DISCRETE EVENT SIMULATION – PRODUCTION MODEL IN SIMUL8

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ABSTRACT

Computer simulation is a method for studying complex systems that are not solvable with the use of standard analytical techniques. This contribution deals with the application of simulation program SIMUL8 to the analysis of production process in company Alteko, Inc. producing radial fans. The main purpose of the computer experiments is to identify the bottleneck processes and to suggest the management the appropriate solution. Computer experiments are aimed at the possibility of the parallelization of contracts in terms of the utilization of shared resources. Acceptable requirements for resources are recommended without the necessity of hiring additional operators. Although more suitable software can be used for the analysis of manufacturing processes, the advantage of SIMUL8 consists of its simplicity and interpretability of achieved results.

INTRODUCTION

The main reason for using computer simulation in the analysis of managerial problems is the impossibility of using standard analytical tools due to complexity of real processes. Many production and logistic problems in reality are suitable for simulation approach because of their dynamic and probabilistic character (Banks, 1998). Analyzing the production process, it is usual to use discrete-event simulation. All activities, their sequence, duration and required resources must be defined. O'Kane et al. (2000) show the importance of discrete-event simulation for the decisions to increase in total production output. The automotive industry is a typical area for the application of computer simulation. Masood (2006) investigates how to reduce the cycle times and increase in the machine utilization in an automotive plant. Montevecchi et al. (2007) show the meaning of simulation experiments representing different scenarios and company strategies. In the following text we present the manufacturing problem in company Alteko, Inc. dealing with the production of radial ventilator fans. The contract of producing 50 pieces is the subject of our investigation. As the company has no experience with simulation models we were asked to help them with it. First, a conceptual model will be created. The whole production process is divided into individual activities being executed on corresponding work centers and using prescribed resources. Then, a simulation model will be developed in the environment of SIMUL8. After debugging the model, results obtained from the simulation runs should show the bottleneck parts of the system and possibilities of improvements. The experiments will be performed with the objective to suggest the management the most responsible decision.

SIMUL8

SIMUL8 is a software package designed for Discrete Event Simulation or Process simulation. It has been developed by the American firm SIMUL8 Corporation (www.simul8.com). The software has started to be used in 1994 and every year a new release has come into being with new functions and improved functionality. It allows user to create a visual model of the analyzed system by drawing objects directly on the screen of a computer. SIMUL8 belongs to the simulation software systems that are widely used in industry and available to students (Greasley 2003). This software is suitable for the discrete event simulation but usually it is not used for the simulation of a production. So the task was if it can be a suitable environment for the given situation. Contrary to similar simulation software like Witness or Plant Simulation (Greasley 2003; Bangsow 2010) that are more suited for the production modelling via 3D animation, SIMUL8 uses 2D animation only to visualize the processes. It is similar to SIMPROCESS which is also aimed at the discrete even simulation (Douhý et al. 2011) but we decided to use SIMUL8 because of the easier way of the queue modelling. On the other hand it is a challenge to create a production model in this software. SIMUL8 operates with 6 main parts out of which the model can be developed: Work Item, Work Entry Point, Storage Bin, Work Center, Work Exit Pont, Resource (Concannon et al. 2007).

Main components

Work Item: dynamic object(s) (customers, products, documents or other entities) that move through the processes and use various resources. Their main properties that can be defined are labels (attributes), image of the item (showed during the animation of the simulation on the screen) and advanced properties (multiple Work Item Types).

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Work Entry Point: object that generates Work Items into the simulation model according to the settings (distribution of the inter-arrival times). Other properties that can be used in this object are batching of the Work Items, changing of the Work Items! Label or setting of the following discipline (Routing Out).

Storage Bin: queues or buffers where the Work Items wait before next processes. It is possible to define the capacity of the queue or the shelf life as a time units for the expiration.

Work Center: main object serving for the activity description with definition of the time length (various probabilistic distributions), resources used during the activity, changing the attributes of entities (Label actions) or setting the rules for the previous or following movement of entities (Routing In / Out).

Work Exit Point: object that describes the end of the modeled system in which all the Work Items finish its movement through the model.

Resource: objects that serve for modelling of limited capacities of the workers, material or means of production that are used during the activities.

SIMUL8 uses various graphic components and 2D animation for a process representation. As the simple illustration (created in older version of SIMUL8) we show the model of petrol station that is used at seminars at the University of Economics in Prague (Dlouhý et al, 2011) - Figure 1.

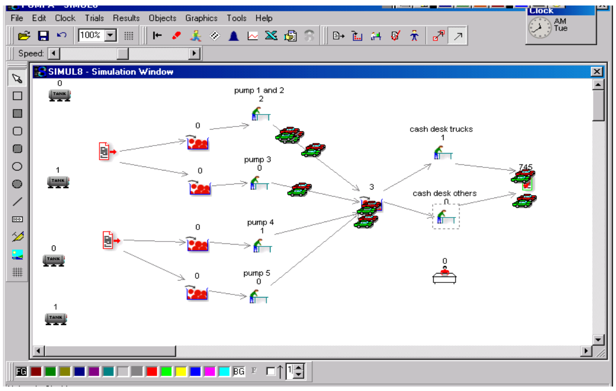

Figure 1: Simulation model of a petrol station in SIMUL8

All objects (except resources) are linked together by connectors that define the sequence of the activities and also the direction of movement of Work Items. The sequence is clear from the Figure 1: there are two Work Entry Points out of which the Work Items (cars) can go to four queues (Storage Bins) waiting to fuel up (four Work Centers), then all continue to one queue (Storage Bin) for two cash desks (Work Centers) and then they are leaving the system (Work Exit Point). All the resources (4 pumps and cash desk) are used during the activities but they are not linked by a line with the other objects.

After the system is modelled, simulation run follows. The animation shows the flow of items through the system and for that reason the suitability of the model can be easily assessed. When the structure of the model is verified, a number of trials can be run under different conditions. Then, the performance of the system can be analyzed statistically. Values of interest may be the average waiting times or utilization of Work Centers and Resources (Shalliker and Rickets 2002).

SIMUL8 can be used for various kinds of simulation models (Concannon et al. 2007). The case studies can be seen also on the website www.simul8.com.

Our experience shows that SIMUL8 is easy to learn (especially when the main components are used without the necessity to use Visual Logic (with different programming functions). It can serve not only for the modelling of different services (Dlouhý et al. 2011), but also for the simulation of various production processes (Ficová and Kuncová 2013).

PROBLEM DESCRIPTION

One of assembled products is low-pressure radial ventilator fan RFC (Figure 2). It is produced in several designs and sizes, in contribution RFC 200 is analyzed. Company Alteko, Inc. characterizes it as follows (2017): „Low-pressure radial fans RFC are one-side suction fans driven directly by flange-mounted motors (IP55). RFC fans are designed for air exchange in residential and industrial premises. The RFC fans may not be used for transporting the air which includes aggressive agents, abrasive additives and fibrous particles. The temperature of transported air may fluctuate between -30 °C into + 85 °C (by fans Ex - 30°C into +40°C)."

Figure 2: Radial fan RFC 200, company ALTEKO, Inc.

MODELLING OF PROCESS

The objective of the computer simulation is to observe whether it is achievable to produce 50 pieces of fans within 30 working days at present production level. The production process belongs to the longest activities in the contract. Based on the analysis using project management and PERT method (Fousek 2016), it has been found out that the production takes about 50 % of the total time to perform the contract. From this point of view, it is necessary the production duration does not exceed 15 working days. The exploration of the utilization of resources is also an integral part of the analysis. As the input entity (Work Item) used in the model we defined material that is continuously processed and assembled with other components and semi-finished products. JIT delivery is not the subject of the model, because the strategy of the company gives sufficient amount of material to the production process. Shift calendar is fixed to 8 net working hours per week (5 working days); breaks and disorders are omitted. Based on the consultation with the director of the company, availability of all workers at the contract was set to 50 % in the first level.

In production process the following resources are temporarily used: machines, work centers and various operators (see Table 1). Because some workers operate at more centers or machines, it was necessary to estimate their movement and its duration.

Table 1: List of resources for RFC 200

Machine / Work center	No. of machines	Operator (ID)
Trumatic	2	2
Cutting	1	3
Folding hub	1	3
Stamp	3	4
Balancer	1	5, 6
Spinning lathe	1	1
Folder	1	7
Lath	2	8, 9
Driller	5	3
Assembling	0	10
Spot weld	2	11
Bending	1	12
Testing room	0	13
Engine depot	0	14
Store	0	14

Assembling of fan requires the sequence of jobs with fixed durations, but after the consultation with workers they were approximated by uniform (UNI) or triangular (TRI) probability distribution. Table 2 summarizes this assignment to resources and work centers with two exceptions determined on the base of the exact calculation (Fousek 2016). These are a transport of engine from warehouse and shipping the final product to the warehouse of finished goods.

Table 2: List of resources, work centers and distribution of jobs duration

Job	Machine / Work center	Operator	Dist. (min)
Bearing plate (1) cutting out	Trumatic	2	UNI (2, 3)
Bearing plate (2) cutting out	Trumatic	2	UNI (2, 3)
Bearing plate (1) turning	Lathe	8, 9	UNI (7, 10)
Liner turning	Lathe	8, 9	UNI (2, 5)
Engine – transport from depot	Engine depot	14	2,07
(M1:) Bearing plate assembly + engine	Assembly	10	TRI (10, 12, 15)
(M2): Assembly (M1) + liner	Assembly	10	UNI (1, 2)
Turning	Lathe	8, 9	UNI (10, 15)
Drilling hub	Lathe	8, 9	UNI (5, 8)
Lathing hub	Lathe	8, 9	UNI (3, 7)
Grooving hub	Groover	7	UNI (7, 8)
Drilling hub	Driller	3	UNI (4, 5)
Cutting blades	Scissors	3	UNI (2, 3)
Stamping blades	Stamper	4	UNI (4, 8)
Dinking cover plate	Trumatic	2	UNI (2, 3)
Assembling rotor wheel and hub	Balancer	5, 6	TRI (10, 15, 21)
Balancing rotor wheel and hub	Balancer	5, 6	TRI (5, 10, 14)
(M3): Assembling (M2) + rotor wheel	Assembler	10	TRI (2, 3, 6)
Dinking pipe mouth	Trumatic	2	TRI (2, 3, 6)
Spinning pipe mouth	Spinning lathe	1	TRI (4, 5, 7)
Cutting plate	Scissors	3	UNI (5, 6)

Folding	Folder	3	UNI (3, 4)
Bending	Bending rolls	12	UNI (3, 5)
Dinking sideboards	Trumatic	2	UNI (4, 6)
Sideboards and right box spot weld	Spot welder	11	UNI (10, 14)
Sideboards spot weld finish	Spot welder	11	UNI (3, 4)
Cutting frames	Scissors	3	UNI (3, 6)
Bending frames	Stamper	4	UNI (4, 6)
Framework spot weld	Spot weld	11	UNI (4, 6)
Angle plate corner bracket pressing	Press	4	UNI (2, 6)
Sideboards and right box spot weld ("spiral")	Spot weld	11	TRI (4, 6, 9)
(M4): Intake port assembly + "spiral"	Assembly	10	TRI (5, 6, 8)
(M5): Assembly (M3) + (M4)	Assembly	10	TRI (10, 12, 16)
Handrail assembly	Assembly	10	TRI (5, 6, 9)
Functionality testing	Testing room	13	UNI (4, 6)
Dispatch to store	Store	14	1,17

MODEL IN SIMUL8

The simulation model was developed in SIMUL8 software. During the modelling process it was necessary to define times for movements of operators between work centers (company data was explored – Fousek 2016). Figure 4 shows the scheme of the whole model.

In verification step it was necessary to check whether the ideas from conceptual model were correctly transformed into computer simulation model. We concentrated on queueing congestion due to wrong way of modelling or real foundation of lower utilization of resources. All factors seemed to be taken into account correctly. Exactly 50 units of RFC 200 entered the system at once. All resources were used in the model that is proved in Table 3. Jobs dependent on resources movement (Operator 3_ Trimmer, Folder, Driller and Operator 14_Transfers), were actually started after workers moved to the required work center.

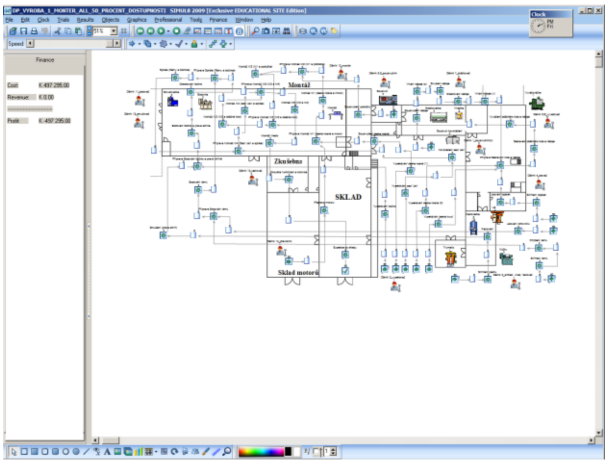

Figure 4: Production Model in SIMUL8

The model is classified as the model with finite horizon, because exact simulation time is stated (14 400 minutes, i.e. 30 working days). Although we know 15 days should be the maximal time for the production we set 30 days as the total maximum to meet the order to see where are the time limits of the production. However, simulation run can be ended earlier in case all fans have been finished. To eliminate negative random events we performed 100 simulation runs with derived 95 % confident intervals for watched random variables.

COMPARISON WITH THE REAL SYSTEM

Despite correctly specified parameters, fixed availability level 50 % for all operators can differ in reality due to utilization of workers by other tasks in other contract activities. Therefore, it is the value that can fluctuate in real system according to a number of contracts and their capacity requirements. On the contrary, according to experience, total production time for producing 50 fans RFC 200 approximately corresponds the situation all operators are busy at the contract on 50 % of their working time.

Total production time is 4876.84 minutes that is 81.28 working hours, i.e. 10.16 working days. The 95 % confidence interval for total production time is <4854.60, 4899.08> minutes, i.e. 10-11 days. In this situation the limit of 15 days necessary for finishing contract would not be exceeded.

Assembly operator is the busiest one, at 94.14 % (Table 3). The assembling utilization is 94.47 % what is, according to available information, close to real experience. The utilization of other resources seems to stay in acceptable range, no one is busy over 80 %. On the contrary, the least-busy resource is obviously the drill (51 %) because there are 5 drills available and only one short job needs this type of resource. Exploring the work centers utilization in detail, we find out the analogous situation in case of jobs requiring the assembly. They are in the waiting mode in major time of the process (as the assembly operator is busy). For example, assembly M2 (M1 and bearing plate) waits 90.37 % of time for the resource (assembly operator) and 8.09 % of time for the entity and only 1.54 % of time it works. The job which has, in comparison with other jobs, the highest proportion of work performed, is assembling rotor wheel and hub (15.70 %). However, more than half of the production time it waits for the entity what concerns of most jobs with the exception of assemblies mentioned above. Assembly logically starts when all components are available. In addition, operations on this work center are most time-consuming ones. It leads to high utilization of resources and consequent generation of long queues.

Table 3: Resource Percent Utilization (Util.)

Resource	**No. of resources**	**Util. (%)**
Spot welder	2	63.79
Operator 1_Turner	1	55.45
Operator 10_Assembly	1	94.14
Operator 11_Spot welder	1	77.27
Operator 12_Bender	1	54.23
Operator 13_Tester	1	55.16
Operator 14_Transfers	1	53.09
Operator 2_Cutting	1	66.78
Operator 3_Trimmer, Folder, Driller	1	72.19
Operator 4_Presser	1	65.18
Operator 5,6_balancing	2	62.75
Operator 7_Scrubbing	1	57.62
Operator 8,9_Turner	2	68.40
Scrubbing tool	1	57.61
Folder	1	54.01
Presser	3	55.06
Assembly	1	94.47
Cutting	1	63.30
Bending	1	53.97
Lathe	2	68.41
Spinning lathe	1	55.53
Trumatic	2	58.45
Drill	5	51.00
Balancing tool	1	75.70

EXPERIMENTS WITH MODEL

According to previous analyzes, the simulation model obviously shows that the assembly is the bottleneck of the whole production process. There is only one operator that is enormously utilized. In computer experiments another operator was added to assemble products. In addition, lower availability of resources was tested (40 % a 30 %). Table 4 shows results for 100 experiment runs.

Table 4: Resource Percent Utilization When Available

Experiment	Confidence interval (hours)		Average production time (hours/days)
	Min	Max	
1 worker 50%	80.91	81.65	81.26 / 10.16
2 workers 50%	46.46	47.00	46.73 /5.84
1 worker 40%	103.03	104.10	103.56 / 12.95
2 workers 40%	58.73	59.47	59.10 / 7.39
1 worker 30%	**142.32**	**144.26**	**143.31 / 17.91**
2 workers 30%	80.32	81.60	80.96 / 10.12

From the results in Table 4 it is clear that if only one operator would be available and his availability is 30 %, the contract would not be finished in time. Therefore, the company must be very cautious in case of realizing parallel contracts to assure the availability at 40 – 50 %, or it should consider to hire an additional operator to assembly job.

CONCLUSION

The aim of the contribution was to demonstrate the applicability of SIMUL8 even in modelling of production processes, for which it is not quite eligible software (e.g. in comparison with Plant Simulation or Witness). According to our experience we can conclude that this software can be used to model the production process - with some simplifications of the reality and with a few special settings forced by SIMUL8. The model, used for the production of 50 radial fans RFC 200 in company Alteko, Inc. was developed on the basis of available information given by employees and obtained from the company's internal documentation. The simulation model should have shown whether it is realistic to perform the contract in 15 days considering the realization of parallel contracts. Although the situation was slightly simplified (e.g. fixing of the percent availability of operators), model corresponds the real situation and proves a possibility to finish the production within required 15 days in case the operator working at bottleneck work center (assembly) would not be engaged in other jobs more than 60 % of his working time. The results recommend to managers what they must concentrate on and what contracts can be parallelized with the analyzed contract. The main success we see in the fact that we have not only created the model to find the solution but we have persuaded the managers of the usability and the advantage of the simulation itself.

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REFERENCES

Aguirre, A., and C.A. Mendez. 2008. "Applying a Simulation-based Tool to Productivity Management in an Automotive-parts Industry". In *Proceedings of the 2008 Winter Simulation Conference*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, 1838-1846.

Alteko. 2016. "Radiální ventilátory s přímým pohonem RFC, RFE". ALTEKO. [Online] [Cit: 2016-04-08] Available:http://www.alteko.cz/922_100020-radialni-ventilatory-s-primym-pohonem-rfc-r.

Bangsow S. 2010. *Manufacturing Simulation with Plant Simulation and SimTalk*. Springer-Verlag Berlin Heildelberg

Banks, J., 1998. *Handbook of Simulation*. USA, John Willey & Sons

Concannon, K. et al. 2007. *Simulation Modeling with SIMUL8*. Visual Thinking International, Canada.

Dlouhý, M., Fábry, J., Kuncová, M. and T. Hladík. 2011. *Business Process Simulation* (in Czech). Computer Press.

Ficová, P. and M. Kuncová. 2013. „Looking for the equilibrium of the shields production system via simulation model". In *Modeling and Applied Simulation 2013*. (Athens, Sept. 25-27). Genova : DIME Universita di Genova, 50–56.

Fousek, J. 2016. „Využití simulačních modelů a programů k analýze a zlepšení chodu výrobního podniku". Master Thesis, University of Economics, Prague.

Greasley, A. 2003. *Simulation modelling for business*. Innovative Business Textbooks, Ashgate, London.

Kuncová, M. and P. Wasserbauer. 2007. „Discrete Event Simulation – Helpdesk Model in SIMPROCESS". In *ECMS 2007* (Prague, June 4-6). Dudweiler : Digitaldruck Pirrot, 105–109.

Law, A. 2000. *Simulation Modelling and Analysis. Boston (USA),* MC-Graw Hill

Masood, S. 2006. Line balancing and simulation of an automated production transfer line, *Assembly Automation*, Vol. 26 Iss: 1, 69 – 74.

Montevechi, J. A. B., et al. 2007. Application of design of experiments on the simulation of a process in an automotive industry. In *WSC'07 Proceedings of the 39th Conference on Winter Simulation*, IEEE Press Piscataway, NJ, USA, 1601-1609.

O'Kane, J.F. et al., 2000. Simulation as an essential tool for advanced manufacturing technology problems. *Journal of Materials Processing Technology* 107/2000, 412-424

Shalliker, J. and C. Ricketts. 2002. *An Introduction to SIMUL8, Release nine*. School of Mathematics and Statistics, University of Plymouth.

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