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ANALYSIS OF SHOP FLOOR MACHINE PARTS MANUFACTURING THROUGH DISCRETE EVENT SIMULATION

BY

EUGEN CARATA*

"Gheorghe Asachi" Technical University of Iaşi,
Faculty of Machines Manufacturing and Industrial Management

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Abstract. Existing model of manufacturing unit was developed and simulated using Arena v.15 simulation package. The job shop production unit were analysed and existing setup bottlenecks were identified in the process. Simulation-based model was developed using Arena 15 simulation package and generated results were tested with real job shop manufacturing. All the values used in the comparison were generated by simulation in Arena 15 at 95% confidence level and validated *i.e.* 65 replication lengths for 30 days run length. This paper provides a verified and validated model to the problem related to resource utilization.

Keywords: DES; ARENA; job shop; simulation; validation.

1. Introduction

Simulation is a useful tool for the manufacturing process. Manufacturing simulation have a positive impact on the manufacturing industry. In manufacturing environment, material movement is controlled by

*Corresponding author; *e-mail*: eugen.carata@academic.tuiasi.ro

various factors. A simulation technique for modeling, analyzing, and optimizing manufacturing systems is discrete-event system simulation (Barlas and Heavey, 2016; Negahban and Smith, 2014; Prajapat and Tiwari, 2017).

Discrete Event Simulation (DES) method has applicability in areas of manufacturing: cellular manufacturing systems (Erenay *et al*., 2015), material handling systems (Meng *et al*., 2013), sustainable manufacturing systems (Caggiano, 2016), quality inspection (Korytkowski and Wisniewski, 2012), planning and scheduling operations (Xu *et al*., 2016), maintenance operations (Paprocka *et al*., 2014; Alrabghi and Tiwari, 2016) inventory management, transportation (Awasthi and Chauhan, 2009). Collaboration of the manufacturing systems with supply chain systems has shifted on working in the achievement of sustainability in a variety of manufacturing systems (Altiok and Melamed, 2010). Supply Chain Management triggers orders of materials and semi-finished parts at suppliers, which are further processed by manufacturing plant to the production of finished products. In this study, the job shop manufacturing process is modelled and simulated.

This study provides a verified and validated model to the problem related to resource utilization. First, existing model of manufacturing unit was developed and simulated using Arena v.15 simulation package.

2. Production Scenario, Model Development and Simulation of Job Shop

Job shop manufacturers parts of three types namely, Longitudinal feed table (P1), Transversal feed table (P2) and Bed (P3). The layout of Job shop comprises of location as following:

– Arrival Station;

– Cell 1 for preparation, guideways plating and threading;

– Cell 2 for milling/ boring/ drilling;

– Cell 3 for stress relief/paint shop;

– Cell 4 for planer;

– Cell 5 for grinding;

– Cell 6 for quality inspection.

Table 1 depicts the operation sequence for each part type along with processing time at each stage of operation.

Table 1
Operation Plan (by Type)

Type of Part	Sequence of operations	Mean Time to process (minutes)
P1	Cell1	150
	Cell2	1000
	Cell3	110
	Cell2	1100
	Cell1	72
	Cell2	310
	Cell5	710
	Cell1	1200
	Cell2	1100
	Cell5	600
	Cell2	800
	Cell6	240
P2	Cell1	120
	Cell2	2000
	Cell3	110
	Cell2	450
	Cell4	60
	Cell1	360
	Cell2	1600
	Cell1	420
	Cell5	300
	Cell6	240
P3	Cell1	210
	Cell4	420
	Cell2	400
	Cell4	1500
	Cell3	110
	Cell2	810
	Cell1	2500
	Cell2	250
	Cell5	1900
	Cell2	300
	Cell1	210
	Cell6	240

Simulation package used in while the development of models is ARENA 15 (Rockwell Automation). System represents manufacturing of parts P1, P2, P3 starting with raw material and ending as a finished product. Parts (Entities) per arrival indicates that between two consecutive arrivals follows uniform distribution between 2880 and 2890 min. The randomness of the simulation allows a statistical estimation of the performance measurement. The following parameters are specified: Job Shop produces 33% of P1, 33% of P2, and 34% of P3. Replication length of each simulation run: 30 days (1 month); Count of independent simulation Runs: 65; Work hours for which simulation done: 24 h per day. Key parameters under consideration are:

– Product flow time;
– Number In/Out;
– Resources utilization;
– Number waiting in queues
– Work in process (WIP);

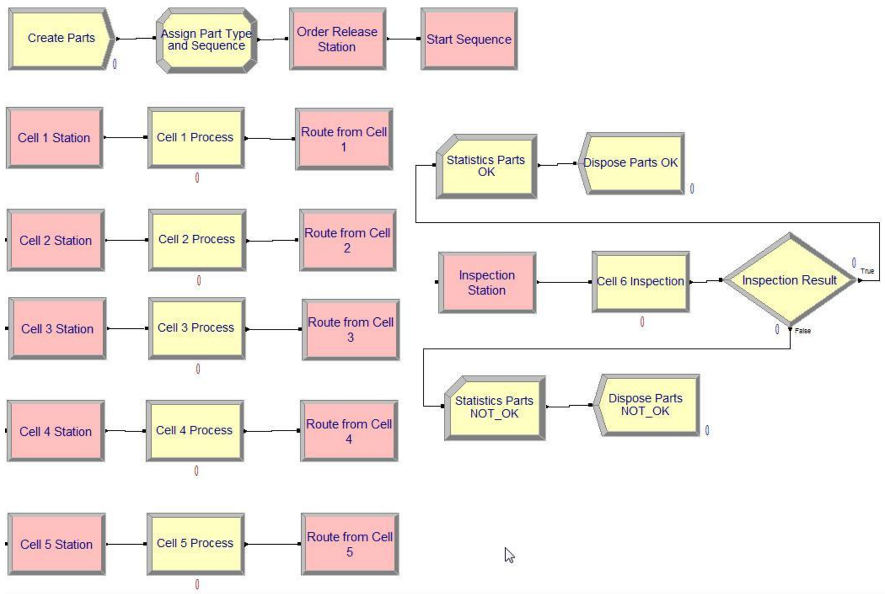

Fig. 1 – Arena model of job shop manufacturing

Table 2
Flow Time of Parts Manufactured [minutes]

Flow time	Average	Maximum	Real Job Shop
Part P1	7066.01	7080.48	
Part P2	5658.26	5663.22	
Part P3	8840.09	8854.82	

Table 3
Parts Number In/Out

	Number In	Number Out	
Part P1	6	4	
Part P2	3	2	
Part P3	6	3	

Overall Arena model composing of all operations performed at job shop manufacturing is shown in Fig. 1. After arrival, each entity proceeds as single unit. The results are presented in Tables 2, 3, 4, 5 and 6.

Table 4
Resource Utilization Model for 30 Days Replication

Cell	Average	Maximum
Cell1	0.5440	1.0
Cell2	0.8930	1.0
Cell3	0.0328	1.0
Cell4	0.2822	1.0
Cell5	0.3102	1.0
Cell6	0.0498	1.0

Table 5
Number Waiting in Queues for 30 Days Replication

Cell	Average	Maximum
Cell1	0.6307	6.0
Cell2	1.1943	4.0
Cell3	0.0050	1.0
Cell4	0.0532	1.0
Cell5	0.0015	1.0
Cell6	0.0038	1.0

Table 6
Work in Process (WIP) for 30 Days Replication

Heading	Average	Maximum
Part P1	1.0307	3.0
Part P2	0.8703	2.0
Part P3	2.1244	5.0

3. Verification and Validation

In job shop manufacturing process, the verification of model is a process for number of replications it makes. The interval of confidence is assumed to be greater than 95%. The number of replications of simulation was calculated by the formula (Kelton *et al*., 2015):

$$n = \frac{(z_{\alpha/2})^2}{d^2}\sigma^2 \quad (1)$$

where: n – replications required, d the sensitivity level; σ – standard deviation; z – critical value from the standard normal table at the assumed confidence level. For job shop model to achieve 95% confidence level, 65 replications are required.

For validation, the total of parts produced per 30 days was selected as the simulation model's output variable. Thus, the model was run for 30 days of production, with 65 replicates each. The value for 30 days of the output variable was determined using the average from the 65 replicates. The data of the simulation results and real production are presented in Table 7.

Table 7
Parts Produced per 30 Days

Parts	Model ARENA Average 65 replicates	Real system Average 3 months
Part P1	4	3
Part P2	2	3
Part P3	3	3

4. Conclusions

The existing job shop production unit were analysed and existing setup bottlenecks were identified in the process. Simulation-based model was developed using Arena 15 simulation package and generated results were tested with job shop manufacturing mentioned in the case study. All the values used in the comparison were generated by simulation in Arena 15 at 95% confidence level and validated *i.e*. 65 replication lengths for 30 days run length.

Discrete-event system simulation is a powerful tool for modeling and analyzing manufacturing systems. It has a good record of applications in the industrial sector. This study illustrates the benefits of the time/cost tradeoff, including the potential advantage of achieving good service levels and helping companies avoid making unnecessary investments.

Presented work scope can be to improve the cost associated with transportation and resources running cost.

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ANALIZA PROCESULUI DE PRELUCRARE ÎNTR-O SECȚIE DE PRODUCȚIE A UNOR PIESE TIP CARCASĂ FOLOSIND SIMULAREA CU EVENIMENTE DISCRETE

(Rezumat)

Lucrarea analizează procesul de prelucrare a unor piese tip carcasă într-o secție de producție din construcția de mașini. Sosirea semifabricatelor pentru trei piese diferite se face după o lege uniformă. Fiecare tip de semifabricat urmează un traseu tehnologic distinct, care se încheie cu un post de control de calitate. Modelul realizat prin simularea cu evenimente discrete a fost dezvoltat folosind mediul de simulare ARENA v.15. Toate valorile utilizate în comparație au fost generate prin simulare în Arena 15 la un nivel de încredere de 95% și validate, realizând 65 de replicări pentru o durată de 30 de zile lucrătoare. S-au obținut valori medii pentru timpul total de prelucrare, pentru fiecare tip de piesă, numărul de semifabricate intrate în sistem și de piese finite realizate în

perioada de simulare, gradul de utilizare a fiecărei celule de producție, lungimea medie și maximă a firelor de așteptare pentru fiecare post de lucru și numărul de piese aflat la un moment dat în proces (WIP). Rezultatele generate de simulare au fost comparate cu rezultatele reale obținute în secția de producție studiată rezultând o bună concordanță.

Pe viitor se dorește continuarea analizei procesului de producție studiat prin propunerea de variante de îmbunătățire a eficienței prin utilizarea de scule mai performante, care să ducă la timp de prelucrare mai mici și de studiere a eficienței economice dată de capacități noi de producție pentru posturile cu o încărcare foarte ridicată. De asemenea, se propune studiul costurilor asociate cu timpul de prelucrare și transport între celulele de producție precum și influența duratei de mentenanță pentru fiecare celulă.