APPLICATION OF COMPUTER SIMULATION TO INCREASE THE PRODUCTION RATE OF PICKLING LINE

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This article describes the practical application of computer simulation of the manufacturing system. The field of modelling and simulation is as diverse as a group of people. Each discipline has developed or is developing its own models and their own approaches and tools for exploring these models.
The simulation includes generating and observation of artificial history of system, whereby is possible to derive conclusions concerning the operating characteristics of a real system that is represented by the simulation. In this article is an example of the practical application of simulation approach for simulating the transport of semi-finished products on pickling line.

Keywords
Production system, simulation, optimization, simulation analysis, pickling line, Production Rate

1. Introduction

The competitive environment in the industry led to the technological changes that enable manufacturing companies to produce better products constantly. It seems that every week another company launches its latest products, each of them has more possibilities, capabilities and thus power. The development in computer industry is unique that often acts as a springboard for other related industries. One of them is the section of simulation software. Hardware becomes more powerful, more accurate, faster and easier to use and it is followed by software.

Number of enterprises using simulation quickly grows. Many managers realize the benefits of using simulation for more than a single purpose. Due to advances in software, managers includes simulation into their daily activities more regularly. [Simeonovova 2013]

2. Modeling and simulation

Simulation in general is to pretend that one deals with a real thing while really working with an imitation. In operations research the imitation is a computer model of the simulated reality. A flight simulator on a PC is also a computer model of some aspects of the flight: it shows on the screen the controls and what the "pilot" (the youngster who operates it) is supposed to see from the "cockpit" (his armchair).

Why to use models? To fly a simulator is safer and cheaper than the real airplane. For precisely this reason, models are used in industry commerce and military: it is very costly, dangerous and often impossible to make experiments with real systems. Provided that models are adequate descriptions of reality (they are valid), experimenting with them can save money, suffering and even time.

When to use simulations? Systems that change with time, such as a gas station where cars come and go (called dynamic systems) and involve randomness. Nobody can guess at exactly which time the next car should arrive at the station, are good candidates for simulation. Modeling complex dynamic systems theoretically need too many simplifications and the emerging models may not be therefore valid. Simulation does not require that many simplifying assumptions, making it the only tool even in absence of randomness.

How to simulate? Suppose we are interested in a gas station. We may describe the behavior of this system graphically by plotting the number of cars in the station; the state of the system. Every time a car arrives the graph increases by one unit while a departing car causes the graph to drop one unit. This graph (called sample path), could be obtained from observation of a real station, but could also be artificially constructed. Such artificial construction and the analysis of the resulting sample path (or more sample paths in more complex cases) consists of the simulation.

Types of simulations: Discrete event. The above sample path consisted of only horizontal and vertical lines, as car arrivals and departures occurred at distinct points of time, what we refer to as events. Between two consecutive events, nothing happens – the graph is horizontal. When the number of events are finite, we call the simulation "discrete event."

In some systems the state changes all the time, not just at the time of some discrete events. For example, the water level in a reservoir with given in and outflows may change all the time. In such cases "continuous simulation" is more appropriate, although discrete event simulation can serve as an approximation.

How is simulation performed? Simulations may be performed manually. Most often, however, the system model is written either as a computer program (for an example click here) or as some kind of input into simulator software. [Arsham 1995]

3. Simulation process

By using simulation software is designed discrete simulation model. Discrete event model may be defined as one in which the state variables are changed only in discrete points in time when the event occurs. The model represents the dynamic characteristics of the physical system. The simulation model has two advantages. At first, simulation model lets you create different variants of technical or logistical solutions. On these variants can be examined, modified, and evaluated the process conditions and other parameters without need to change the current production system. It also means that there are not losses caused by damages of semi-finished products or production equipment. The second advantage is that the model shows (with some degree of confidence) the behaviour and status of processes in the future. Based on the outputs of the simulation model (its variants) can be analyzed the behaviour of an existing, or even non-existing production system, can be identified its bottlenecks, can be increased the productivity of system or optimized the utilization of resources, etc. Testing of variants and evaluation of behaviour of system on the real system is in all aspects disadvantageous and often dangerous because probability of damages on the equipment or manufactured product is too high. [Arsham 1995]

4. Simulation analysis

Fig. 1 shows the sequence of steps of simulation analysis. These steps should guide the compiler of the model to the correct process of developing a simulation model.

Similar data and their interpretation can be found in other sources, such as Pegden, Shannon, and Sadowski (*Introduction to Simulation Using*) and Law and Kelton (*Simulation modeling and analysis*). The following text is drawn from the source by the authors Banks, Carson, Nelson, and Nicol (*Discrete-event system simulation*).

1. ***Formulation of the problem***
   Every simulation study begins with the formulation of the problem. If the problem is defined by who entered the treatment of the problem (client) simulation analyst must be extremely careful to make sure that the problem is clear.
2. ***Setting objectives and overall plan of project plan***
   Simply stated, in this step a proposal is prepared. When a

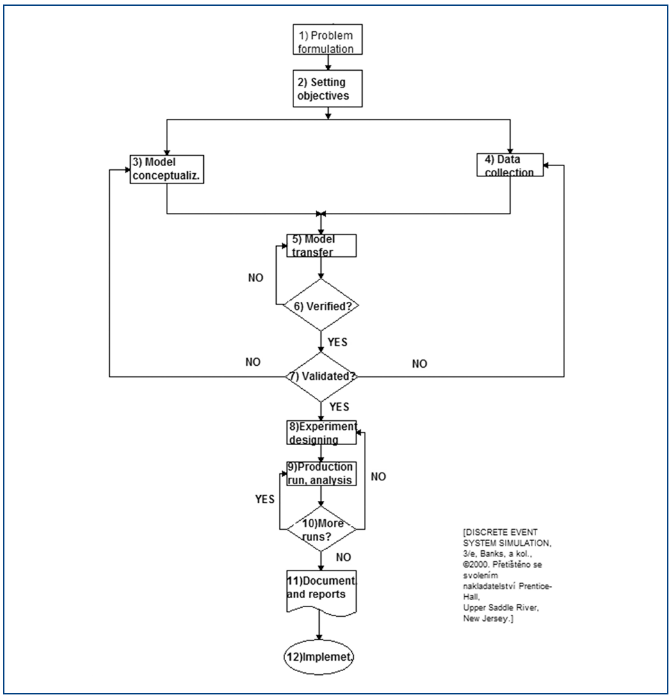

Figure 1. *Flowchart of sequences simulation study*

proposal is created it does not put emphasis on the location of the analyst and client, as internal and external consultant. Objectives defines the questions to be answered during the simulation study. The project plan should include a variety of scenarios that will be investigated.

3. ***Conceptualization of model***
   The subject of investigation is a real system. It is abstracted by a conceptual model, a series of mathematical and logical relationships relating to components and system structure. Creating a simulation model should start simply, by modelling of basic components and relationships of the system. During the development should model become more complex to achieve target complexity of model.
4. ***Data collection***
   Shortly after the proposal is adopted, the plan of data requirements should be submitted to the client. In the best case, the client should collect the kind of data that is needed, even in required format. Collected data should be sent in electronic form to simulation analysts.
5. ***Model transfer***
   Conceptual model assembled in Step 3 is to be encoded into a computer recognizable form, i.e. as an operational model.
6. ***Model verification***
   Once an operating model had been assembled, verification (verification of accuracy) can be performed. It shall be verified that the operating model works correctly.
7. ***Model validation***
   Validation determines that the conceptual model is an accurate representation of the real system. Validation answers the question of whether it can be a model representing the real system used for experimentation.
8. ***Experiment designing***
   For each scenario to be simulated, must be decided on the length of the simulation run, the number of cycles (replications) and initialization method.
9. ***Production run and analysis***
   The production run, and its subsequent analysis, are used to estimate the performance measures for scenarios that are being simulated.
10. ***Other runs***
    Based on the analysis of runs that have been completed, the simulation analyst determines whether other scenarios are needed, and if it must be simulated.
11. ***Documentation and reports***
    Creating documentation is necessary for many reasons. If the simulation model will be used again by the same analyst or other, it will be necessary to understand how the simulation model works. Documentation strengthens confidence in the simulation model, so the customer can decide on the basis of the analysis.
12. ***Implementation***
    Report prepared in Step 11 is only supporting information that the client used to making his decision. If the client was involved in the preparation of the study, and if the simulation analyst consistently followed all the steps, then the probability of successful implementation increases. [Pegden 1995] [Law 2000] [Banks 2000]

5. Practical application of simulation access

By using the steps of simulation analysis described above was created simulation model of transport of semi-finished products on pickling line (Fig. 2).

5.1 Input parameters of simulation model

In the simulation model of pickling line can be inserted different input parameters. Input parameters of crane can be specified, specifically lifting speed, travel speed or minimal distance between 2 cranes, which means that 2 cranes can not approach each other less then distance specifies. In the case that the value of this parameter is 0, the behaviour of cranes can be modelled. Cranes may crowd out each other, or crane with semi-finished product with lower priority can wait or be relocated. It depends on manufacturing control.

It is necessary to define input parameters of baths, for example name, icon, time of processing semi-product on bath, the time required for draining the semi-product, distance from beginning of crane track, etc.

Not least the pickling sequence has to be specified. This sequence determines the order of processing of semi-finished product on baths. Two products can have different pickling sequences.

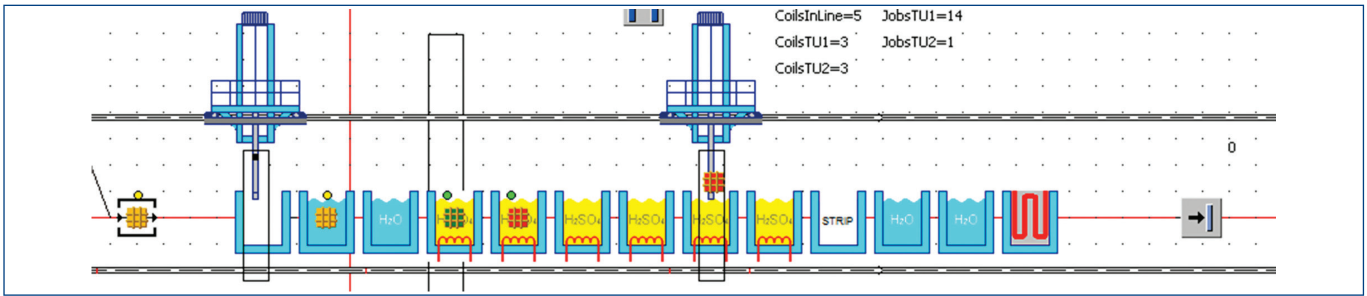

Figure 2. *Simulation model layout of transport of semi-finished products on pickling line.*

Simulation Start	Simulation End	Simulation Period	Total productior	Production Rate			Bath name	Exposition time
7.10.2013 0:00:00	9.10.2013 22:00:00	70:00:00	431	6,16	Recipe A	Recipe B	P03	223,2858859
							P04	0
							P05	329,4915165
							P06	87,58918919
							P07	24,98558559
							P08	608,8927928
							P09	629,3216216
							P10	246,2711712
7.10.2013 0:00:00	9.10.2013 22:00:00	70:00:00	398	5,69	Recipe A	Recipe B	P03	244,2858859
							P04	0
							P05	331,4915165
							P06	101,5891892
							P07	24,98558559
							P08	623,8927928
							P09	682,3216216
							P10	246,2711712

Figure 3. *Table with output parameters*

5.2 Design and selection of alternatives

Several alternatives had been created. On these alternatives is possible to investigate the effect of changes of input parameters on the behaviour of the production system.

After simulation of the alternatives are found optimal parameters of pickling line. The goal of modelling pickling line may be for example to optimize transport times, finding a suitable rehanging position, optimizing resource utilization and transport parameters, etc.

Fig. 3 shows the output table. Table of outputs includes the duration of the simulation runs, total production, Production Rate and exposure times in the tanks with acids. An initial model alternative has been simulated and the simulation model outputs has been found (see Fig. 3).

5.3 Simulation outputs

The outputs of the simulation of initial alternative suggest that the exposure times in individual tanks with acids exceed the limit for the maximum stay of semi-finished product in acid (see Fig. 4). If this should happen in real production system, the semi-finished products would be re-pickled and it may lead to their destruction. By use of simulation runs with different input parameters was found optimal alternative of simulation model.

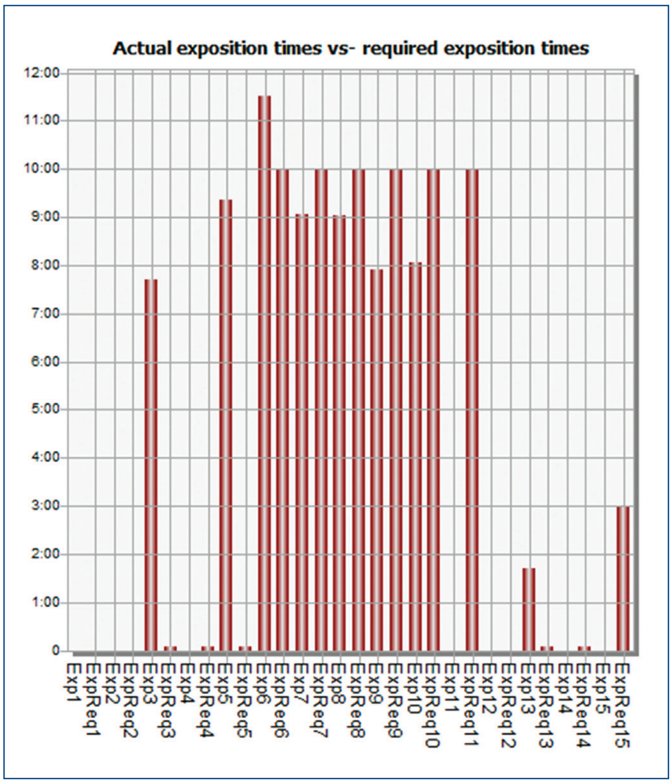

Figure 4. *Graph with required exposition time (ExpReq) and actual exposition time (Exp) of baths*

6. Conclusions

Advancements in computing power, availability of PC-based modeling and simulation, and efficient computational methodology are allowing leading-edge of prescriptive simulation modeling such as optimization to pursue investigations in systems analysis, design, and control processes that were previously beyond reach of the modelers and decision makers. Dynamic modeling in organizations is the collective ability to understand the implications of change over time. This skill lies at the heart of successful strategic decision process. The availability of effective visual modeling and simulation enables the analyst and the decision-maker to boost their dynamic decision by rehearsing strategy to avoid hidden pitfalls.

Based on the outputs of simulation runs, it was found that the changes applied to the initial alternative of simulation model leads to increase of PR (Production Rate) and reduces exposure times in tanks with acids. It confirms, that computer simulation is suitable tool for lead time reduction in manufacturing systems and performance increasing of these systems. [Arsham 1995]

References

[Arsham 1995] Arsham, H. Systems Simulation: The Shortest Route to Applications. National Science Foundation, 1995, [online]. 2/11/1995 [15/1/2014]. http://home.ubalt.edu/ntsbarsh/simulation/sim.htm.

[Banks 2000] Banks, J., Carson, J. S., Nelson, B.L., Nicol, D. M. Discrete-event system simulation. New Jersey: Prentice-Hall, 2000. ISBN 01-308-8702-1.

[Law 2000] Law, A. M. and Kelton, W. D. Simulation modeling and analysis. New York: McGraw-Hill, 2000. ISBN 00-705-9292-6.

[Pegden 1995] Pegden, C. D., Shannon, R. E and Sadowski, R. P. Introduction to Simulation Using SIMAN. New York: McGraw-Hill, 1995.

[Simeonovova 2013] Simeonovova, I., Hofman, R. Use of simulation software for advanced planning and scheduling (In Czech). Automa, 5, 2013, 1-2, ISSN 1210-9592.

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