Contents

1. METHODS OF TIME MANAGEMENT (OBTAINING DATA)

1.1 Basic concepts

We can divide up data in many different ways:

- Product data
- Equipment data
- Resource data
- Numbers
- Quantities
- Times, deadlines, dates
- The sizes of different factors
- Working conditions
- Personnel data
- Order data
- Key figures
- Accounting data
- Request and performance data, etc.

Data can be structured according to different criteria. For example into:

Dependent and independent data
The values of the dependent variables depend on those of the independent variables.

- The average speed of a vehicle (dependent variable) depends on a number of factors, such as the type of vehicle, the condition of the road, the length of the journey, the traffic density, etc.
- The cutting speed (dependent variable) depends of factors such as the speed of rotation, feed rate, cutting material, cutting edge etc.

Quantitative and qualitative data
Quantitative data is measurable or countable.

- Times taken for work processes - measured with a stopwatch
- The actual masses of workpieces - measured with a micrometer
- The number of parts manufactured - which can be counted
- The weight of a workpiece - which is weighed

Data from measurements can have a very high degree of accuracy.
Qualitative data is determined only by assessment (evaluation).

- An employee may be good, excellent or not suitable for an activity.
- The performance of an employee can be very good, good or not so good (assessment of the employee).

There are many forms of data that cannot be a quantitatively assessed.

These include things like human efficiency and responsibility. Assessing qualitative data requires special care and experience.

Fixed and variable data
Fixed data does not change over the course of time, at least over a longer period.

- Temperature in an air conditioned room
- The speed of a machine
- The number of strokes of a punching machine
- Rent of a garage

Variable data changes over the course of time.

- Contamination of filters
- Performance of an employee
- Number of employees
- Wear and tear of a machine
- Sharpness of a tool

Absolute and relative data
Absolute data is raw data without reference to a standard value:

- a certain amount, such as 10 pieces
- a specific time, such as 2 hours
- a specific unit of time, such as 1 minute

Relative data is based on a reference unit:

- such as 10 hours/min
- a speed of rotation of 600 min-1
- a speed of 35 m/s

Raw data is more expressive and more usable when given a reference unit.

1.1.1 The uses of data

Data is used for

- **Planning**
  Before submitting an offer, a preliminary cost estimate must be made. The price must be calculated and this is only possible if the appropriate data is available (has been determined). Existing data also shows whether the resources are available to perform the new job or not.

  Data is needed when comparing several working methods. There is also the need to plan investment in capital equipment. New equipment is only purchased if it can be shown that the purchase is worthwhile. This is done, of course, on the basis of the data collected.

- **Management**
  Dates must be set up and machines assigned. Material must be ordered. All of this is only possible with the relevant data.

- **Monitoring**
  When an order is finished, the final costing takes place. Was the data available for the preliminary costing accurate, or does it need to be corrected? How efficient were the machines, how much sick leave was taken, and how high is the waste?

- **Pay**
  Data (times) are also the basis for piecework remuneration or bonus schemes.

1.1.2 Time as data

This booklet focuses on the identification, i.e. the collecting and processing, of time data for work process steps.

If, for example, the task is to 'lathe a shaft', we can identify the following steps:

1.	**Fit shaft into three-jaw chuck**	**0.30 minutes**
2.	**Adjust tool**	**0.25 minutes**
3.	**Lathe the shaft**	**2.80 minutes**
4.	**Retract support**	**20 minutes**
5.	**Remove and store shaft**	**30 minutes**

These times say nothing about the conditions under which they have been determined. They are not enough on their own.

We also need to know:

- the factors on which the times for each section depend.
    - How hard was the shaft?
    - From which material was it made?
    - Was it turned lengthwise or planar?
    - Was it rough-machined or finished?
    - Which tool was used?
    - What speed did the machine run at?
    - Was the feed by hand or automatic?
    - Which machine was used?

- the reference quantities, to which the times are related. Does the time refer to 1 piece, 4, 10 or 100 pieces?

- the working conditions under which the work was done.
    - Is the worker at the machine skilled, semi-skilled or unskilled?
    - Has he or she already performed similar work?
    - How is the supply regulated?
    - What is the state of the equipment?
    - How is the lighting in the workplace?
    - How much noise was there?

1.1.3 Reproducibility of data

The data should be reproducible. If, for example, times are determined, they are actual times. An evaluation should then convert them to target times. The data is only reproducible if the process which underlie the times are accurately described, working conditions are known and the data is collected with a certain accuracy. Often, existing data cannot be used again, because these things were not considered at the time.

1.2 Process types (analysis)

Workflows are divided (analysis) into sections to determine data and descriptions. People, resources and the object of the work come together in a workflow.

The interaction of people, resources and the object of the work are described by process types. In this way, the professional learns a language that allows him or her to describe processes clearly and precisely. Process types offer the possibility to use the times for different sections of the work flow in a variety of ways. Key figures can be formed which express how effective the interaction of people, resources and the object of the work is.

There are a number of ways of splitting up procedures. For example, a process can be divided into setup and execution, and into parts that can be influenced and those that cannot.

1.2.1 Setup (S) and execution (E)

Each task requires some tasks to be done, so that the real work can be performed. An employee receiving an order, must first of all accept it, read it, possibly look at a drawing, prepare the machine for the order, etc.

Setup (S) is preparing a working system for the performance of a task and subsequently putting it back to its original state. Setup generally occurs only once for each assignment.

Examples for setup stages (S):

Accepting the order, reading the order, looking at drawings, collecting tools and devices, setting-up the machine, fitting tools, removing and returning tools, filling in the order sheet, passing on the order, etc.

Execution (E) is changing the starting material in line with the task.

In the task "Grind shafts", the grinding is the execution stage (E), whereas preparing the workplace for this special order and putting it back to its initial state afterwards is the setup (S).

Task 1.1:

Are the following procedures setup (S) or execution (E)?
The order is: "Construction of drilling jig".

Process type:
- Drawing on a transparency
- Fitting the transparency
- Fill in with ink
- Get additional information
- Replacing a scale on the drafting machine

Task 1.2:

Are the following procedures setup (S) or execution (E)? The order is: "Drilling with a drilling jig".

Process type:
- Drilling of workpieces
- Clamping the drilling jig
- Clamping the workpieces in the drilling device
- Clamping the drill in the drill chuck
- Measuring the parts
- Cleaning the machine
- Writing time for the order form

1.2.2 Process parts which can be influenced (I) and those that cannot (U)

Process parts can be divided into those that one can influence and those that cannot.

When we say that a process can be influenced, we mean that the time it takes to be executed can be affected by people.

Examples:
- Changing a wheel
- Looking at a drawing
- Feeding a machine by hand
- Cleaning a machine

We say that a process cannot be influenced if the execution time cannot be affected by people.

Examples:
- automated operations such as automatic tool changing
- positive-controlled operations

Task 1.3:

Can the following tasks be influenced (I) or can they not be influenced (U)?

Process type:

- Reading a user manual
- Nailing a box together
- Grinding with an automatic feed
- Drilling with manual feed
- Filing by hand
- Monitoring the production process of a CNC machine

1.2.3 Further ways of breaking down process types

A further way to divide work processes and process sections up is through the descriptions of
- the human activity,
- the use of the equipment,
- the path of the object of the work in process types.

Process types based on people

There are abbreviations for all types of processes. The abbreviations relating to human activity start with an uppercase M.

The structure of process types relating to humans includes all events which might occur within the total time a person is available in the context of his or her employment. The period considered may be over several shifts, a single shift, or the duration of the execution of an order.

The first differentiation is:

1.	**The person is active**	**in use**	**MI**
2.	**The person is not active**	**not in use**	**ML**
3.	**The person is not active**	**shutdown**	**MR**
4.	**The process type cannot be assigned**	**not recognizable**	**MX**

According to REFA (organization for work design, industrial organization and company development), the following definitions apply:

In use: MI
The person is in use when performing tasks during the working hours set.

Not in use: ML
The person is not in use if he or she is not available to execute tasks during the working hours set or cannot be employed by the company for a longer period of time: Disease; treatment at a health resort; participation in training; lack of orders

Shutdown: MR
This covers statutory, agreed or operational breaks and other occasions during which the plant is wholly or partially non-operational: Set operating breaks; public holidays; reduced working hours; disasters.

Not recognizable: MX
It may be that the process section is not clearly recognizable as any of these. In this case, MX is used. One should try, however, to assign a type subsequently by getting additional information, for example, by asking the employee.

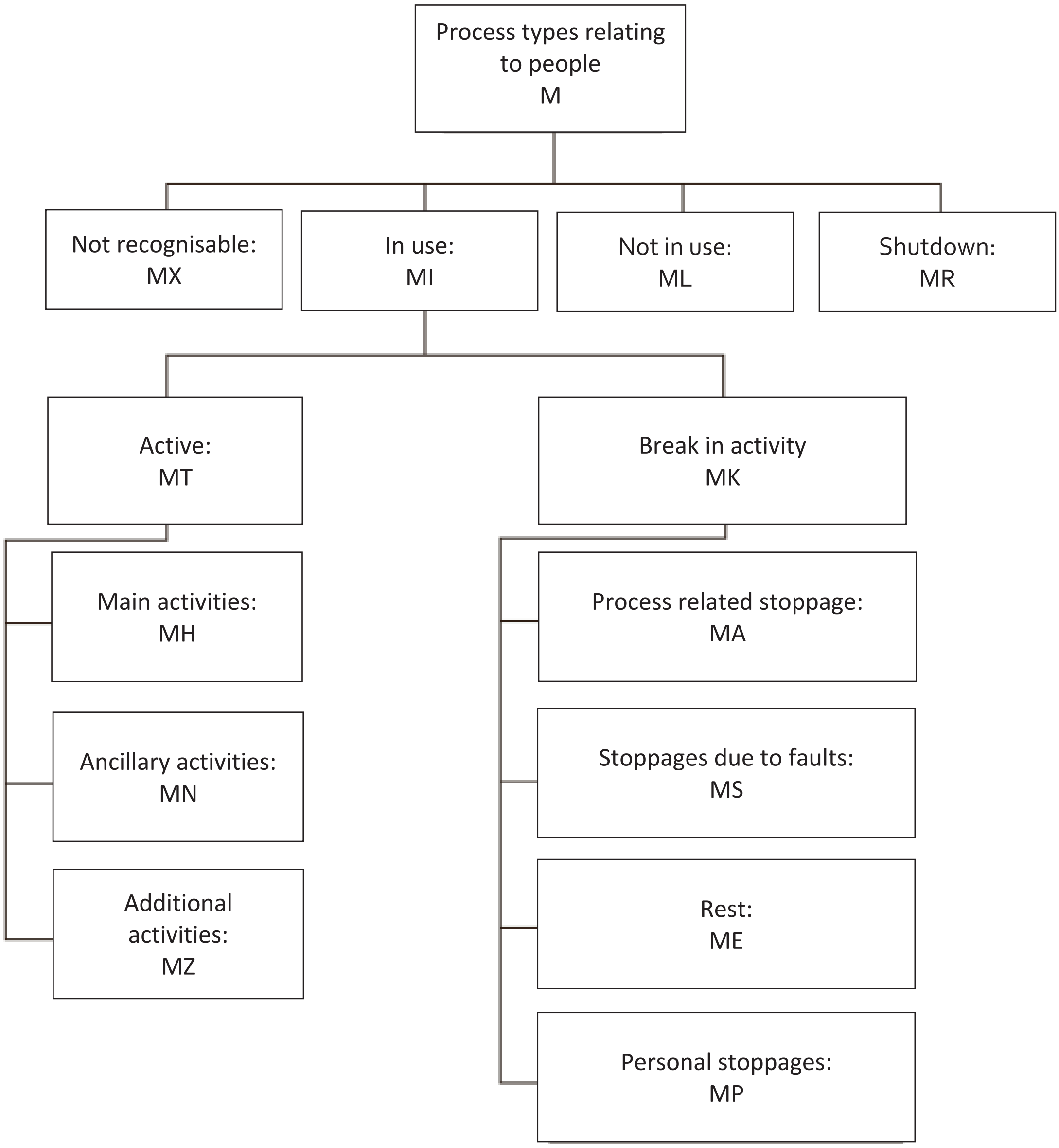

Figure 1.1: Task structure (analysis of process types) relating to people (according to REFA)

Task 1.4:

Assign the following examples to the process types mentioned (MI, ML, MR and MX).

Process type:
- A plasterer helps build scaffolding.
- A fitter suffers an accident and goes to the doctors.
- A department has to go on reduced working hours.
- An employee takes his holiday.
- All employees of a company have 14 days company holiday.
- A foreman is sent on a training course.
- A foreman distributes work orders.
- An employee is away for 4 weeks having treatment at a health resort.
- There is a works meeting.
- The plant is closed for a public holiday.
- There are no tasks for the employees to do.
- An unskilled labourer sweeps up shavings.
- She brings a snack for her colleagues.

The process type "in use" is divided further into "Active MT" and "Break in activity MK".
The "MT activity" can once again be divided up. See figure 1.1.

Main activities: MH
A main activity is the fulfilment of a scheduled activity which directly serves to carry out the tasks necessary on the object of the work.

Examples:
- Grinding on a grinding machine; painting a wall
- Typing on a computer; installing a switch
- Monitoring an automatic operation

Ancillary activities: MN
An ancillary activity is the fulfilment of a scheduled activity which only indirectly serves to carry out the tasks necessary on the object of the work.

Examples:
- Clamping of parts for grinding; Mixing paint
- Putting paper in a printer
- Putting parts out ready to mount

Additional activity: MZ
Additional activity is activity whose occurrence or process cannot be determined in advance.

Examples:
- Reworking;
- Helping others; special cleaning work
- Filing down a burr on an incorrect part supplied
- Eliminating a short disruption to some resources
- Collecting material which has not been delivered

Task 1.5:

Assign the following examples to the process types mentioned (MH, MN, and MZ).

Process type:
- Putting paper in a printer
- Typing on a computer
- Cleaning a lathe
- Tightening a chuck
- Turning
- Clamping or removing a workpiece
- Reworking a part
- Helping a colleague
- Monitoring an automatic operation
- Fetching missing parts
- Painting a wall
- Mixing paint
- A bricklayer makes concrete
- A bricklayer lays bricks
- A bricklayer helps to set up a crane

Alongside dividing activities into main, ancillary, and additional activities, the following assignment can also be made:

Execution: MV
In execution, the human being general makes visible movements. The performance can be influenced fully or at least partially.

Monitoring, observing, controlling: MU
Monitoring, observing, and controlling is generally not able to be influenced.
Mental activity: MG
Mental activity in the strict sense might be able to be influenced and might not.

Execution is predominantly an activity requiring the use of the muscles. Monitoring, observing, controlling and mental activity do not predominantly need the muscles.

Stops in the work can also be divided up further:

Process related stoppage: MA
This is a planned stoppage where a person has to wait for the end of a process step carried out by independently operating equipment.

Examples:
- Waiting for paint to dry
- Waiting on an assembly line for the next piece; waiting for a mould to cool
- Processing times for resources

If such stoppages are long, the working person could perform further work (such as control multiple machines).

Stoppages due to faults: MS
Stoppages due to faults are when people have to wait due to technical or organizational faults or lack of information.

Examples:
- Power failure; waiting for material
- Interruption by a foreman
- Waiting for a locksmith to repair damage

Rest: ME
Rest in the sense of the time studies is a break in activity, to reduce work fatigue caused by the activity.

Examples:
- Relaxing after having to concentrate hard; Resting after performing heavy physical work
- Resting outside the heat zone after working under heat stress

Personal stoppages: MP
A personal stoppage is when someone interrupts his or her work for personal reasons.

Examples:
- Going to the toilet
- Going to vending machines; starting work late
- Finishing work early
- Interruption of activity due to private conversations with colleagues

Task 1.6:

Assign the following examples to the process types mentioned (MA, MS, ME and MP).

Processes:
- Waiting due to a power failure
- Resting after transporting heavy objects
- Going to the toilet
- Conversation with the foreman (about work)
- Private conversation with a work colleague
- Arriving late for work
- Wait for materials
- Wait for materials to solidify the when casting
- Resting after working next to a furnace outside the heat zone
- Waiting for the end of a drilling process with an automatic feed
- Warming up a blank for drop forging
- Buying drinks at the canteen

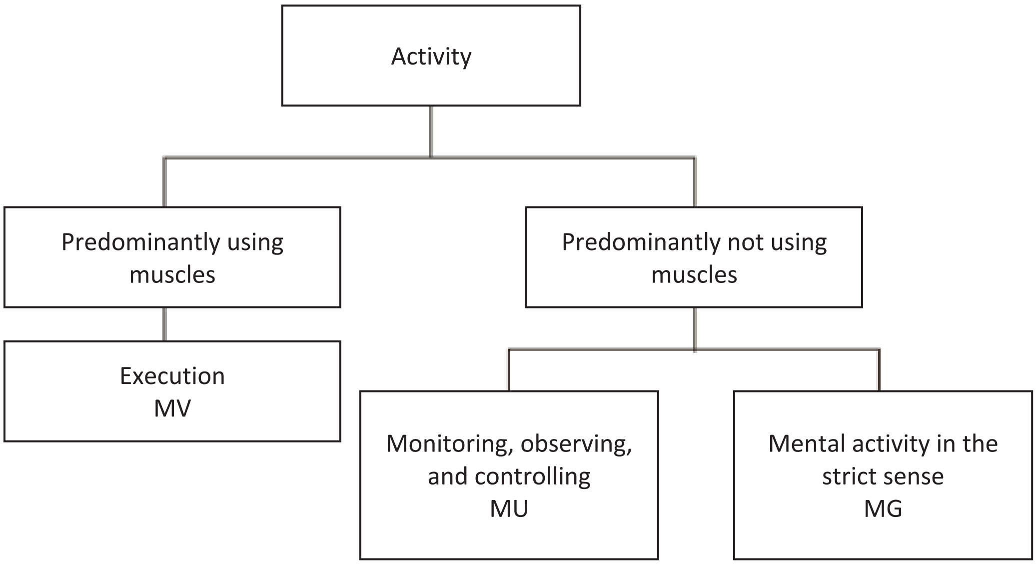

Figure 1.2: Breakdown of activities (according to REFA)

Process types based on resources

Structuring the process types based on resources can cover all events that occur:
- during the 24 hours of the day
- during one or more shifts or parts thereof
- during a specific order
- during an operational accounting period (month, year)
- a period from the buying of equipment up to its sale or scrapping

Breaking down processes by resources is similar to what we saw for people, except that the capital letter B is used here.

According to REFA, the following definitions apply:

In use: BI
The equipment in use, if it is ready and operational and occupied with work orders.

Not in use: BL
Equipment is out of use if it is not available over a longer period of time or is not occupied by orders over a longer period of time.

Examples:
- no order: a planning error
- the operator has an unplanned absence
- faults in the equipment

Shutdown: BR
Not recognisable: BX
This is explained in an analogous way to MX.

There is a further subdivision of the process type "in use", into "being used BT" and "interruption in use BK".

Both can be subdivided further:

Main use: BH
The term "main use" refers to scheduled use of equipment directly for its purpose.

Examples:
- Chip removal on a milling machine
- Annealing parts in a furnace
- Carburising of parts in a carburising furnace
- Writing on a computer
- Driving a laden truck.

Ancillary use: BN
Ancillary use is planned indirect use of the equipment, when preparing it for the main use, loading it, emptying it or returning it to its original state and where it is at rest for checking the object of the work within the equipment.

Examples:
- Clamping a part on a milling machine
- Preheating a furnace
- Preheating a brine bath
- Loading a printer with paper
- Loading, unloading, emptying a truck

Additional use: BZ
Additional use is main and ancillary use of the equipment, which cannot be planned in advance.

Example:
- Using the equipment for reworking

Process related stoppage: BA
A process related stoppage is when a resource is not in use because it is waiting for the activity of a person, a change of the objects of the work or the end of sections of work processes being done on other resources and such a stoppage is planned.

Examples:
The equipment is at a standstill, because the worker

- is checking the piece that has been worked on
- is bringing pieces or removing them
- is reading instructions

Stoppages due to faults: BS
Stoppages due to faults are when the resource has to wait due to technical or organizational faults.

Examples:

- power failure;
- minor repairs of equipment, tools and devices.

Rest-related stoppage: BE
Rest-related breaks are to allow the equipment to rest.

Personal stoppages: BP
Personal stoppages are stoppages caused by humans.

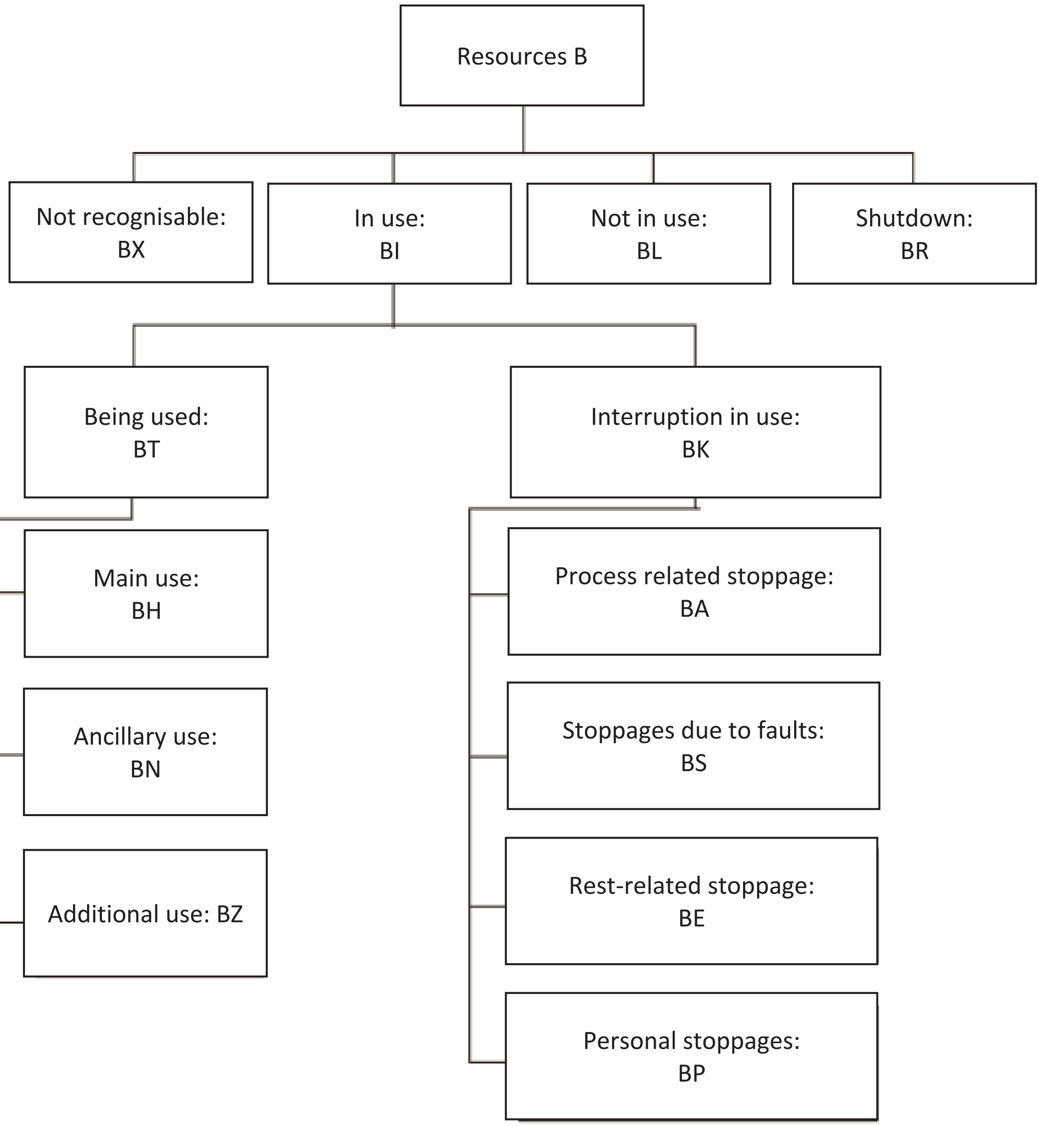

Figure 1.3: Breakdown of process types (analysis of the trace types), according to resources (REFA)

Task 1.7:

Assign the following examples to the process types mentioned (BI, BL, BR and BX):

Process type:

- A drill is used to bore a hole.
- Tools are mounted on an automatic lathe.
- A digger is stored for the winter in a building yard.
- An assembly group is called away for a short time, the resources remain at the location.
- During a period of short-time work, the resources are not used.
- A new press is set up.
- Some machines are out of use due to lack of orders.
- The resources are at rest during the lunch break.
- There are no jobs for a vehicle to perform.
- A cutting tool is installed on a press.

Process types related to the object of the work

Structuring the process types based on objects of the work can cover all events:
- during a specific order
- during one or more shifts
- during an operational accounting period (month, year)
- from the arrival of the goods until their leaving

The capital letter A is used for the process types relating to objects of the work.

The following definitions are from REFA

Changing:
Change in this context can be of the condition, shape, position or location of an object of the work.

Change can be:

Action upon: AE
This is either a change of shape, AEF (machining and processing) of an object of the work or a change of state AEZ.

Changing the shape: AEF
Cutting, pressing, drawing out

State change: AEZ
Solidifying after casting; drying after gluing; setting of concrete; heat treatment of steel.

Conveying: AF
Conveying is changing an object of work's location and place. It is divided into changing position (handling – AFH) and location (transporting – AFT).

Handling is a movement of the object of the work within the workplace, starting or finishing an action, check or storage:
- Fitting and removing
- Inserting into device
- Loading and unloading means of conveyance

Transport is conveyance of objects of work from workplace to workplace or from the workplace to storage.

- Transport on conveyor belt
- Transport of an object of the work with a truck, forklift, crane

Additional change: AZ
An additional change is acting upon or conveying an object of work when this cannot be determined in advance.
- Reworking;
- Bring parts which have been delivered to the wrong place to the right place
- Restacking incorrectly stacked pieces

Checking: AP
Checking, here is of objects of the work in the material flow.

- Checking a shaft in a measuring device; check an engine on a test bench
- Checking the state of the surface of parts; checking parts by counting or weighing

Lying up:
This is when the changing or checking of objects of work depend on processes or on interference. We distinguish between process-related (AA) and additional (other) (AS).

Process-related lying up: AA
- Storage of parts (buffering)
- Providing parts between work areas; lying up of the parts provided during preparatory work on the resources

Additional lying up: AS
Parts are laid up as a result of repairs to equipment, power failure, organizational problems, people's personal stoppages.

Storage: AL
Storage is laying up objects of work in storage areas. Storage areas are areas where goods are received, raw goods are stored, goods are stored temporarily, parts are stored, products are stored for sales or places for final storage.

Task 1.8:

Give the process types in their abbreviations (AE, AF, AZ, AP, AL, AS).

Process type:
- Transporting an object of work with a crane
- Cutting a rotary part
- Drawing the wing of a car
- Drying after painting
- Setting concrete
- Restacking incorrectly stacked parts
- Visual inspection of rolling elements
- Counting parts
- A fault on a resource
- Power failure
- Personal absence
- Bringing forward an urgent order
- Storing half finished parts in the storage depot

Task 1.9:

Assign the following examples to the process types mentioned:

No.	Process step	M	B	A
1	Filling a printer with paper			
2	Writing on a computer			
3	Tightening a chuck			
4	Longitudinal turning (with auto feed)			
5	Sawing with a hacksaw (automatic)			
6	Fitting a new blade to a saw			
7	Rejects have been created on a milling machine which need to be reworked			
8	The foreman is consulted because something about the order is not clear			
9	A machine has no material as the crane is occupied			
10	Time tickets are received			
11	Material is collected by an operator as it has not been supplied			
12	A break is taken after clamping a heavy part on a machine			
13	An order is read and a drawing studied			
14	A workpiece is unclamped			
15	An order form is filled in and submit-ted			

Task 1.9 is designed to train you to detect and determine the process types in relation to people, resources and objects of work. Multiple selections are possible as additional information may be required.

Summary

The terminology for process types is part of the technical language of a work study engineer. With their help, he or she is able to describe processes precisely and unambiguously. Understanding these terms and their meanings are extremely important for work study engineers.

1.2.4 Time band representation

We have already seen that people, objects of work and resources work together in a workflow. This interaction is described via the process types. In Tasks 1.1 to 1.9 you were asked to determine the process types as they relate to people, resources and objects of the work.

If we consider the process types relating to people, we understand that the majority of the working time should be active and that "breaks" should not be too common.

Resources should be used as well as possible and "stoppages" should not occur, where possible. For the objects of the work, the lead time should be as short as possible and "laying up" and "storage" should be uncommon.

It should be obvious that as part of the interaction of labour, resources and the object of work, it is not always possible to simultaneously occupy the staff, use the equipment and change the object of the work.

By representing the processes in a time band, we can get a good overview.

Example 1.1:

A time band representation should be created for the following workflow.

No.	Segment	Time (min)	M	B	A
1	Clamping	0.60	MN	BN	AFH
2	Turning (automatic)	1.90	MA	BH	AEF
3	Removing	0.50	MN	BN	AFH

Scale: 1mm represents 0.10min

If we colour the boxes then we can see the interaction of people, resources and objects of the work at a glance.

The direct processes are **green**, the worker is active, the resources used, the work item changed.

The indirect processes are **yellow**. These are the processes that are needed so that the direct tasks can be completed. For example the resource must be loaded so that the actual task can be done.

The object of the work must be transported and fitted so that it can be changed, for example by turning. Yellow processes are therefore required so that the green ones can take place.

Red processes are, however, undesirable in every case. This is, for people, the interruption of the activity, for resources interruption in the use, and for the object of the work lying up or storage.
On the basis of the time band representation for the turning workflow described we can clearly see that there is an unwanted process type for the person (a process-related break). Occurs. In these 1.90 minutes he could be employed for other work.

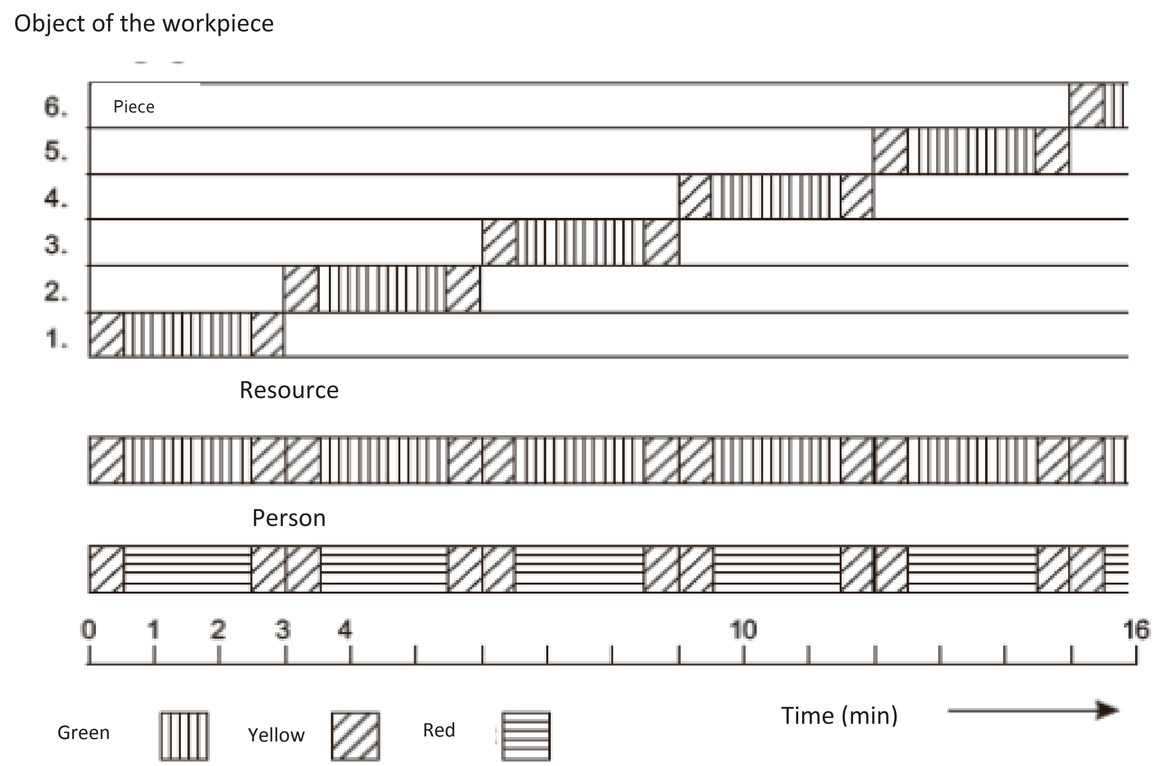

Figure 1.4: Time band representation

Task 1.10:

Create a time band representation for the following workflow.

No.	Segment	Time (min)	M	B	A
1	Clamping	0.30			
2	Milling (with auto feed)	2.00			
3	Removing	0.20			
4	Deburring by hand (during the milling process)	0.80			

Object of the workpiece

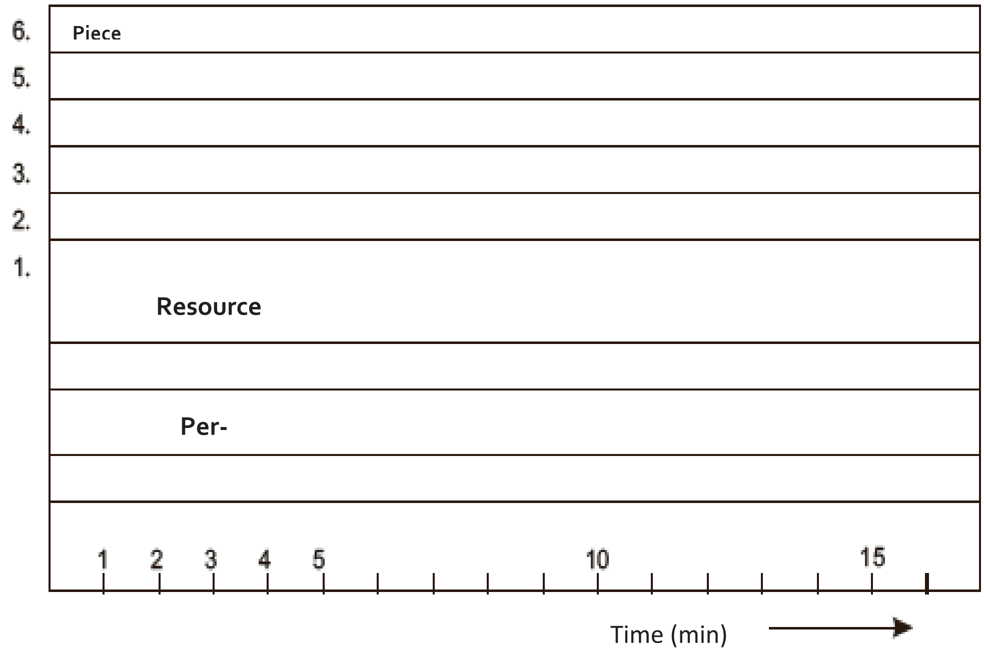

Figure 1.5: Time band representation for Task 1.10

Summary

Time band representations show and make clear the interaction of labour, resources and the objects of work in a diagram. If it is colored, weaknesses in the workflow can be easily identified.

1.3 Synthesis (Expected times)

In Section 1.2 we divided the workflow into sections (analysis) and described it via the process types. The time needed for the sections of the workflow, time types, can be determined in several ways. The synthesis of the times of work processes consists of concatenate the time types for sections of the workflow to create expected times. The expected times are target times.

Target times are used for planning, control, monitoring and payment. If target times are also to be used as expected times, then they need to be related to a reference quantity and reference performance.

The time for an order can be order-dependent or order-independent. Order-dependent expected times relate to an order with, for example, 40 pieces. Order-independent expected times relate to a specific unit of measurement, for example, 1, 100, or 1000.

If the expected time is determined for human labour, then we call it the order time. If it is determined for the resources, then is the occupancy time.

Target times are used for planning, control, monitoring and payment and they must relate to a reference volume and reference performance.

If target times are used as expected times, they must include additional times alongside the planned times. Target times are expected time for workflows carried out by people and resources.

Expected times for people include basic times, rest time and additional time.

Expected times for resources include basic times and additional times.

1.3.1 Order time

How the process types are mapped to the time types of the expected time (order time) can be derived from figure 1.7.

The time types listed in figure 1.7 can be defined as follows:

- The order time T is the expected time it will take to complete an order. It consists of the setup time and execution time.

  Order time = setup time + execution time

  T = t_r + t_a

- The setup time is the amount of time needed to prepare the workplace to perform a job. It is subdivided as follows:
  Setup time = basic setup time + additional setup time + setup rest time

  t_r = t_{rg} + t_{rer} + t_{rv}

  Basic setup time is the time used to prepare the workplace.
  Setup rest time is the time used to compensate for the work-related fatigue of setting up.

  Additional setup time is the additional time needed for unforeseeable interruptions during setup (see additional time). -Execution time is the time used to execute the task. It is calculated from the quantity of the order times the time per unit.

  Execution time = quantity · time per unit

  t_a = m • t_e

- The time per unit is time needed to carry out the task for one unit.

  It consists of all scheduled time types (basic time), all unscheduled time types (additional time) and perhaps a rest time.

  Time per unit = basic time + rest time + additional time

  $t_e = t_g + t_{er} + t_v$

- The basic time is the sum of all the target times for all the process steps. The basic time consists of work time and waiting time.

  Basic time = work time + waiting time

  $t_g = t_t + t_w$

  Sometimes work time can be influenced, sometimes not.
  Work time = work time that can be influenced + work time that cannot be influenced

  $t_t = t_{tb} + t_{tu}$

  The time type "work time" consists of all main activity MH process types and all ancillary types MN.
  So, work time is given by

  $t_t = \Sigma\, t_{MH} + \Sigma\, t_{MN}$

  Waiting time is the sum of the target times of the stoppage process types MA.
  Thus waiting time is given by

  $t_w = \Sigma\, t_{MA}$

  Both work time and waiting time only include scheduled times.

- Additional time consists of the sum of the target times of all process sections over and above the scheduled times which require the use of people.
  Additional time is divided into the following two time types:
  Additional time = functional additional time + personal additional time

  $t_v = t_s + t_p$

  As can be seen in the overview, functional additional time consists of the sum of all time for additional activity and the sum of all times for stoppages due to faults.

  Functional additional time = sum of all times for additional activity + sum of all times for stoppages due to faults

  $t_s = \Sigma\, t_{MZ} + \Sigma\, t_{MS}$

The target times for personal stoppages go into the personal additional time.
Personal additional time = sum of all times for personal stoppages

$t_p = \Sigma\, t_{MP}$

Additional process segments occur irregularly and are not predictable precisely. Therefore the additional time is often assigned as a percentage to be added to the basic time.

Then:
Additional time percentage = functional additional time percentage + personal additional time percentage

$z_v = z_s + z_p$

The additional setup time can also be given as a percentage, z, to be added. If the additional time percentage is given, the additional time can be calculated with this formula.

$t_p = \frac{z_v}{100} \cdot t_g$

We cover how to determine the additional time percentage in a later section.

- Recovery time is the sum of the target times of all process sections necessary for people to recover.

  Recovery time = sum of all recovery times for people

  $t_{er} = \Sigma\, t_{ME}$

  (less any other times which also function as recovery times)

  The time per unit may contain process-related stoppages or those due to faults which can be included as recovery times under certain conditions. Therefore in the expected time, the recovery time taken into consideration if referred to as residual recovery time.

  The recovery time is often given as a percentage just like additional time.

  $z_{er} = \frac{t_{er}}{t_g} \cdot 100\%$

  See figure 1.6 the assignment of the time types of expected times

Sometimes, even the recovery time is specified directly in minutes. The recovery time or the percentage can be determined using different systems.

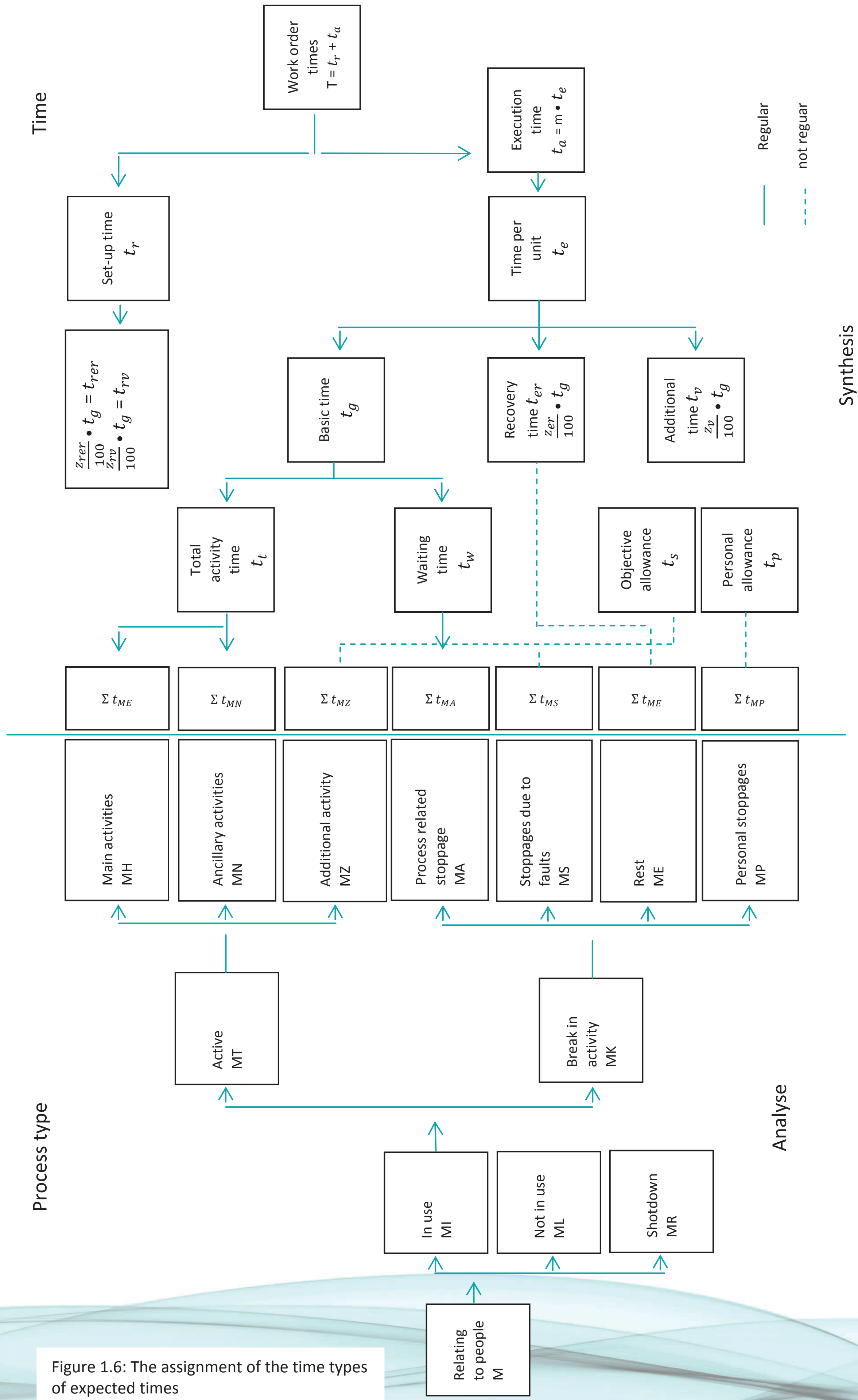

Figure 1.6: The assignment of the time types of expected times

- Freely agreed recovery times as a percentage. The percentage is laid down by an agreement between management and the works council. This method is used for workloads that do not differ too much in terms of recovery needed.
- Recovery times given according the systems from work studies.
- Percentages obtained by methods which take into account type, extent and duration of workload, and environmental influences. These apply to companies and workshops with differing requirements.
- Physiologically based recovery times. Here, the workload is measured directly for those bearing it. This system applies where heavy loads, heavy physical work, heat, occur, attention is needed etc.. Here the recovery time is often given in minutes.
- Granting paid, organised breaks. This method is usually found on assembly lines.

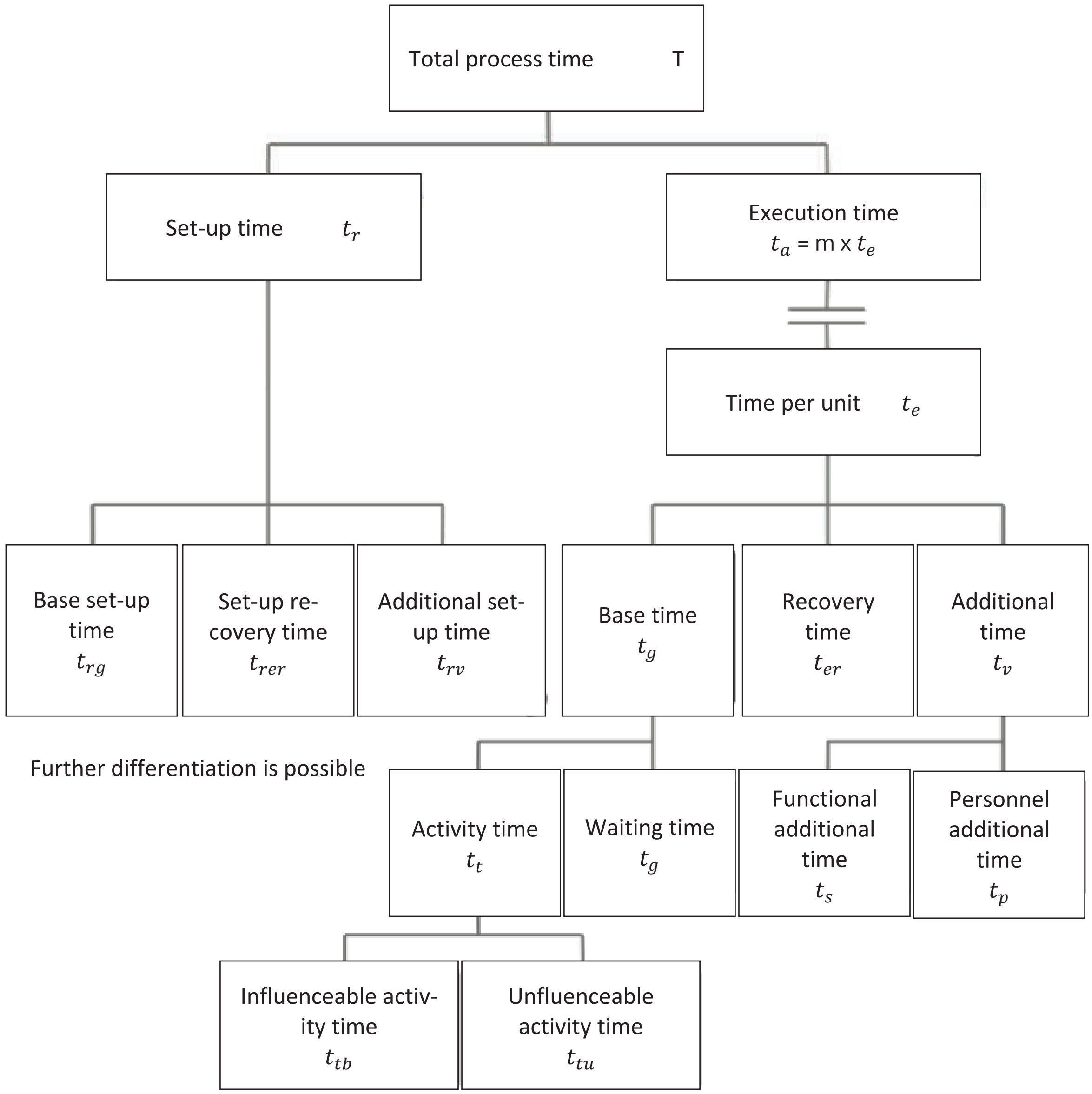

Figure 1.7: Timing structure of order time (according to REFA)

T = t_r + t_a
T = t_r + m • t_e
T = t_{rg} + t_{rer} + t_{rv} + m • (t_g + t_{er} + t_v)
T = t_{rg} + t_{rer} + t_{rv} + m • (t_g + t_w t_{er} +t_s t_p)

$t_v = \frac{z_v\,\%}{100} \bullet t_g$

$t_{rv} = \frac{z_{rv}\,\%}{100} \bullet t_{rg}$

$t_{er} = \frac{z_{er}\,\%}{100} \bullet t_g$

$t_{rer} = \frac{z_{rer}\,\%}{100} \bullet t_{rg}$

T = t_{rg} + t_{rer} + t_{rv} + m • (t_{tb} + t_{tu} t_w +t_{er} t_s + t_p)

Task 1.11:

The following data is known for turning:

Main time	t_{MH}	= 37 min
Ancillary time	t_{MN}	= 13 min
Basic setup time	t_{rg}	= 19 min
Additional time	z_{rv} =z_v	= 15 %
Order quantity *m*		= 50 items

Determine the expected time.

Task 1.12

The following times are valid for a machine:

Main time	t_{MH}	= 14.2 min
Ancillary time	t_{MN}	= 7.6 min
Basic setup time	t_{rg}	= 45 min
Additional time	z_p	= 5 %; z_a = %,z_{rv} = z_v

Determine the expected time for 80 pieces.

Task 1.13:

The following process segments occur when soldering a workpiece on an assembly line:

Preparing the soldering point	t_{MN}	= 0.90 min
Soldering the first soldering point	t_{MH}	= 1.00 min
Letting it cool	t_{MA}	= 0.55 min
Checking the first soldering joint	t_{MN}	= 0.45 min
Soldering the second soldering point	t_{MH}	= 1.00 min
Letting it cool	t_{MA}	= 0.55 min
Checking the second soldering joint	t_{MN}	= 0.45 min
Soldering the third soldering point	t_{MH}	= 1.00 min
Letting it cool	t_{MA}	= 0.55 min
Checking the third soldering joint	t_{MN}	= 0.45 min
Functional additional time	t_s	= 0.20 min/piece
Personal additional time	t_p	= 0.75 min/piece

Calculate the time per unit.

Task 1.14:

Five pieces are attached to one piece of equipment at one time for milling work.

Attaching and removing	= 1.6 minutes
Milling (automatic feed)	= 5.8 min/piece
Checking (every 25th piece)	= 0.9 min/piece
Additional time	= 12%
Setup time	= 50 min/batch
Quantity ordered	= 600 pieces/batch

Determine the expected time of the order.

Task 1.15:

A time study has determined that there were 2 minutes of work time that cannot be influenced and 3.6 minutes that can. The number of items is 1200. The additional time is 11% of the basic time. The basic set up time is 20 min and the additional set up time is 11% of the basic setup time.

a) Calculate the order time *T*.
b) By what percentage would the order time fall, if the work time that can be influenced were reduced by a third?
c) How many more pieces could be made in the time initially needed for the order?

1.4 Performance level

1.4.1 Basics

Suppose different people are carrying out the same work under the same conditions. The method and process are the same, and they are using the same resources and materials. They may well take differing amounts of time to complete the work. The reason for this is the difference in performance of the individuals.

Humans have differing levels of performance. Under certain conditions at the work place, the difference can be a ratio of between 1:1.5 to 1:2. While one employee needs 6min/piece for the performance of a task a different employee may need 9 to 12 min/piece.

It is not normally possible to use the actual time or performance of one worker as a target time or performance for another. Target times are, however, necessary for planning, control, monitoring and payment.

The actual times are converted to target times using the performance level.

A performance level based on a target time is referred to as the reference performance.

The reference performance is equivalent to an efficiency of 100%.

Example 1.2:

A worker produced 8 piece/min (actual performance volume). His or her performance has been assessed as a level of 130%.

So the reference performance volume is:
$= \frac{8\ pieces/\min \bullet 100}{130}$ = 6.1 pieces/min

If this work is done by someone else, a target performance of 6 pieces/min should be set.

Performance level = actual volume produced during an observed session • 100%
2828 reference volume for a session

The performance level can also be calculated as the ration of the actual and target times.

Performance level = $\frac{target\ time}{actual\ time}$ • 100%

Example 1.3:

The actual time to complete a task is measured at 1.8 min/piece. The worker was assessed as having a performance level of 115%. Thus, the target time is:

Target time = $\frac{1.8\frac{min}{piece} \bullet 115}{100}$ = 2.07 min/piece

A target or expected time of 2.07 min/units would then be assigned to this task.

The actual time/quantity produced by a worker at a workplace can be determined easily. Time can be measured, quantities measured or counted. However, the target time or the reference performance is not known from the start. What level can one expect from a worker? How quickly should a piece be built?

For this, we use a performance level determination:

Assessing the degree of performance consists of observing the carrying out of a process and comparing this with that envisioned in order to make a decision about a performance volume expected in relation to the reference performance set.

The performance level cannot be calculated, only evaluated.

Assessing the level of performance requires expertise in the process observed under the given conditions. This includes being able to envisage how the process observed should be, to achieve the reference value in terms of speed (intensity) and control (effectiveness) of the movements and their order. Now this mental image is compared to the actual process, and the difference between the two in per cent of performance is expressed.

The assessment of performance level is only done for those processes where the results of the work can be influenced by the workers.

The recorded actual time of process segments that can be influenced must be converted into target times using the efficiency.

Actual times that cannot be influenced do not need to be converted (actual = target).

Performance level assessment means assessing qualitative data. Through experience and training, performance level assessment be made sufficiently objective so that a sufficient approximation of the level of performance can be obtained. The table gives a rough reference:

Performance	Performance level
extremely high, not sustainable for a long time	140%
very high, rarely sustainable	130%
just possible in the long term	120%
fluent, confident, unerring	100%
moderate, weak	90%
slow, uninterested	80%

1.4.2 Evaluating the carrying out of processes

Evaluating the carrying out of processes is the basis on which performance level is assessed.

Two significant features characterise the carrying out of processes by humans: the intensity and effectiveness:

- **Intensity**

Intensity can be seen in the speed of and the physical exertion in the execution. The speed (tempo) is a good characteristic for evaluation, providing that the workflow allows for an individual speed to develop.

Sometimes the worker cannot arbitrarily choose the speed at which he or she works. It is determined by the type work performed. The speed is higher for shovelling sand than for assembling precision mechanical units. In assessing the speed, physical exertion must be considered. Movements where weight plays a factor are slower than movements where it does not.

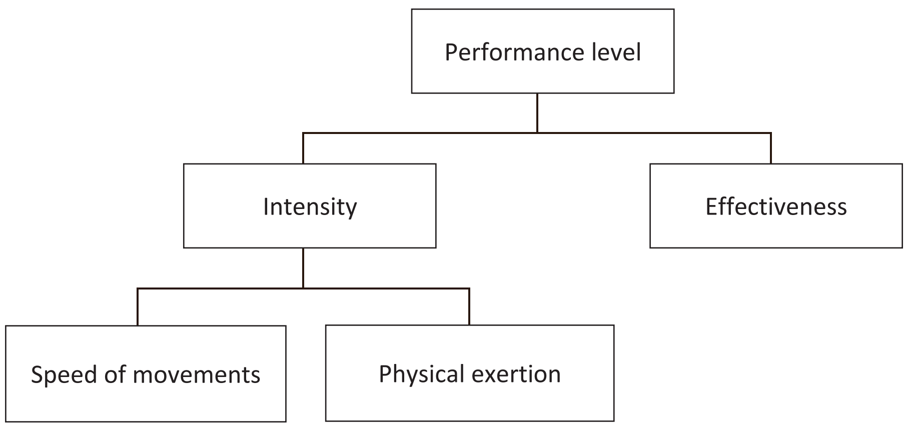

Figure 1.8: Performance level of process (according to REFA)

Effectiveness

When observing several working parties, it can be observed that when doing the same work at approximately the same speed, the performance varies. The worker with the higher performance does not have a higher working speed, but rather that their way of working is more effective.

No movement is wasted. Therefore not only the intensity is useful for the evaluation of performance but also another feature, the effectiveness.
Effectiveness is a measure of the quality of the working method of the worker. The effectiveness can be seen by how natural, swift, harmonious, quiet, unerring, and rhythmic the work is.

Summary of intensity and effectiveness

Effectiveness, speed and physical exertion are closely linked. Efficiency can only be properly assessed when these three factors are considered together. High intensity can compensate for a low efficacy and vice versa.

In assessing the performance level, work intensity and effectiveness are not always equally valued. For work where accuracy is important, such as assembly, the effectiveness is most important. In practice, the performance level is assessed as a whole and assessments of partial-performance based only on intensity or effectiveness are discouraged.

1.4.3 REFA normal performance

One hundred per cent performance, the reference performance is also known as REFA-normal performance.

It can be described as follows:

REFA normal performance is the carrying out of an action which, with regard to the individual movements, an observer finds the sequence of movement and their coordination especially harmonious, natural and balanced. Experience shows that it can be achieved by any worker for a longer period of time and in the middle of a shift if they are sufficiently suited, familiar with the work and if they have the necessary practice, so long as the times given include those for personal time and, where necessary rest or recovery time, and so far as the free development of the worker's abilities is not hindered.

A worker is suitable, if he has the physical and mental facilities, necessary for the execution of the tasks entrusted to him. A worker with will be physically unsuitable for assembly work with a hand injury. Similarly, a person with no knowledge of technical drawing in unsuitable for a task in which they have to read a technical drawing. A worker is practised when he or she has mastered the working movements required for the work. A machinist doing drilling, is likely to have drilled many times before, so that he or she is able to bring a certain level of practice to this special drilling work.

A worker is fully familiar when he or she is familiar with the technical and organisational terms of his work and the conditions of working with others necessary. If the machinist above has been made familiar with the special drill work and all the influences on this special work, we can say he or she is fully familiar.

1.4.4 Checklist for assessing performance level

The performance level of an employee depends on many factors which are not precisely measurable. A person doing a time study must, however, recognise them. REFA has put together a number of key questions. Taking them into consideration should make the assessment more objective.

a) Questions before the timing starts
- Does the observer know the process well enough to make a judgement?
- Is the worker performing the work suitable, for, and familiar with the work and does he or she have enough practice?

- Is extreme performance a possibility? Can the performance level be judged with sufficient accuracy?
- Is the work to be performed according to the method prescribed?
- Are reasonable workloads being exceeded?
- Can the process part be influenced by the worker?
- Does carrying out the task involve recognizable movements?

b) Questions for each individual assessment of the level of performance
- Can the workers display his or her skills without hindrance?
- What is the effectiveness of the movement observed?
- What is the intensity - speed and physical exertion – in the movement observed?
- What performance arises from the combination of effectiveness and intensity?
- Would faster movements or more physical exertion call into question the quality necessary?

c) Questions after the timing has finished
- Have many extremely low performance levels been observed despite the suitability, practice and familiarity required being in place?
- Were extremely high performances observed, or did many of the process sections contain unusually high performance contrary to the initial estimation?

In hindsight, is the judgement invalid, as the prescribed or even a uniform working method was not in place.

1.4.5 Performance level / labour utilization rate

Alongside the performance level, there is the term labour utilisation rate. The terms are often confused so we will explain the difference here.

a) Performance level
When timing is done, the actual time for a task which can be influenced is assessed, taking into account the performance.

An activity which has been recorded, taking 2.4 min, and which is able to be influenced is assessed as being a performance of 120%. As the expected time for normal performance is longer:

$$t = \frac{t_i \cdot L}{100\,\%} = t = \frac{2.4\,\text{min} \cdot 120\%}{100\%} = 2.88\,min$$

The time recorded is converted into a target time using the assessment of performance.

b) Labour utilisation rate

Employees want to undercut target times so that they earn more. A worker is assigned a job with an order time (expected time) of T = 22h. By committing him or herself fully, he or she finishes the job in 19.5 hours (actual time).

Because the job was completed faster, he or she has provided a higher level of performance. The ratio of the target time to the actual time is called the labour utilisation rate (Z).

$$labour\ utilisation\ rate = \frac{target\ time \bullet 100\%}{actual\ time}$$

Target and actual times can include order times or entire accounting periods. They include set-up times, basic times of both tasks that can be influenced and those that cannot, rest times and additional times.

In the above example, the worker would have a labour utilisation rate of

$$Z = \frac{T \bullet 100}{T_i} = \frac{22h \bullet 100\%}{19.5\ h} = 113\%$$

The labour utilisation rate is determined for a period in the past (order, month, etc.). It can be calculated for one or more workers, a division or a whole company. Depending on the labour utilisation rate, target times may be undercut.

The labour utilisation rate is a key figure in planning.

The labour utilisation rate is very important for pay.

Example 1.4:

A worker earns €15/h.

He or she has taken 8h to complete a task which has an expected time of 10h.

His or her labour utilisation rate is

$$Z = \frac{target\ time \bullet 100\%}{actual\ time} = \frac{10\ h \bullet 100}{8h} = 125\%$$

For completing the task with a normal performance, he or she gets 10 h • € 15/h = € 150

Because he or she did the job in 8 hours, the hourly rate becomes

$$\frac{€\ 15}{8\ h} = 18.75\ \frac{EUR}{h}$$

If a worker achieves a labour utilisation rate of 125%, he or she earns 125% of the normal wage. A high labour utilisation rate is, however, only possible with high commitment, i.e. with good performance level during the execution of the order.

How high the labour utilisation rate can be and thus the wages depends significantly on what percentage of the expected time is able to be influenced.

Example 1.5:

A worker receives two orders; each has a 20h target time. The time for the first order can be influenced fully, the second only 50% of it. Assuming that he or she provides a performance level of 125%, the first order is finished in

$\frac{20\ h}{1.25} = 16\ h$, the second order, however, we have

$\frac{10\ h}{1.25} (can\ be\ influenced) + 10\ h\ (cannot\ be\ influenced) = 18\ h$

For the first order, he or she has a labour utilisation rate of

$$Z = \frac{target\ time \bullet 100\%}{actual\ time} = \frac{20h \bullet 100\%}{18h} = 125\%$$

in the second case, the labour utilisation rate is

$$Z = \frac{target\ time \bullet 100\%}{actual\ time} = \frac{20h \bullet 100\%}{18h} = 111\%$$

For the first order, the worker would earn 25% more than normal, but for the second, only 11% more.

When working with a significant proportion of times the worker cannot influence, it is not possible to achieve a high labour utilisation rate even when the workers are very committed.

For this reason, for example, the collective wage agreement for commercial workers in the Bavarian metal industry has the following regulations for piecework.

Times within an expected time for which no assessment of performance is possible, are multiplied with the following factors:

Share of time of up to 50 per cent of the basic time is a factor τ of 1.20

Share of time more than 50 per cent of the basic time is a factor τ of 1.25

These factors are not applied if there are operational rules in place to ensure corresponding compensation.

This idea plays an essential role in the piecework remuneration.

Summary

The performance level is judged. This is used to transform the actual times into target times. The labour utilisation rate is calculated. It is the ratio of target to actual time for entire orders or periods. The labour utilisation rate can be used as parameter in planning.

A worker can earn more money by increasing the labour utilisation rate. Target times with a large share of times which cannot be influenced do not allow for significantly higher labour utilisation rates. This fact can be taken into account by tariff or operational agreements.

Task 1.16:

The following actual times have been recorded as set-up an execution times:

No.	Operation	Time (min)
1	Getting the order	5.2
2	Reading the order	2.6
3.	Getting the materials and tools	14.0
4.	Setting up the machine	18.4
5.	Attaching the workpiece	2.8
6.	Turning the workpiece	0.6
7.	Measuring the workpiece (every 4th piece)	1.1
8.	Drilling the workpiece	0.9
9.	Cutting the thread (by hand)	0.3
10.	Removing the workpiece	0.3
11.	Dismantling and returning tools	7.6
12.	Cleaning machine	5.0
13.	Delivering the order	4.2

The worker was assessed as having a performance level of 125 %.

Additional time	12% (for setup and execution)
Recovery time	4% (for setup and execution)
Number	290 pieces

Calculate the order time.

Task 1.17:

A piece is assembled from three parts:

Operation no.	Operation	t_g (min)
1.	Getting and readying the parts for five assemblies	1.30
2.	Preparing Parts A + B	0.75
3.	Screwing Parts A + B together	0.30
4.	Fitting Part C into A + B	0.60
5.	Screwing in Part C	0.25
6.	Putting five assemblies into a box for transportation	0.65
7.	Take transport boxes with 15 assemblies for storing	0.65
8.	Make ready transport boxes for 15 assemblies	0.15

t_{rg} = 18.5 min; z_{rv} = z_v = 11%

(a) What is the time per unit?
(b) What is the order time for 200 assemblies?
(c) How long would it take with a labour utilisation rate of 115%?

1.5 Methods for determining actual and target times (Part 1)

There are different methods to determine times for sections of workflows.

- Actual times can be collected by:
  - Enquiring
  - Measuring
  - Recordings taken by employees themselves
  - Recordings taken by others (timings)

- Target times can be determined by
  - Estimating
  - Comparing
  - Calculating
  - Systems of predetermined times
  - Planned times

It is not our task here, to consider all the procedures for actual and target time calculation in detail. Staff in departments such as production scheduling, work study, manufacturing planning, production control and others need to acquire further knowledge.

We refer you to REFA's further educational program in Darmstadt, Germany.

1.5.1 Timing

Introduction

Timing is the description of work process, working methods and working conditions and the acquisition of reference quantities, influencing variables, performance levels and actual times for individual segments of a workflow.

Their evaluation results in target times for certain sections of the workflow.

The aim is to achieve the following:
(a) Times relating to human labour are determined.
(b) The times determined are used for management, monitoring and pay.
(c) They should be designed in such a way that they can be used to determine planned times.

People who do work studies observe the workflow and record the result of their observations. To do this, he or she needs a stopwatch and a record sheet. The record of the timing, i.e. the information on the timing sheet, must be reproducible. The circumstances under which the times have been collected, must be noted just as carefully as the times themselves.

All the information about the work and the actual times are recorded on the timing sheets.

Since most companies use REFA time studies, we now describe the REFA timing sheet Z2.

REFA timing sheet Z2

See figure 1.9.

Task:
Brief description of the task, such as turning a shaft or planning a plate.

Order quantity:
Amount m of the order for which the timing was carried out.

Date, time, amount, duration:
The beginning, end, and duration of the timing. Also the amount of products there were at the start of the timing and at the end of the timing.

Space for drawing:
Sketches can be drawn here, for example of the arrangement of resources and objects of the work.

Time per unit:
The target time identified on the rear (fig. 1.10) is entered here.

Specific times, like recovery time, additional time and set-up time, can be separately recorded. How they arise is to be specified.

Working procedure and methods:
The working procedures and the working method are to be described clearly.
It must be possible to reproduce the work sequence in order to recognise any changes in the workflow.

Object of the work, persons, resources
Information on the object of the work, people and resources must be carefully recorded for reproducibility.

Environmental influences:
All the environmental influences affecting the process must be recorded. It is irrelevant, whether the influence comes from the work observed itself or the environment.

Remuneration:
An indication of the form of remuneration.

Comments:
Room for noting further working conditions.

Quality of the products:
The quality of the work observed can be recorded here.

Agent:
The name of the person carrying out the study is written here as well as the date it was completed and the period the expected time calculated is valid for.

Z2 New	REFA timing sheet	No. Page of pages

Task			
Order number	Order Quantity	Department	Cost centre
Date of the timing	Start time/quantity	End time/quantity	Duration

· ·	Time per unit identified	Time in	cause
	Basic time t_g		
	Recovery time $t_{e\,r}$ at $z_{e\,r}$ = %		
	Additional time t_v at z_v = %		
	Other additions		
	Time per unit t_{e1}		
	$t_{e1}/t_{e100}/t_{e1000}$ in min/h		
	Setup unit t_r in min/h		

Working procedure and methods

Object of the worl	Description	Material	State of input	Drawing no.	Material no.	Measurements, shapes, masses

Persons	Name	Personnel no.	M	F	Age	Extent of practise: Similar activities	Extent of practise: the activity examined

Resources	Description, type	Amount	No.	Year of construction	Technical data, condition

Environmental influences	remuneration

comments

Quality of the products			
Agent	Tested	Date	Valid from till

Figure 1.9: REFA timing sheet Z2

No.	Process segment, measuring point	Ref. quantity	Variable	Meas-urements classes	Zy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	∑ L/n	L	$t = \frac{\bar{L}}{100} \cdot \bar{t_i}$	Time type
					m_z																$\sum t_i/n$	t_i		
					L																			
					t_i																			
					F																			
					L																			
					t_i																			
					F																			
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					t_i																			
					F																			

N=	K=	Sum of times in run			$\sum t_z$	$\sum t$
$T_z = \sum t_z/n$ = / =		Spread of 5 runs			$\sum R_z$	
$R_z = \sum R_z/k$ = / =		Z= (R_z/t_z) • 100%=(/) • 100% = %	€ = %	€ = %	N =	

No/ RN	From	To	Duration	Additional segments of the workflow							

Figure 1.10: REFA time sheet Z2 (back)

Sheet Z2 is used for workflows in mass production with regular repeat measurements.

See figure 1.10.

No.
Sequential numbering of the process segments examined.

Process segment, measuring point:
The individual segment is described and the measuring point is specified in the small box. The measuring point is the designated end of a segment (such as letting go of the tool used). The three rows under the process parts are for statistical evaluation.

Reference quantity:
Record of the amount that will be processed at the same time in a measurement.

Variables, measurements, classes:
The most important factors for the determination are entered here, (such as cutting speed, feed rate, weights of parts, dimensions of the parts, etc.).

Run RN:
Numbering of the runs recorded 1-15.

Running total
Here, in the 1st run, the amount produced at the end of that run. For the last run, it is the total produced at that time.

	1st line: Blank
L	2nd line: Performance level
t_i	3rd line: Actual individual time
F	4th line: Total time

If the times are able to be influenced, the performance level L for the actual individual times is entered here as a percentage.

The actual individual time is either calculated from the total time or read directly off the stopwatch. Total times can be determined with a split-time stopwatch. A split-time stopwatch facilitates the reading and increases its accuracy.

$\Sigma \frac{L}{n}$	$\bar{L}$		
$\Sigma \frac{t_i}{n}$	$\bar{t_i}$	$t = \frac{\bar{L}}{100} \bullet \bar{t_i}$	Time type

The columns are for evaluating the actual times, ti, and the performance levels L seen above.

n Number of performance levels assessed
ΣL Sum of the performance levels assessed in the process part

$\frac{\Sigma L}{n} = \bar{L}$ **Mean performance level**

Σt_i Sum of the actual times of the process part
n Number of actual times

$\frac{\Sigma t_i}{n} = \bar{t_i}$ **Mean of actual times**

The target time is determined from the mean performance level and the mean of the actual times:

$t = \frac{\bar{L}}{100} \bullet 100$ (min)

Time type:
The symbol belonging to the process type can be put in this column.

Additional segments of the workflow:
If unforeseen additional segments occur during the timing (personal, conversations, errors, etc.), they are noted in the bottom part of the sheet.

The run and the number of the process type (No./RN.) should be recorded, as well as the start (from) , the end (to), the duration (time), and a description.

Computational analysis of a timing

The following timing (fig. 1.11 and fig. 1.12) has been carried out and is to be evaluated. The task has been divided into 4 segments. In Process Part 1, 5 units are timed together (reference quantity 5). In Parts 2, 3 and 4, only one unit at a time (reference quantity 1). The individual times t_i for Parts 3 and 4 are so small that a performance level has been assessed for all 5 units together. The timing was recorded via the total time. Before the individual times are determined, it is useful to be clear about the order of the segments. Only the next higher total time needs to be used. The order of the total times is: 40-82-123-. 165-183-201-239-261 (1/100 minutes), etc. In this example, the order of the segments changes.

The individual times of the segments planned t_i are obtained by subtracting successive total times, for example Part 1, Run 1 (No./RN 1/1): t_i = 40 - 0 (the beginning of the timing at 0) = 40, No./RN 1 / 2 : t_i = 82-40 = 42; No./RN 1 / 3 : t_i = 123 82 = 41.

The duration of the additional sections is calculated similarly. Which gives No./RN-2/8 3.00 min, No./RN 4/10 0.60 min. Between No./RN 4/7 = 6.98 min and No./RN 2/8 = 10.41 min, the duration is 10.41 - 6.98 = 3.43 min. Of this, 3.00min belongs to the additional process part No./ZY 2/8 and so should be removed so the individual time for No./RN = 2/8 is only 3.43 - 3.00 0.43 min.
When all the individual times have been calculated, any outliers are determined. Outliers are times that are significantly different from other times for the same segment. They are to be deleted including their performance level. In this example, there are no outliers present, since the decision on the use or deletion of these can only be made at the time.

The sum of all individual times is cross checked against the grand total. All actual times are added horizontally and the sums added vertically. All individual times from additional segments are also included. The sum must equal the duration of the timing. To determine the target times, the mean values of the performance and the actual times are used according to the equation

$t = \frac{\bar{L}}{100} \bullet \overline{t_i}$

(the last but one column). These are then added (0.98 min), the sum is transferred to the front of the sheet.

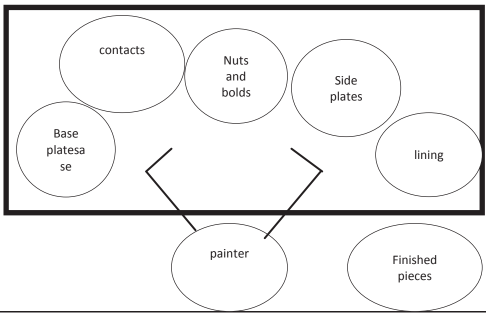
Z2 New	REFA timing sheet	No. *2/110* Page *1* of pages

Task *Electronic subgroup preasembly*

Order number *1190*	Order Quantity *500*	Department *Electronic*	Cost centre *8211*

Date of the timing *8.4.20* Start time/quantity *09:15/200* End time/quantity *09:35/215* Duration

· ·work bench



Time per unit identified	Time in	cause
Basic time t_g		
Recovery time t_{er} at z_{er} = %		
Additional time t_v at z_v = %		
Other additions		
Time per unit t_{e1}		
$t_{e1}/t_{e100}/t_{e1000}$ in min/h		
Setup unit t_r in min/h		

Working procedure and methods *All the individual parts are made available by internal transport to the workstation; take base plate and lining; press lining in; Up side plate and loosely screw onto ground plate; adjust contact and side piece and screw them in tightly; put subgroup to the side.*

Object of the worl	Description	Material	State of input	Drawing no.	Material no.	Measurements, shapes, masses
	Base plates	*Al*	*Sharp edge*	*Z 123*		
	Lining	*Polystyrene*		*Z 124*		
	Contacts	*Ceramic*		*Z 213*		
	side plates	*Al*		*Z 125*		
	Nuts and bolts	*Al*		*Z 315*		*M 5*

Persons	Name	Personnel no.	M	F	Age	Extent of practise: Similar activities	Extent of practise: the activity examined
	painter	*1418*	*X*		*36*	*5 years*	*4 months*

Resources	Description, type	Amount	No.	Year of construction	Technical data, condition
	Work bench	*1*	*82114*		*Good condition without problems*

Environmental influences *none*	Remuneration *bonus*

Comments *training example with contrived task*

Quality of the products *good*

Agent	Tested *Tei*	Date	Varlid from *immediately* till -------

Figure 1.11: A timing recorded on the REFA form

No.	Process segment, measuring point	Ref. quantity	Variable	Meas-urements classes	zy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	∑ L/n	L	$t = \frac{\bar{L}}{100} \cdot \bar{t_i}$	Time type
					m_z																$\sum t_i/n$	t_i		
					L																			
					t_i																			
					F																			
					L																			
					t_i																			
					F																			
					L																			
					t_i																			
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					F																			
					L																			
					t_i																			
					F																			
N=		K=		Sum of times in run																	$\sum t_z$	∑		
$T_z = \sum t_z/n=$ / =				Spread of 5 runs																	$\sum R_z$	t		
$R_z = \sum R_z/k=$ / =				$Z= (R_z/t_z) \cdot 100\%=($ / $) \cdot 100\%$ = %					€ = %			€ = %			n=									
No/ RN	From	To	Duration	Additional segments of the workflow																				

Figure 1.12: Timing

No.	Process segment, measuring point	Ref. quantity	Variable	Meas-urements classes	zy	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	$\sum L/n$	L	$t = \frac{\bar{L}}{100} \bullet \bar{t_i}$	Time type
					m_z																$\sum t_i/n$	t_i		
					L																			
					t_i																			
					F																			
					L																			
					t_i																			
					F																			
					L																			
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					t_i																			
					F																			
N=	K=			Sum of times in run																	$\sum t_z$	$\sum$		
$T_z = \sum t_z/n=$ / =				Spread of 5 runs																	$\sum R_z$	t		
$R_z = \sum R_z/k=$ / =				Z= (R_z/t_z) • 100%=(/) • 100% = %							€ = %			€ = %		N =								
No/RN	From	To	Duration	Additional segments of the workflow																				

All times in 1/100 of a minute

Figure 1.13: Timing

Summary

In timings, actual times are measured and evaluated to identify target times. We have only dealt with timings for repeating processes.

Questions

1.1
What is meant by determining data?

1.2
What is quantitative data and what is qualitative data?

1.3
When is the reproducibility of data guaranteed?

1.4
Name the independent variables in a turning operation.

1.5
An employee's performance was excellent. What type of data is it?

1.6
What is a reference performance?

1.7.
What questions should be considered before starting a timing?

1.8
What features are considered when assessing a performance level?

1.9
At a performance level of 115%, 420 pieces are manufactured in 8 hours. How many pieces are manufactured at a performance level of 95% and of 130% in this time?

1.10
The actual time for a process has been determines as 5.7 min/piece. The performance level is evaluated at 125%.
a) Calculate the target time.
b) How many parts produced with normal performance in an hour?

1.11
The performance level was evaluated at 115%. The additional time is 12%.
a) Calculate the time per unit.
b) How many pieces can be produced in 8 hours with normal performance?

1.12
The following actual times were recorded in a timing:
t_{rgi} = 36 min
t_{MAi} = 1.6 min
t_{tbi} = 2.1 min
t_{ui} = 0.8 min

The setup was carried out with a performance of 115%, the execution 130%. Calculate the order time *T* for a job of 120 pieces.
z_v = z_{rv} = 11%
z_{er} = 3%

1.13

The following actual times were identified during a timing:

Duration of activity that can be influenced	2.05 min
Duration of activity that cannot be influenced	1.82 min
Process related stoppage	0.74 min
Performance level of worker observed	125%

a) Calculate the target time.
b) Calculate the order time T for 80 pieces, if the set-up time is 35 min, the additional time is 9% and the recovery time is 4%.
c) Streamlining reduces the time that can be influenced by 15%, and that that cannot by 22%. All the other data remains unchanged. Calculate the new order time.

SOLUTIONS TO THE EXERCISES IN THE TEXT

1.1.

The order is: "Construction of drilling jig".

Drawing on a transparency	A
Fitting the transparency	R
Filling in with ink	A
Getting additional information	R
Replacing a scale on the drafting machine	R

1.2.

The order is: "Drilling with a drilling jig".

Drilling the workpieces	A
Clamping the drilling jig	R
Clamping the workpieces in the drilling device	A
Clamping the drill in the drill chuck	R
Measuring the parts	A
Cleaning the machine	R
Writing time for the order form	R

1.3

Reading the manual	B
Nailing a box together	B
Grinding with automatic feed	U
Drilling with manual feed	B
Filing by hand	B
Monitoring the production process of a CNC machine	U

1.4

A plasterer helps build scaffolding.	MI
A fitter suffers an accident and goes to the doctors.	ML, possibly MS, MP
A department has to go on reduced working hours.	MR
An employee takes his holiday.	ML
All employees of a company have 14 days company holiday.	MR
A foreman is sent on a training course.	ML
A foreman distributes work orders.	MI
An employee is away for 4 weeks having treatment at a health resort.	ML
There is a works meeting.	MR
The plant is closed for a public holiday.	MR
There are no tasks for the employees to do.	ML
An unskilled labourer sweeps up shavings.	MI
She brings a snack for her colleagues.	MI

1.5

Putting paper in a typewriter	MN
Writing on a typewriter	MH
Cleaning a lathe	MN
Tightening a chuck	MN
Turning	MH
Clamping or removing a workpiece	MN
Rework a part	MZ
Helping a colleague	MZ
Monitoring an automatic operation	MH

Fetching missing parts	MZ
Painting a wall	MH
Mixing paint	MN
A bricklayer lays bricks	MH
A bricklayer makes concrete	MN
A bricklayer helps to set up a crane	MZ

1.6

Waiting due to power failure	MS
Resting after transporting heavy objects	ME
Going to the toilet	MP
Conversation with the foreman (about work)	MS
Private conversation with a work colleague	MP
Arriving late for work	MP
Waiting for materials	MS
Wait for materials to solidify the when casting	MA
Resting outside the heat zone after working next to a furnace	ME
Waiting for the end of a drilling process with an automatic feed	MA
Warm up a blank for drop forging	MA
Buying drinks at the canteen	MP

1.7

A drill is used to bore a hole.	BI
Tools are mounted on an automatic lathe.	BI
A digger is stored for the winter in a building yard.	BL
An assembly group is called away for a short time, The resources remain.	BL
During a period of short-time work, the resources are not used.	BR
A new press is set up.	BL
Some machines are out of use due to lack of orders.	BL
The resources are at rest during the lunch break.	BR
There are no jobs for a vehicle to perform.	BL
A cutting tool is installed on a press.	BI

1.8

Transporting an object of work with a crane	AF (AFT)
Cutting a rotary part	AE (AEF)
Drawing the wing of a car	AE (AEF)
Drying after painting	AE (AEZ)
Setting concrete	AE (AEZ)
Restacking incorrectly stacked parts	AZ
Visual inspection of rolling elements	AP
Counting parts	AP
A fault on a resource	AS
Power failure	AS
Personal absence	AS

Bringing forward an urgent order 47474747AS
Storing half finished parts in the storage depot 4747AL

1.9

No	M	B	A
1	MN	BN	AFH
2	MH	BH	AE
3	MN	BN	AA
4	MA	BH	AE
5	MA	BH	AE
6	MN	BN	AA
7	MZ	BZ	AZ
8	MS	BS	AS
9	MA	BS	AS

No	M	B	A
10	MP	BP	AS
11	MZ	BS	AF
12	ME	BH	AA
13	MN	BA	AA
14	MN	BN	AF
15	MN	BA	AA

If you have chosen a different process type that the one in the solution, it may not be wrong. The process type for people "out of use" and the process type "stoppage due to faults" overlap, for example. Sometimes the work must be described more fully which is not possible here in the examples. For example, when a bricklayer is helping set up a crane, it may be part of his or her main activity. A bricklayer will undertake many other tasks in a construction team, which for him or her will count as main activity.

1.10

No.	M	B	A
1	t_{MN}	t_{BN}	AFH
2	t_{MA}	t_{Bh}	AEH
3	t_{MN}	t_{BN}	AFH
4	t_{MH}	-	AEF

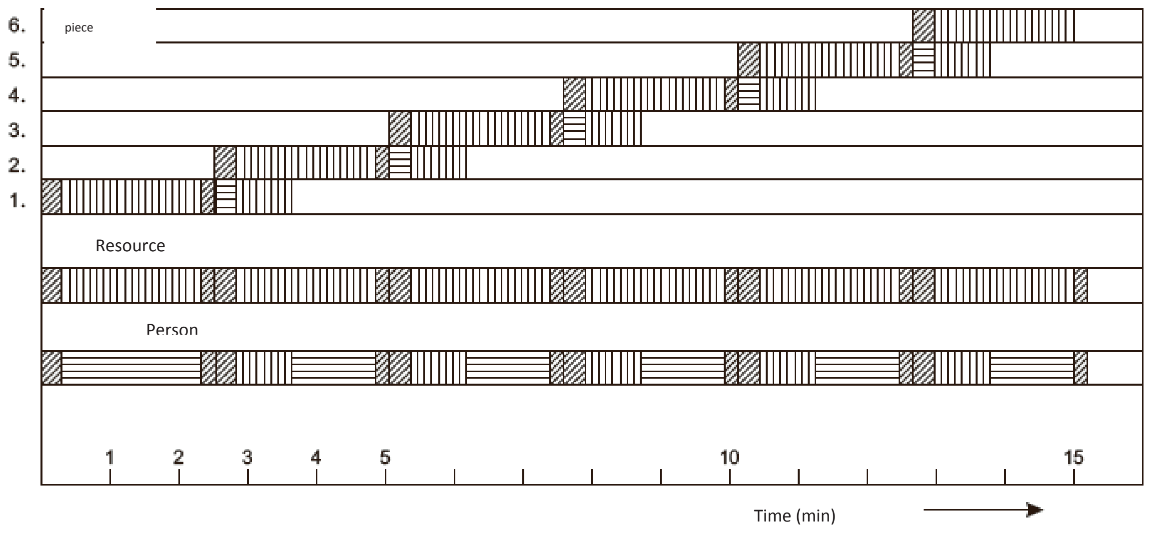

Fig. S. 1: Time band representation

1.11

t_{MH} = 37 min
t_{MN} = 13 min
t_t = 50 min
T = t_r + m x t_e
T = t_{rg} + t_{rv} + m • (t_t + t_v)

Unspecified times like t_{rer}, t_w, t_{er}, are simply omitted.
T = 19 + 19 • 0.15 + 50 • (50 + 50 • 0.15)

The factor of 0.15 is equivalent to 15% additional time. Another way of writing it would be:
T = 19 • 1.15 + 50^2 • 1.15

The factor 1.15 corresponds to 100% basic time + 15% (of the basic time) additional time, a total of 115% of the basic time.

T = 21.85 + 2875
T = 2,896.85 = 2,897 min

1.12

T = t_{rg} • z_{rv} + m • (t_{MH} + t_{MN}) • z_v;
T = 45 • 1.11 + 80 • (14.2 + 7.6) • 1.11
T = 49.9 + 1,935.84
T = 1,986 min

z_v = z_s + z_p
z_v = 5% + 6%
z_v = 11%
z_{rv}= 11%

1.13

t_e = t_g + t_{er} + t_v
t_e = t_r + t_w + t_{er} + t_s + t_p
t_e = Σt_{MH} + Σt_{MN} + Σt_{MA} + t_{er} + t_s + t_p
Σt_{MH} = 1.00 + 1.00 + 1.00 = 3.00 min
Σt_{MN} = 0.9 + 0.45 + 0.45 + 0.45 = 2.25 min
Σt_{MA} = 0.55 + 0.55 + 0.55 = 1.65 min
t_e = 3.00 + 2.25 + 1.65 + 0.20 + 0.75
t_e = 7.85 min

1.14

t_t = 1.6 + $\frac{0.9}{25}$ = 1.636 min

t_w = 5.8 min
t_r = 50 min
t_g = 1.636 + 5.8 = 7.436 min
t_e = 1.12 • 7.436 = 8.328 min
T = 50 + 600 • 8.328 = 5,046.8 min/los

1.15

a)

T = t_{rg} + t_{rv} + m • (t_{tb} + t_{tu} + t_v)

T = 20 + 20 • 0.11 + 1,200 • $[3.6 + 2.0 + (3.6 + 2.0) \bullet 0.11]$

T = 20 • 1.11 + 1,200 • (3.6 + 2.0) • 1.11

T = 22.2 + 7,459.2 = 7,481.4

b)

The order time would be 5,883 min, i.e. a 21.36 % drop.

c)

At 5883 min for 1200 pieces, the time for one piece is:

$\frac{5{,}883}{1{,}200}$ = 4.9025 min

In 7,481.4 min, therefore,

$\frac{7{,}481.4}{4.9025}$ = 1,526 pieces

can be produced. So 326 more pieces could be produced.

1.16

a)

We divide up the process into set-up and execution T = T_r + T_s

Set up times t_{rg}

t_{rg} is for process segment no. 1, 2, 3, 4, 11, 12, 13

t_{rgi} = 5.2 + 2.6 + 14.0 + 18.4 + 7.6 + 5.0 + 4.2

t_{rgi} = 57 min

Fitting, removing, measuring are active times (t_t)

Working is process related stoppage time (t_w).

Execution t_s.

Operations

No. 5:	t_{tbi} = 2.8 min
No. 6:	t_{wi} = 0.6 min
No. 7:	t_{tbi} = 1.1 min
No. 8:	t_{wi} = 0.9 min
No. 9:	t_{tbi} = 0.3 min
No. 10:	t_{tbi} = 0.3 min

b)

Transforming the actual times into target times using the performance level:

t_{rg} = t_{rgi} • $\frac{L}{100}$ = 57 • $\frac{125}{100}$ = 71.25 min

t_w = t_{wi} (time that can not be influenced) = 0.6 + 0.9 = 4.5 min

t_{tb} = t_{tbi} • $\frac{L}{100}$ = (2.8 + 1.1 + 0.3 + 0.3 • $\frac{125}{100}$ = 5.625 min

c)
Calculating the order time:

t_r = t_{rg} + t_{rer} + t_{rv}
t_r = 71.25 + 71.25 • $\frac{4}{100}$ + 71.25 • $\frac{12}{100}$
t_r = 82.65 = 83 min

t_e = t_g + t_{er} + t_v
t_e = (t_t + t_w) + t_{er} + t_v
t_e = 5.625 + 1.5) + (5.625 + 1.5) • $\frac{4}{100}$ + (5.625 + 1.5) • $\frac{12}{100}$
t_e = 8.265 min

T = t_r + m • t_e
T = 83 + 290 • 8.265
T = 83 + 2396.85
T = 2479.85 min = 41.33 hours

1.17
Calculating the basic time for an assembly:

Operation:	No. 1: $\frac{1.3}{5}$	= 0.26 min
	No. 2	= 0.75 min
	No. 3	= 0.30 min
	No. 4	= 0.60 min
	No. 5	= 0.25 min
	No. 6: $\frac{0.65}{5}$	= 0.13 min
	No. 7: $\frac{0.65}{15}$	= 0.044 min
	No. 8: $\frac{0.15}{15}$	= 0.01 min

t_g = 0.26 +0.75 + 0.30 + 0.60 + 0.25 + 0.13 + 0.044 + 0.01
t_g = 2.344 min

a)
t_e = t_g + t_v
t_e = 2.344 + 2.344 • $\frac{11}{100}$
t_e = 2.602 min

b)
t_r = t_{rg} + t_{rv}
t_r = 18.5 + 18.5 • $\frac{11}{100}$
t_r = 20.5 = 21 min

T = t_r + m • t_e
T = 21 + 200 • 2.602
T = 542 min = 9.04 hours

c)

$$Z = \frac{target\ time\ (T) \bullet\ 100}{actual\ time\ (T_i)}$$

$$T_i = \frac{T \bullet 100}{Z}$$

$$T_i = \frac{542 \bullet 100}{115} = 472 \text{ min}$$

ANSWERS TO THE REVISION QUESTIONS

1.1
Data determination is the collection and processing of data

1.2
Quantitative data is measurable or enumerable data. Qualitative data is determined by assessment.

1.3
The reproducibility of data is only guaranteed if the workflow is accurately described, the working conditions are known and the data collected has a certain accuracy.

1.4
The speed of the lathe, the material from which the tools and workpieces are made, the feed rate, cooling lubricants.

1.5
Qualitative data

1.6
A performance that is used to determine a target time is called a reference performance. It corresponds to a performance level of 100%, and is also known as the REFA normal performance.

1.7
Is the observer familiar with the workflow? Is the worker suitable? Are there extreme performances? Is the work done according to the prescribed method? Are reasonable maximum limits exceeded? Are the process segments influenced by the employees?

1.8
Intensity and effectiveness

1.9
Target productivity = $\frac{actual\ productivity \bullet\ 100\ \%}{L}$

= $\frac{420 \bullet\ 95\ \%}{115}$ = 347 piece with L = 95 %

= $\frac{365 \bullet\ 130\ \%}{100}$ = 474 piece with L = 130 %

1.10
t_{ei} = 5.7 min/piece; L = 125%

a)
$t_e = \frac{t_{ei} \bullet 125\ \%}{100} = \frac{5.7 \bullet 125\ \%}{100}$ = 7.13 min

b)
number of units = $\frac{60\ min/hour}{7.13\ min/piece}$ = 8.4 pieces/hour

1.11

t_t = t_{th} + t_{tn}
t_{ti} = 11.4 min
t_e = t_{ti} + t_v

t_e = t_{ti} • $\frac{L}{100}$ + t_v
t_e = $\left(11.4 \cdot \frac{115}{100}\right)$ • 1.12
Factor 1.12 correspondence with the basic time (100 %) and the distribution time (12 %)

t_e = 13.11 • 1.12
t_e = 14.69 min/piece

b)
piece in 8 hours = $\frac{480\ min}{14.69\ min/piece}$ = 32.7 pieces

1.12

t_{rg} = t_{rgi} • $\frac{L}{100}$ = 36 • $\frac{115}{100}$ = 41 = 42 min

t_{MA} = T_{MAi} = t_w = 1.6 min

t_{tu} = t_{tui} = 0.8 min

t_{MAi} and t_{ui} are times that can not be influenced

We have target time = actual time

t_{tb} = t_{tbi} • $\frac{L}{100}$ = 2.1 • $\frac{130}{100}$ = 2.73 min

t_t = t_{tbi} + t_{tu} = 2.73 + 0.8 = 3.53 min
t_g = t_t + t_w = 3.53 + 1.6 = 5.13 min
t_e = t_g + t_{er} + t_v
t_e = 5.13 + 5.13 • $\frac{3}{100}$ + 5.13 • $\frac{11}{100}$ or
t_e = 5.13 • 1.14
t_e = 5.85 min

t_r = t_{rg} • z_v = 42 • 1.11 = 46.6 min
t_r = 47 min
T = t_r + m • t_e = 47 + 120 • 5.85
T = 47 + 702 = 749

1.13

a)
t_{bi} = 2.05 min with L 125 %
t_{bi} = t_{bi} • $\frac{L}{100}$ = 2.05 • $\frac{125}{100}$ = 2.5625 min
t_{tui} = t_{tu} = 1.82 min; time can not be influenced: actual = target
t_{wi} = t_w = 0.74 min; time can not be influenced: actual = target

b)

t_g = t_{tb} + t_u + t_w

t_g = 2.5625 + 1.82 + 0.74

t_g = 5.1225 min

t_e = t_g + t_{er} + t_v

t_e = 5.1225 + 5.1225 • $\frac{4}{100}$ + 5.1225 • $\frac{9}{100}$ or

t_e = 5.1225 • 1.13

t_e = 5.79

c)

T = t_r + m • (t_{tb} + t_{tu} + t_w + t_{er} + t_v)

T = 35 + 80 • (2.5625 + 1.82 + 0.74) • 1.13

T = 498 min

t_{tb} = 2.5625 • 0.85 = 2.178 min/piece

t_u = 1.82 • 0.78 = 1.4196 min/piece

t_g = 2.178 + 1.4196 + 0.74 = 4.34 min/piece

t_{er} = $\frac{4}{100}$ • 4.34 = 0.1736 min/piece

t_v = $\frac{9}{100}$ • 4.34 = 0.3906 min/piece

t_e = 4.34 + 0.1736 + 0.3906 = 4.9 min/piece

T = 35 + 80 • 4.9 = 427 min/batch