.2. Agent based simulation

In Agent based simulation method (ABS), system components are modelled as “agents” . Agents and their interactions are specified with the use of simple rules, while behaviours, patterns and structures within the system emerge from interactions between certain agents [9]. Unfortunately ABS method is a quite new simulation tool, there is no specific definition of an agent, and furthermore current scientific descriptions imply that agents should interact according to the experience gained during simulation [10]. However due to the immaturity of available agent-based software there is a problem with defining initial agents experience. The user is supposed to program the experience prior to simulating the system, and it may be a quite time consuming process, as it has to be conducted for each kind of system separately.

3.3. Discrete Event Simulation

The third type of simulation methods is discrete event simulation (DES). By now it's the most developed simulation method as many available user friendly commercial software, with ready-made drag-and-drop components can be found on the market. Exemplary environments like Enterprise Dynamics or Flexsim Simulation Software give the user ability to include stochastic elements as well as deterministic rules. That gives the possibility to implement true to life randomness and analyse the system in a real time. Also the level of detail is adjustable to get only data needed at certain situations. DES systems allow tracking of individual system components and manufactured products. Components of the system are modelled as objects (e.g. machines, workers) with attributes (e.g. availability, reliability, the time required to perform sample task). Objects may change their states in response to certain "events" that occur in the system (e.g. machine breakdown, arrival of new work order) during simulation [11].

3.4. Selection of a simulation method

In the Table 1 three simulation methods have been compared and best method for simulating mixed-model production system has been pointed. The marks for meeting the requirements were from 1 to 5, where 1 – doesn't meet the requirement, 5 – fully satisfies the requirement.

Table 1 Comparison of simulation methods

Criterion	**SD**	**ABS**	**DES**
Ease of use	3	3	5
Available commercial software	4	3	5
Ready-made components	1	1	5
Possibility to implement stochastic elements	1	5	5
Possibility to track individual system components	2	5	5
Total	11	19	25

The above comparison points out that simulation method most adequate for simulation of mixed-model production systems is Discrete Event Simulation method. By now it is the most developed method, easiest in use and most user-friendly, as the available commercial software is equipped with ready-made drag and drop components. What is more, most of DES software have their own programming languages, that allow user to implement elements specific to the simulated real system [12].

4. Flexsim simulation software of simulation software environments

An example of Discrete Event Simulation is Flexsim software. In this section brief description of the system is given.

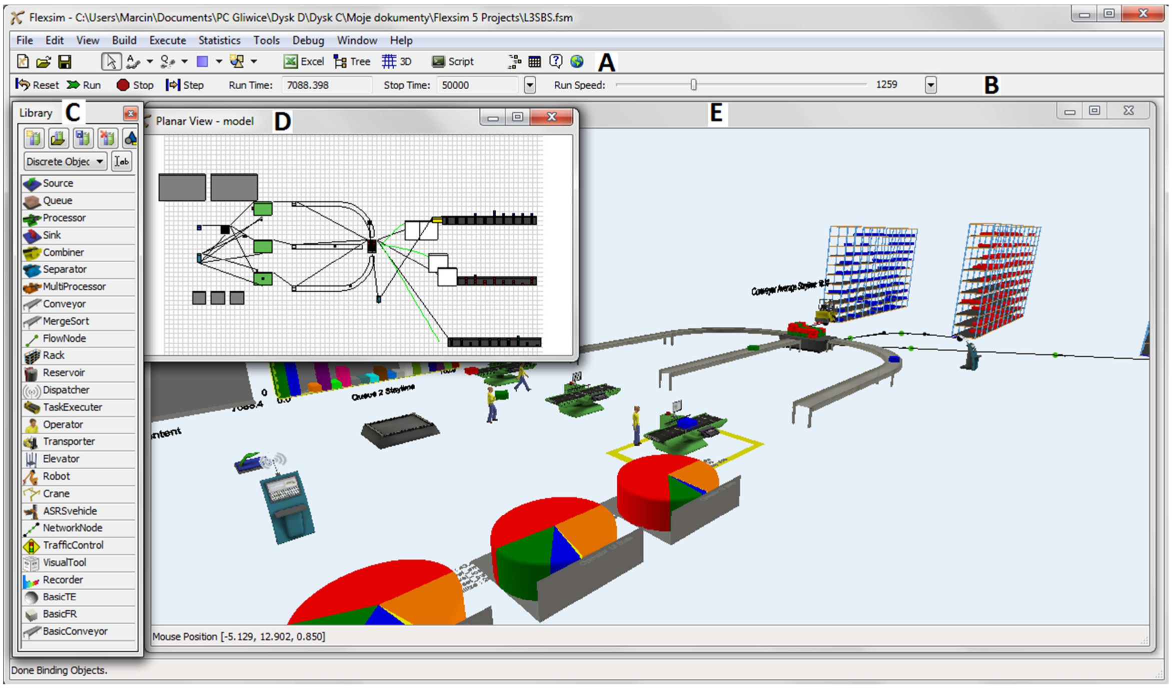

Figure 2 Flexsim software working space

Flexsim simulation software is designed as a tool for simulating processes not only in manufacturing companies (*Flexsim*) but also in container terminals (*Flexsim CT*) and health care services (*Flexsim Health Care*). Simulating production of liquids is also possible with the use of *Flexsim Fluid Library*. The main working space consists of the following elements labelled on Figure 2:

A) Flexsim toolbar,
B) Run panel,
C) Object library,
D) Planar view window,
E) 3D view window.

To create a system model user picks up desired element from the object library and drops it on planar or 3D view window. After gathering all required elements on the view window user connects them with each other and defines all the parameters of each object. After creating the model with the use of Run Panel user resets the model and runs the simulation. Flexsim software gives possibilities to check the state of each object and to track each product in a real time (e.g. with the use of diagrams). After each simulation user is able to change the running scenario, or even to redesign the whole system.

Thanks to graphical communication impact of the different parameters on the system can be observed during simulation and basing on them the decision about the system structure can be made. Flexsim simulation software allows also management of vehicles and human resources in the system. With the use of *Dispatcher* object rules governing the operation of above can be programmed.

5. Conclusions

Computer aided simulation is a tool that helps the companies save time and money in processes of design and optimisation of operation of any production system. In the article three main simulation methods have been described and compared. In order to select the most proper system a brief characteristic of each method has been given and an analyse has been conducted. Due to the highest current development, available user-friendly commercial software and possession of properties most adequate to simulate mixed-model production systems Discrete Event Simulation method has been pointed out. Commercial Discrete Event Simulation system has been presented, in order to give the reader an insight into DES software possibilities.

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