(REFEREED RESEARCH)

A STOCHASTIC MODEL TO DETERMINE THE ELEMENTS OF PRODUCTION CYCLE TIME IN TEXTILE INDUSTRY IN SERBIA

ÜRETİM ÇEVRİM ZAMAN ELEMENTLERİNİN SIRBİSTAN TEKSTİL ENDÜSTRİSİNDE BİR STOKASTİK MODEL İLE TESPİTİ

Sanja STANİSAVLJEV[1], Milivoj KLARİN[2], Vesna SPASOJEVİĆ BRKİĆ[3], Dragan ĆOĆKALO[4], Dejan ĐORĐEVİĆ[5]

[1]*University of Novi Sad, Technical faculty "Mihajlo Pupin" in Zrenjanin 23000 Zrenjanin, Djure Djakovica bb, Republic of Serbia*

[2]*University of Novi Sad, Technical faculty "Mihajlo Pupin" in Zrenjanin 23000 Zrenjanin, Djure Djakovića bb, Republic of Serbia*

[3]*University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, Republic of Serbia*

[4]*University of Novi Sad, Technical faculty "Mihajlo Pupin" in Zrenjanin 23000 Zrenjanin, Djure Djakovica bb, Republic of Serbia*

[5]*University of Novi Sad, Technical faculty "Mihajlo Pupin" in Zrenjanin 23000 Zrenjanin, Djure Djakovica bb, Republic of Serbia*

Received: 10.03.2015 Accepted: 09.09.2015

ABSTRACT

This paper presents a model for the stochastic determination of the elements of production cycle time is proposed and experimentally verified in this survey. The originality of the model is reflected in the idea of using a work sampling model to monitor the production cycle, as one of the most significant indicators of production effectiveness and efficiency, instead of applying classical methods. Based on experimental investigations in this paper has been proved that in the practice of small and medium-sized enterprises with serial production it is possible to design and apply a very simple but accurate enough stochastic model to determine the elements of working cycle time and in this way optimize the duration of production cycle time. Proposed stochastic model uses mean value calculations to establish control limits on 3 standard deviations for the individual elements of working time and thus to master the process. It is proposed that further investigations should focus on the application and testing of the model in other types of production, for example, assembly and the like and also at the problem of reducing the elements of transport time. The model was applied and involved a larger number of Serbian enterprises. The results obtained for two characteristic textile enterprises will be presented in this paper.

Keywords: Production cycle, work sampling, stochastic determination of the elements of production cycle time, textile industry.

Corresponding Author: Sanja Stanisavljev, sanja@tfzr.uns.ac.rs

1. INTRODUCTION

The most important organizational-technical indicators of production successfulness are the level of capacity utilization and the production cycle. These indicators are actually influenced by a series of organizational-technical, mutually interconnected, factors which impact on the elements of working time related to the machine capacity utilization and production cycle of a certain product. The goal is, in general, to reduce the total production cycle time, especially that associated with different types of stoppage and the optimization of lead time and machine time within the sphere of machine capacity utilization. Additionally, the optimization of time for transport, control, and packing is also of importance for the production cycle. Reduced cycle time can be translated into increased customer satisfaction. Quick response companies are able to launch new products earlier, penetrate new markets faster, meet changing demand, and make rapid and timely deliveries. They can also offer their customers lower costs because quick response companies have streamlined processes with low inventory and less obsolete stock.

Consequently, the aim of this paper is to set up and prove a model for the stochastic determination of the elements of production cycle time, that consequently will be able to be optimized to increase customer satisfaction. Using a modified work sampling method, it has been experimentally proved in this paper that for a corresponding representative set the elements of working time range according to normal distribution law. Also, dynamically viewed, it is possible, using mean value calculations, to establish control limits on 3 standard deviations for some individual elements of working time and thus to master the process.

2. LITERATURE REVIEW

In the past, in both theory and practice (1),(4),(5) ,(6) and (7) increased attention was focused on the level of machine capacity utilization because machines were more costly and thereby had a greater impact on production effectiveness. A special contribution here was made by L. H. C. Tippet (1) who first applied his method of work sampling in the textile industry . Nevertheless, the classical work sampling method established by Tippet is not appropriate for contemporary production systems, because in his research the main stoppage was due to poor material quality. Despite its shortcomings, this method is still used in production practice and is found in all industrial engineering text-books. The indispensable modification of the method presented in aims to explain and justify both the necessity and importance of using the shift level of the utilization of capacity as the stochastic variable in determining the total level of capacity utilization in the production process by using the method of work sampling on a sample comprising 74 Serbian companies. The conclusion drawn is that the shift level of capacity utilization as the stochastic variable in work sampling is the model which solves the problem of determining the total level of capacity utilization in a convenient way with accurate results. On the other hand, on the basis of, Elenkave & Gilad propose a digital video-based approach to enhance work measurement and analysis by facilitating the generation of rapid time standards, which serves as a computerized tool for remote work measurement with the ability to derive the rapid generation of time standards. The application of the modified work sampling method in the processing industry indicates that the methods of monitoring capacity utilization applied in the processing industry such as cement production may also be used in the metalworking industry which has a high level of capacity utilization. Hence, the results of the analysis indicate that when the level of capacity utilization is high, this variable may be observed per day as stochastic, while, per machine, it may be a random variable (6). It is evident that today the more significant problem of monitoring and influencing the production cycle (the period from the item’s entry into the production process to the receipt of a finished product and its packing) is by far less present in the literature.

In (7) an experimental example illustrates the determination of the elements of production cycle time, showing that production cycle C is divided into only three elements of cycle time, $C = T_1 + T_2 + T_3$

T_1 = running time to produce one unit of output,

T_2 = normal time to service a stopped machine,

T_3 = time lost by normal operator working because of machine interference.

Screening performance requires the precise definition not only of technological and mathematical problems, but also of the practical screening process and the establishment of working time elements. Thereafter, the elements of production cycle working time should be defined and, in particular, the difference against the elements of working time related to machinery, i.e. for the purpose of establishing the machine capacity only or within the production cycle, because these two are not the same. The elements of working time are determined according to the references (2),(3) and (13). Theoretically speaking, the sequence of operations may be serial, parallel or combined. Therefore, depending on the type of sequence of operations, we know in advance that this portion of cycle time lasts much longer in a serial type, where before moving on to the next operation the whole series waits to be completed by a single machine operation, while in a parallel type, after one machine part is completed on one machine, it immediately moves on to the next. In companies, the most common type of sequence of operations is combined. Not infrequently, one part of the production cycle is parallel, another serial, and a third combined. Technological machine time ttm, viewing production against machinery, is exclusively linked to machine performance and the quality of technological calculations, and is mainly a deterministic category. However, if the production cycle is viewed from the aspect of a serial sequence of operations, the elements of working time differ, depending on the automation level. If production is automated, then ttm for a series will be simply a sum of individual n equal operations. However, if each part has to be manually or mechanically conveyed for processing from a joint crate or some other room where a certain series of parts is stored, manual placement on the machine is ancillary manual time – tpr (in theory, this refers to individual pieces). Such time is not frequently encountered in literature pear examples are papers (5) and (7) dealing with the division of working time elements. In our investigations, ancillary manual time will be treated as technological machine time – ttm. It is also logical to add ancillary machine time (for example, support moving a lathe) to ttm. Manufacturing lead time includes receipt of work order with documentation and study of tasks, receipt of equipment, preparation of other components necessary for work, transport of finished pieces for quality control and cleaning up of work place, after a certain number of pieces (n) are manufactured, one at a time, non-stop (number of pieces in a series).

In paper (14) an approach to improve MRP-based production planning by means of targeting minimal product cycle times is presented. A number of works (8) and (9) consider the impact of machine breakdown on production cycle time, while Barbiroli & Raggi (10) studied technical and economic performances related to innovations in the production cycle environment. An inventory model is linked with production cycle optimization in (11), whereas paper (12) gives an optimal algorithm for minimizing production cycle time for assembly lines, using linear mathematical programming which requires extensive calculations.

3. MATERIAL AND METHOD

The production cycle is the period from the entry of a product part or a series of products into manufacturing to their receipt in the warehouse of finished products (or parts). The production cycle is indirectly dependent on the factors of the total supply-sales cycle as its part, but some elements of cycle time are also mutually influential. For example, any increase in the supply time for parts from cooperating companies leads to a stoppage in the production cycle.

For the purpose of analysis, the production cycle is essentially divided into production time – t_p and non-production time t_{np}. More details can be found in literature (13) Non-production time involves diverse stoppage factors related directly or indirectly to man's positive or negative attitude towards production. These stoppages, characteristic of small and medium-sized enterprises in the metalworking industry, are, as a rule, longer than the necessary production times and are more difficult to shorten. The optimal production cycle is that which is the shortest for the same product quality and price. The most common division of production cycle time in literature is presented in Fig. 1 based on (13) and (17).

Models based on stochastic functions, or instantaneous observation methods (work sampling). Our research is directed at designing a new original method for monitoring the production cycle and its time elements by using a stochastic work sampling method, whose basis was set up by Tippett. However, this method we innovate and adapt to research the production cycle.

A modified work sampling method enable the determination of the participation percentages of working time elements against the total duration of the production cycle and production. As this method is statistic and is based on a certain number of instantaneous observations of a certain activity, it is simpler to use and more efficient than the continual streaming method. Monitoring within the production cycle involve technological time with lead time and manufacturing time, non-technological time with times for transport, control and packing, while non-production time includes stoppage due to poor production organization, lack of materials, lack of tools, including the failure or breakdown of machinery and other types of stoppage, their interdependence, as well as impact factors such as series size, organizational level and product characteristics pertaining to the factors mentioned. A data sheet for the application of the method to determine the elements of production cycle time is shown in Table1.

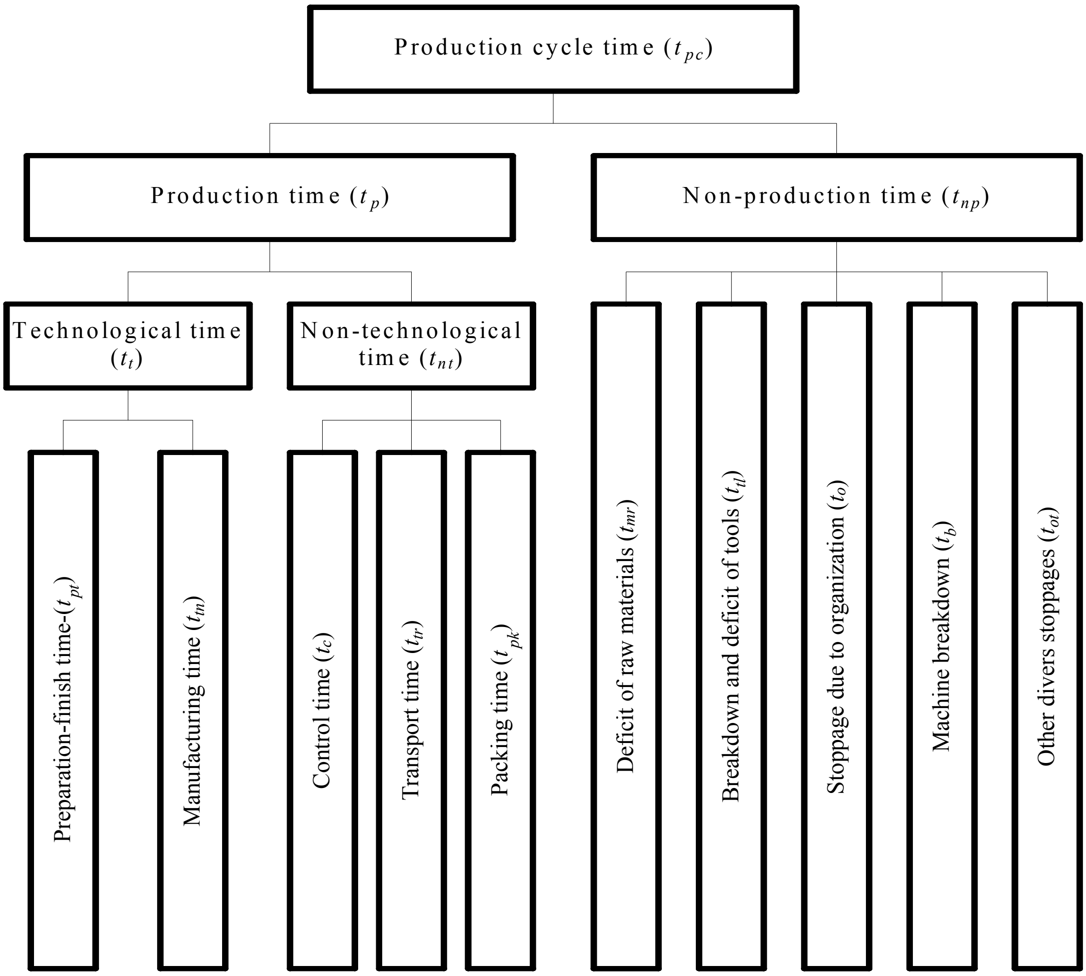

Figure 1. Production cycles elements

Table 1. Data sheet for the application of the method to determine the elements of production cycle

N_o	Time		Production time					Non-production time				
	Hour	Minutes	t_{pt}	t_{tn}	t_c	t_{tr}	t_{pk}	t_{mr}	t_{tl}	t_o	t_b	t_{ot}
1												
….												
N												
Σ												

Representative screening time is related to the length of the production cycle time. It is clear that it must not be shorter than the production cycle time and that under identical production conditions it must be repeated a certain number of times in order to make the sample representative. Production and productivity are also related to the production dynamics which are planned at the operational level on a daily, weekly or monthly basis. Hence, the production cycle for the above mentioned periods is also provided for the purposes of monitoring and comparing. The third criterion for determining screening time duration is the adopted margin of error in the stochastic model applied in these investigations, i.e. the number of instantaneous observations and their distribution per working time element.

4. RESULTS AND DISCUSSION

The model was applied and involved a larger number of Serbian enterprises. The results obtained for characteristic textile enterprises are presented.

The experiment is related to a plant that produces military and firemen clothing. The results of cycle monitoring are represented by diagrams only in Figs 2. Screenings were carried out from September 27, 2011 to November 13, 2011. Monitoring comprised 26 production cycles of different types of clothing and different series sizes, from 9 – 117 pieces, with time durations from 355 min for the shortest to 3700 min for the longest, while instantaneous observations ranged from 21 – 90.

It is noticeable from the diagrams in Figs 3 that the rates of time element level in the production cycle are very similar. Despite the significantly lower number of production cycles monitored for this enterprise, the stochastic variable of production time level is more stable. Minimal deviation from the control limits is found in two points only (two samples): No 5 which exceeds the upper control limit AC by 0.57 per cent; (0.8064-0.8007), while the lower point, No 9, exceeds the lower control limit BC by 1.84 per cent (0.5926 – 0.611). The production time level mean is μ_{tp} = 0.7092, the upper control limit AC = 0.807, and the lower control limit BC = 0.611. The average levels for working time elements amount to μ_{tpt} = 0.1167; μ_{tm} = 0.2334; μ_{tc} = 0.1454; μ_{tr} = 0.0871 and μ_{tpk} = 0.1266; for production time and the sum of times respectively, μ_{tp} = 0.7092 and μ_{tmr} = 0.0664; μ_{tl} = 0.0135; μ_{to} = 0.0637; μ_{tb} = 0.009 and μ_{tto} = 0.1382 for non-production time, or the sum of times μ_{tnp}= 0.2908.

Considering the results given above, the analysis should be directed towards the problem of the elements of transport time which can be reduced. Also, the distribution of time elements in other types of stoppage should be considered from a mathematical standpoint in such a way that the most significant stoppage will be segregated within it.

The data obtained for textile enterprise shown in Tables 1 and 2. The data given in the Tables represent the mean values and SDp for groups of screenings for PCs per series size. It is noticeable that there are 11 groups containing at least 9 units in a series, while the largest group has 115 units in a series.

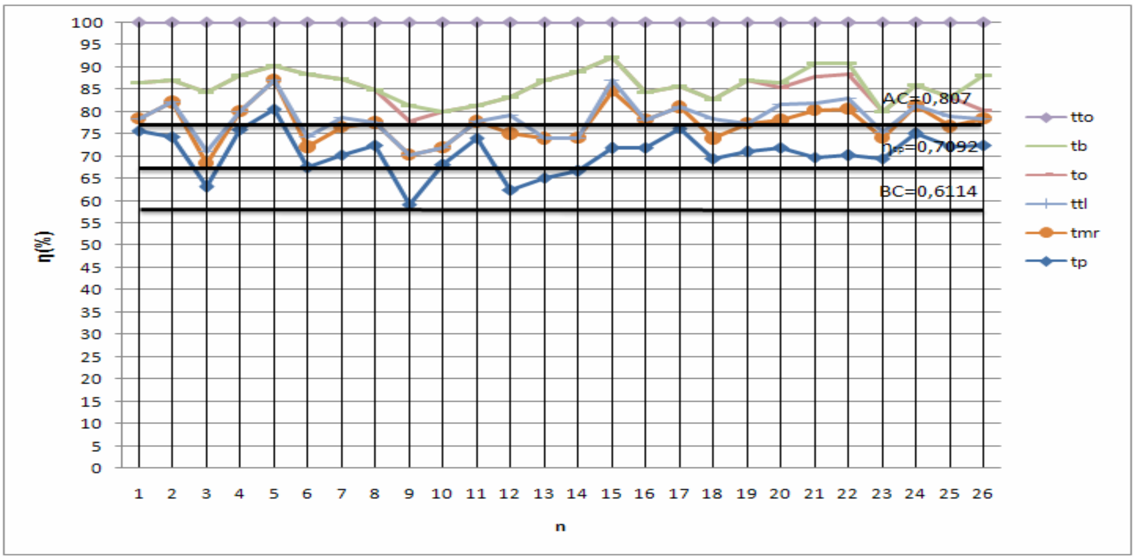

Figure 2. The levels of cycle time elements for enterprise in 2011

Table 1. PC time per unit in a series and production time in %

Number of items (n)	t_{pcu} (min/kom)	t_p (%)	SD_{tp}(%)
9	53.33	67.2	0.99
9	53.33	67.22	
$\overline{x}$	**53.33**	66.21	
10	52	59.26	5.64
10	46	62.49	
10	87.6	72.56	
$\overline{x}$	**61.87**	64.77	
12	66.08	67.44	2.07
12	65	70.21	
12	63.33	72.5	
$\overline{x}$	**64.8**	70.05	
14	37.14	76.19	3.32
14	38.57	69.56	
$\overline{x}$	**37.86**	72.88	
17	54	75.68	5.22
17	54	74.36	
17	54	63.16	
17	37.65	73.6	
17	37.65	80.64	
17	35.88	74.08	
$\overline{x}$	**45.53**	73.59	
18	34.44	66.67	0
$\overline{x}$	**34.44**	66.67	
63	15.87	75	0
$\overline{x}$	**15.87**	75	
67	15.82	70.4	0
$\overline{x}$	**15.82**	70.4	
106	13.4	71.95	1.22
106	13.4	69.69	
106	13.21	69.13	
$\overline{x}$	**13.27**	70.26	
112	8.64	72.33	0
$\overline{x}$	**8.64**	72.33	
115	7.19	71.8	0.41
115	6.96	71.87	
115	6.96	70.97	
$\overline{x}$	**7.04**	71.55	

Table 1 shows the size of each group with the number of units in a series for the PC time per unit (tpcu) and the production time (tp) as well as the mean values by groups and SDp in % for (tp). Table 1 displays the mean values ($\bar{t}_p$) and (t_{pcu}), SDp and the number of PCs screened by groups and number of units in a series in those cycles. Table 2 also shows the log taken for the number of units in a series – log (unit/ser).

The mean value for all the groups is $\bar{\bar{t}}_p = 70.53$ (%) and ranges from the bottom control limit BC = 63.92(%) to the upper control limit AC=77.14(%). The stratification of groups was again unsuccessful, because SDp=4.5(%) and σ'= 4.584(%), which is approximately equal.

In 2012, after model initial application, experiment is again conducted to check if there are some improvements in production cycle elements.

In textile enterprise screening were also made in 2012 to check if there are some improvements in production cycle elements. Fig. 4 shows that almost all data SD ± 2 control limits, and show higher precision then before. Time tm is the largest part of production time, with very low oscillations. The mean value for all groups with the same number of units in a series obtained is = 85,22 %, much larger then in 2011.

This indicates that experiment design and repeated screenings should focus on a possible size and frequency and whether the designed (anticipated) stoppages per type will emerge at all. The technical level of machine time elements μ_{tmi} deviates very little from the control limits (Fig.3) which for μ_{tm} = 0.2334 amount to: AC = 0.2570 and BC = 0.2097.

Table 2. Number of cycles and number of units in a series

No	No of cycle (f_i)	unit/ser	$\bar{t}_{pcu}$ (unit/ser)	$\bar{t}_{pi}$ (%)	SD_{tp}	log (unit/ser)
1	2	9	53.33	66.21	0.99	0.954
2	3	10	61.87	64.77	5.64	1
3	3	12	64.80	70.05	2.07	1.079
4	2	14	37.86	72.88	3.32	1.146
5	6	17	45.53	73.59	5.22	1.23
6	1	18	34.44	66.67	0.00	1.255
7	1	63	15.87	75.00	0.00	1.799
8	1	67	15.82	70.40	0.00	1.826
9	3	106	13.27	70.26	1.22	2.021
10	1	112	8.64	72.33	0.00	2.049
11	3	115	7.04	71.55	0.41	2.061
	N=26			$\bar{\bar{t}}_p = 70.53$ (%)		

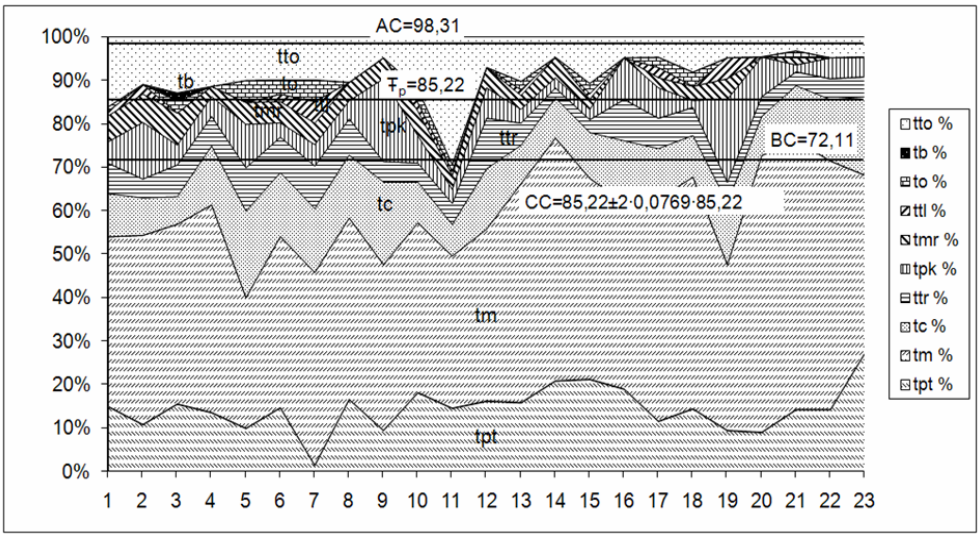

Figure 3. Data for all cycles elements monitored in textile enterprise in 2012

5. CONCLUSIONS

Multidimensional model for production scheduling and monitoring that we propose enables connection of operation time elements per different machines, products and operators, which cannot be identified from conventional Gantt's charts, being in one plane. That is the reason why we think so that multidimensional model is tool for effective production planning useful to manufacturing industry today.

The specifity of proposed method refers to machine utilization observations that are not performed by shifts and days using current observations of machines, but through PC time components monitoring the items of work. The PC trends can be thus observed as a process, while the efficiency of the process is possible to observe through control charts. The application of the method in production practice indicates that in organized production conditions with a higher PC time level (0.5-1), for sufficient number of PCs they range according to normal distribution (whereas in capacity utilization observations they range by binomial distribution) and within control limits determined by 3 SDs.

Based on our experimental investigations it has been proved that in the practice of small and medium-sized enterprises with serial production it is possible to design and apply a very simple but accurate enough stochastic model to determine the elements of working cycle time and in this way optimize the duration of production cycle time. After optimization of production cycle time object costing approach, such as one described in (15), could be applied.

It has been proved that it is possible to master the process by applying a modified work sampling method for a corresponding representative set of working time elements, whose range along normal distribution law, dynamically viewed, is enabled using mean value calculations to establish control limits on 3 standard deviations for some individual working time elements. It is proposed that further investigations should focus on the application and testing of the model in other types of production, for example, assembly and the like. Further analysis should be directed at the problem of reducing the elements of transport time, and the further division of time elements in other types of stoppage so that the most important elements within time are segregated.

Acknowledgement

This work was supported by the Serbian Ministry of Education and Science: Grant TR 35017.

REFERENCES

1. Agrawal A., Minis I. And Nagi R., 2000, Cycle time reduction by improved MRP-based production planning, *International Journal Product Research*., Vol. 38, No. 18, 2000, pp 4823-4841.
2. Barber, K D; Dewhurstz, F; Pritchard, M.C. 2006, Cost allocation for business process simulation models, *Proceedings of the Institution of Mechanical Engineers;* 220, B5; pp.695-706
3. Barbiroli G., Raggi A., 2003, A method for evaluating the overall technical and economic performance of environmental innovations in production cycles, *Journal of Cleaner Production* ,Vol.11,No. 4, pp 365-374.
4. Barnes, R., *Work Sampling*, 2 nd edn, New York : Wiley, 1957.pp. 5.
5. Čala I.,Klarin M.,Radojčić M., 2011, *Development of a Stohastic model for determing the elements of production cycle time and their optimization for serial production in Metal processing industry and recycling processes*, I International Symposium Engineering Management and Competitiveness, Tehnical faculty "M. Pupin", Zrenjanin, Serbia, pp. 21-25
6. Ćoćkalo, D., Stanisavljev, S., Đerđević, D., Klarin, M., Brkić, A., 2014, Determination of the Elements of Production Cycle Time in Serial Production: the Serbian Case, *Transactions of the Canadian Society for Mechanical Engineering,* Vol. 38, No 3, pp. 289-304.

7. Elnekave M., Gilad J.,2006, Rapid video-based analysis for advanced work measurment, *International Journal of Production research* ,Vol.44,No. 2, 2006., pp 271-290.

8. Giri B., C.,Yun W.,Y., 2005, Optimal lot sizing for an unreliable production system under partial backlogging and at most two failures in a production cycle, *International Journal Production Economics* ,Vol.95, No. 2, pp 229-243.

9. Klarin M.,M., Cvijanović M.,J., Spasojević-Brkić K.,V., 2000, The shift level of the utilization of capacity as the stochastic variable in work sampling, *International Journal Product Research*., Vol.38, No 12,pp 89.

10. Klarin M.,M., Milanović D.,D., Spasojević-Brkić K.,V.,Misita M.,Jovanović A. 2010, A method to assess capacity utilization in short cycle functional layouts, *Proc Instn Mechanical Eng., Part E*, Vol.224, No E1, ,pp. 49-58.

11. Kodek D., M., Krisper M., 2004, Optimal algorithm for minimizing production cycle time of a printed circuit board assembly line, *International Journal Product Research*., Vol 42, No 23, pp 5031-5048.

12. Kun-Jen Chung, Kno-Lung Hon, Show-Ping Lan,2009, The optimal production cycle time in an integrated production –inventory model for decaying raw materials, *Applied mathematical Modeling*, vol.33, pp 1-10,

13. Maynard, H. B., *Industrial Engineering Handbook*, Pittsburgh, PA: McGraw-Hill, 1971. pp 22.

14. Moder, J.J., 1980, Selection of work sampling observation times – Part I*: Stratified sampling. AIIE Transactions*, 12 (1), pp 23-31.

15. Richardson, W.J., Eleanor, S.P.,1982, *Work Sampling, Handbook of Industrial Engineering*, Salvendi G.,editor, New York : Wiley.

16. Tzu-Hsien Lee, 2009, Optimal production run length and maintenance schedule for a deteriorating production system, International Journal Adv.Manut. Technol, Vol.43 No. 9-1,pp 959-963.