

## Determining time of technological operations in clothing production

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**Abstract:** Time management of production is a comparative advantage for clothing manufacturers in global markets today, because it is reflected in the quality, cost and productivity of production. Therefore, it is necessary to make a thorough research of the structure of time of work and methods for determining the time of technological operations.

**Keywords:** time, methods, analysis of losses.

### 3.1 Methods for determining the time of technological operations in the production of clothing

All modern systems of production organization are based on the accurate and real time standards, stabilizing workplaces and methods of work and the rationalization of movement, i.e. following the model: Time – Accuracy – Quality.

The work study includes a variety of scientific methods of analyzing the work profile and production time, and allows finding the most economical work profiles and the time required by the average skilled worker with specific expertise to carry out a working operation, with normal effort.

Ralph M. Barnes (1947) used the name of the Time and Motion Study to emphasize that it is necessary first to define the appropriate method and then to determine the time. The time and motion study is defined as follows: “The time and motion study analysis methods, materials, tools and equipment used or to be used in the performance of a work – the analysis that is conducted with the intention to

- find the most economical way of performing this work;
- standardize the method, materials, tools and equipment;
- determine precisely the time required for the qualified and appropriately trained worker, who works at normal intensity, to do the task;
- assist in training workers for the new method.”

Clothing production deals with norm working. Norm is the time the average skilful worker of appropriate expertise needs to perform a specific technological operation with normal effort and fatigue, at normal environmental action and under normal conditions of work. This definition suggests the following three conditions:

- (1) Qualified and well-trained worker;
- (2) Working at a normal pace with which a trained worker performs the task under normal conditions with a normal level of consumption of his own energy. Normal human consumption of energy is the one at which the employee can withstand the pace of work – neither too fast nor too slow. Carrying out of time norm that most of the skilled workers can perform is 100%.
- (3) Performing a specified task which has a certain prescribed method of work, materials specification, specification of tools, accessories and the equipment used, position of intermediate storage before and after performing the task, displaying additional requirements related to safety, quality, workplace regulations and activities to ensure the carrying out of the task.

Working norms vary according to the method of determining, how organization works and the method of expressing.

According to the method of determining, they can be

- technical – which are determined by the predefined standard elements of work,
- statistical – which are determined on the basis of statistical data, obtained over a longer period of time, by keeping a record of the work carried out,
- experiential – which are determined on the basis of experience and comparisons with norms for the same or similar jobs.

According to the method of work organization, they can be

- individual – these are characterized by the fact that the work is done independently by one person;
- group – these are characterized by the fact that the work is performed by two or more workers in the joint, same or similar work, which is not possible or is not rational to be separated per each individual;
- organizational units – these are characterized by the fact that the work is performed by all employees and units, i.e. when the job is not possible or is not rational to be separated per groups of workers or individuals.

According to the method of expressing, they can be

- Quantitative norms – number of pieces that should be made in a period of time, and the ratio of the daily working time ( $T_d$ ) and time norm (e.g., pieces/h).
- Time norms – express the number of seconds, minutes, hours or days required for making one piece, operation or garment.

According to the number of workers, a single norm can be used for each position (e.g. for each operation in a sewing room) or a group norm for a group of workers in a particular phase of work where changes of models and even items frequently occur (e.g. in a cutting room, on final ironing – one employee often works on several presses for ironing). The joint effect is achieved by the participation of workers, the number of hours and the work category. Then a joint effect is shared among the individuals.

A time norm is most often used in garment industry. It helps in

- (1) determining the cost of production, and thus determining the selling price of the product.
- (2) developing the plan for machine engagement, the implementing manufacturing operations and determining workers necessary for the realization of production, delivery of materials and inventory management.
- (3) balancing the assembly line and assembly line speed.
- (4) specifying the qualifications and assessing the desired abilities and skills of workers.
- (5) making payment of incentive pay.
- (6) calculating the cost reduction according to given suggestions based on most economical method.
- (7) calculation of feasibility procurement of new equipment in accordance with the height of production costs.
- (8) monitoring performance in relation to the budget–wage and measuring results of leadership and management.

In case that some of the conditions, under which the norm was given, change (the technological process, stabilization of the workplace, machinery, materials, environment, etc.), a norm can be changed, but not the worker because he is not a condition of work. During the standardization, problems may occur because the norms are often set unrealistic because of

- Mis-prescribed norms.
- Miscalculated norms.
- Too high or too low on certain norms.

- Same norms, but new method of work.
- Roughly set norm, and so on.

Standardization of work is a sensitive area of management activity, so mistakes are very common to occur. The risk of error is twofold: if the standards are set too low and if they are set high. In both cases the work efficiency is being lost. In the first case, the worker will easily reach the target norm, perhaps after 3–4 hours of work, which means that he will achieve the full effect with half of his real possibilities. This damages the PBS, because the available human resources are not fully exploited. In another case, the worker will not be able to reach 100% of norm, he will be paid less, and if other positions in the same working process are properly normalized he will represent the so-called “bottleneck” of the process. Therefore, it is important to determine the required effort the worker can really put into 8 hours of work during the day. Different jobs require different efforts, and how much effort an individual will make, depends on the level of his work motivation. Thus, by measuring the effort (the highest possible performance for a specific work task and its variations), the level of work motivation of individuals can be measured as well.

Standardization of work and determining of standards are carried out through seven steps:

Step 1 – The choice of work.

Step 2 – Inform employees that the performance of their work is the subject of time study.

Step 3 – Divide the work into smaller elements.

Step 4 – Determine the size of the sample.

Sample size is determined by formula:

$$n = \left[ \left( \frac{z}{a} \right) \left( \frac{s}{\bar{x}} \right) \right]^2 \quad [3.1]$$

Where:  $z$  = number of standard deviations with the corresponding error risk,

$s$  = standard deviation of the sample,

$a$  = degree of accuracy,

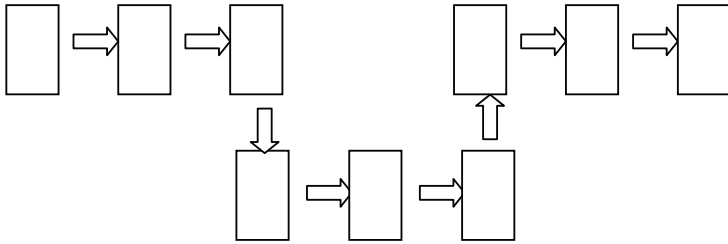
$\bar{x}$  = average value of the sample.

Step 5 – Measure the time of performing each element of work.

Step 6 – Calculate the usual time.

Step 7 – Assess the standard time.

Technological processes of clothing production belong to the piece manufacturing with the “chain systems” of a production flow of materials, so the time basis for determining the norms of production capacities of



3.1 Schematic diagram of the chain system.

workplaces and successful organization of production are very real. The “chain system” of manufacturing involves the performance of working operations one after another in a specific order from one workplace to another, at a certain time (rhythm) and with the shortest spatial area. This system (Figure 3.1) doesn’t have any intermediate storages and it is suitable for products with a smaller number of work operations where changes of models are not frequent. Advantages of “chain systems” are small work space, fast flow of materials, and low production of unfinished and less engaging financial resources. Disadvantages of “chain systems” are sensitivity to frequent changes of model, the lack of workers causes a delay (spare worker is needed), individual ability of workers cannot be seen and maximum productivity is not achieved.

The main characteristic of the chain system is moving of the object of work following the already defined rhythm (“tact in” German) regardless of the transport of the object of work. According to the method of transporting the subject, we differ human work linked by rhythm and human work caused by rhythm.

A rhythm of a group means an average time of keeping the object of work on a working place and means a maximum allowed time load of a workplace in human work linked by rhythm. Shift related to the human work linked by rhythm is related to the speed of moving of transport. The worker must be in the specified time (rhythm) to perform the operation, because otherwise there is a “bottleneck” for production or waiting to work. In a system with continuous motion a conveyor speed must be adjusted to the time of making the object of work. Time of the pass of work object is calculated from:

$$T_{pr} = \frac{t_1}{ORO} \cdot 100 \tag{3.2}$$

Where:  $t_1$  – the production time,  
 ORO – working load operation.

Thus rhythm of a group is calculated from the formula:

$$t_g = \frac{T_{pr}}{R} [\text{minutes}] \quad [3.3]$$

Where: R – the number of workers.

In qualifying the human work caused by rhythm with inserting bundles (packages), a rhythm of a group of workers can be determined on the basis of the average production time and number of workplaces, because the differences are undermined by helping slower workers, i.e. it is calculated from the formula:

$$G = \frac{t_1}{R} \quad [3.4]$$

To achieve the continuity of production, it is necessary to control the rhythm of a group (e.g. every 2 hours). The rhythm of production causes a range of problems. A worker, given the demands of high training, does the same operations for years and his work becomes monotonous. As a result of this manufacturing strategy, various occupational diseases may occur, as well as injuries, disability, and increased fluctuation of employees. To overcome such phenomena, the establishment of group and team work is required. Thanks to the introduction of rotating workplaces within the group, additional effects are achieved. A rotating workplace allows introduction of innovations in production and reduction of work load, and it gives the quality of production.

With small series, work operations are performed uniformly in order to increase productivity and quality of clothing. So the overall costs of production are therefore reduced and they are normed easier, i.e.

$$y = T_b + \frac{T_o - T_b}{\frac{x}{2n}} [\text{minutes}] \quad [3.5]$$

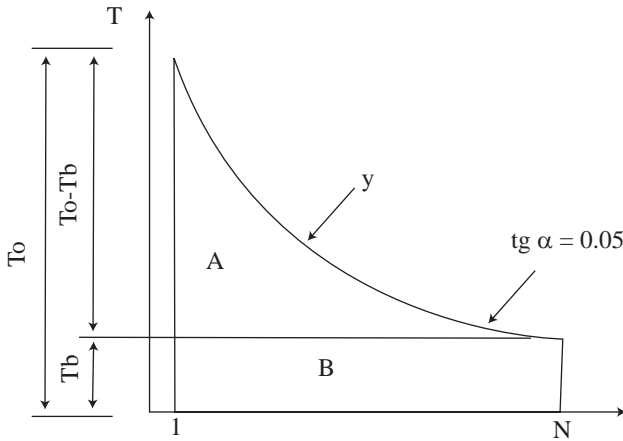
Where:  $T_o$  [minutes] – initial time of duration of operation,

$T_b$  [minutes] – minimum time of duration of operation,

$n$  – number of repeated operations when the time is reduced to half of the previous time,

$x$  – number of repetitions of the same operation.

Figure 3.2 shows the continuity of production.



3.2 Continuity of production (“well trained” production).

### 3.2 Determining the production time

Normal production time and labour standards are an important tool for solving many problems in the work of a PBS. The quality of planning, the relationship among employees, offers, contracts etc., depends on the reality of normal production time. Establishing normal production time allows

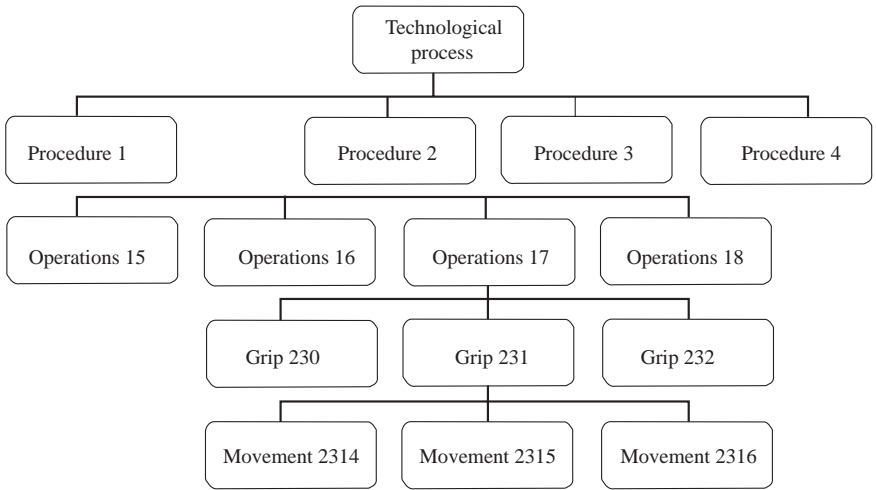
- Planning and scheduling of production.
- Estimation of earnings.
- Calculation of the earnings performance.
- Deciding about cooperation.
- Calculation of buying the machinery and equipment.
- Calculation of delivery deadlines.
- Calculation of costs of production.

To obtain the normal production time it is necessary to analyze the constituent elements of operations, such as grips, movements and micro-movements (Figure 3.3).

The term operation implies the processing of cases on one machine, or at one workplace. An operation consists of all the works from the moment of its starting point to the moment of its storing on the planned location. Operation is then divided into grips.

A grip is a direct effect of tools on the subject of work during the operation. Grips can be of the following types:

- (a) Pre-final grips – these include activities related to the preparation of workplace and workers to perform the operation, activities which



### 3.3 Elements of technological process.

deal with cleaning up the workplace after the operation was finished; receiving and studying the technical and technological documentation; receiving and review of material; submitted documents; receiving and replacement of standard tools and supplies. These grips are performed once during the performance of operation. They are most commonly given in the table depending on the type of machine and the type of production.

- (b) Additional grips – these include all ancillary activities in the workplace and on the machine itself which allow the performance of grips (placing and removal of work object on the machine, positioning of work objects, setting certain parameters of machine, switching the machine on and off, etc.). They are most commonly given in the table depending on the type of machine and the type of production.
- (c) The processing grips – they are the direct processing of work object, and they can be elementary grip processing, complex grip processing and group grip processing.

In elementary grip processing a certain surface on the work object of processing is formed by one tool and its moving (e.g. drilling holes, cutting holes with a knife, putting rivets on garment). Complex grip processing is a part of the processing operation where one tool is used for the final formation of a complex area according to technical–technological requirements. Group grip processing is a completely or partially simultaneous process of forming a number of surfaces with a number of appropriate tools according to technical–technological requirements, where certain elements of the



process may be the same or different (embroidery machine).

Movement is the element of grip and includes an activity of workers with tools or accessories. Movement is, for example, scrolling tools, cutting threads, scissors staying away, changing direction of rotation of the work object, raising pedals, etc. Movements can be divided into micro-movements that can not be split into smaller parts.

The structure of a component time required for performing an operation (Taborsak, 1971) consists of production time, additional time and a pre-final time.

(1) *Production time* ( $t_{iz}$ ) includes the time required from the first to the last movements of the work of employees. It consists of a technological time ( $t_t$ ) and help-time ( $t_p$ ). Technological time is the time required for a specific operation, and may be machine-technological time (on sewing machines), machine-hand technological time (on ordinary sewing machines and special sewing machines) and hand-technological time (for hand makes). Distinguishing these times, by Martinovic (2002), is necessary because of the following:

- Replacing of machine and hand works in one operation (allows employees to work on two machines).
- Large taking part of machine work in performing an operation (30%) allows employees to work on many machines.
- High-speed working machines due to which grips and movements related to the work of machines cannot be corrected.
- Abilities to calculate a machine-technological time and a machine-hand technological time mathematically and not to perform their measurements.

Machine-hand technological time in the process of sewing a meter of seam is determined by the formula:

$$t_1 = \frac{\sum_{i=1}^n t_{ui} + \sum_{i=1}^n t_{ni} + \sum_{i=1}^n t_{ki}}{P \left( \sum_{i=1}^n \int_{t_{pc}}^{t_{ppc}} (t) dt \right)} \cdot 1000 \quad [3.6]$$

Where: n – the number of machine and machine-hand technological grips,

P [mm] – transport of object of work or length of stitch,

$t_{ui}$  [s] – time acceleration of the main shaft of sewing machines,

$t_{ni}$  [s] – working time of sewing machines,

$t_{ki}$  [s] – time of slowing down the main shaft of sewing machines.

Help-time is the time required for grips that enable and assist in performing the process (e.g. switching machines on, control during working, replacement of sewing needles, thread changes, lubrication and cleaning of machines, etc.).

- (2) *Additional time* ( $t_d$ ) – it is the time of the loss of working time which does not depend on the worker himself, and is expressed by three coefficients: fatigue coefficient ( $K_n$ ), the coefficient of environmental influence ( $K_a$ ) and the supplementary coefficient ( $K_d$ ).

The fatigue coefficient is required because of the reduction of performance due to physical and mental fatigue of workers during working time caused by monotony, hard work, body position, etc.

With physical fatigue, as a consequence of dynamic muscle strain, exhaustion and fatigue may occur (if the work is limited to some constant movements and muscle groups), and as a result of static muscle strain (if the limbs are immobile and if there is a permanent contraction of muscle groups). Muscle fatigue is a lack of oxygen, and occurs whenever a bigger impact within a unit of time is required than it corresponds to the amount of oxygen that is available.

Normal positions of the body while working are standing, while all others require higher power consumption. The most appropriate one is the sitting position, because then the man spends only 5% more energy than when lying. Standing requires more static muscle strain, that's why the power consumption is 10–15% higher.

The coefficient of environmental influence is the activity caused by inadequate temperature, relative humidity, steam, noise, etc.

Supplementary coefficient is required because of the prescribed resting of 30 minutes, which is the time required for the personal needs of employees and organizational losses, e.g. waiting for the material. For determining of supplementary coefficient, about 15% are taken, including (Adamovic and Alihodzic, 2002):

- 5% for personal needs,
- 4% for interruptions caused by personal fatigue,
- 2% for a very unfavourable position of the body,
- 2% for insufficient light,
- 2% for precise work.

- (3) *Pre-final time* ( $t_{pz}$ ) is the time required for preparation of workplace and its cleaning after finishing the work, and it's divided into:

- (a) preliminary time ( $t_{pr}$ ) – the time required for preparation of machines

and tools, i.e. the workplace before and during the work, preparation of materials, and receiving and reviewing of documents,

- (b) final time ( $t_z$ ) – the time required for cleaning of materials and cleaning of machines and tools.

It is still a characteristic in garment industry that 80% of time is spent on handling the case work, assembling of parts of clothes, positioning and alignment, and only 20% of time is used for performing of machine and machine-hand grips.

In order to record the time on a proper way it is necessary to be prepared for recording, which includes the following activities:

- (1) Analyze selected operations through grips, movements and micro-movements, in order to specify the parts of the operation whose duration should be recorded.
- (2) Determine which parts of the operation are repeated and which are specific; separate machine work from hand work; define the start and the finish.
- (3) Make selection of methods and recording tools.
- (4) Recording of conditions under which the operation is carried out, because working conditions are subject to change.
- (5) Selection and preparation of workers – a number of workers of different abilities, or a worker of average ability.
- (6) The choice of number of recording on the basis of statistics.

Production time is determined using several conventional methods:

- (a) *Continuous time method* uses a stopwatch timer with hour mechanism in which a minute is divided into hours, and hour into 10000 parts. There are two large watch hands, with only one of them moving smoothly during the recording, and the other one which can be stopped (e.g. when it is necessary to wind the lower thread on spool). The recorder takes only a total time and calculates the average production time.

Advantages of this method are as follows: it measures the total time of entire operation; working time is not wasted; there's no need for another watch for control; training of workers doesn't last long.

Disadvantages of this method are as follows: it's difficult to track a worker and record if grips in operation are bypassed; it can not determine the error of chronometer; it's difficult to record grips shorter than five seconds.

Stopwatch time study was developed by Frederick W. Taylor in 1880 and it was the first technique to be used to set the engineering time standard.

- (b) *Snapback time method* uses a stopwatch timer, where a large dial is divided into one hundred parts, each of them being a one hundredth part of a minute



3.4 Stopwatch timer and electronic stopwatch.

worth. When a big watch hand makes full circle, then a small watch hand on a small dial moves for one degree and shows the value of one minute.

Advantages of the method are as follows: it's possible to identify all the errors during work; there's no subsequent calculation of individual times; the employee may skip the grips because they are noted separately; it's possible to record short grips.

Disadvantages of this method are as follows: error must not be bigger than 1.5% so the recorder must practice more; quick reflexes are required as well as large concentration of a recorder; there are losses due to the return of the watch hand to the starting position.

In Figure 3.4, the stopwatch timers are shown.

- (c) *Three-Watch Time Study* is a better technique than both the continuous and the snapback ones. Three continuous stopwatches are used on one board for each stage. When the worker finishes the grip, the recorder pulls a common switch and presses it down. One watch is stopped so a reading can be made, the second watch is restarted and the third watch is reset to zero waiting for the time of the next grip.
- (d) *Method of recording with film and video cameras* is used for technological grips and movements of very short duration, which requires a large measurement accuracy.
- (e) *Measurement method using the computer* – there are several modern methods, for example the method of measuring process parameters (MMPP) is based on measuring the time of the main shaft speed and the calculation of real and average sewing speed, acceleration, number of stitches in the seam, etc.

Basic procedure of measurement consists of three phases:

- (1) Analysis – this is the phase in which the job is divided into smaller sections, i.e. procedures, elements;
- (2) Measurement – this phase refers to measuring the time necessary for a qualified employee to perform each element within a particular job under certain conditions;
- (3) Synthesis – in addition to the basic time required for a particular job, displaying the total time required for a particular job is done in this phase. The basic time, defined in the measurement phase, is added to the time for resting, for possible errors, etc.

A snapback time method with stopwatch timer is most widely used in garment industry. The calculated time is multiplied with the coefficient of efforts which gives the normal production time ( $t_n$ ):

$$t_n = t_o \cdot K_{pz} = t_o \cdot \frac{P_z}{100} \quad [3.7]$$

or

$$t_n = \frac{1}{n} \sum_{i=1}^n t_o \cdot P_z \quad [3.8]$$

Where:  $t_o$  – the average value,  
 $K_{pz}$  – the coefficient of efforts (rating factor),  
 $p_z$  – the constant.

Assessing the rating factor is determined by the scale which ranges from 70% to 130%, with five percent leaps (e.g. 70%, 75%, 80% ...).

However, a worker must increase the strain while carrying out work tasks. Therefore, it is necessary to add the time which will make up these elements of non-working. Additional time ( $t_d$ ) is a time of loss of working time which does not depend on the worker (expressed by three coefficients: the fatigue coefficient, the coefficient of environmental influence and the supplementary coefficient). The real time ( $t_s$ ) is obtained through the formula:

$$t_s = t_n \cdot (1 + K_n \cdot K_a) \quad [3.9]$$

The real time may be technological time and help time:

$$t_{ts} = t_n \cdot (1 + K_n \cdot K_a) \quad [3.10]$$

$$t_{ps} = t_n \cdot (1 + K_n \cdot K_a) \quad [3.11]$$

And since the production time is, by definition, equal to the sum of technological time and help time:

$$t_i = t_t + t_p = t_{ts} + t_{ps} \quad [3.12]$$

The real time is equal to the production time on the basis of which we get the time norm:

$$T = t_i \cdot (1 + K_d) \quad [3.13]$$

As an example, the times recorded in the factory for production of sports clothing are given. In the Table 3.1 there are the results of the observed time of making the shoulder seam on a special sewing machine (SM-o5) with continuous time method.

*Table 3.1* Results of recording production time of a shoulder seam on men's polo shirt

Time				
dmh*	h	Number of notes	Σ Notes	Coefficient of efforts (%)
91	0.0091		4	130
94	0.0094		9	125
97	0.0097		7 + 9	120;115
100	0.0100		22	110
102	0.0102		10 + 10	105;100
105	0.0105		23	90
108	0.0108		12	80
111	0.0111		3	75

dmh units = HOUR/10 000

According to Table 3.1, normal production time (basic time) of shoulder seam on a special machine, according to the formula [3.7], is  $t_n = 0.01$ . If the fatigue coefficient of worker is  $K_n = 0.11$  and the coefficient of environmental influence is  $K_a = 1.3$ , then the real time is calculated according to the formula [3.8]  $t_s = 0.01 (1 + 0.11 \cdot 1.3) = 0.01143$ . The real time equals the time of production ( $t_s = t_i$ ). If the supplementary coefficient (extra time) is  $K_d = 0.15$ , then the norm is calculated according to the formula [3.13]:  $t_i = 0.01143 (1+0.15) = 0.01322$  [hour/operation].

In order to calculate the time norm other methods can be used, such as (Adamovic and Alihodzic, 2002):

- (1) Michelin methods – they are used to calculate the time norms according to which it is necessary to verify the number and quality of recording (observing) operations. The results sorted in the order of recording are divided into two equal groups, Ma and Mb, and the arithmetic mean of Ms is calculated.

$$M_s = \frac{Ma + Mb}{2} \quad [3.14]$$

Then the deviation of allowable 5% is determined and, according to this method, the normal time is obtained as the arithmetic mean of the minimum ( $Tiz_{min}$ ) and middle ( $Tiz_{sr}$ ) production time. This time is called “the standard production time” ( $Tiz_{tip}$ ) and it is calculated from the formula:

$$Tiz_{tip} = \frac{Tiz_{min} + Tiz_{sr}}{2} \quad [3.15]$$

Pre-final time is calculated from the formula:

$$T_{pz} = 0.2 \cdot Tiz_{tip} \quad [3.16]$$

Additional coefficient:

$$T_d = 0.15 \cdot Tiz_{tip} \quad [3.17]$$

Therefore, a time norm is obtained from the formula:

$$T_{pn} = T_{pz} \cdot T_d \cdot Tiz_{tip} \quad [3.18]$$

- (2) The method of average value – it is similar to the previous method because it is based on the arithmetic mean of obtained results. The mean value, the minimum value and the standard production time are the same in this method.
- (3) The method of maximum frequency – it takes the value of maximum frequency as a normal production time and other data are obtained as in the Michelin method. For example, for one operation the following times are recorded in this order: 6,7,8,8,9,9,9,10,11,12,13. On the basis of this a chart for the frequency of time is formed (Figure 3.5), which clearly shows that 9 time units is the most frequent time and it usually appears three times during the measurement. Therefore, the frequency is  $f = 3$ ,



3.5 Frequency of time.

and T = 9 (time units, e.g. seconds).

Michelin method is most suitable for the owners, and the method of maximum frequency for the workers.

Table 3.2 Results of observed time of sewing placket on the front of the men’s polo shirt on a sewing machine

Time,s	Number of notes	Σ Notes	Coefficient of efforts (%)
33	II	2	130
34	III	3	125
35	II	2	120;115
36	IIIIII	6	110
38	III	3	105;100
39	II	2	96
40	II	2	80
	Σ	20	

As an example, Table 3.2 shows the results of recording time of the first operation of producing men’s polo shirts on a sewing machine.

On the basis of the results of recording, four methods for calculating working norms were used:

- (1) The method for calculating working norm with the coefficient of worker’s efforts:

Normal production time is  $t_n = 38.89s$ . If the fatigue coefficient of workers is  $K_n = 0.11$  and the coefficient of environmental influence is  $K_a = 1.3$ , according to the formula the real time is  $t_s = 38.89 (1 + 0.11 \cdot 1.3) = 45.59 s$ . The real time equals the production time ( $t_s = t_p$ ). If the additional coefficient (extra time) is  $K_d = 0.15$ , then the production time is  $t_1 = 45.59 (1+0.15) = 52.46 s = 0.0145$  [hour/operation].

- (2) The Michelin method for calculating time norm:

The obtained results are divided into 2 groups and their arithmetic means are calculated, as well as the arithmetic mean of the set Ms:

$$Ma = 35.8 s; Mb = 36.8 s$$

$$Ms = \frac{35.8 + 36.8}{2} = 36.3_s$$



In order to determine the quality of results, the arithmetic mean of set is increased by five percent (or  $0.05 \cdot 36.3 = 1.815$ ) and the deviations are determined:

$$|Ms Ma| = |36.3 - 35.8| = 0.7 < 1.815$$

$$|Ms Mb| = |36.3 - 36.8| = -0.5 < 1.815$$

Recorded times are divided into three approximately equal groups and the biggest, i.e. the last value from the first group is taken as the minimum time  $T_{iz\_min} = 35$  s. Since  $T_{sr} = Ms$ , normal (standard) production time is

$$T_{iz\_up} = \frac{35 + 363}{2} = 36.65 \text{ s} = 0.010 [\text{hour/operation}].$$

Therefore, pre-final time and additional coefficient are

$$T_{pz} = 0.2 \cdot 36.65 = 7.99 \text{ s} = 0.002 [\text{hour/operation}]$$

$$T_d = 0.15 \cdot 36.65 = 5.99 \text{ s} = 0.0015 [\text{hour/operation}]$$

According to the Michelin method, the norm for the first operation of sewing men's polo shirt is

$$T_{pn} = 0.002 \cdot 0.0015 \cdot 0.010 = 0.0135 [\text{hour/operation}]$$

(3) The method of average value:

On the basis of the obtained results the arithmetic mean, which is the minimum value at the same time, is calculated:  $T_{t\_min} = 36.3$  s;  $T_{iz\_sr} = T_{t\_min} = 36.3$  s. Normal (standard) production time is  $T_{iz\_tip} = 36.3$  s = 0.01016 [hour/operation]. As in the Michelin method:

$$T_{pz} = 0.2 \cdot 36.3 \text{ s} = 7.26 \text{ s} = 0.002 [\text{hour/operation}].$$

$$T_d = 0.15 \cdot 36.3 \text{ s} = 5.99 \text{ s} = 0.0015 [\text{hour/operation}]$$

The norm, according to this method, is

$$T_{pn} = 0.002 \cdot 0.0015 \cdot 0.0101 = 0.0136 [\text{hour/operation}]$$

(4) The method of maximum frequency:

The Table 3.2 shows that the value of the highest frequency is considered a normal production time (36 seconds are repeated six times):

$$T_{iz\_tip} = 36 \text{ s} = 0.01 [\text{hour/operation}]$$

$$T_{pz} = 0.2 \cdot 36 \text{ s} = 7.2 \text{ s} = 0.002 [\text{hour/operation}]$$

$$T_d = 0.15 \cdot 36 \text{ s} = 5.9 \text{ s} = 0.0015 [\text{hour/operation}]$$

According to the method of maximum frequency, the standard is  $T_{pn} = 0.002 \cdot 0.0015 \cdot 0.01 = 0.0135$  [hour/operation].

The values of calculated time norms, according to four methods mentioned above, are shown in Table 3.3. The obtained results indicate the variations in production planning.

Table 3.3 Values of norms according to different methods

Method	Time norm		Working time (hour)	Quantitative norm - number of pieces
	s	hour/operation		
1.	52.2	0.0145	7	483
2.	48.6	0.0135	7	518
3.	48.9	0.0136	7	514
4.	48.6	0.0135	7	518

### 3.3 MTM method

Increasing demands for productivity encourage scientific researches in the field of work study, in order to find procedures and methods that would ensure required performances without any additional efforts. The important place among the scientific methods for determining the optimal way of performing the work process belongs to the Methods Time Measurement (MTM), developed in the 1940s by Maynard, Schwab and Stegemerten, which was later called the MTM-1.

MTM system is the most famous one in the world and it is mostly used in garment industry. It is used for the rationalization of existing work procedures and for providing objective data to design new work processes. This system is a time system which divides every manual technological operation into basic movements which are given certain time values depending on the nature of movements and the conditions in which they are carried out. MTM system consists of tables of time for movements: 9 basic movements of fingers, hands and arms, 2 eye movements, 10 movements of the body, legs and feet with about 400 standard time norms of basic movements. Basic movements of MTM system, used in garment industry, are

- (1) Reach (R) – stretching out fingers, hands or arms to a certain position or an object of work. Time amounts of movements depend on the length of movement, dynamics of performance (type 1, 2, 3) and position of object of work (A, B, C, D, E).
- (2) Grasp (G) – establishing control and contact with the object of work.
- (3) Move (M) – changing the position of object of work.
- (4) Release (RL) – termination of control over object of work.
- (5) Position (P) – when the hand or fingers with one or more micro-movements put the object of work into a precisely defined position.

- (6) Turn body (TB) – swivelling body  $45^\circ$  to  $90^\circ$  with the relocation of one or both legs.
- (7) Walk (W) – moving body from one position to another.

Duration of movement is given in units of TMU (Time Measurement Unit) with  $1 \text{ TMU} = 0.00001 \text{ h} = 0.036 \text{ s}$ .

Standard time in the tables does not include extra time for physiological needs, resting and other relevant conditions (micro-climate, noise, body position, etc.).

The procedure of applying MTM (Maynard and Schwab, 1984) occurs in the following order:

- (1) Selection of technological operations on the basis of analysis of technological operation plans for sewing and finishing (for example, analysis of Table 2.6).
- (2) A detailed description of all operations on the basis of the obtained data (type of seam, seam length, type of stitches, density of stitches, etc.) and detailed determining of all relevant parameters for machine, tools and accessories, the object of work, working conditions and requirements in terms of quality.
- (3) Designing of workplaces on the basis of technological, technical, ergonomic and economic principles.
- (4) Rational division of technological operations onto grips.
- (5) Determining of basic action movements.
- (6) MTM analysis of basic movements (body, arms, legs, feet and eyes).
- (7) MTM analysis of the performance capabilities of combined movements and all movements that can be performed simultaneously.

Combined movements are a set of basic movements, which are simultaneously performed by the same part of the body (left leg, right leg, left arm, right arm, torso and head). A set of basic arm movements (fingers, hand, forearm and upper arm) allows combining of performances such as reaching, moving, grasping, swivelling, pressing and disassembling. A set of basic movements of the head contains the possibility of turning the head and eyes in the horizontal ( $\pm 55^\circ$ ) or vertical direction ( $\pm 45^\circ$ ).

Simultaneous movements are performed simultaneously with different parts of the body (with both hands, arms and legs or both hands and a foot) and allow less fatigue of workers, greater speed and accuracy in work. According to their character, simultaneous movements can be identical, similar and different movements, and they are systematized into three classes:

- Class I – basic movements that are easy to perform simultaneously.
- Class II – basic movements that are performed simultaneously, but with the necessary training.
- Class III – basic movements that can not be performed simultaneously, so they are analyzed separately.

- (8) Defining work methods and determining the amount of time for the operations, grips and movements.
- (9) Calculating the cumulative time for working elements, adding extra time (in case of working on a machine the possibility of simultaneous performance of certain work operations with machine work is considered) and expressing in TMU.
- (10) Determining of normal production time.
- (11) Checking up whole procedure so as to correct possible errors.

Example of MTM analysis for making six straight holes on sewing automatic machine on the front of men's shirt is given in Table 3.4.

Table 3.4 MTM analysis for making six straight holes on sewing automatic machine on the front of men's shirt

Left hand	Symbol	TMU*	Symbol	Right hand
1. Taking the pieces of garment				
reaching the front part	R30B	14,2	R20B	reaching the front part
			G5/G2	taking the front part
taking the front part	G5	8,8	M15B	up the front part
reaching the bordures of front part	R15B			
taking the front part	G1A	2,2		
2. Putting the front part on automat				
up the front part	mM10B	4,3	mM10B	up the front part
putting on the machine	M30A	12,7	M30A	putting on the machine
closing tapes	M45B	16,8		
up the part of machine	M10A	6,0		
down the front part	RL1	2,0	RL1	down the front part
balance of the front part(twice)	R10B	12,6	R10B	balance of the front part(twice)
taking the front part	G5	2,0	G1A	taking the front part
3. Position of the front part on the sewing machine				
		6,8	M10B	taking to the stitch place
		5,8	M6C	putting on the stitch place
		16,2	P2SE	putting on the mark
		2,0	RL1	down the front part

		15,6	R40B	reaching the front part
		0,0	G5	taking the front part
down the front part	RL2	0,0		
taking the switch	R20A	7,8		
switching on machine	G5/AF	3,4		
4. Making 6 button holes with automatic movement				
machine work		739,0		
5. Walking to next machine				
rotating body at 90°	TB2	37,2		
rotating body at 45°	TB	18,6		
walking	WM1,5	26,1		

Where:

- TMU – Time Measurement Unit =  $10^{-5}$  h ( $3.6 \cdot 10^{-2}$  s),
- R30B – reaching work object whose position can be changed (the length of movement of 30 cm),
- R20B – reaching work object whose position can be changed (the length of movement of 20 cm),
- G5/G2 – grasping work object by touch and re-grasp,
- G5 – grasping work object by touch,
- M15B – moving work object to the indefinite position by the length of movement of 15 cm,
- R15B – reaching up object whose position can be changed (the length of movement of 15 cm),
- G1A – grasping work object that is easy to grasp,
- mM10B – moving work object,
- M30A – moving work object to delimiter,
- M45B – moving work object to the indefinite position,
- M10A – moving work object to the delimiter (the length of movement of 10 cm),
- RL1 – dropping work object,
- R10B – reaching work object whose position can be changed (the length of movement of 10 cm),
- M6C – moving work object to a specific position,
- RL2 – placing work object,
- G5/AF – grasping work object by contact touch and pressing by force (by finger),
- TB2 – rotation of body of worker for 45° to 90° with the relocation of both legs for balance,
- TB – rotation of body of worker for 45° to 90° with the relocation of one leg,
- WM1.5 – step-walking 1.5 m.

Garment industry also uses the German MTM Association Table (Table 3.5) on the basis of which the sewing speed is determined ( $v_s$ ) by reading values for stitches sewing speed ( $v_b$ ) and the density of stitches ( $g_b$ ).

Table 3.5 MTM

values stitches sewing speed $v_b$ (stitches $\text{min}^{-1}$ )							sewing time $t_t/\text{TMU}$							
density of stitches $g_u$ (stitches $\text{cm}^{-1}$ )							sewing speed $v_s$			seam length $l_s$ (cm)				
2	2,5	3	3,5	4	4,5	5	2	5	10	20	30	40	50	
40	50	60	70	80	90	100	2	175	425	842	-	-	-	
80	100	120	140	160	180	200	4	92	217	425	842	-	-	
120	150	180	210	240	270	300	6	64	147	286	564	842	-	
160	200	240	280	320	360	400	8	50	113	217	425	633	842	
200	250	300	350	400	450	500	10	42	92	175	342	509	675	842
240	300	360	420	480	540	600	12	36	78	147	286	425	564	703
280	350	420	490	560	630	700	14	32	68	128	247	366	485	604
320	400	480	560	640	720	800	16	29	61	113	217	321	425	530
360	450	540	630	720	810	900	18	27	55	101	194	286	379	472
400	500	600	700	800	900	1000	20	25	50	92	175	258	342	425
440	550	660	770	880	990	1100	22	24	46	84	160	236	312	388
480	600	720	840	960	1080	1200	24	22	43	78	147	217	286	356
520	650	780	910	1040	1170	1300	26	21	41	73	137	201	265	329
560	700	840	980	1120	1260	1400	28	20	38	68	128	187	247	306
600	750	900	1050	1200	1350	1500	30	20	36	64	120	175	231	287
640	800	960	1120	1280	1440	1600	32	19	35	61	113	165	217	269
680	850	1020	1190	1360	1530	1700	34	18	33	58	107	156	205	254
720	900	1080	1260	1440	1620	1800	36	17	32	55	101	147	194	240
760	950	1140	1330	1520	1710	1900	38	17	30	52	96	140	184	228
800	1000	1200	1400	1600	1800	2000	40	17	29	50	92	134	175	217
840	1050	1260	1470	1680	1890	2100	42	17	28	48	88	128	167	207
880	1100	1320	1540	1760	1980	2200	44	17	27	46	84	122	160	198
920	1150	1380	1610	1840	2070	2300	46	17	27	45	81	117	153	190
960	1200	1440	1680	1920	2160	2400	48	17	26	43	78	113	147	182
1000	1250	1500	1750	2000	2250	2500	50	17	25	42	75	108	142	175
1100	1375	1650	1925	2200	2475	2750	55	17	24	39	69	99	130	160
1200	1500	1800	2100	2400	2700	3000	60	17	22	36	64	92	120	148
1300	1625	1950	2275	2600	2925	3250	65	17	21	34	60	85	111	137
1400	1750	2100	2450	2800	3150	3500	70	17	20	32	56	80	104	128
1500	1875	2250	2625	3000	3375	3750	75	17	20	31	53	75	97	120
1600	2000	2400	2800	3200	3600	4000	80	17	19	29	50	71	92	113

1700	2125	2550	2975	3400	3825	4250	85	17	18	28	48	67	87	107
1800	2250	2700	3150	3600	4050	4500	90	17	18	27	46	64	83	101
1900	2375	2850	3325	3800	4275	4750	95	17	17	26	44	61	79	96
2000	2500	3000	3500	4000	4500	5000	100	17	17	25	42	59	75	92
2200	2750	3300	3850	4400	4950	5500	110	17	17	24	39	54	69	85
2400	3000	3600	4200	4800	5400	6000	120	17	17	22	36	50	64	78
2600	3250	3900	4550	5200	5850	6500	130	17	17	21	34	47	60	73
2800	3500	4200	4900	5600	6300	7000	140	17	17	20	32	44	56	68
3000	3750	4500	5250	6000	6750	7500	150	17	17	20	31	42	52	61

Sewing speed can be calculated by the formula:

$$V_s = \frac{0.1 \times v_h}{g_h} \quad [3.19]$$

Sewing time in TMU is calculated from the formula:

$$T_t = 4.63 \cdot v_s \quad [3.20]$$

In terms of large series and mass production, as well as in cases of highly repetitive operations in administration, commerce and other service industries the usage of MTM is justified. Systematic analysis of the work process with the application of MTM in garment industry makes it possible to

- Specify the duration of technological operations.
- Determine the rhythm of the group.
- Establish the optimal method of performing work.
- Rationalize the existing procedures of work.
- Plan the technological process of clothing optimally.
- Determine the real work norm.
- Organize work on several machines.
- Determine the real costs of apparel production.

For small series production and individual activities which require high speed of analysis, MTM-2 and MTM-3 were developed, where a single logical set of basic movements create standard grips.

MTM-2 uses the reduced structure of basic movement and its variant cases. Compared to MTM, MTM-2 provides the results of deviations up to 15%, but the usage is simple, fast and cheap (it can be used in garment assembling or in the warehouse).

The variant of MTM-3 is a further simplification related to the MTM-2. Differentiation of movements is reduced to:

- Object handling and management by hand or fingers in order to put it in a new position.

- Transport (placing of object by hand into a new position).
- Step made by leg.
- Bending with the correction.

With the development of computer support in the field of work measurement, MTM Association has developed a 4M system (Micro-Matic Methods and Measurements). The 4M identified two sets of movements, such as:

- GET – reach with inclusion in appropriate combinations and
- PLACE – set on the place with possible variations referring to the fixing of object of work.

Software package for the application of 4M makes getting of reports possible, i.e.:

- (1) Analysis of the operation which includes, for each of the two basic elements, the corresponding variation of time for each hand, total allowed time and normal production time.
- (2) Instructions for worker how to do operations.
- (3) Time for left and right hand, total time and performance.
- (4) Analysis of operations with sets of code movements and their variations.

### **3.4 Method of relationship between the speed of forming stitches and time**

Within the production of clothing, in the structure of technological operations of sewing, only 20–30% of machine and machine-hand grips are used, and they determine the technological time of sewing on the machine. The biggest problem is to determine the machine-hand times, because the movements of workers are affected by different factors, such as: technical characteristics of the sewing machine, type of seam, type of stitches, seam path curvature, psycho-physiological and cybernetic characteristics of workers, random grips when a needle is broken, material processing, short delays and so on. When performing machine grips, time is specified by construction of a sewing machine and it does not depend on the worker, so the fatigue coefficient, the coefficient of environmental influence and the supplementary coefficient are not added.

The researches in garment industry, which have been made since 1960, have not found a unique method for determining the time of technological operations, so different methods based on different scientific researches are used nowadays.



Heckner R. (1975) developed, through systematic researches, a method for calculating machine-hand times which introduces the parameter of curvature of seam and the correction of stitches sewing speed depending on the specific density of stitches. Heckner discovered that the decrease or the increase of stitches sewing speed is also affected by psychophysical abilities of workers beside the machine. When a specific density of stitch is smaller (2–3cm), due to increasing the sewing speed, it is necessary to adjust the time of machine-hand grips of sewing, because the worker reduces the stitches sewing speed unconsciously. In Table 3.6 the correction factors of stitches sewing speed are given.

Table 3.6 Correction factors of stitches sewing speed

Seam description	Type seams on cloth	Correction factor (fz)
Long, flat	Side seam of trousers	0.6-0.7
Medium long, slightly curved	Hem on the women's jackets	0.5-0.6
Short, slightly curved	Darts	0.45-0.5
Short, highly curved	Cover pocket	0.35-0.45

A practical test of methods for determining the time of sewing in real production conditions was done by Lohman (1987), who analyzed and compared five methods:

- (1) Method of relationship between the speed of forming stitches and time.
- (2) Method with calculated time of pressing pedals.
- (3) MTM method (Deutsche MTM – Vereinigung).
- (4) Conrad's method MTM.
- (5) Heckman's method (sewing speed depends on the curvature and the length of seams, but also on the active reaction of workers).

Lohman thus proved that more accurate times of sewing can only be determined on the basis of average stitches sewing speed, but he did not consider the stages of acceleration and deceleration of the main shaft of sewing machines, the number of segments of joining one seam, the accuracy of joining seams and the level of training of workers.

Hopf (1978) proved, through researches and analysis of machine-hand time, that sewing time of stitches depends on the stitches sewing speed, the density of stitches, the accuracy of compiling the edges and skills of workers, applying the theory of ray lengths by MTM system.

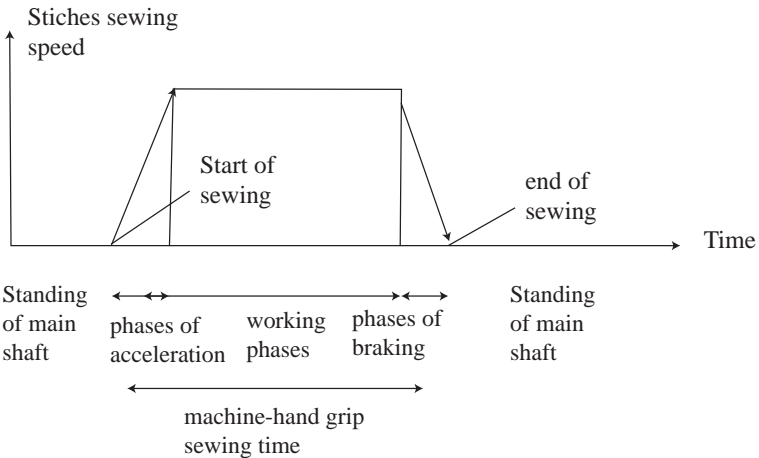
### 3.5 Method with calculated time of pressing pedals

Oeser (1969) was the first one who started dealing with the problem of determining the time of sewing knitwear and he examined the maximum dynamic possibilities of sewing machines for overloch knitted seaming. He is one of the first authors who showed a diagram of dependence of stitches sewing speed upon the time in garment technology (Figure 3.6). He defined the occurrence of the acceleration main shaft, the work up to the achieved fixed stitches speed (by then it had only been a maximum sewing speed of stitches) and the deceleration of the main shaft.

Oeser indirectly pointed out, by calculating the level of efficiency, that the dynamic characteristics of the sewing machines depend on the moment of inertia of all moving mechanisms of sewing machines, the moment of inertia of the transmission system and electric motor, considering the phases of acceleration and braking.

Möller (1986) was the one who improved Heckman’s method and who, apart from the stitches speed sewing, introduced the skills and abilities of workers to respond and the time for pressing the pedal while starting and stopping of electric motors into mathematical formulas for determining the machine-hand time.

Krowatschek and Ludermann (1974) did some researches about the mechanical and dynamic characteristics of the sewing machine. They developed a very modern equipment at that time for measuring the moment of inertia of sewing machine and electric motors, a device for measuring stitches sewing speed and the number of stitches in the seam by using oscilloscope with light paper. That is



3.6 Oeser’s diagram of sewing machine with the phases of acceleration and braking.

how they proved that short seams do not need sewing machines working at high speed because their speed cannot be fully expressed in the short seam.

### 3.6 Other methods

One of the important elements of time study and modern researches of norms is the analysis of losses of working time. Losses in work can not be avoided, and therefore it is necessary to determine, classify into reasonable and unreasonable ones and reduce them to the least possible measure by organizational or technological-technical measures. The analysis of losses first requires observing the work place according to the level of organization.

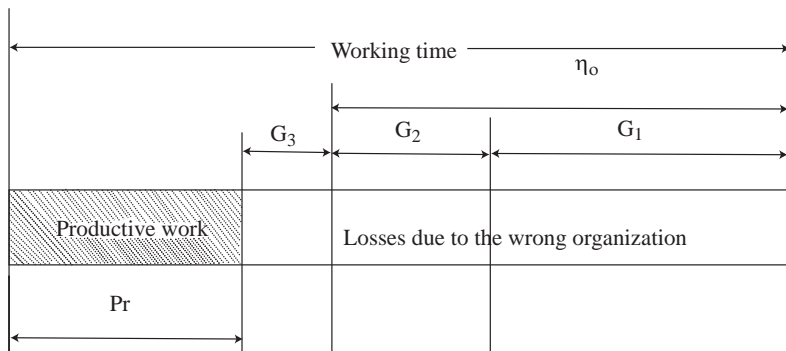
There are three types of production work places are as follows:

- (1) Open workplace – where the worker leaves the workplace during work to take work objects and resources. It is suitable for low-level organizations as well as individual production workplaces. Here, the worker loses a lot of production work time, work productivity is reduced, the machine remains unused and the production cycle is longer, so the involvement of resources in production is bigger. Researches showed that an employee works 4 hours effectively, everything else is a useless work. The manager prepares jobs for workers, and it takes him just an hour or two to do the job of an instructor.

The structure of available time for open workplace is shown in Figure 3.7, where:

$G_1$  [h], [%] – interruption in work because of wrong organization (no materials, machine failure, etc.),

$G_2$  [h], [%] – the work of employees as a result of wrong organization (wrong planning and division of work),



3.7 Structure of available time for open workplace.

$G_3$  [h], [%] – the effect is not realized because of wrong organization (wrong method of work),

$Z$  [h], [%] – the involvement of employees (part of a total available time in which the employee works),

$\eta_k$  [h], [%] – the degree of utilization of machine capacities in the workplace,

$\eta_o$  [h], [%] – the degree of openness of workplace (part which remains untapped due to wrong organization),

$P_r$  [h], [%] – the effect or productivity of workplace.

Thus, the absorption of workers in the open workplace is

$$Z^o = \frac{RV - G_1}{RV} 100 [\%] \quad [3.21]$$

Where:  $RV$  – the available working time (e.g. 7 or 8 hours)

The degree of utilization of machine capacities in the open workplace:

$$\eta_{k^o} = \frac{(RV - (G_1 + G_2))}{RV} 100 [\%] \quad [3.22]$$

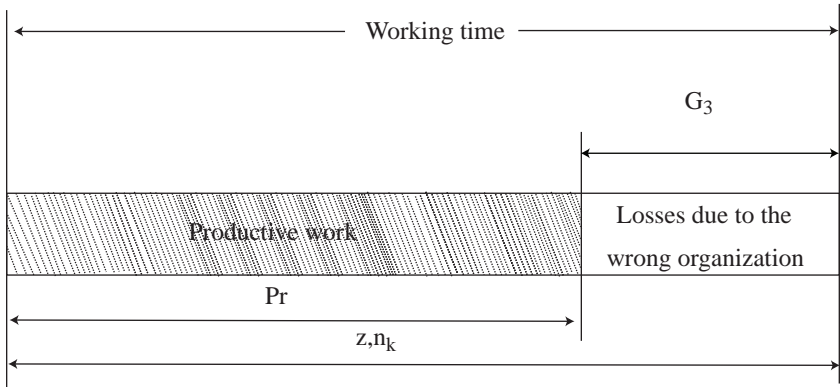
Degree of openness of the workplace:

$$\eta_{o^o} = \frac{G_1 + G_2}{RV} 100 [\%] \quad [3.23]$$

The productivity of the open workplace:

$$P_{r^o} = \frac{(RV - (G_1 + G_2 + G_3))}{RV} 100 [\%] \quad [3.24]$$

- (2) Closed workplace – where production is well-prepared. Workers are beside the machine, and work objects and resources are brought by other workers. This type of workplace is a characteristic of serial and mass production. Basic characteristics of this workplace are: working time is completely used for performing of operations so work productivity is increased, as well as specialization of workers and technical division of work; production cycle is shortened and means of work are less engaged; the degree of utilization of machines is bigger, so is the case with profitability. The employee works seven-eight hours effectively, as well as his supervisor. The structure of available time of the closed workplace is shown on Figure 3.8.



3.8 Structure of available time for closed workplace.

Involvement of workers in the closed workplace is

$$Z^z = \eta_{kz} = 100 [\%], \quad [3.25]$$

and productivity:

$$P_{rz} = \frac{RV - G_3}{RV} 100 [\%] \quad [3.26]$$

- (3) Stabilized workplace – a complete rationalization and the economy of work on the workplace was made, as well as the mechanization of work and the division into the smallest operations. The employee does the same work for six instead of eight hours, because his work is easier and simplified. Apart from the job of an instructor, the manager finds new ways to simplify the work of employees. The stabilized workplace (Figure 3.9) is a characteristic of large series and mass production.

The involvement of employees in the stabilized workplace:

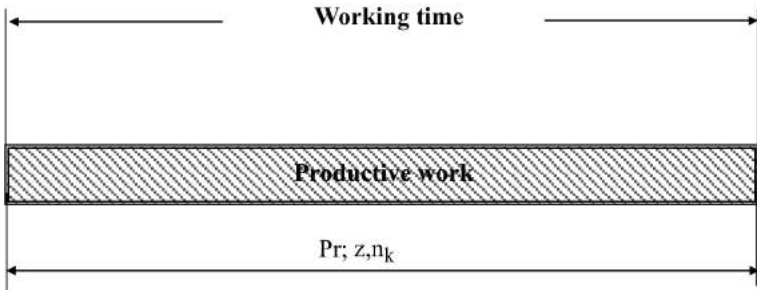
$$Z^s = \eta_{ks} = Pr^s = 100 [\%] \quad [3.27]$$

Degree of openness of the workplace:

$$\eta_{oz} = 0 [\%] \text{ because: } G_1 = G_2 = G_3 = 0 [\text{hour}] \quad [3.28]$$

In the apparel production, workplaces are open workplaces with the lowest degree of organization where the employee often stops working and leaves the workplace, so the most important causes of losses of working time are

- (a) organizational-technical causes (insufficient coordination, irregular flow of material, improper scheduling of workplaces, lack of materials or



3.9 Structure of available time for stabilized workplace.

low quality materials, staff incompetence, lack of information, irrational movements while working, inappropriate division of work, overloaded workplaces, inadequate or defective internal transportation, the lack of working area, non-discipline, inadequate control while working, inadequate categorization or evaluation of work, the lack of tools or inappropriate tools, old or broken machines, etc.).

- (b) organizational-biological causes (inadequate room temperature, poor lighting, inadequate ventilation and air-conditioning, inappropriate vacation schedule, unsuitable working furniture, inadequate hygiene at work, too big a distance between the rooms, etc.).

In order to solve this problem it is necessary to determine the losses and set the higher organizational level, such as stabilized or closed workplace, where working is most effective and humane. Aiming to transform the open workplace into the closed one, it is necessary to perform a range of activities in order to eliminate losses (Bulat and Bojkovic, 1999):

- (1) Programming of production.
- (2) Profit analysis of products.
- (3) Selection of production programmes.
- (4) Determining the optimal production plan.
- (5) Calculating the optimal size and number of series of products from the optimal plan.
- (6) Choosing the optimal types of resources (tools, machines) following the production programme.
- (7) Determining the required number of resources per types.
- (8) Determining the required number of workers per shifts and the professions.
- (9) Determining the required number of workplace per types.
- (10) Determining the optimal schedule of work.
- (11) Optimal division of work.
- (12) Determining the optimum order of performing work tasks.

- (13) Scheduling production and launching of work tasks.
- (14) Supply of workplaces with jobs.
- (15) Study, measurement, improvement and humanization of the workplace, etc.

In order to determine the loss of working time, two methods are used:

- (1) Picture of working day is a simple method of recording losses in one day of at least three employees with a stopwatch timer.
- (2) The method of current observation (Work sampling, Ratio delay method, Méthode des observations instantanées) – recording the losses of workplaces randomly chosen, and counting the number of employees working at that moment. This statistical method of observation of phenomena on the basis of their frequency was first applied by the British statistician LNC Tippett in 1934 in the textile industry, and it has been mostly applied ever since.

Work sampling is used for:

- (1) Determining the degree of capacity utilization.
- (2) Determining the degree of openness of the workplace, groups of workplaces and organizational units.
- (3) Calculating the level of organization of organizational units.
- (4) Determining the preliminary–final time, help-time and additional component time within the calculation of the normal production time.

The process of implementation of method of current observation by Martinovic (2002) is as follows:

- (1) Determine the aim of recording, the aim of applying methods.
- (2) Inform the people who work in workplaces that will be recorded about the aim and the method of recording.
- (3) Make a schematic view of objects that will be recorded.
- (4) Define the path of a recorder, determine the best position of the recorder for each object to be recorded and draw a schematic view.
- (5) Create forms (document) for recording.
- (6) Train the employees who will record.
- (7) Determine the time of a starting point of each recorder by using a table of random numbers.
- (8) Adopt the accuracy of the indicators that should be determined by the work sampling.
- (9) Calculate the required number of notes and tours.
- (10) Control whether the process of recording is performed normally. If not, stop the recording.
- (11) Sort out the recorded material.

- (12) Calculate indicators (parameters, values, size, etc.) and determine their accuracy.
- (13) Undertake analysis of the results obtained.
- (14) Make appropriate conclusions.
- (15) Take the necessary measures.

After you complete the recording of data by the method of current observation, the analysis of recorded data is performed, i.e. (Sajfert and Nikolic, 2002):

- (1) recording by elements,
- (2) developing circular diagrams,
- (3) calculating of capacity utilization,

$$q = \frac{\text{number of work notice}}{\text{total number of notice}} \cdot 100 [\%] \quad [3.28]$$

- (4) calculating the losses in work,

$$p = \frac{\text{number of non work notice}}{\text{total number of notice}} \cdot 100 [\%] \quad [3.29]$$

- (5) calculating the additional coefficients

$$K_d = \frac{\Sigma G_p}{\Sigma R + \Sigma G_{NP} + \Sigma G_{NE}} \quad [3.30]$$

Where:  $G_p$  – recognized losses in the working norm,  
 $R$  – number of notes,  
 $G_{NP}$  – unrecognized losses,  
 $G_{NE}$  – losses because of indiscipline.

In order to test the accuracy of indicators of capacity utilization degree, this formula is used:

$$t = 100 \cdot \left[ 1 - 2 \sqrt{\frac{l-q}{q \cdot n}} \right] \quad [3.31]$$

Where:  $n$  – total number of notes

As an example of method of current observation, Table 3.7 shows the observed document obtained in a sewing room during a working week (six working days).



Table 3.7 Sheet for recording of working time losses

Date	Time of rounds	Direct work	Prepare machine for operation	No job	The machine does not work	Short justified delay	Unjustified delay	No material, tools, documents	Not work because of quality control	The worker is not in the work place	Σ Losses
15 September 2008.	7h10										12
	8h10										9
	9h10										3
	10h10										10
	11h10										7
	12h10										3
	13h10										7
	13h45										/
16 September 2008.	7h10										10
	8h10										12
	9h10										/
	10h10										8
	11h10										10
	12h10										7
	13h10										9
	13h45										/
17 September 2008.	7h10										10
	8h10										8
	9h10										8
	10h10										4
	11h10										12
	12h10										9
	13h10										1
	13h45										/
18 September 2008.	7h10										14
	8h10										4
	9h10										4
	10h10										10
	11h10										10
	12h10										5
	13h10										6
	13h45										/
19 September 2008	7h10										4
	8h10										3
	9h10										2
	10h10										8
	11h10										3
	12h10										11
	13h10										5

(Continued)

20 September 2008.										
7h10										7
8h10										2
9h10										1
10h10										5
11h10										1
12h10										2
13h10										/
13h45										/
$\Sigma$	734	46	30	18	40	45	20	37	30	1000

After the recording of data by Method of current observation has been completed, the analysis of recorded data is performed (Table 3.8).

On the basis of data from Table 3.8, the level of capacity (q) is calculated, as well as losses in work (p) and an additional coefficient ( $K_d$ ). The level of capacity to [3.28] is  $q = \frac{780}{1000} \cdot 100 = 78\%$ .

Table 3.8 Data obtained by work sampling

Number	Description	Number of notice	%
1.	Direct work	734	73.4
2.	Prepare machine for operation	46	4.60
3.	No job	30	3.00
4.	The machine does not work	18	1.80
5.	Short justified delay	40	4.00
6.	Unjustified delay	45	4.50
7.	No material, tools, documents	20	2.00
8.	No work because of quality control	37	3.70
9.	The worker is not in the workplace	30	3.00
	Total:	<b>1000</b>	100

Losses in work [3.29] as  $p = \frac{220}{1000} \cdot 1000 = 22\%$

Calculating the additional coefficient by [3.30]:

$$k_d = \frac{\Sigma G_p}{\Sigma R + \Sigma G_{NP} + \Sigma G_{NE}} = \frac{30 + 18 + 40 + 20 + 37}{780 + 30 + 45 +} = 0.169$$

The accuracy of indicators of capacity utilization over the formula [3.31] is

$$t = 100 \left[ 1 - 2 \sqrt{\frac{1 - 0.78}{0.78 - 1000}} \right] = 96.64\%, \text{ i.e. with 1000 notes the uncertainty is}$$

3.36%.

Considering the fact that the machine delay  $Z = \frac{220}{1000} 100 = 22\%$ , then the

reliability is  $t = 88.1\%$ . In order to make the accuracy of machine delay 95%, it is necessary to calculate the number of notes:

$$n \geq \frac{4 \cdot 10^4}{5^2} \cdot \frac{1 - 0.22}{0.22}$$

$$n \geq 1596$$

According to this, 1000 notes were sufficient for capacity utilization  $q$ , whereas the machine delay required 1596 notes.

Testing the accuracy of other indicators:

- direct the work  $t = 96.19\%$  (3.81% uncertainty),
- preparing machines for work  $t = 71.19\%$  (28.8% uncertainty),
- no job  $t = 64\%$  (uncertainty 36%),
- machine failure  $t = 53.28\%$  (46.72% uncertainty),
- short justified delay  $t = 69\%$  (31% uncertainty),
- unjustified delay  $t = 70.8\%$  (29.2% uncertainty),
- no materials, tools and documents  $t = 55.72\%$  (44.28% uncertainty),
- no work because of quality control  $t = 67.7\%$  (32.3% uncertainty),
- employee is not in the workplace  $t = 64\%$  (uncertainty 36%).

Method of current observation can also be used as a method for determining the normal production time, if one operation is performed on many workplaces. Working time, break time, time for physiological needs, acknowledged delays etc. During the application of method of current observation a time of recording is established simultaneously, as well as the number of pieces produced and the mean value of rhythm of workers' performance. Obtained values in percents are converted into the corresponding times in minutes, according to the formula:

$$t_{iz} = \frac{\text{total time} \cdot \text{percent of work} \cdot \text{mean value of rhythm}}{\text{total number of operation pieces produced}} \quad [3.32]$$

There are many advantages and disadvantages of method of current observation which can be defined on the basis of this example. The advantages

are as follows: one recorder can record a number of workplaces; less work and less costs than in continuous recording; the period of observation can be extended to avoid periodical variations; workers, in time, relieve themselves of feeling continuously observed, and they have a normal attitude to work – more accurate data; it takes less time for the recorder to prepare for recording; computer data processing can be used. Disadvantages of method of current observation are as follows: non-economical for applying in one workplace; not getting detailed information; and production workers find it hard to understand.

Reducing the number of workers in manufacturing, automation, and increasing the number of employees in administration will make this method of current observation, as a method for determining the normal production time, widely used in the future.

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