New Work Item Proposal

Ergonomic Work Allowance (EWA) for cyclical industrial work

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Due to the importance of the matter and its span of impact, this document aims at supporting the application of a NWIP as international standard (harmonized ISO/CEN).

The NWIP, named Ergonomic Work Allowance (EWA), wants to be a reference for the process of setting the proper ergonomic allowances to keep the biomechanical load generated by human cyclical work under control. The control limits used by the EWA are the limits defined in the ISO 11228 and 11226.

The EWA is a percentage applied on an underlying quantity, which is the result of a measure of work (see Figure 1 - Standard Time Setting Process). For this reason, the present NWIP will also refer to some key concepts, which are typical industrial engineering topics, considering them as an input and not included within the scope of this proposal.

In the EWA calculation process, we will recommend the most suitable techniques to maximize the accuracy and the efficiency of the required measures. However, given the references set by this NWIP, we leave the freedom to adopt and apply any work measurement technique available on the market.

As far as the biomechanical load measurement is concerned, this NWIP adopts the Ergonomic Assessment Work-Sheet (EAWS), which compounds several risk areas (postures, forces, manual handling of loads and high frequency motions of the upper limbs) on a single measurement scale and which considers the work organization as an influencing factor (shift duration, number of breaks and type of work process).

By ergonomic allowance we mean a percentage used to increase a planned execution time of a given manual task in order to reduce the biomechanical load (fatigue) generated by awkward postures, forces and movements. In the ergonomic allowance we do not include the physiological need allowance, which is a constant value, independent by the type of work (physiological need allowance typically ranges from 4% to 5%), used to allow 2 breaks of about 10 minutes each, distributed within the shift. The ergonomic and physical allowances belong to the personal allowance class.

Other existing allowance classes, work allowance and learning allowance classes, are not considered within the scope of the present NWIP.

In the following pages of the document, the terminology will refer to the process map described in Figure 1 - Standard Time Setting Process:
2.1 Scope of the proposed NWIP.

The scope of the NWIP is any cyclical human work planned and executed in an industrial competitive environment. The most typical cases are within industries where there is the need to define an expected output (products or services) based on the optimization of the trade-off between labor productivity and ergonomics.

Estimated world manufacturing population impacted by the procedure: 200 mln workers (30 mln in EU28, 12.5 mln in US, 100 mln in China and 60 mln in India).

The most sensitive organizations to this proposal would be those in labor-intensive manufacturing industries with series and large batch production systems (cycle times < 1 hour):

- Automotive (OEM and Tier 1 and 2 suppliers)
- Industrial Automotive (trucks, buses, agricultural and mining equipment)
- Industrial Manufacturing (small domestic and industrial equipment/machinery)
- Domestic appliances and consumer goods (white goods)
- Plastic and rubber products (tires, doors, windows, shoes)
- Consumer electronics (PC, TV-sets, printers, radio, Hi-fi, alarm systems)
- Furniture
- Textile/apparel
- Food preparation
- Packaging

The following industries would also benefit with minor adaptation efforts:

- Aerospace and Defense
- Rail and Ship
• Large domestic and industrial equipment/machinery
• Logistics

2.2 Purpose and justification of the proposal

The NWIP sets a standard procedure to determine the quantity and distribution of the recovery periods to keep the biomechanical load under control in industrial environments with repetitive cycles.

Present Issues

• Recovery periods are assigned based on a partial evaluation of the load intensity (usually body postures and forces)
• Recovery periods are not influenced by the load duration (action frequency and duration of static actions)
• Recovery periods are independent from the work organization (shift duration, break periods duration and distribution)
• Lack of a recognized “ergo-compliant” work performance to measure manual work
• Lack of ergonomic holistic evaluation systems
• Ergonomic risk mapping systems use different units of measure (scales)
• Ergonomic approach is mainly reactive rather than proactive (preventive ergonomics)

2.3 Proposed approach

• Define a standard work performance, meeting the following key requirements:
  − Facilitates the compliance with ISO 11228.1/2/3 and ISO 11226
  − Be recognized as a leading global standard
  − Be supported and distributed internationally (governance, independence and availability)
  − Be objectively measurable
• Recommend a standard language to identify and describe human movements
• Recommend the use of an holistic biomechanical measurement system
• Define an engineered model to calculate the recovery periods and their distribution along the shift in different production systems

2.4 Expected Benefits

• Improve working conditions, safety and ergonomics of workers in manufacturing industries
• Support the ergonomic evaluation in the earliest stages of product/process development, when changes are still feasible and the cost of a change is affordable (preventive ergonomics)
• Link ergonomic improvements with labor cost reduction (improve ergonomics \(\rightarrow\) reduce costs \(\rightarrow\) justify investments in ergonomic improvements)
• Reduce the cost and the deviation of the ergonomic risk mapping process by linking the biomechanical load measurement with work measurement and organization
• Be an objective reference for the Employers and the Unions when setting up gainsharing contracts based on labor productivity (industrial relations)
3 Technical Content of the NWIP

The determination of the correct work content of a given activity is a fundamental task for a company in order to be competitive on the market, as well as to safeguard workers’ health and to guarantee a proper quality of the performed activity. The setting of a standard time of a manual task requires the following steps (see Figure 1 - Standard Time Setting Process):

1. Design of a standard working method
2. Work measurement
3. Task assignment and work organization
4. Biomechanical load measurement
5. **Ergonomic Work Allowance (EWA)**
6. Setting of a Standard Time (Tstd)

3.1 Design of a standard working method

The Design of a standard working method is the key driver to achieve operational excellence levels of productivity and safety. This task is under the main responsibility of Industrial Engineers, who have to blend wisely several fields of knowledge to coordinate humans, machines, and materials to attain a desired output rate with the optimum utilization of energy, knowledge, money, and time. It employs certain techniques (such as floor layouts, personnel organization, time standards, wage rates, incentive payment plans) to control the quantity and quality of goods and services produced. It is clear that the design of a working system determines the ergonomic conditions of the worker and therefore it is fundamental to bring the ergonomic knowledge into the earliest stages of the product and process development process.

![Figure 2 - New product development process](image)

Major industrial companies use a predetermined motion-time system (PMTS) as a tool in their operating model to design a work system. A PMTS is a set of data of elementary human motions, of which a basic time is predetermined, which can be used as a reliable language to plan and measure a future activity.

The last developments among available PMTS aimed at creating specific tools for designing work systems in the earliest stages of product and process development, rather than simply measuring them. In this way, it is possible to find the most efficient and ergonomic solutions when it is still feasible to make product and process changes and the cost of the change is affordable. Indeed, usually in those
early phases, investments in tools and equipment have not yet been released and changing a CAD file or a design is not too expensive. Standard times play a key role in setting internal transformation process costs and purchasing costs of goods and services. World Class companies’ purchasing departments monitor direct purchasing or outsourced services costs thanks to an analytical calculation based on the most appropriate PMTS system. As far as ergonomics is concerned, if we have a tool to pre-calculate the biomechanical load based on a planned working method, it becomes economic and effective to preventively reduce the risk due to an excessive work load.

3.2 Work Measurement

The determination of the Basic Time (T_b, Step 2 in Figure 1) is built on the concept of standard work performance, equivalent of the much-discussed fair day’s work. The standard work performance represents an effort level that could be easily maintained year in and year out by the physically normal operator without in any way requiring him/her to draw upon his/her reserves of energy. Working at standard performance brings the worker to get to the end of the fair day’s work without physical stress.

Many work measurement techniques make use of performance rating to ensure that times calculated or derived are times for ‘an average qualified worker’ to carry out the work being measured. Since this average qualified worker is not actually observed, performance rating is used to modify what is observed and thus convert it to ‘basic time’.

![Stop-watch procedure](image)

<table>
<thead>
<tr>
<th>Stop-watch procedure</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop watched time $T_{sw}$</td>
<td>Stop watched time $T_{sw} = 100$</td>
</tr>
<tr>
<td>Rated Performance $P$</td>
<td>Rated Performance $P = 90%$ (MTM scale)</td>
</tr>
<tr>
<td>Standard performance $\bar{P}$</td>
<td>Standard performance $\bar{P} = 100%$</td>
</tr>
<tr>
<td>Basic time $T_b = T_{sw} \times \frac{P}{\bar{P}}$</td>
<td>Basic time $T_b = 100 \times \frac{90}{100} = 90$</td>
</tr>
</tbody>
</table>

*Figure 3 - Stop watch procedure to set a basic time*

Some measurement techniques such as predetermined motion-time systems (PMTS) do not require the observer to rate the worker being observed, but such techniques have used performance rating in the derivation of the data, which is applied to the observed motion pattern. Thus performance rating is an integral part of work measurement.

Unfortunately, there are a number of different performance rating systems and scales and this makes it difficult to compare directly standard times derived by different methods or in different organizations.

**Standard work performance**

Increasing globalization of large companies means that many organizations are now using a number of different work measurement techniques in different parts of the organization. This happens because different techniques have assumed a greater degree of usage in particular countries. These global organizations are now looking to establish compatible (or at least comparable) time standards across the organization to simplify planning and control processes.

Each of the rating systems/scales starts from a different conceptual viewpoint. For example, the Bedaux System assumed that ‘normal’ performance was 60 ‘minutes of work’ per hour, that 80 ‘minutes of work’ per hour was incentive performance and that 100 was a theoretical maximum.

All work measurement systems use time units to represent work content - the quantity of work involved in carrying out a particular task, operation or job. Thus the unit, such as ‘standard minute’, is an expression of quantity of work, rather than of time. It only converts to an equivalent time assuming that the operator works at standard performance (on the performance rating scale used) and takes the agreed level of allowances built into the work content value.
Different rating systems claim to rate different factors - commonly these are some combination of speed, effort, skill, dexterity, consistency, conditions.

One of the common problems of rating is that it is often linked to remuneration, through the setting of 'daywork' rates or through graduated incentive payment schemes. This results in pressure from employees and unions on work study practitioners to 'slacken' their ratings to give 'looser' time values for jobs.

Thus, even though the same rating system and scale is in use in different organizations, there is no guarantee that the concepts of normal and incentive performance are the same in each - this is especially true if the organizations carry out no rating validation through rating clinics.

In some countries/organizations, trade unions have a right to observe time studies or to carry out parallel studies to check on the times produced by work study practitioners. Where incentive payment schemes are involved there is understandably a desire to challenge rating and allowances used by the practitioner - since most rating systems are based on subjective judgment, this debate is difficult to resolve in the absence of some means of validating ratings.

The choice of a well-known level of standard performance is crucial for the process of designing safe and ergonomic work systems, especially as far as the upper limbs risk evaluation is concerned. Indeed, a higher level of standard performance would bring to shorter basic times of each elementary motion and consequently an expected increase of action frequency of the upper limbs planned motions. When most of the work measurement systems were developed, there were no ergonomic standards available and the good ergonomic solutions were left to the individual experience of the industrial engineers. Nowadays, the correlation between the biomechanical load and the probability to incur a work-related musculoskeletal disorder is proved and relevant ISO/CEN standards set clear references.

One objective of the present NWIP is to take a formal position against the use of the different performance levels to set basic times within the industries. The availability of different performance rating scales is not an issue. When measuring a temperature, regardless the scale used, if the water starts boiling, the value read on each scale is different but well known and equivalent (100 °C or 212 °F or 373.15 °K indicate the same level of heat). In the same way, it is important to establish a fair level of work performance, which keeps the biomechanical load under given limits. Several tests have been run by the technical committee of the International MTM Directorate (see Appendix 3.1), using the MTM scale as a reference, and the results can be summarized as follows:

In Figure 4 the statistical distribution of the action durations is represented, excluding body motions and visual controls, which do not generate any upper limb action. The statistics were obtained from a large sample of real industrial MTM analyses made up with more than 3,000 motions.
Figure 4 - Distribution of action durations

The ISO standard 11228.3 sets the max number of actions at 70 Technical Actions per minute (see OCRA system), equivalent to 40 Real Actions per minute (see EAWS system). Considering the durations shown in Figure 4, the average duration of one action is in the range of 31-35 TMU (Time Measurement Unit – 100,000 TMU = 1 hour), equivalent to 1.2 s and generating a Real Action frequency per minute equal to 50. In a real workplace, if we now consider that we usually have a distribution of motions between the two upper limbs (left and right) and some body motions and visual controls, which do not generate any Real Action and therefore dilute the frequency of actions, we have good chances to have a frequency of action, which does not cause an excessive biomechanical load.

If we repeat the same experiment using a higher level of standard performance to calculate the basic times and the planned actions, we would calculate a higher expected frequency of Real Actions/minute.

Conclusion: MTM performance, combined with a good method design, does not harm workers and supports productivity. The use of any work measurement system should refer to the MTM standard performance to set an “ergonomically compatible” basic time. Incentive systems based on labor productivity should not motivate workers to work at higher levels of performance, since the biomechanical load would increase rapidly, reaching areas of excessive risk. The main labor productivity driver is the method design, which can minimize costs and improve ergonomics, especially when product and processes are conceived by a cross-functional team with multi-skills capabilities (product and process engineering, ergonomics, production, cost engineering, quality, etc.).

3.3 Task Assignment and Work Organization

Task assignment in a manufacturing industry is very important, especially when assembly lines are considered (line balancing). Indeed, once the total work content is calculated (total basic time of all the actions necessary to accomplish the complete task), given a targeted quantity of units to produce and the net working time available in a shift (shift duration minus breaks and non-productive time), it is possible to set the pace of our production flow (Takt Time $T_b$). $T_b$ then becomes the maximum capacity of each workstation along the flow if we want the operators to work at a controlled performance and to produce the planned output. $T_b$ is like the capacity of a glass, the water we pour in it is the set of tasks we assign to a workstation and $T_b$ is the quantity of liters of water poured into the glass. Without a standard level of work performance, it would not be possible to balance the work assignment.
Once the tasks are assigned to a workstation and the T\textsubscript{k} is set, the action frequency is determined and the calculation of the workload can be accomplished accurately.

### 3.4 Biomechanical load measurement

Load results from the gravity linked with the work and the working conditions. The load describes the objective demands of work, which are to be fulfilled in a period. It is independent of the individual who performs the activity.

At present several ergonomic analysis systems are available to measure the workload. Each system was designed to deal with a specific risk area and it works with its own measurement scale (e.g. Lifting Index, OCRA Index and Strain Index).

EAWS is an ergonomic system developed to provide an overall load evaluation that includes several biomechanical risks to which an operator may be exposed during a working task. General body postures, action forces, manual material handling and repetitive motions of the upper limbs, when they generate a load, this is measured on a single scale and the resulting load is the composition of all loads in a unique final index.

**Ergonomic Assessment Work-Sheet (EAWS)**

EAWS is a risk assessment method for biomechanical load of the whole body and upper limbs used mainly in manufacturing industries as a process design tool for preventive ergonomics and adopted in the production departments for biomechanical stress mapping purposes (we estimate 630,000 workers mapped with EAWS worldwide).

EAWS is an open system, freely available, part of the International MTM Technical Platform, managed by the International MTM Directorate (www.mtm-international.org), a network of Non-Profit organizations dedicated to the development of the body of knowledge regarding the scientific management of work (all official systems in the international technical platform are available in the main languages, including Chinese).

EAWS offers compliance with the relevant CEN/ISO standards and it is structured in four sections, each one covering a specific risk area: Body Postures, Action Forces, Manual Materials Handling and Upper Limbs in repetitive tasks.

Each section is designed to measure with a score the load level for a given task (workplace). The structure of the EAWS analysis is as follows:

- Macro-Section “Whole body”:
- Section 0: Extra Points
- Section 1: Body Postures
- Section 2: Action forces
- Section 3: Manual material handling
- Macro-Section “Upper limbs”
  - Section 4: Upper limb load in repetitive tasks

Figure 6: EAWS Forms

The EAWS sheet provides one score for each Macro-Section, which is shown in a traffic light scheme (green, yellow, red) in compliance with the Machinery Directive 2006/42/EC (EN 614).

<table>
<thead>
<tr>
<th>Points</th>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25</td>
<td>Green</td>
<td>Low risk: recommended; no action is needed</td>
</tr>
<tr>
<td>&gt; 25</td>
<td>Yellow</td>
<td>Possible risk: not recommended; redesign if possible, otherwise take other measures to control the risk</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>Red</td>
<td>High risk: to be avoided; action to lower the risk is necessary</td>
</tr>
</tbody>
</table>

Figure 7: Overall Evaluation

Whole body and upper limbs scores are evaluated on the same scale.

EAWS generates two scores: whole body score and upper limbs score. The whole body score sums up the risk associated to the combination of body posture, force actions and manual material handling of loads (EAWS sections 1, 2 and 3), while the upper limb score (EAWS section 4) covers the risk associated to the high frequency movements and awkward postures of upper limbs. The EAWS final risk score is the highest between whole body and upper limbs scores.

The EAWS system is explained in details in the reference user manual ([16]), which is translated in the most important languages and distributed worldwide by the IMD.

3.5 Ergonomic Work Allowance (EWA)

Since the definition of the basic time $T_b$ assumes there is no physical stress, if the working task generates stress, industrial engineering practices recommend the allowance of a recovery time sufficient to compensate the extra effort. The objective is to level the physical effort (biomechanical load) within the
standard limits referenced by the work performance and thus reducing the likelihood to incur work-related musculoskeletal disorders. In other words: the EWA would allow more time to execute a task, thus reducing the demand of performance of the worker.

The Basic Time $T_b$ is determined based on the standard work performance. In the previous paragraph we have selected the MTM standard performance as the reference, as it sets an action frequency which is likely to be compliant with the ISO 11228.3 if there are no other risk factors present in the work task (e.g. awkward postures and forces). However, what if those additional risk factors are detected? The Ergonomic Work Allowance (EWA) model was designed with the main objective to calculate a time allowance as a function of a fatigue index. The stronger the demanded fatigue, the larger the EWA.

The fatigue index considers the various sources of physical stress and it condensates the evaluations in a unique number. For this reason, the choice of the ergonomic evaluation model fell on the EAWS system (Ergonomic Assessment Work-Sheet), which is part of the technical platform of the International MTM Directorate.

The main innovation, with respect to other existing allowance systems, is the introduction of the concept of Duration. Indeed, the traditional methods (like the ILO recommended table of allowances), based the determination of the allowance as a function of the main body posture and of the force/load level (intensity), regardless the duration or the frequency of the motions. The allowance is then applied on each single motion, and, for this reason, the model is called “single-motion allowance”. For example, to lift a load of 40 pounds, the ILO Recommended Allowance gives a value of 9% ([14]), regardless the number of repetitions of the action during the shift.

The EWA model assigns an Ergonomic allowance (fatigue allowance) as a function of the EAWS score, which is an index tightly linked to the concept of physical workload. In EAWS the physical workload is calculated as follows:

**Work-load = Intensity x Duration**

- Intensity is proportional to the degree of awkwardness of the postures, to the force intensity or the load weight etc.
- Duration depends on the duration of the static actions and the frequency of the dynamic actions.
To reach a significant level of workload, it is necessary to have a medium intensity with a medium duration. If either one of the two factors is negligible, the resulting workload would be low, even if the other factor is high.

The main advantages of the EWA model are:

- Link with relevant ISO/CEN standards in measuring the physical load (mainly CEN 1005 and ISO 11226, 11228)
- Data consistency granted by the link with the work cycles (if a work method or a piece of equipment is modified, the ergonomic assessment would be updated to reflect the changes of the cycle time)
- Integration of two job profiles (method engineer and ergonomist) into one (ergo-engineer) with ensuing cost savings (lean philosophy)
- Focus on work method as a means to improve consistently productivity and ergonomics
- Easier to justify investments in ergonomic improvement projects, since product cost is linked with the physical workload level (higher load results in higher fatigue allowance and therefore higher costs)

The ergonomic allowance is necessary to dilute standard times and recover from physiological strain (as a matter of fact, the maximum saturation level is limited or extra breaks are allowed). The nature of physiological strain depends on the type of muscular contraction involved. There are two types of muscular contractions:

- Dynamic, involving rhythmical contractions of large muscle groups where the length of the muscles is changing (isotonic)
- Static, involving prolonged contraction without a change in the length of the muscles (isometric)

The EWA model (see Figure 10 - EWA model) was built upon the fundamental principle to allow a sufficient recovery time to keep the physical load within controlled limits.

The design method used was experimental:

The first step was to crosscheck the allowances against recovery periods calculated with a formula defined by the German school of occupational physiologists [15]:

\[
RA = \max \left\{ \left[ \left( \frac{M}{4.2} - 1 \right) \times 100 \right] ; 0 \right\}
\]

Where \( RA \) is the rest allowance as a percentage of the basic time, \( M \) is the metabolic cost of the work in Kcal/min, and the constant, 4.2 Kcal/min, represents the basic cost of work that does not require rest allowance. The 4.2 Kcal/min was derived from calculated energy requirements of workers whose nutritional needs were followed for a prolonged time during World War I and II.

In the following table some energy expenditure values are exerted from the energy expenditure table published by the authors:

<table>
<thead>
<tr>
<th>Task</th>
<th>M (kcal/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small item packing</td>
<td>2.5</td>
</tr>
<tr>
<td>Mop tables</td>
<td>4.5</td>
</tr>
<tr>
<td>Window washing</td>
<td>5.0</td>
</tr>
<tr>
<td>Wet mop stairs (1 kg mop)</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Considering for example a well known task like the wet mop lobby room, using the values in Table 1, it can be calculated that that task requires an energy expenditure approximately 50% higher than the basic cost value of 4.2 kcal/min, generating, using the above equation, a \( RA = 50\% \). It means that out of one hour, 40 min are working time and 20 min are rest. Following the same procedure, it can be calculated...
that for window washing, RA = 19%. These tasks were then analyzed using the EAWS system and the scores plotted with the RA values.

*Table 2 - EWA data-points*

<table>
<thead>
<tr>
<th>Task</th>
<th>Basic level (kcal/min)</th>
<th>Small item packing</th>
<th>Mop tables</th>
<th>Window wash</th>
<th>Wet mop stairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>0%</td>
<td>7%</td>
<td>19%</td>
<td>55%</td>
<td>55%</td>
</tr>
</tbody>
</table>

The EWA model was determined setting a curve that starts from 0% and increases exponentially up to 51%, trying to match the plotted values and generating a set of RA very sensitive to the variations of load, particularly within the medium risk zone (25 < EAWS score < 50), which represents the most common case in the manufacturing industry. To identify the best fitting EWA curve, numerous calculations were run within a research project, which took place at the FCA Mirafiori automotive plant on the Musa-Ideal final assembly line in the period 2005-06. The drivers in the identification of the function were the following:

- Match the data-points obtained from the energy expenditure model (see Table 2)
- Size the EWA values in order to reduce the workload enough to exit from the red area (see the following paragraph Experimental justification of the EWA curve)

Figure 10 - EWA model shows the proposed model, where the traffic light colors indicate three load levels corresponding to three risk zones: low risk (green), medium risk (yellow) and high risk (red).

In the period 2006 up to now, hundreds of practical field applications of the EWA model have proved its validity, pushing the users to a continuous improvement of the ergonomic conditions to increase productivity and reduce labor costs.
3.5.1 Experimental justification of the EWA curve

Figure 11 shows the experimental results leading to the determination of the EWA curve in the 50-90 EAWS score interval. The following approach was adopted:

- Different cases in the red zone (50-90 EAWS points) were studied, considering each EAWS section separately.
- For each case, it was determined the ergonomic allowance factor to be considered, in order to lower the risk factor to the yellow zone.

As it is clearly shown, the behavior of the single sections is not uniform. In particular, considering the calculation algorithm, EAWS Section 3 (manual material handling) requires the highest ergonomic allowance to mitigate the index.

However, it has to be taken into account that:

a. The EAWS final score is the highest score between the sum of the scores of sections 1, 2 and 3 (whole body) and section 4 (upper limbs). If the whole body score is predominant, the score is in most of the cases composed by a combination of sections 1, 2 and 3, and not by a single section.

b. If an activity involves only (or mostly) one EAWS section, usually it is section 4, which is activated by the motion frequency of the upper limbs.

Considering the above points, the ergonomic allowance curve that best fits the goal of reducing the risk score is the one proposed by the EWA model, which is more conservative than the allowance required by section 4.

![Ergonomic Allowance curve in the 50-90 EAWS score interval](image)

3.6 Setting of a Standard Time (T_{std})

The calculation of the Standard Time (T_{std}) is made with the following formula:

\[ T_{std} = T_b \times (1 + EWA) \]

T_{std} is used for planning the quantity of units to be produced (Q) and the size of the necessary workforce.

EWA can be applied with two different strategies in order to minimize the workload:

**Strategy A: limit the worker’s saturation**
In this case the Net Working Time (NWT) = Gross Working Time – Breaks Time and

\[ T_{std} = T_b \times (1 + EWA) \rightarrow Q = \frac{NWT}{T_k} \]

where \( T_k \) is the takt time of the process (usually is the longest \( T_{std} \) among a series of workstation forming a line sequence – e.g. assembly line)

This strategy is recommended when the load is driven mainly by body postures, significant action forces and manual material handling (EAWS whole body score > EAWS upper limbs score)

**Strategy B: reduce the NWT**

\[ NWT = \text{Gross Working Time} – \text{Breaks Time} – \text{Recovery Breaks Time} \]

\[ T_{std} = T_b \] (work assignment based on basic times)

Recovery Breaks Time = \( Q \times (T_k - T_b) = Q \times (EWA \times T_b) \)

This strategy is recommended when the load is driven by the repetitive motions of the upper limbs (EAWS whole body score < EAWS upper limbs score)
4 Appendices

4.1 International MTM Directorate

IMD - The International MTM Directorate, Inc., originally constituted in Paris on June 25, 1957, by an assembly of representatives from six countries including the National MTM Associations of the U.S.A., France, the Netherlands, Sweden and Switzerland, is a Federation of National MTM Associations incorporated under the laws of Ohio on November 6, 1968.

The general objective of the IMD and its member National MTM Associations is to develop, spread and employ knowledge concerning man at work, so as to improve his productivity, his job satisfaction and his working conditions.

More specifically, the objectives of the IMD are to encourage close cooperation among all those interested in the study of man at work, whether it is in research, training or field of application.

The major areas of activity of the IMD to reach the general objective are:

1. Research

   To widen the scope of and improve MTM (meaning the system and its data), to develop the knowledge of application of MTM, to develop new ways of processing MTM data and information on working conditions, to further the integration of work measurement systems and to deepen the knowledge of man at work by coordinating the research activities of the National Associations, by suggesting or initiating research which is not yet being performed by the National Associations and by encouraging and coordinating the publication of research reports.

2. Standards of Practice

   To ensure international standards of MTM practice, which includes uniformity of basic MTM data, internationally approved data systems, definitions, application rules and minimum requirements for training and examinations, by defining MTM, by coordinating training and examination development and practice internationally and by recommending publication of international standards of practice.

3. Membership Development

   To encourage and coordinate the creation of new National MTM Associations and their admission as aspirant members and/or members, by determining minimum requirements for membership, by collecting information on MTM activities in non-member countries, and by assisting National Associations in their efforts to develop new members.

4. Communication

   To improve knowledge of members and other circles in the business and academic world on developments and achievements of MTM research, training and application, its growth and its acceptance, by collecting and spreading information, by promoting seminars, conferences and printed publications, and by encouraging members to exchange information.

ADOPTED BY THE GENERAL ASSEMBLY IN LONDON, MAY 1969, TO BE APPLIED FOR EXECUTIVE PURPOSE.
4.2 Methods-Time Measurement

MTM: Methods-Time Measurement is a procedure, which analyzes any manual operation or method into the Basic Motions required to perform it, and assigns to each motion a predetermined time standard, which is determined by the Influencing Factors under which it is accomplished.

MTM is the abbreviation of Methods-Time Measurement. Methods-Time Measurement means that the time required to perform a specific task depends on the method chosen for the activity.

The MTM method was developed in the USA in the 1940s as a system of predetermined times and was published in the book “Methods-Time Measurement” in 1948. Since that time, MTM has been used both as an analytical tool for directly analyzing manual work processes, as well as, a tool for developing standardized building blocks from the MTM basic system (MTM-1). These building blocks are being used to economically describe, quantify and design a wide range of work processes.

Compared to other systems of predetermined times, MTM enjoys the greatest worldwide distribution as an instrument of industrial engineering and time management. In addition, building block systems were developed based on MTM-1 for application in different process types (mass production, batch production and one-of-a-kind and small variable batch production). MTM offers a worldwide uniform standard for businesses to use in describing and quantifying manual work processes. As early as the 1990s, MTM began the gradual transformation from a system of predetermined times to a productivity management system. Today, the MTM method includes a framework of MTM building block systems used to model the full range of work processes.

MTM supports the design of work processes (business processes) through describing, structuring, planning and analyzing/synthesizing, using process building blocks designed for content and time. MTM systematically classifies and organizes processes, while making the Influencing Factors that control them transparent, thus achieving the goal of “First Time Right” in the design of work systems.

An essential goal of a company consists of maintaining and increasing competitiveness. A system of comprehensive data and time management linked throughout every level of a company’s operation is an indispensable instrument of productivity management in reaching this goal. By designing its processes according to a standard production system (e.g. the Toyota Production System), it is possible for a company to create work systems that precisely meet its objectives from their inception. Using these concepts, a production system can be developed as a Best-Practice solution. MTM is taught and used both as a tool in the truest sense, as well as, a method or principle in the broader sense. Within a production system, MTM serves the function of a common language providing a standard for design, as well as, serving as the basis for measurements, comparisons and modifications made at all levels of this system.

As today’s companies transition from individual to team based manufacturing, especially through the formation of production teams responsible for their own competitiveness, comes a change in focus from time standards to market standards. Low costs, high quality, flexibility and the ability to deliver on time form the new standards in the marketplace. Meeting these new standards not only determines success, but insures job security. Rational controlled processes are indispensable requirements to success in this new environment, necessitating that work and time studies always remain current.

However, the role of the employee changes, such that he or she now joins the specialist in taking responsibility for improving the work processes. Communication with the involved employees becomes a central principle. Workshops, presentation techniques, problem solving in teams, visualization and mutual determination of performance characterize the new method of manufacturing.
5 References


[12] Gabriele Caragnano, Ivan Lavatelli et al., EAWS construct validity – on the field comparison with other systems in 24 station of automotive sector.


