QUALITY AND LEAN MANAGEMENT APROACH IN MAINTENANCE

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Abstract: The article deals with the possibility of utilization of the lean production method, in particular the methods of work measurement, in the frame of rationalization of maintenance. Compendium of methods for measuring and utilizing work of workers in maintenance was created. The article follows advantages and disadvantages of all methods regarding their suitability for optimal run of the workplace and effective utilization of the workers. Application of individual methods to specific company data with the view of verifying the applicability of these methods in practice can be found in the case study. In the final part of the article assumptions and recommendations are introduced for subsequent utilization of methods for determing number of workers in maintenance.

Keywords: indirect labour, lean manufacturing, maintenance, methods time measurement, personal costs, work efficiency.

1 INTRODUCTION

The introduction section of this article deals with general characteristics of different methods of time analysis and respective benefits of their use with regard to how this field is addressed in professional literature. There has been long-term lack of interest in researching this scientific field, which caused significant lack of professional literature. Despite this fact, in the enterprises the standardization of overhead work seems to help to shorten the running time of production significantly. For that reason the methodology of standardization should be adapted to specific needs of auxiliary and service works, especially in maintenance. Standard procedures should be replaced by new approaches in the study and work designing, analyses and standardization that comply with the specific conditions in these processes. The main tool for achieving this goal is the selection of an appropriate method of time analysis, which objectively evaluates time consumption of individual work tasks [8].

1.1 Methods for Determining Labour Input and Work Structure

The following chapture deals with the compendium of the methods which according to the professional literature objectively evaluates time consumption of individual work tasks in the auxiliary and servicing processes.

Monitored are all activities performed by a worker working on his own, inclusive of measuring their time utilization. The actual recorded data is entered onto an observation sheet. This kind of a working day snapshot comprises the most detailed record of all work activities and an uninterrupted monitoring of working time utilization during a shift. Instant monitoring partly replaces the traditional method of a working day snapshot. Its application is simpler and less time consuming for the observer. The principle of this method based on the probability theory and the theory of random choices lies in the time evaluation of a representative number of randomly selected short periods of time during a work shift. Evaluation of such samples corresponds with the results, providing that both comprehensive monitoring and all data collection are complete [1]. Zonal and Multilateral Monitoring was developed to detect utilization of workers in non-stationary workplaces and combines simultaneous monitoring of work processes in designated zones with the use of suitable assessment software, where individual zones are defined by work operations performed there. Chronometry allows a thorough examination of the operations and time corrections, all without the actual use of a normative base, although its lengthy and laborious use poses a disadvantage [6].

Predetermined time values methods are based on combination of time and motion studies. It divides manual labour into basic movements that are necessary for its completion. To each of such basic movements, a predetermined time value relates, determined by the nature of the basic movement and any influences that affect its implementation. The original MTM (Motion Time Method) method is for setting indirect labour standards prohibitive because of its extreme labour intensity. Using the MTM method, it takes 8 hours for an analyst to process 1 minute of an operator's labour. Basic MOST (Maynard Operating Sequences Technique) System was developed based on the requirement to measure work faster than when using the MTM System, while maintaining the same accuracy level. Most companies use it in their production systems, but using it for the description of indirect labour is very restrictive due to its limited datacard of predetermined moves [17]. A specific method Maxi MOST created directly for evaluating activities such as handling, transportation of goods on trucks, and bringing materials, i.e. activities connected with auxiliary and service processes in the production. Derived from the method MTM are also UAS (Universal Analysing System) System, system SMA (Standards de Manutention Analytiques) System and system SMB (Standards de Manutention de Basse) System. The UAS System links basic movements together in sequences that enables a rougher breakdown of types of grips, precision of location and length, and is therefore suitable for the description of indirect labour. SMA System and SMB System were developed specifically for measuring time consumption during material handling and in terms of its labour intensity level corresponds to the UAS System. However these methods are being used only in Francophone countries.

The UMS (Universal Maintenance Standards) System can be applied only when standardizing maintenance work on buildings or equipment. The system rests on two basic pillars: the definition of the range of work activities and time comparison of the individual activities [7]. Normative Systems for Work Planning were created in the 1980s at the Institute of Work Planning in Heavy Industry. However, their use is nowadays limited due to their outdated data and their lack of normatives for operations that use electronic systems and other tools associated with the developments of recent years.

1.2 Methods for Setting Staff Number Standards

Methods for determining time standards can be divided in accordance with professional literature into two main groups: Analytical Methods and Summary Methods [9]. An analytical method analyses work time, time of generally requisite breaks and time of conditionally requisite breaks. However, the method displays considerable inaccuracies when used in cases where standards are not met or exceeded, and where the amount of items in a batch varies. In the summary methods the time standard is determined by a single time value by means of regressive analysis, statistically, by summary comparison, or through estimates. A significant factor in deciding which suitable normative to select is the repetition of work. Both methods can be used when monitoring work in auxiliary and service processes such as maintenance and material handling. If the occurrence and duration of operations performed by staff is mainly of a random character, then queueing theory can be used for setting standards, which in turn enable the description of the course of the process for a different number of workers. Calculation of the number of workers from the operating standard is then based on the proportion between the number of operated units and the operating staff standard. Capacity planning should be based on a list of tasks that need to be done, on their priorities and on the usable time fund. The following sections describe the methods which can be applied when dealing with this issue.

- Analytical methods for setting staff number standards (Queueing Theory, Standardized Labour Input Method, Idle Time Method);

- Summary methods for setting staff number standards (Regressive Analysis).

The complexity of Queueing Theory rests in establishing an accurate calculation model. In practice two basic undesirable situations occur in service work: operating staff are either overloaded and requirements thus accumulate, or there are not enough requirements on operating staff, resulting in idle time [4]. The staff number standard, i.e. the optimal number of operating staff depends on the ratio between the unit value (costs and profits) of a time applicants spend waiting for operation and unit value of idle time of operating staff. In this situation the economic aspects must be taken into consideration, which include the cost of applicants waiting in the queue and the costs of operating staff waiting (costs of service channels operation).

The use of Regressive Analysis is conditioned by a sufficient amount of input data. When determining the number of staff, this method monitors the dependency between individual aspects of a production process and the number of workers involved in this process [2]. Input data for estimating regressive functions include information on the number of workers linked to a relevant group of machinery and the average size of a batch. The regressive analysis enables the estimation of the value of a certain random variable based on the knowledge of other variables.

The Standardized Labour Input Method is applicable on the condition that the scope of performed work is known and the time standards for all operations are available. This method essentially determines the overall scope of work and compares it with a usable time fund of an individual employee. On the contrary, the Idle Time Method is based on establishing time when workers performing auxiliary and servicing work are not used to their full capacity. Based on the resulting time loss, the number of workers is subsequently reduced to the optimum. The method is particularly demanding in terms of basic data collection and their further evaluation [12].

2 OBJECTIVES AND METHODOLOGY

Classification of the methods

The analyzed methods were divided into two groups; initially into a group of methods determining time usage and structure of work (table 3), and subsequently into a group of methods suitable for determining the number of workers (table 4). According to criteria the individual methods in both groups were then sub-divided into categories A - C in line with their suitability for the use in the plastic-processing industry.

Conditions for Use of Method for Describing Indirect Labour

Category A Method suitable without limitations.

Category B Use of method suitable under certain conditions.

Category C Use of method for description of given activity unsuitable.

The primary objective of the research in the given field is the selection of a suitable method for determining labour input and work structure. The most suitable method for measuring and analysing time usage that were used and applied to maintenance work is the UMS (Universal Maintenance Standards) System. In this method, the datacard’s range of indexes incorporates a large variance from one production cycle to another [15]. The extended datacard offers a wider scope of predetermined times for the use of tools and instruments typical for description of work in maintenance. After compiling normatives in the system UMS, the author of article sees an ideal solution in creating a database system which would enable its users to perform measurements and obtain required data without the need for a deeper understanding of the principles of standardization. In turn, this would allow the group of potential ‘evaluators’ to be enlarged by people who have been only briefed about this system, which subsequently brings the desired simplifications and speeds up the process of creating indirect labour standards.

The next step was to select and test a group of methods suitable for determining the number of workers in the maintenance department.

3 CASE STUDY

All methods were applied to data from a specific company with the view of verifying their applicability in production company conditions. The results clearly show that there is no universal method suitable for standardizing all types of indirect labour.

Basic requirements for maintenance of assets (buildings, machines, equipment, different facilities etc.) include:

1. asset controlling and maintaining in operating and capable (functional) state,

2. prevention of failure occurrence and following fault,

3. operational corrective maintenance,

4. reduction of the environmental impact of machine and equipment operation,

5. operational safety assurance,

6. maintenance of optimum cost structures.

Fulfillment of asset requirements on maintenance and achievement of defined maintenance quality characteristics require to create, introduce, maintain and improve maintenance quality management system as an instrument of effective asset maintenance management in organizations [5].

3.1 Application of the Queueing Theory

The aim of research activity was to find out whether it is possible to set with queueing theory optimal number of number of workers in maintenance for required working area. Further it approached to check of current capacity utilization of machines according to the costs. Total costs were calculated and according to equation (1) was found optimal number of operating staff [3].

Optimal solution with lowest costs for the company was found in the minimum of the function (1).

$$Nc(S) = \frac{\lambda}{\mu}(C - C_{SV}) + C_{SV}S + \frac{x\lambda C_W}{S\mu(S\mu - \lambda)} \qquad (1)$$

λ arrival rate

μ service rate

S number of service channels

C cost of service capacity (cost per server)

Cw waiting cost

Csv downtime cost

Nc total costs

x total number of requests per hour

$$\rho = \frac{\lambda}{S\mu} \qquad (2)$$

λ = 16,56 requests/hour

μ = 7,45 requests/hour

ρ - intensity of output

Tab. 1: Optimal selection of number of workers in maintenance. Source: author´s own

Number of workers	3	4	5	6
Lp	0,895	0,247	0,061	0,008
Ln	0,127	0,041	0,009	0,002
r.Crv [Kč/h]	885	1180	1475	1770
Lp Cm[Kč/h]	1121,43	309,49	76,43	10,02
Ln Cm[Kč/h]	159,13	51,37	11,28	2,51
C´ [Kč/h]	2165,56	1540,86	1562,71	1782,53

Note.: Lp – average length of the priority adjustments per hour, Ln - average length of the priority adjustments per hour, (calculation by SW STORM)

3.2 Application of Standardized Labour Input Method

Methodology of the Standardized Labour Input Method is quoted in Kroupa (1985). It consists of following parts:

- Drawing up a list of work tasks that are to be completed within a given period;
- Determining labour input of individual operations in man-hours;
- Determining the overall labour intensity in man-hours, including the degree of fulfilment of standards;
- Determining usable time fund of an individual worker, or respectively the volume of idle time that cannot be eliminated;
- Determining the necessary number of workers according to the equation (3).

$$P = \frac{Q}{k_n F_c} \tag{3}$$

P - number of workers

Q - overall labour intensity in standard-hours [Nh]

k_n - coefficient of fulfilment of standards

F_c - usable time fund in hours

Standard work shift fragments are according to equation (4).

$$T = t_{A1} + t_{B1} + t_{C1} + t_2 + t_3 + t_D + t_E + t_F \tag{4}$$

t_{A1} - work time for the unit

t_{B1} - work time for the batch

t_{C1} - shift work time

t_2 - time generally requisite breaks

t_3 - conditional requisite breaks

t_D - individual lost time

t_E - lost time due to organizational problems

t_F - more superior lost

The current situation in the factory: 21 machines are being adjusted by 4 workers (2 specialist for reparations, 2 workers for prevention of failure occurrence (TPM). Time consumption for workers in maintenance was according to the evidence system settled:

Overall labour intensity in standard-hours = 26490 Nh/year.

Effective time fund in hours (of the worker) = 6900 Nh/year (84 % utilization of the worker)

Usable time fund in hours (of the worker) = 7848 Nh/year

$$P_1 = \frac{2 \times 6900}{7848}$$

P_1 = 1,75 (rounded 2 workers)

3.3 Application of Regressive Analysis

On the example presented in the table 2 can be seen the dependency between individual aspects of a production process (labour intensity in standard-hours [Nh] and production volume) and the number of workers involved in this process. The regressive analysis enables the estimation of the value of a certain random variable based on the knowledge of other variables. In the table 2 can be seen difference between predicted standard and number of currently employed workers. This method is valuable especially within preparation of the predictive model for capacity planning. For creating of regressive function can be used any statistical software or MS Excel applications.

According to data gained within the research – dependent variable Y (required number of working shifts) and independent variables (x), see list of independent variables below:

- number of machines (x_1),
- average length of reparations (x_2),
- complexity of the reparation (x_3),
- ability to fulfill the production plan (x_4).

The aim is to set a regressive function in order to create a model for determining the optimal number of workers in maintenance:

$$Y = e^{-10,083} . x_1^{0,0441} . x_3^{0,051}$$

Tab. 2 - Determining the optimal number of workers by regressive function. Source: author´s own

Working shifts required	Number of machines x_1	average lenght of reparation x_2	Regressive estimation	Difference betw. standard and estimation
4	17	65	4,061	0,061
4,5	33	64	5,023	0,523
5	36	66	5,304	0,304
5,5	33	80	5,759	0,259
7,4	40	89	6,614	0,786
4,5	40	45	4,59	0,09
5	35	50	4,505	0,495
6	35	83	6,023	0,023
5,5	39	75	5,907	0,407
6	34	82	5,914	0,086

3.4 Application of Idle Time Method

The current situation in the factory: 21 machines are being adjusted by 4 workers (2 specialists for reparations, 2 workers for prevention of failure occurrence (TPM). Time consumption for workers in maintenance was according to the evidence system settled:

Overall labour intensity in standard-hours = 27 600 Nh/year

Effective time fund in hours (of the worker) = 6 900 Nh/year

Usable time fund in hours (of the worker) = 7 848 Nh/year

Utilization of the worker:

T1 working time = 88 %

T2 + Td = time requisite breaks + individual lost time = 7 %

Te = lost time due to organizational problems = 5 %

4 CONCLUSION

The analyzed methods were divided into two groups; initially into a group of methods determining time usage and structure of work (table 3), and subsequently into a group of methods suitable for determining the number of workers (table 4). According to criteria the individual methods in both groups were then sub-divided into categories A-C in line with their suitability for the use in the plastic-processing industry.

Tab. 3 - Overview of the methods for determining the number of workers in maintenance in the plastic-processing industry. Source: author´s own

Method	Suitability for use in plastic-processing industry	Reason
Standardized Labour Intensity Method	YES	Providing that database of normative is created.
Queueing Theory	YES	Description of randomly arising requirements.
Regressive Analysis	Partially	With sufficient volume of data, comparable with actual situation.
Idle Time Method	YES	Laborious in terms of data collection, suitable also for improvements.

Tab. 4 - Overview of the methods for measuring and analysing time usage that were used and applied to maintenance in the plastic-processing industry. Source: author´s own

Method	Suitability of Method	Categ.	Justification of suitability/unsuitability of use
Working DaySnapshot	YES	A	Particularly suitable for collection ofprimary data.
Instant Monitoring	YES	B	Suitable in uninterrupted flow operations.
Zonal/Multilateral Monitoring	YES	A	Suitable for material supply and warehouse work.
Continuous Chronometry	YES	A	Suitable, providing that monitored tasks occur in regular sequence.
Selective Chronometry	YES	B	Partially suitable, for irregular operations.
Instant Measuring	YES	B	Suitable for irregularly repeating operations, for small production batches.
MTM	NO	C	Unsuitable, disproportionate labour intensity of data processing.
Basic MOST	NO	C	Unsuitable, disproportionate labour intensity of data processing.
Maxi MOST	NO	C	Unsuitable, does not allow description of necessary operations.
UAS	YES	A	Suitable, using movement cycles.
UMS	YES	A	Absoulely Suitable, provide description of all activitvies.
SMA	NO	C	Unsuitable, limited
SMB	NO	C	Unsuitable, focused on descreption of data maintainance.
Systems of Normatives	ANO	B	Applicable method, but data not updated.

The main objective of the article was to analyse various methods for standardization of indirect labour and formulation of conditions for their use in the plastic-processing industry. Methods were firstly applied to a selected group of workers in maintenance. Suitable methods were then selected based on the results, which were recommended for the description of these activities in the plastic-processing industry. System UMS was selected as the most suitable method. This system offers a wider scope of predetermined times for the use of tools, instruments in maintenance. Secondly, the established values were used with the purpose of determining which of these methods are appropriate for determining the optimal number of workers needed for executing a given activity. It is not possible to determine a universal method for setting labour standards in logistics on the bases of the completed analysis. Maintenance much like other overhead activities, is affected by time variability and fluctuation of workload. As a result from this research, the methods listed in the tables 3 and 4 are possible to select depending on specific conditions and on variation and repetition of performed work. Despite this fact it is possible to predict that selected methods should have broader applications for planning indirect labour in the medium-sized enterprises in the car-manufacturing industry specializing in plastic components production. The next step of the research will be selection of the suitable methods for standardization of other indirect labour, formulation of conditions for their use in practice and subsequent proposal and creation of a model for indirect labour capacity planning.

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