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Comprehensive Comparison of MTM and BasicMOST, as the Most Widely Applied PMTS Analysis Methods

Zsolt J. Viharos[1,2], Bernadett Bán[2]

[1]*Centre of Excellence in Production Informatics and Control, Institute for Computer Science and Control (SZTAKI), H-1111 Budapest, Hungary, viharos.zsolt@sztaki.hu*
[2]*John von Neumann University, H-6000 Kecskemét, Hungary, viharos.zsolt@gtk.uni-neumann.hu, banberni98@gmail.com*

***Abstract* – This paper focuses on giving a comparison and review about two of the most popular Predetermined Motion Time System (PMTS) analysis and improvement methods: MTM and BasicMOST. Methods Time Measurement (MTM) is the most popular PMTS as it is the oldest one, while Maynard's Operation Sequence Technique (MOST) was created and is based on MTM, therefore being the second most popular PMTS method. Both methods are used to analyses human motions during work activity, and they are attempting to improve and optimize a given process, to be as effective as it is possible. MTM is more precise, therefore, it is more popular; BasicMOST is simpler and so, it can be applied quicker.**
In order to give a detailed comparison and review of the two methods, numerous other scientific studies were studied, and more than a dozen aspects were collected that can be used to compare these two methods. This comparison is mostly useful for those, who are looking for improving a process but are unsure about which method to choose. The comparison mentions many aspects that can potentially be more useful than just looking at accuracy and the easy usage of the given method.

Keywords – Predetermined Motion Time System (PMTS), MTM, BasicMOST, Comparison

I. INTRODUCTION

Predetermined Motion Time Systems (PMTS) are part of the work measurement family incorporating testing, diagnostics and inspection of the related (e.g. production or logistics) processes. It is an examination system that is based on the analysis of the human motions during working. It sets a standard that it is required for an average worker to perform a task under a given time without overworking. It is important to note that PMTS focuses on making a work process optimal rather than making the employee work harder [1][2].

However, there are some different PMTS systems and it is difficult to identify by an industrial user which one fits to a given process optimization task. The current paper reviews shortly the possible candidates and compares on a very detailed level the two most often applied methodology: MTM and BasicMOST.

The next paragraph reviews the PMTS systems and the two most popular methodologies. The third paragraph describes in details the aspects and their meanings that are used for the comparison and also for the structuring of the scientific literature presented in the next paragraph. The same organization is applied in the next paragraphs to describe the main features of the MTM and BasicMOST methods and also to appoint the superiority of one of the methods above the other. The analysis is closed with a comparison of an industrial motion measurements with MTM and BasicMOST, finally the conclusions, outlook and references close the paper.

II. PREDETERMINED MOTION TIME SYSTEMS AND THE MOST FREQUENTLY APPLIED METHODS

Before applying any PMTS method to a work process, one should consider using the Japanese 5S method for a work place redesign, therefore making it easier to make analysis on the given work place.

There are three PMTS methods that are usually applied in a work process, however, the first two methods are much more popular than the third one.

- Methods Time Measurement
- Maynard Operation Sequence Technique
- MODular Arrangement of Predetermined Time Standards.

MTM and MOST are the two most popular PMTS methods, mainly because they are similar in some aspects and their main concept is not that difficult to understand, though MTM can be difficult to some manner.

MODAPTS uses a different kind of coding and time measurement system, therefore the comparison wouldn't be as effective and representable as between MTM and BasicMOST.

A. MTM

Methods Time Measurement was developed by H. B. Maynard and it is the oldest PMTS, all the other methods are inherited from MTM. Even though it is a reliable method that is able to tell if a motion is necessary or not in a work process, its application is very time consuming and often requires several people [1].

There are several variants of MTM: MTM-1; MTM-2, MTM-UAS, MTM-MEK, MTM-SAM, this paper focuses on MTM-1, as it is the base of all other methods.

There are overall 19 basic, elementary motions in MTM-1 and their combinations can be used to describe a work process, including Turn (T), Move (M), Grasp (G) and Reach (R) major groups. Using these motions, any work process can be analyzed and optimized.

MTM uses Time Measurement Unit (TMU) to describe how much time is needed for a motion, so, these methods serve also with standardized motion times, the smallest unit is called 1 TMU = 0,036 second.

MTM is overall a method that can be used both to create a non-existent process and optimize an already existing one as well. The method is mainly applied to manual operations, as they can easily be described by human motions. The usage of the method is especially intensive in the manufacturing industry, but there are various other examples when it is used in other industries as well.

B. BasicMOST

Maynard Operation Sequence Technique, or as we call it MOST was developed in 1972, Sweden [2]. Originally it was called BasicMOST as it was the only existing MOST technique, later MiniMOST and MaxiMOST was developed, therefore there is a whole family of MOST as well, like at MTM.

BasicMOST is very similar to MTM it also uses TMU, but doesn't differentiate 19 basic motions like MTM. Instead, it has only 3 Movement Sequence and this simplicity makes analyzing much quicker and more flexible. The three sequences are:

- *General Move Sequence* – basic movements that are required to move an object freely in the air without any machines.
- *Controlled Move Sequence* – movements that are supported by a flat surface or a machine.
- *Tool Use Sequence* – movements that use a hand tool like a hammer, screwdriver or a scissor [2].

Unlike MTM, BasicMOST doesn't require precise measurements, which makes MTM so time consuming and hard to work with.

BasicMOST is usually applied to process from 10 seconds to 10 minutes long. BasicMOST is applied when a process is done minimum of 150 and maximum 1500 times a week [2].

Overall, it can be stated that BasicMOST can also be used when optimizing an already existing process or when creating a non-existent one. It is used in every kinds of industry, especially manufacturing industries apply the method, but like in the case of MTM, there are also examples when it was applied in other sectors.

III. COMPARISON ASPECTS

After the rough review of the state-of-the-art various aspects for comparison were defined to support the later comparisons and the next but precise state-of-the-art review. These aspects are listed and explained in the next sections ordered into four groups: method, applicability, effects and applications.

A. Method

Number of motion elements: in this aspect the amount of motion elements are compared that are used by both methods.

Breakdown of the analysis: it is important to know if a method is detailed or not. The elaboration of both methods was taken to look to see how detailed they actually are.

Informational element breakdown: when applying a method, it is important to have detailed informational elements that help in the application process.

Length of the process: in this aspect the different lengths of processes were compared and it shows how long a process can be when applying any of the methods. Too long and too short is not ideal.

Software support: there are different software for both methods that can be used to help in analysis of the process.

B. Applicability

Clarity of the movements: if a method has unclear movements, it makes applying and analyzing more difficult and time consuming.

Applicability of the method: in this aspect it was analyzed if a method can be applied easily by anybody or needs a seriously trained person for applying it in order to avoid making mistakes during analysis.

Sensitivity of the method: this aspect shows if a method is sensitive for any kind of changes after the analysis process. An example for this if there is e.g. a 5 cm change in the length of one of the motions and how the method reacts to that and how it affects the end results of the analysis.

Clarity of the method: it is important to know if a method is easily to understand and clear as a methodology.

Trainability of the method: in this aspect it was evaluated if a method can be trained and studied easily or

takes long time and many practice to learn.

Limits of the method: there are limitations to every method, either it is in the analyzing process or in the application phase, in this aspect these limitations are appointed.

Flexibility of the method: this aspect means that a method can be changed for better results or not. By combining different methods, one might achieve results that the original method cannot achieve alone.

C. Effects

Improvement magnitude: in this aspect it was explored what is the amount of an improvement that was achieved in general with the methods. It is possible to reach bigger improvement with one method than the other, that's why this aspect is especially important.

Accuracy of the analysis: it is important to know if a method is able to give accurate enough results or not. If the accuracy is too low, the optimizing process can serve with uncertainty in its application, but if it is "too accurate" it may require too much efforts.

D. Applications

Process types: not every method can be applied in every process improvement assignment. Where one method thrives the other might fail, that's why the aspect was studied to show the type of process people usually apply the methods in.

Industry branches: this aspect shows the industries the methods where they are usually applied in.

Ideal applications: in this aspect it was studied how a method can be applied ideally. A usual process has different phases, either it's designing or optimizing an already existing process. Where one method can be used to design a process, the other cannot.

IV. RELATED LITERATURE

The following sections group the contributions of the scientific papers into typical groups.

Scientific articles that use MTM as the main PMTS method have one interesting thing in common. They all tried to use MTM as a method to improve a company and its work environment. There was one article that used MTM in the case of learning factories, as a tool to design an ideal work place [4], while another one used MTM in a country where it was almost completely unknown [5]. This one article studied, how MTM can be used for Digital Human Modelling [12]. The last article in this category used MTM-Logistics to analyze a work process and contributed to the CSR implementation at the level of industrial production [13].

Scientific articles that examine MTM but don't use it to analyze a work process. These articles usually just introduced MTM as a method and its basic attributes. They introduced either the applicability of the method [6], or the limits and in which environment the method is best to use in [3].

Scientific articles that study the computerized versions of the two methods are very limited. There was one article that proved to be useful of introducing the methods and said computer software is a way that is easily understandable for everybody [9].

Scientific articles that introduce both methods but at a very basic level and don't use comparison between them, they are limited and are usually very short. In these articles the main focus wasn't on the PMTS methods, but rather another work analysis method and the PMTS methods were only introduced as showcase the other possibilities, either it is a computer application of a work analysis method [8], or a case study [11].

Scientific articles that introduce both methods and applies them to compare the two methods. They went fairly deep into the introduction. These articles used real experiment to compare the methods and usually only studied one or two most important aspects. One article compared the methods (only) by how accurate both methods are [7], while another tried to use two aspects, mainly accuracy and elaboration [10].

Scientific articles that use one method and briefly mention the other one were also very limited. It was the case of analyzing a work process with MOST, but the article also introduced MTM, as it is the base for MOST. One article used MOST to determine Non-Value Added activities [14], while the other used it for enhancing productivity and minimizing production time [15].

Scientific articles that only introduced MOST and did not make an analysis were very rare. As MOST is a method that is best used in real-life, researchers did not really bother only introducing the method. Those who did, used a real-life problem and tried to find a solution through the literature, and in conclusion, the article presented some aspects of MOST, that are useful for those, who want to know more about the method [24].

Scientific articles that used MOST to analyze and improve a work process were common and there are many of them. What's common in all of them, is that they used MOST to analyze and improve either productivity, manufacturing time or the workplace. Some articles used MOST in Automotive [16][18][19], while others used it for Aerospace Industry [17]. As said earlier, it was very popular to improve productivity in some articles [20][21][23] or develop ergonomics in the work environment [25]. One article used MOST to filter out unnecessary expenses in the work process [22], while another one used MOST for calculating process time [27] or to re-design an already existing work process in order to reach maximum effectiveness [26].

The Table 1. orders these papers to the above enumerated analysis aspects, to show whether an aspect is somehow handled or described in the given paper.

V. COMPLETE COMPARISON OF MTM AND BASICMOST

Beyond the review of the two most popular PMTS methods of MTM and BasicMOST a support is required for the positioning and the selection of the appropriate technique in a given application. To serve this need, main features according to the above listed, sophisticated aspects are extracted from the scientific publications and they are presented in Table 1. for a comprehensive overview of the state-of-the-art.

Table 1. Main features of the MTM and BasicMOST methods according to the comparison aspect.

Group	Aspect	MTM	BasicMOST
Method	Number of motion elements	23 different motions [5] 26 motions [9] 19 motions [10] 20 motions [12] 10 categories for motions [14]	3 motion sequence [9][18][20][22][23]
	Breakdown of the analysis	Very detailed method but requires a lot of effort to apply [3][5][8][10][11][14]	Not as detailed and time consuming as MTM, therefore it is quicker to apply [10][11]
	Informational element breakdown	Quite detailed data tables [12]	Very detailed data tables [2]
	Length of the process	Shorter, repetitive process [3][6][15] Maximum 10 minutes long, but most precise at maximum of 10 seconds long process [7]	From 1 minute to 10 minutes long process [7][21][27] From 20 seconds to 2 minutes long process [8][18][23][15]
	Software support	4M [9]	Computer BasicMOST [9]
Applicability	Clarity of the movements	The motions are represented with detailed pictures [3]	The motions are easily understandable [2]
	Applicability of the method	Only trained individuals can apply the method [6][8][13]	Only trained individuals can apply the method [8] The method is easy to understand and apply [18][24]
	Sensitivity of the method	5cm change in the environment shows a total of 5%-time change [10]	5cm change shows a total 0% change in time [10] The method is sensitive in a sense that it is easy to pick alternative methods with the help of it in the aspect of time and cost [21]
	Clarity of the method	For many companies the use of MTM is complicated and they rather not use it [4]	The method is easy to learn and use [17][21]
	Trainability of the method	Individuals need throughout training to fully understand the method and many companies choose practical training rather only academic training [3][4]	It is easy to learn and apply, even non-engineers can easily use it with little training [9][20][21][24][27]
	Limits of the method	It is limited to only manual process [3][4] Used with other methods the limits can be overcome [5]	You can't add any motions to any of the motion sequence [2][20]
	Flexibility of the method	The method can be used with stopwatch study and lean method [5]	It can be used both to repetitive and non-repetitive process [21]

Effects	Improvement magnitude	10% less time in manufacturing [7] 18% of the process was shown as NVA activity [14] 17% decrease in use of manpower and 34,5% increase of manufacturing [15]	The decrease in manufacturing time varies between 10-60% [7][16][17][19][22][23][24][14][15][26][27]
	Accuracy of the analysis	1,51% more accurate than BasicMOST [7] Comparing with stopwatch study, MTM is the most accurate [10]	Accurate method [16][15][27] At 95% confidence interval it can show a 5% difference between MTM and BasicMOST [17][20][21][24] In comparison with stopwatch study in a shorter process it is shown that the method is 33% better in the aspect of time [10]
Applications	Process types	MTM is mainly used in industries where there is some kind of manufacturing involved [1]	Industrial environment [16][24][25][27] It can be used in manufacturing, administration or in a process where the motions can be described clearly [20][21][24]
	Industry branches	Automotive [5][7][14][15] Fenestration [11]	Automotive [7][16][18][19][23][14][15] Aerospace [17] Fenestration [11] Electronics [22]
	Ideal applications	In the process planning phase [3][4][5][6][7] Optimizing a process [4][5][6][13]	Planning phase of a process [7][14][15][26] Optimizing a process [16][24][26] Making a process cost-efficient [17][21][15] Productivity boosting [19][26]
	Industrial trends	Computerized version of the method [8][9][12] Productivity improvement [5][15] Automation [10] CSR [13] NVA process [14]	Computerized version of the method [8][9] Automation [10] Productivity improvement [16][20][21][15] Tool efficiency improvement [17] Cost saving [22][23] Process optimizing, re-designing [24][26] NVA process [14]

Beyond the comprehensive review of the state-of-the-art according to the various aspects the authors evaluated which method is superior by each aspect listed before, it is also a recommendation if the given aspect is important. This literature-based but additionally by the authors evaluated superiority between the two analyzed methods are presented in Table 2. The concrete capabilities of the two methods are appointed by the aspects with the determined superiority, moreover, a short argumentation is also given, supporting this selection.

Table 2. Superiority of the methods according to the appointed aspects

Group	Aspect	MTM	BasicMOST	Superiority	Argumentation
Method	Number of motion elements	19 overall motions	3 motion sequence	BasicMOST	The "Tool Use Sequence" gives more freedom and variety to the analysis
	Breakdown of the analysis	Very detailed method but requires a lot of time to apply	Quite detailed method and can be applied much quicker than MTM	BasicMOST	Almost as detailed as MTM but can be applied nearly 40 times quicker [2]
	Informational element breakdown	Detailed data tables	Detailed data tables	Equal	The data tables have the same detail level

	Length of the process	Shorter process, but can be used up to 10 minutes long process	From couple seconds to 10 minutes long process	BasicMOST	MTM loses accuracy when used to longer process, whereas BasicMOST thrives when used for a couple minutes long process
	Software support	There are a couple useful software that can be used on multiple platforms	Very few software	MTM	The amount of software and the quality of the software is better for MTM
Applicability	Clarity of the movements	The movements are presented with detailed pictures	The motions are easily understandable	MTM	The motions are not only well explained, but shown with pictures too [3]
	Applicability of the method	Only trained individuals can use it	Easy to learn and use with very little training	BasicMOST	The method requires only very little training to use
	Sensitivity of the method	5cm change in the process can cause a 5% change in time	5cm change in the process causes 0% change in time	MTM	Easier to achieve better results when optimizing a process with only a few cm of changes in the workplace
	Clarity of the method	For many companies the method is too complicated and they avoid using it	Easy to understand and learn	BasicMOST	While MTM may be too complicated for many, BasicMOST can be learned and applied easily
	Trainability of the method	The harder movements can be improved with practice, therefore many companies choose practical training instead of only academic	Easy to learn and use, even non-engineers can use it easily	BasicMOST	The method is easier to learn and makes it a more accessible method for everyone
	Limits of the method	Can only be used for manual work	All 3 motion sequences are fixed and no additional motion can be added	MTM	MTM can always be improved by being open to new motions
	Flexibility of the method	Can be used well with other methods like stopwatch study or lean method	The method can be used both for repetitive and non-repetitive process	BasicMOST	BasicMOST can be used for almost all process with zero to no problem, where with MTM, you have to use other methods in order to be as effective as BasicMOST
Effects	Improvement magnitude	The improvements in production time vary between 10-20%	The improvements in production time vary between 10-60%	BasicMOST	There is a chance of greater improvement when using BasicMOST

	Accuracy of the analysis	When compared with BasicMOST, it gives a 1,51% better result in production time	When compared with MTM, it gives a 1,51% worse result in production time	MTM	Even if the result is very little, MTM is still more accurate, than BasicMOST
	Process types	MTM is mainly used in industries where there are some kinds of manufacturing involved	BasicMOST is used in industrial environment, but can also be used for administration or developer environment	BasicMOST	BasicMOST is more versatile and can be used in more types of process than MTM
	Industry branches	MTM is mainly used in automotive and there are very few examples of other industries	BasicMOST is used in every kind of industry, most popular is automotive	BasicMOST	The more industries can use a method, the better
	Ideal applications	It is used both in the process planning and optimizing phase	Used in optimizing, planning, making cost efficient, productive and ergonomic a workplace and a process	BasicMOST	BasicMOST can be used for more than just planning and optimizing

The tables above have shown the different capabilities of the two methods and compared them in the most detailed way possible. Overall, it can be identified that BasicMOST is the winner in most of the aspects, however, one cannot underrate MTM, as it is still the most popular method that can give very accurate results and is very useful when designing or optimizing a process.

VI. COMPARISON OF INDUSTRIAL PROCESSES WITH MTM AND BASICMOST

An industrial validation was also performed in the automotive sector for analyzing the same process with both of the methods, moreover, manual measurements were performed in the shop-floor of the company. As a key aspect of the comparison, the differences or similarities in the time of the individual process steps were compared, as shown in Fig. 1.; longer, more complex processes are handled as process groups.

The two methods were used for a repackaging process analysis and optimization, where clear differences were discovered. Because of the detailed analysis MTM is capable of, the analysis was very long but gave a good overall view of the motions that were unnecessary. For example, in MTM it was clear that the distance between two packages was too long, whereas in BasicMOST it is nearly impossible to discover these nuances that sum up at the end.

Based on the real analysis experiences, the overall improvement in the process time with MTM was more, than 20%, whereas with BasicMOST it was only 6%. The reason behind this is those nuances, because the analyzed process was almost 3 minutes long, so, small changes make a significant difference at the end.

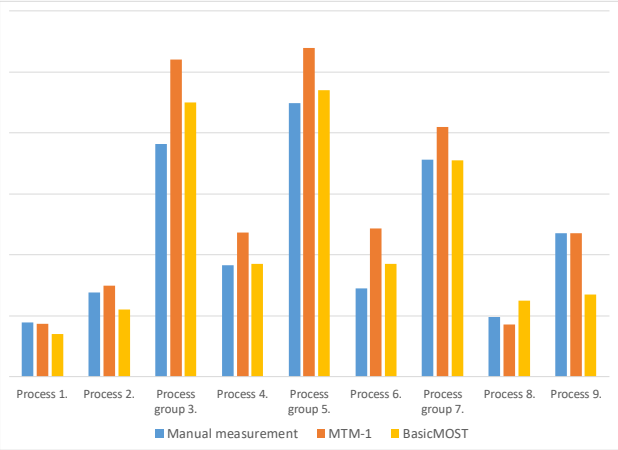

Fig. 1. Comparison of real measurement, MTM and BasicMOST in Automotive sector.

As presented, the measurements, MTM and BasicMOST calculations serve with roughly similar values, however, is most of the cases MTM estimates (much) longer process times and BasicMOST estimates are closer to the real values.

VII. CONCLUSIONS AND OUTLOOK

The paper presented a review and comprehensive comparison of the two, most popular PMTS methodology, MTM and BasicMOST. A sophisticated viewpoint set was generated, explained in details and the state-of-the-art literature was structured according to it. The relevant scientific publications were analyzed, and the key features presented in these contributions were extracted and are presented also according to the viewpoint set. As results of the comprehensive comparison, the authors appointed which method is superior to the other by the viewpoints. Overall, it can be identified that BasicMOST is the winner in most of the aspects, however, one cannot underrate MTM, as it is still the most popular method that can give very accurate results and is very useful when designing or optimizing a process.

Finally, the two techniques were also compared through their accuracy in a concrete industrial case in automotive sector. The manual measurements, MTM and BasicMOST calculations serve with roughly similar values, however, is most of the cases MTM estimates (much) longer process times and BasicMOST estimates are closer to the real values, however, improvement in the process time with MTM was more, than 20%, whereas with BasicMOST it was only 6%.

A. Outlook

As next step for the improvements of the method(s) three directions can be appointed:

- Digitalization, software realization and support of the techniques, e.g. camera based human motion detection and measurement.
- Using/extending the techniques to robot based movements in manufacturing.
- Integration of the complete methodology into the fully connected, Industry 4.0 ready environment, e.g. real-time connection, information sharing about the motions, real-time optimization and control, etc.

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