Industrial Engineering and Ergonomics

Unit 5
Modeling and optimizing manual work processes with MTM
Fall Winter 2012/2013

Univ.-Prof. Dr.-Ing. Dipl.-Wirt.-Ing. Christopher M. Schlick
Chair and Institute of Industrial Engineering and Ergonomics
RWTH Aachen University
Bergdriesch 27
52062 Aachen
phone: 0241 80 99 440
email: c.schlick@law.rwth-aachen.de
Learning Targets

- Learning the basic principles of the sequence-analytical time modeling (predetermined motion-time systems) of manual work processes
- Getting to know and generally being able to independently apply MTM (“Methods Time Measurement”)
- Being acquainted with concentrated MTM data systems
- Being capable of choosing the correct MTM data system in practice
- Being acquainted with the possibilities and limitations in the usage of MTM
Introduction: Automobile assembly

How to conduct “line-balancing” of manual tasks in an assembly line, so that the utilisation is as high as possible without constraining the employees by the process design?

Illustration for line-balancing (Gantt-Chart)
Due to the differences in actual and target times, it is necessary to clarify the causes.

There are different methods for time calculation. Experimental procedures serve for the calculation of actual times. Mathematical procedures are the basis for the calculation of target times.

The definition of predetermined motion-time systems clearly indicates that the use of predetermined motion-time systems is primarily limited to manual activities. Mental activities that go beyond simple yes/no decisions cannot be modeled with predetermined motion-time systems. Furthermore, a PMTS application is only possible if the worker can completely influence the work procedures. So-called process times are to be determined via time measurements. Only the activity times can be acquired through predetermined motion-time systems. No additional or recovery times are contained within the standard time values.
Application of Predetermined Motion-Time Systems (PMTS)

PMTS applications

- **design of the work system**
  - planning of the operating process
  - optimization of the operating process
  - design of tools and equipment
  - design of the manufacture

- **time determination**
  - creation of planned times
  - determination of standard time for performance-related remuneration
  - pre-costing

- **work instruction**
  - description of the operating processes for education and instruction materials
Taylor stipulated that the actor’s work during a time study should be broken down into simple ‘elementary movements’; each elementary movement must be precisely ‘described’ with an indication of the time duration and then classified in such a way that it can easily be found again at any time, if necessary. Combinations of elementary movements that reoccur in the same sequence should be classified so that they can easily be reused. When enough elementary movement times and their combinations have been classified, the time necessary for performing almost any work can be synthetically determined through addition of the corresponding supplements. With the help of film recordings, Taylor’s student Gilbreth analyzed motion sequences, among other things, and assumed that movement elements exist that cannot be further divided. He defined 17 such elements and named them “Therbligs”, which is simply his own name spelled backwards. With these elements, Gilbreth then connected the idea of being able to synthetically determine the time needed for any type of work. The first system of predetermined times was then also presented by A.B. Segur, Gilbreth’s colleague, in 1924.

The copyrights for the MTM procedure were transferred from the developers of the U.S. MTM Association for Standards and Research founded in 1951. This operates on a non-profit basis. Due to the fast distribution of the MTM procedure a number of additional national MTM associations subsequently formed. The umbrella organization of these national MTM associations forms the International MTM Directorate. The U.S. MTM Association transferred to the national associations, represented in the international MTM Directorate, the copyright of the MTM-1 procedure for the scope of their charter. The German MTM Association (registered association) was formed in 1962 by well-known Germany industrial enterprises. It is one of the world's largest national MTM associations.

Additional information can be found under: www.dmtm.com

In 1972, Kjell Zandin published MOST (Maynard Operation Sequence Technique), which predominantly examines the movements of objects, in Sweden. It distinguishes between three motion sequences: General Move, Controlled Move and Tool Use.
Many industrial work processes were filmed to distinguish the fundamental motions from each other. The actual time was determined by counting the number of pictures that resulted for each movement. The time variances resulting from the inter-personnel performance variance were balanced with the LMS procedure. The MTM standard performance times were processed, like the influencing variables calculation, with the aid of statistical methods. This was done in order to balance the measured value variance and to establish the functional correlations between influencing variables and time. The result of this development is formed by the MTM-1 metric card.
Development of MTM-1 -
The Lowry-Maynard-Stegemerten method

actual time according to video analysis / time recording • median LMS-performance level of the evaluation group = MTM standard performance

A standard performance of 100% is described within the LMS method as "performance of a moderately high trained person who can show this performance in perpetuity without work fatigue".

LMS: Lowry, Maynard, Stegemerten (names of the developers of this method)

performance index according to LMS

influences dependent from people
- dexterity
- effort
- constancy of execution time

influences independent from people
- working conditions (e.g. lightning)
The currently valid version of the MTM system’s MTM-1 metric card is the MTM-Data-Card 101 A, 1955 edition, of the U.S. and Canada MTM Association. The national cards recognized by the international directorate are based on this card. As a result, an agreement regarding the data exists on the international level.

(Deutsche MTM-Vereinigung e.V., course documents regarding MTM-1).

Today, the analysis of manual work processes with MTM usually occurs with the aid of a computer, e.g., with the help of TiCon-Base (www.dmtm.com).
Experiments have shown that the five specified fundamental motions are the most frequently occurring in practice. They are also referred to as the fundamental motion cycle since they usually occur in the specified sequence.
The fundamental motions can be divided according to their difficulty to learn: Simple motions such as Reach and Move can be mastered almost immediately; their execution can hardly be improved by any training. In contrast, motions such as Grasp and Position have to be categorized as difficult; their execution can be improved by training, so that the time needed to perform these actions decreases when increasing the number of repetitions. This fact has been proved by studies of Rohmert & Schlaich (1967) and Rohmert & Kirchner (1969).
A characteristic of applying pressure and disengaging is the increasingly controlled muscular strength that acts upon an object without any considerable movement occurring. Turning is the fundamental motion that is executed when the empty or engaged hand is moved around the longitudinal axis of the forearm.
Shifting of the view is the movement of the eyes that take place in order to direct the focus of the eyes from one place to another. A shift of focus is only analyzed if it occurs as an independent fundamental motion, i.e. the eyes must have fulfilled their task before the next fundamental motion can be performed.

Eye focus is the eye activity that takes place in order to determine easily noticeable characteristics of an object within the normal field of vision (circular surface with a diameter of 10 cm found at a distance of 40 cm from the eyes).

During eye focus a difference can be seen between control and focus features. Control features are characteristics that are only to be examined in terms of their existence (e.g. drilling occurring?). Focus characteristics are to be qualitatively evaluated (e.g. casting resin cleanly poured?).
15 fundamental motions for body movements:

- Without shift of body axis
  - Foot motion
  - Leg motion

- With shift of body axis
  - Side step
  - Turn body
  - Walk

- With inclination of body axis
  - Bend
  - Arise from bend
  - Stoop
  - Arise from stoop
  - Kneel on one knee
  - Arise from kneel on one knee
  - Kneel on both knees
  - Arise from kneel on both knees
  - Sit
  - Stand
The time for reaching is determined by the measurement of the three influencing variables (distance moved, case of motion, type of motion path). The distance moved is the actual path covered. The case of motion is dependent on the required degree of control of a movement. The degree of control is small in the cases of A and E, moderate with case B, and high with cases C and D.

Three types of motion paths can occur during the reaching movement. In most cases the hand starts and ends in the resting position. The normal reaching movement therefore points to an acceleration and deceleration phase (type I). Type II is present if the acceleration and deceleration phase is missing (e.g. reaching to a machine lever that is moved without a delay in movement after being reached).

Type III movements (missing acceleration and deceleration components) very rarely come into practice.
“Grasp” (G) is the fundamental motion which is accomplished to keep one or several items in check with fingers or hand, so that the following fundamental motion can be carried out.

<table>
<thead>
<tr>
<th>Case</th>
<th>TMU</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1A</td>
<td>2.0</td>
<td>Pick Up Grasp: Small, medium or large object by itself, easily grasped.</td>
</tr>
<tr>
<td>G1B</td>
<td>3.0</td>
<td>Very small object or object lying close against a flat surface.</td>
</tr>
<tr>
<td>G1C1</td>
<td>7.3</td>
<td>&gt; 12 mm Ø</td>
</tr>
<tr>
<td>G1C2</td>
<td>8.7</td>
<td>6 to 12 mm Ø</td>
</tr>
<tr>
<td>G1C3</td>
<td>10.8</td>
<td>&lt; 6 mm Ø</td>
</tr>
<tr>
<td>G2</td>
<td>5.6</td>
<td>Re Grasp. Shift of the control point of an item without losing control of item</td>
</tr>
<tr>
<td>G3</td>
<td>5.6</td>
<td>Transfer Grasp. One hand takes over control of an item while other releases.</td>
</tr>
<tr>
<td>G4A</td>
<td>7.3</td>
<td>&gt; 25x25x25 mm</td>
</tr>
<tr>
<td>G4B</td>
<td>9.1</td>
<td>6x6x3 bis 25x25x25 mm</td>
</tr>
<tr>
<td>G4C</td>
<td>12.9</td>
<td>&lt; 6x6x3 mm</td>
</tr>
<tr>
<td>G5</td>
<td>0.0</td>
<td>Contact, sliding or hook grasp. Gain sufficient control over item through contact so that following fundamental movements can be executed.</td>
</tr>
</tbody>
</table>
MTM-1: Time-influencing factors considering grasping as example

**Pick up grasp G 1**

- **G 1 A**: Highly frequent in practice
- **G 1 B**: Frequent in practice
- **G 1 C**: Seldom in practice

**Regrasp G 2**

- **Start of motion**
- **Motion**
- **End of motion**

**Transfer grasp G 3**

- **Right hand (dashed) to left hand**
- **Handing over**
- **Right hand (dashed) has taken on check on the item**

**Select grasp G 4**

<table>
<thead>
<tr>
<th>G 4 A</th>
<th>G 4 B</th>
<th>G 4 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 25 x 25 x 25 mm</td>
<td>&gt; 6 x 6 x 3 mm</td>
<td>&lt; 6 x 6 x 3 mm</td>
</tr>
<tr>
<td>7.3 TMU</td>
<td>9.1 TMU</td>
<td>12.9 TMU</td>
</tr>
</tbody>
</table>

Two partial dimensions should fall in the respective category.
The MTM standard data card gives neither information about the spreading of the time consumption nor about the probability of the mistakes made by a person while planning, performing and controlling a motion.
In this example, the grabbing and assembling of bolts by an employee has been modeled. The bolts (8x12 mm, fully symmetric) are stored mixed in a box that is 40 cm away from the employee. The employee picks up one of the bolts and places it in a hole in front of him. The assembling tolerance is tight, but the handling is categorized as easy. The bolt is released by opening the fingers.
Sequentially occurring movements are presented in the example. However, the goal of the work design is motion sequences in which, for example, both hands carry out movements simultaneously.
A combined movement is carried out when a movement, or several movements, are performed during a fundamental motion and the motion sequence is not hindered.
Movements can be carried out simultaneously when the control effort is low to moderate. A high level of control effort, however, creates such strong demands on a person’s attention span that the movements cannot be usually carried out at the same time.
A table is shown on the front side of the MTM-1 metric card. This table can help in reaching a decision about whether fundamental motions can be performed simultaneously or sequentially. Three degrees of difficulty for the performance of simultaneous movements are thereby distinguished: (1) easy, (2) with practice, (3) difficult.
The given illustrations show two possibilities of inserting two bolts into a pinboard. In the upper illustration the bolts are inserted consecutively with just one hand. The lower illustration shows the operation carried out with both hands simultaneously. With the simultaneous use of right and left hand the operation can be carried out much faster as it is shown in the tables above.
Possibilities and limitations in the application of MTM-1

Application of MTM-1
- mass production in large batches
- limited model variety
- short-cyclical workflows
- exactly defined basic conditions
- experienced, highly trained employees
- workstations with a detailed-oriented design

comparison of processes  comparison of design alternatives  process optimization  evaluation of short-cyclical workflows  creation of the work plan and training
The MTM basic procedure, also known as MTM-1 and MTM basic system, forms the basis of the method level of mass production. Compressed MTM analyzing systems were developed for analyzing small and single item production and thus increasing analyzing speed due to changed customer demands.
Among others, the following MTM analyzing systems have been developed in the German-language area lead-managed by the Deutsche MTM-Vereinigung e.V.:

- MTM standard data basic values
- MTM-UAS (Universal Analyzing System)
- MTM-MEK (MTM for single-part and small-series production).

The MTM-UAS analyzing system is the one that has the most widely spread use in Germany. In particular, it is used for manual assembly in the automobile industry and by the automotive supply industry. Typical areas of application of MTM-MEK are assembly in the aircraft industry or the creation of die cutting and forming tools. MTM-1 is now used in only a few German companies.
The development of consolidated analyzing systems results through a higher or lateral compression of data based on MTM-1. During high compression data is modularly consolidated according to the multi-level bill of material principle. The data summary takes place either additively or statistically. During lateral compression influencing variables and their values are reduced to a specific data level in each case. The fundamental motion Release is assigned to the motion sequence Get in order to enable multiple executions of placing (e.g. stamping cards with pushing the stamp on the stamp pad after each process of stamping). The stamp is released only once after all stamping operations.
For soldering a plate tin is picked up from a device with the left hand and the soldering irons with the right. With the soldering iron the tin is heated up at the connection that needs to be soldered until this is liquid and fixes the units in order to connect them. Afterwards, the soldering iron and the tin are placed in their devices. The comparison of the analysis of the soldering procedure with Basic MTM-1 and with MTM-UAS shows that the same working process with MTM-1 is described with 14 basic movements and with MTM-UAS with only four basic procedures. UAS combines the movements reach, grasp, move and position the tin solder into the basic procedure „get and place “(AC2). Reaching, grasping, moving, positioning and releasing the solder iron are consolidated to the basic procedure „aids to handle “(HC2). The placing of the tin on the table is expressed by „placing “(PA2) in an approximate position. Furthermore UAS doesn't differentiate between parallel and sequential movements of the left and the right hand. Despite the compression of the movements through MTM-UAS the total time in this example diverges only around 6,5%.
The compression of the data, which results from the further development of the MTM system, leads to a reduced number of MTM components needed to describe a work task. The example of the subassembly of a carburetor shows that MTM-1 needs more than 5 times the number of components as MTM-UAS for describing the same task. The reduced number of components in MTM-UAS leads to a less time needed to perform the analysis. But this advantage comes along with a less accuracy of the analysis; it especially induces a lower level of methodology, i.e. the work task is described less detailed. This is reflected in the differently analyzed execution times: Due to the lower level of details, MTM-UAS usually has a higher analyzed time than MTM-1.
Advantages

- It is possible to already determine operating processes and execution times explicitly in the planning phase of a work system.
- Training periods can be reduced since employees can already be trained before the introduction of new work processes.
- It is possible to design work systems in a target-oriented way, as influencing variables concerning the execution times become transparent by means of the MTM methodology.
- MTM time values are based on a 100% standard performance. An evaluation of the performance rate – as to be found in REFA Stop watch time study – is not necessary.
- The coding of the motion elements leads to an internationally homogenous, reproducible description of the operational procedures.

Disadvantages

- The implementation of MTM is limited to manually operated tasks.
- The analysis effort is rather high.
- The analysis can be influenced subjectively.
Quick Knowledge Check

✓ What is the purpose of predetermined motion-time systems?
✓ What was the procedure during the development of MTM-1?
✓ Which 5 fundamental motions of the finger-, hand-, and arm-system can be distinguished within MTM-1?
✓ What is the procedure for the application of the MTM method?
✓ What are the preconditions for the application of MTM-1?
✓ What are the reasons for the development of concentrated MTM methods?
✓ How do you determine which MTM analyzing system should be applied in operational practice?
✓ What are the advantages and disadvantages of the MTM method?