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Comparison of Time Standardization Methods on the Basis of Real Experiment

Marek Bures[a]*, Pavlina Pivodova[b]

[a]*Department of Industrial Engineering and Management, University of West Bohemia, Univerzitni 22, Pilsen 30614, Czech Republic*
[b]*Department of Industrial Engineering and Information Systems, Tomas Bata University, Mostni 5139, Zlin 760 01, Czech Republic*

Abstract

The paper focuses on mutual comparison of currently most common methods for time standardization. For comparison of selected methods an experimental research in conditions of automotive assembly production was performed. Compared methods were direct measurement according to REFA methodology and two predetermined time systems MTM-1 and BasicMOST. Mutual comparison of results obtained by means of those 3 methods was performed. The experiment was performed on 21 assembly workplaces where time span of analyzed operations oscillated between 4 to 29 seconds. The main goal of the research was to demonstrate reliability, mutual accuracy and deviations of selected methods. A hypothesis needed for verification was stated, that individual methods should have maximal accuracy deviation ± 10%. Findings about time demands for performing the analysis according to selected method was a partial goal of our research.

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1. Introduction

Production represents the heart of each industrial company. Its effective control and planning is the key factor for whole company success and prosperity. Main resources appearing in production are material, human and financial. These resources are closely connected and in time they undergo transformation, which makes the time consumption during production one of the most observed parameters. There are different methods for observing and

* Corresponding author. Tel.: +420-731-575781; fax: +420-377-638400.
E-mail address: buresm@kpv.zcu.cz

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measuring time demands. Basically we can divide these into measuring methods and calculating methods [1]. Measuring methods have some limitations and their usage is possible only in production that already exists. In this case we can measure time directly with stopwatches, indirectly from video, or statistically from frequency of observed activities.

The direct measurement method used in our experiment is called REFA. The REFA (Reichsausschuss für Arbeitszeitermittlung) is an abbreviation for the name of a German organization which is involved in organization and work improvement in industrial companies. Although the organization's portfolio of services is great, it is most commonly known for time studies. This method describes concrete methodological approach to direct time measurement with stopwatch. Differences of the REFA method from the others are in specific time division, calculation of total time, determination of performance level or in special time units called hunderte minutes [2].

Predetermined time systems can be considered as calculating methods. One of the main benefits of these methods is the possibility of using them already during preproduction phases, when the workplace still does not physically exist. Furthermore these methods are very useful as a tool for optimization and rationalization.

There are quite a lot of predetermined time systems existing these days. The reason is historical. Since 1948, when the MTM system was officially introduced, many variations that ease the analysis have been developed. For example UAS system was specifically developed for serial assembly production or batch production and in these days is very common in automotive industry [3]. On the other hand the MEK system is more suitable for piece production [4]. Also many of these predetermined time systems have been modified in order to respect ergonomic parameters of the job like ErgoMOST or ErgoSAM [5, 6]. The predetermined time systems are typical for automotive industry as mentioned before but also many other applications can be found in other types of industry e.g. textile [7], wood processing, furniture production etc. In this paper we will focus on the possibility of using the two probably most frequently used predetermined time systems (MTM-Method Time Measurement and MOST-Maynard Operation Sequence Technique) for production planning and their mutual comparison.

The MTM method was developed by Maynard in the United States in 1948. One reason why the MTM system became the most widespread is probably due to the fact that it was made publicly available with no economic or judicial claims on behalf of the inventor. The MTM Association for Standards and Research was founded in the United States in 1951. The managing director of the Volvo Car Corporation took the responsibility of introducing MTM in Sweden, and the first installation of MTM was made at the Volvo engine factory in Skövde in 1950. The work led to the foundation of the Swedish MTM Society in 1955 [8]. The strong interest in the MTM system may be explained by the potential it holds in the rationalization of work. Nowadays, the MTM system and its modern versions are widely used in many companies to calculate production times for line balancing, line pace setting and in calculation of business tenders.

An analysis using the basic level of MTM, MTM-1, is a very time-consuming task. This led already during the 1950s to initiatives to combine MTM data in order to simplify and thus decrease time needed for analysis. The Swedish MTM society took the initiative to a task that led to the development of MTM-2 that in 1965 was accepted by the International MTM Federation as an international standard [9]. Similar systems, one of which is MOST, have been developed for much the same reason.

The MOST method was developed by K. B. Zandin from Maynard Corporation company in 1980. The main idea of this method is that we can define the same motion sequences for the majority of all operations. Individual motion sequences are described by basic equations which occur during manipulation of objects. Within these motion sequences single motion activities have their firm place in the sequence. [10]

MOST has similarly like MTM different levels of complexity. Maxi MOST is characterized by the highest level of operation analysis complexity. It is suitable for operations which are performed less than 150 times per week. Recommended duration of operation ranges from 2 minutes to hours. BasicMOST is the most common level of analysis which is used by the majority of operations. These operations are of a middle level of complexity which means that they are performed more than 150 times but less than 1500 times per week. Operations in this category usually last from several seconds to 10 minutes. Mini MOST is the lowest and most detailed level of analysis. This form of analysis is suitable for operations performed more than 1500 times per week and their average durations are shorter than 1.6 minutes, usually from 2 to 10 seconds [10]. The sequences of BasicMOST represent the two basic activities necessary to measure manual work: General Move and Controlled Move. The two remaining sequence models include in BasicMOST were added to simplify the measurement of hand tool use and activities with mental process and the movement of objects by manual crane.

2. Methodology

As mentioned earlier, for comparison of the three selected methods a real experiment was used. That means comparison with real situations which take place in production. The company where the experiment was performed is a part of a transnational concern from the automotive industry. The company's production portfolio consists of small motion elements (small motors) for wipers, windows or lock gearing. The product variability is quite wide. Characteristic operations are assembly and control testing.

During the experiment 21 assembly workplaces were compared. At all these workplaces time analyses with MTM-1 as well as with BasicMOST were performed. The basic assumption of the experiment was verification of several hypotheses. The biggest discussions always deal with accuracy and mutual exchange so that is why the most important thing for us was comparison of analyzed time deviations and following their incidental dependences. The default assumption about the size of these deviations is between 5% and 10%. Secondarily we focused on the demands of analysis execution with both mentioned methods. It is generally valid, that MTM-1 method is more detailed and thus more time demanding than complex BasicMOST which works on the basis of sequence models. However the goal was to find out concrete dependencies regarding time needed for analysis and also extension of the documentation. Accuracy and time demand of the methods are theoretically described however there is no detailed survey for public. Results of this research may be valuable assets for assembly companies for which the area of time rationalization is crucial for calculation of capacities and outputs.

Within the comparison the following parameters that should point out the benefits of individual methods were observed.

- Resultant analyzed time.
- Accuracy of the analysis (deviations).
- Comparison of analyzed time with time directly measured in production.
- Analyzed time spent evaluating the analysis.

For comparison of analyzed time with time measured in real production several verification measurements according to REFA methodology needed to be performed. At each of the 21 workplaces included in the comparison process measurements were performed using this method. 15 measurements in two shifts with different workers were performed at each workplace.

Each author of this paper was responsible for detailed analysis of all workplaces with one selected method from the predetermined time systems. Both authors are certified specialists in the time rationalization area which ensures a higher value of the resulting information.

3. Results

Every analytical work begins with data gathering. First of all an observation was performed at all 21 workplaces. During this observation video recordings were obtained and a detailed study of documentation and production standards of all operations was performed. The next step was to perform direct time measurements in production with the aid of the REFA method. The REFA method works with a so-called performance level which is used for correction of measured time so that different intensities of work by individual employees can be taken into account. If a man is aware that he is being measured he can consciously or unconsciously perform his work at a different speed. Sometimes he can intentionally extend the time of the operation if he is worried that the new time standard will be used for remuneration, another time he can shorten the operation time when he is under pressure (stress). REFA´s performance level enables the observer to adjust and recalculate the measured time to so-called normal performance level with value 100%. Under the normal performance level we understand performing harmonious, natural and balanced motions and their coordination. It can be performed during the whole shift permanently by every worker who is experienced, educated and trained and is following safety instructions [11]. One of the disadvantages of this approach in evaluation of performance level is a certain level of subjectivity which is included in the result by the analyst. The assumption for getting possibly the most accurate result is that the analyst is familiar with the production process, has enough experience to evaluate performance level in praxis and is able to assess on the basis of influences of the actual degree of process interference.

All performed direct measurements are listed in Table 1. There are values of measured time, performance level for this measured time and recalculated time for 100% performance level. This time was later used for comparison with analyzed times with MTM-1 and BasicMOST methods.

Table 1. Values gathered from direct measurements with method REFA.

No. of workplace	Measured time (sec.)	Performance level L (%)	Recalculated time (sec.)
1	4.11	115	**4.73**
2	4.48	115	**5.15**
3	8.84	115	**10.17**
4	21.88	100	**21.88**
5	16.45	100	**16.45**
6	12.26	100	**12.26**
7	7.66	110	**8.43**
8	20.07	90	**18.06**
9	20.45	90	**18.41**
10	19.15	90	**17.24**
11	15.23	100	**15.23**
12	9.27	110	**10.20**
13	8.61	100	**8.61**
14	11.73	100	**11.73**
15	16.37	100	**16.37**
16	26.51	110	**29.16**
17	25.61	85	**21.77**
18	6.29	90	**5.66**
19	4.8	100	**4.80**
20	4.86	110	**5.35**
21	6.31	100	**6.31**

From measurements we can see these statistics. Average operation time is 12.76 sec. The shortest operation time is 4.73 sec. on the other hand the longest time is 29.16 sec. This means that the operations are not very long, so every tenth of a second has its importance in production of this character. The information obtained about length of operations determines the selection of applied methods. Both MTM-1 and BasicMOST are suitable for operations with length up to 10 minutes.

After data gathering and performing measurements in production we approach the next phase of experiment that is analysis with MTM-1 and BasicMOST methods. Especially shorter and less complicated operations were analyzed directly in production together with observation and data gathering. Longer and more complex operations were analyzed from video records. In the following Table 2 values of analyzed times with MTM-1 and BasicMOST in TMU and after conversion to seconds are listed.

Table 2. Values of analyzed times with methods MTM-1 and BasicMOST.

No. of workplace	MTM-1 (TMU)	MTM-1 (sec.)	BasicMOST (TMU)	BasicMOST (sec.)
1	126.1	**4.54**	120	**4.32**
2	159.3	**5.73**	150	**5.40**
3	288.6	**10.39**	280	**10.08**
4	610.44	**21.98**	500	**18.00**
5	444.3	**15.99**	360	**12.96**
6	312.98	**11.27**	338	**12.17**
7	231.7	**8.34**	220	**7.92**
8	512.9	**18.46**	520	**18.72**
9	482.5	**17.37**	380	**13.68**
10	443.8	**15.98**	460	**16.56**
11	328	**11.81**	330	**11.88**
12	282.7	**10.18**	325	**11.70**
13	224	**8.06**	250	**9.00**
14	291.4	**10.49**	367.2	**13.22**
15	432.7	**15.58**	430	**15.48**
16	744.1	**26.79**	807.2	**29.06**
17	525.4	**18.91**	530.8	**19.11**
18	160.13	**5.76**	161.42	**5.81**
19	132.8	**4.78**	140	**5.04**
20	139.2	**5.01**	142.8	**5.14**
21	186.1	**6.70**	170	**6.12**

On the basis of these values a comparison of results was made. One of the most interesting compared parameters is the accuracy of the methods. We compared the deviation of MTM-1 method from BasicMOST method, deviation of MTM-1 from direct measurements with REFA and similarly deviation of BasicMOST from direct measurements with REFA. Values of these deviations in percentage are listed in Table 3. In the first column the deviation of MTM-1 from BasicMOST is noted. A positive value means that analyzed time with MTM-1 is longer than BasicMOST and otherwise the negative value means the time of MTM-1 is shorter than BasicMOST. It is similar when comparing MTM-1 and BasicMOST with direct measurements. Prevailing values are negative which means that most analyzed times were shorter than direct measurements in production. On average all negative and positive deviations were balanced and a very satisfactory accuracy value of -1.57% for deviation of MTM-1 from BasicMOST was obtained. Similarly low values were obtained in the other two comparisons. Graphic representation of results can be seen in Fig. 1.

Table 3. Calculated deviations.

No. of workplace	Deviation MTM-1 from BasicMOST (%)	Deviation MTM-1 from REFA (%)	Deviation BasicMOST from REFA (%)
1	5.08	-3.95	-8.60
2	6.20	11.31	4.81
3	3.08	2.20	-0.85
4	1.91	0.44	-1.44
5	-3.41	-2.77	0.67
6	-7.40	-8.10	-0.75
7	-7.70	-1.02	7.24
8	-1.37	2.22	3.64
9	-1.53	-5.62	-4.16
10	-3.50	-7.28	-3.92
11	-0.61	-22.47	-22.00
12	-7.31	-0.19	7.68
13	-10.40	-6.34	4.53
14	2.46	-10.57	-12.72
15	0.65	-4.83	-5.44
16	-7.82	-8.14	-0.35
17	-1.02	-13.11	-12.22
18	-0.80	1.83	2.65
19	-5.14	-0.40	5.00
20	-2.52	-6.26	-3.84
21	9.47	6.17	-3.01
Average	**-1.51**	**-3.66**	**-2.05**

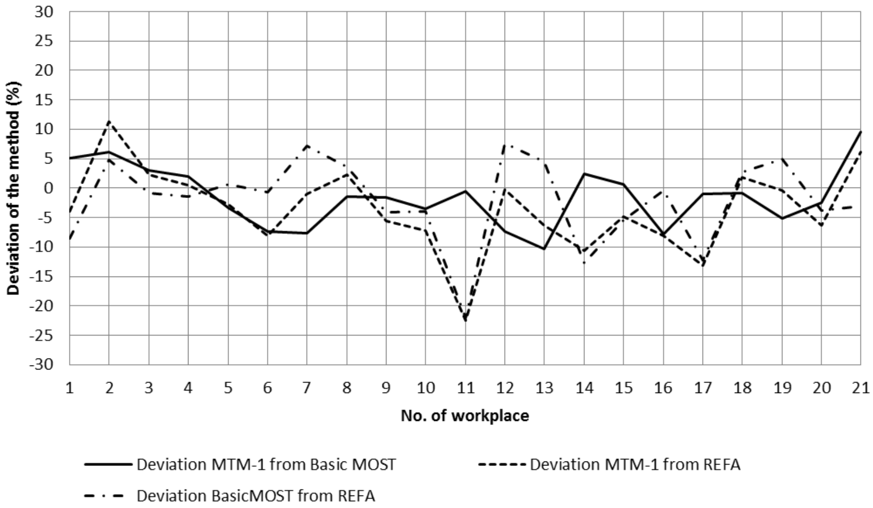

Fig. 1. Accuracy of the methods - deviations.

Although the average values of deviations are very low it is necessary to look in detail at individual workplaces as well. Within the comparison between MTM-1 and BasicMOST the highest positive deviation of 9.47% and highest negative deviation of -10.4% were obtained. This result confirms the starting hypothesis that deviations of resulting times analyzed by the mentioned methods will lie within the interval of 5% till 10%. If we evaluate deviations according to length of operations we will find out that those highest positive and negative deviations belong to operations shorter than 10 seconds. This conclusion is completely understandable because when the operations are short even a small difference in time results in great deviation and BasicMOST, because of its complexity does not achieve the required accuracy with shorter operations. When comparing the predetermined time systems methods with direct measurements according to REFA we can find even higher deviations than 10%. Always there is a logical cause that needs to be explained. Workplace no. 11 can serve as an example for this situation. Identified deviations between predetermined time systems methods and REFA measurements are of -22.47% and -22%. This means that the measured time is longer than analyzed. Deviation between MTM-1 and BasicMOST is however very small, only -0.61%, which is actually the lowest mutual deviation ever. There are two explanations for this phenomenon. It can be assumed that the times stated with the help of predetermined time systems methods are valid indeed and in reality a bad performance level during REFA measurement was stated. Another explanation is that there is a bad working standard at the workplace and its different explanation by the worker can have a significant impact on the length of the operation.

During creation of the time analyses with the help of MTM-1 and BasicMOST methods and notes about time spent by the analysis were made. In this way we wanted to get enough data to be able to determine how much time is needed to perform the analysis.

The evaluation report with MTM-1 method is quite difficult to create. The dividing the tasks into elementary motion elements and describing each movement separately has a significant effect on the extent of the documentation which may include dozens of items. By monitoring the time needed for the analysis with MTM-1 method the following fairly linear dependence was detected. During 30 minutes an average of 33 items was analyzed which corresponded with the time of 234 TMU. From these values we can establish the following conclusion. To analyze one item it takes approximately 1 minute and during this time the analyst produces 7.8 TMU on average.

Within the BasicMOST method a rapid reduction of time needed to perform the analysis can be tracked down. This results in higher productivity of the analyst in the form of large quantities of produced TMU in 1 minute. This is caused by the use of sequential models in the BasicMOST method. When monitoring the time required for operation evaluation by the BasicMOST method the following data were detected. During 30 minutes an average of 26 sequences were analyzed which corresponded with the time of 897 TMU. The following conclusion can be established from these values. To analyze one motion sequence it takes approximately 1.16 minute on average and during this time the analyst produces 29.9 TMU.

4. Discussion

Predetermined time systems methods are nowadays used in most countries in various industries. This is due to their use in the planning stages and thanks to the unified performance level. Interchangeability of these methods and applicability to various types of operations is always the subject of discussion. Within our experimental research a validation of three selected methods at 21 assembly workplaces was performed. The selected methods were MTM-1 and BasicMOST. For direct time measurements in production a REFA method was used. These measurements were then used for the comparison of deviations of times analyzed by methods MTM-1 and BasicMOST. The observed average operation time was 12.76 seconds. The shortest operation time was 4.73 seconds and on the other hand the longest time was 29.16 seconds. Within the analyses a deviation between MTM-1 and BasicMOST, deviation MTM-1 from REFA measurement and deviation of BasicMOST from REFA measurement were calculated. When comparing deviations of predetermined time systems methods very good results were achieved. The average deviation was -1.54% which means that MTM-1 time was generally slightly shorter than the time set by BasicMOST. The highest negative deviation was -10.40% and the highest positive deviation was 9.47%. From these results an obvious conclusion about the accuracy of these two methods can be established. Mutual deviation in measurement ranges of up to 10%. Similar result was achieved when comparing MTM-1 and UAS methods with the help of digital factory software as described in [12]. Calculated deviation in this case was -7.8%. Time calculated by MTM-1 was shorter than time calculated by UAS method. However previous comparison was performed only on one workplace which makes the results from current experiment more reliable.

All these results indicate that MTM-1 method is more detailed when compared with BasicMOST. The research has proven that the MTM-1 method is more suitable for detailed analysis of shorter operations with durations of up to 10 seconds. In these cases BasicMOST does not achieve the required accuracy. From the opposite point of view punctuality is one of the main disadvantages of MTM-1 when compared with BasicMOST with regard to time consumption. The research showed that analysis when using MTM-1 produces in 1 minute 7.8 TMU while when using BasicMOST it is 29.9 TMU.

Experimental research has also pointed to the necessity of addressing this area in the future. The methods selected for the experiment are not completely the same with respect to the detail of the analysis. One of the additional goals for future research will be extension of the analysis to a larger number of workplaces for wider data volume and therefore more accurate resulting values. Other tasks aim for involvement of MTM-2 and Mini MOST methods in the matching process. The current research proposes a hypothesis that the comparison of methods at similar levels with regard to the analysis detail could result in deviations even smaller than 10%. Therefore in the future it will be necessary to compare methods MTM-1 vs. Mini MOST and MTM-2 vs. BasicMOST.

Conclusion

Within the research described in this paper a comparison of three selected methods was performed. A method for direct time measurement called REFA was used and two predetermined time systems MTM-1 and BasicMOST were selected. Main goal of the research was to verify reliability and accuracy of these methods. A hypothesis was stated at the beginning of the research that maximal accuracy deviation should be ± 10%. The comparison was performed experimentally in real production on 21 assembly workplaces. Hypothesis and goals stated at the beginning of this research were obtained and validated. It was found that the deviations between times analyzed by predetermined time methods were maximally around 10%. The average deviation was -1.54%. The highest negative deviation was -10.40% and the highest positive deviation was 9.47%. It is crucial to say that these deviations were obtained also on very short operations even shorter than 10 seconds. Furthermore deviations between analyzed time from time measured directly in production, time demands of analyses and their ranges were observed.

In conclusion we can say that there were also some gaps identified in the described research and possibilities of further development in the future. Identified deviations pointed out the necessity to widen the spectrum of measurements in order to achieve more accurate results. In follow up studies we must take into account other methods like MTM-2 and Mini MOST. In the next comparison study deviations between those two methods as well as between all five mentioned methods should be performed.

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