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# 1-INTRODUCTION

\* Frederick taylors' most important experiments were the showeling, and pig iron handling.

\* Frank Gilbreth's theories were that: 2 ml work is composed of 17 basic movements (therbligs). 2/there is one best method for every task.

\* Work is defined as an activity in which a person exerts physical and mental effort to accomplish a given task or perform a duty.

\* commercial value: the task/duty contributes to the buying & selling of something which provides the means of paying for the work.

\* A worker performing a task must apply certain skills \$ knowledge to complete the task.

\* in physics, work is the displacement that an object moves in a direction multiplied by the fore acting upon it.

\* Work consists of tasks, which are an amount of work assigned to a worker.

\* Tasks can be repetetive or nonrepetetive.

\* Tasks consist of several work elements which consist of basic motion elements.

pyramidal structure of tasks ⇒ work elements basic motion elements

- \* Basic motion elements are actuations of the limbs and other body parts while engaged in performing the tasks.
- \* Work elements are a series of work activities that are logically grouped together because they have a unified function within the task.
- \* work elements usually take G seconds or longer while a basic motion element may take less than a second, # the entire task may take 30 seconds to several minutes if its a repetetive task, or more if it's a nonrepetetive task.
- Time is important in business \$ industry:
  1/New product introduction: the manufacturer introducing a new product to the market in the shortest time gets most profits.
  2/product cost: the amount of Cabor hours that goes into creating a product is a significant portion of the total manufacturing cost.
  3/delivery time: customers select the fastest supplier.
  4/ Overnight delivery: refer to delivery time.
  5/ Competetive bidding: proposals must be submitted by a specific date \$ time.
  6/ production scheduling: the production schedule is based on dates \$ times.
- \* Most workers are paid according to the amount of time they work & must arrive at work on a specific time.
- \* when workers are paid on an incentive plan, their bonuses dre based on how much time they save relative to the standard time.

- \* Labor & Staffing requirements are computed using workloads measured in units of time. \* A work system can be defined as a physical entity and a field of proffessional practice.
- \* As a physical entity, a work system consists of humans, information, \$ equipment designed to perform useful work.



Work Science: a work system including work methods, work measurement, and work management as a field of professional practice.
 Work methods: consists of the analysis & design of tasks & jobs involving humans. operations analysis, methods engineering, and motion study are work methods.
 Motion study is limited to the physical motions, tools, & workplace layout used by a worker to perform a task. the others are less limited & include the analysis & detign of complex processes consisting of materials & info. Johns through multiple operations.
 Work measurement the analysis of a task, to determine the time that should be "alvo called" "time study" allowed for a qualified worker to perform the task, the time thus determined is called the standard time.
 Standard time is used to compute product cost, assess worker performance, & determine worker requirements.
 time Study includes work situations in which an operation is performed by automated equipment, & determining the cycle time for the operation.

time study covers all work situations in which we have to determine how long it takes to accomplish a given unit of work.

| 3/ Work management: the various | organizational & administrative functions that must be accomplished |
|---------------------------------|---|
| to achieve                      | high productivity of the work system of supervision of workers.     |
| • functions : -                 | organizing workers to perform the specialized tasks that constitute |
|                                 | the workload in each department of the company.                     |
|                                 | motivating workers to perform the tasks.                            |
| -                               | - evaluating the jobs in the organization so that each worker is    |
|                                 | paid an appropriate salary.   |
|                                 | - appraising the performance of workers to reward better-performing |
|                                 | workers.  |
|                                 | - comparative workers using a rational payment sustem for the       |
|                                 | and a house and a house pullicity officer for the                   |
|                                 | work they perform.  |

★ The bureau of Labor Statistics of the U.S. department identifies <u>821</u> occupations in its Standard Occupational Classification (SOC), organized into <u>23</u> major groups, based on type of work ¢ industry sector.

 \* We have 4 categories that reflect the work content & function of jobs: 1/Production workers: the work involves making products. (manufacturing, construction).
 2/Logistics workers: the work involves moving materials, products, or people. (transportation, material handling.)
 3/Service workers: the work involves providing a service, applying existing information & Knowledge, & communicating. (retail, government, healthcare).
 4/Knowledge workers: the work involves creating new knowledge, solving problems, & managing. (creative work, problem solving, management).

| *Worker Category | production  | Logistics  | Service   | Knowledge   | • |
|------------------|---|--|---|---|---|
| *type of work    | Hostly Physical   | Mostly physical  | Hostly cognitive  | Mostly cognitive  |   |
| * Job titles     | - Laborer<br>- Machine operator<br>- Assembly worker<br>- Machinist<br>- Quality inspector<br>- Construction worker | - truck driver<br>- Airplane pilot<br>- Ship captain<br>- Material handler<br>- Order picker<br>- Shipping clerk | - bank teller<br>- police officer<br>- Nurse<br>- physical trainer<br>- Bales person<br>- Foreman | - Manager<br>- Physician<br>- Designer<br>- Researcher<br>- Lawyer<br>- Teacher |   |

\* productivity: is defined as the level of output of a given process relative to the level of input.

- \* process: an individual production or service operation, also can be used in the context of a national economy.
- \* productivity is an important metric in work systems because improving productivity is the means by which worker compensation can be increased without increasing the costs of the products & services they produce.
- 4 Capital: the substitution of machines for human labor Cire investing in an automated production machine to replace a manually operated machine.

\* Technology: a fundamental change in the way some activity or function is accomplished, more than using a machine in the place of a human; it is using a new type of machine to replace the previous type.

• new technologies almost always require capital investments

\* labor productivity: the most common productivity measure.  $\rightarrow LPR = \underbrace{UU}_{LH} \quad \text{ourk units of output} \\ \text{output}. \end{aligned}$ 

\* although Labor productivity is a commonly used measure, Labor does not contribute much to improving productivity.

\* problems encountered in labor productivity measurement:

1/ nonhomogeneous output units: the output work units are not always the same.
2/ multiple input factors: often labor is not the only determinant of productivity (i.e. materials, energy).
3/ price \$\$ cost changes: the prices of output work units \$\$ the costs of input factors change unpredictably.

4/ product mix changes: the relative proportions of products that a company sells.

\* Labor productivity index: a productivity measure that compares yearly output/input ratios.

\*  $LPI = \frac{LPR_{I}}{LPR_{I}}$  ·  $LPR_{I} \Rightarrow$  labor productivity ratio during time period of interest LPR<sub>I</sub> ·  $LPR_{I} \Rightarrow$  labor productivity ratio during a defined base period.

\* Work is not usually performed in the most efficient way possible, a given task will consist of: 1/basic productive work content: the theoretical minimum amount of work required to accomplish a task, where the amount of work is expressed as time.

2/excess nonproductive activities: the extra & unavoidable physical & mental actions performed by the worker that add no value to the task, or facilitate productive work content that does add value.

• three categories: 1. caused by poor design of product/service.
 a. caused by inefficient methods, poor work layout, \$\$ interruptions
 3. caused by the human factor.

| * Examples of excess nonproductive oretivities:                                   |
|---|
| 1/poor design: • products designed with more parts than necessary.                |
| • product proligeration (more choices than needed)                                |
| • Irealient design changes - changes in tooling methods & langut                  |
| • what he are materials   |
|   |
| Quality shandards mole stringent than necessary.                                  |
| 2/inefficient methods: • plant layout that requires excess movement of materials. |
| · workplace layout that requires excess motions.                                  |
| • inefficient methods \$ material handling.                                       |
| <ul> <li>Wasted space, long setup times, workers waiting for work.</li> </ul>     |
| · frequent equipment breakbdowns  |
| 3/the human factor: • absentecism & tardiness.                                    |
| • Workers socializing \$ working slow   |
| • inadequate training   |
| • indu strial accidents   |
| <ul> <li>hazardous materials causing accupational sickness.</li> </ul>            |
|   |

2-MANUAL WORK

\* Work systems are classified into three categories:

1/Manual work systems: consists of a worker performing tasks without the aid of powered tools, & usually uses hand tools.
2/Worker-machine system: a worker operates powered equipment.

3/ Automated work system: a process is performed by a machine without the direct participation of a worker.

\* The work accomplished by a work system is almost always acted upon the work writ.

\* In production the work alters the geometry of a work part, in logistics the work involves transporting material from a warehouse to a customer; in service work a sales prospect is transformed into a paying customer by a persuasive salesperson, in knowledge work a designer takes a product concept & converts it into specifications & engineering drawings:

\* Manual work is the most basic form of work, engaging the human body to accomplish some physical eask, without an external source of power (hand tools are often used but the power to operate them derives from the strength # etamina of a worker) with or without cools, the worker must use physical energy to accomplish the task using other human facilities like hand-eye coordination # mental effort.

\* there are two types of mental work.

4/pure manual work involves only physical & capabilities with no machines, tools, or other implements employed. examples: a material handling worker, a casino dealer, an affice worker filing documents, workers loading furniture. 2/manual work using hand tools: a tool is a device for making changes to some object (cutting, grinding, and otriking). 2/manual work using hand tools: a tool is a device for making changes to some object (cutting, grinding, and otriking). 2/manual work using hand tools: a tool is a device for making changes to some object (cutting, grinding, and otriking). 2/manual work using hand tools, a workholder is a some object (cutting, grinding, and tools, a workholder is employed to grasp the work unit & position it securely during processing. examples: a machinist using a file, assembly worker using a screwidriver, a sculptor using a carving knife

\* manual tasks usually consist of a work cycle that is repeated with some degree of similarily, & each cycle conesponds to the processing of one work unit

- \* if the work cycle is relatively short, & has a high degree of similarity from one cycle to the next, it is repetetive, & if it takes a long time & is not similar, it is non repetetive.
- \* tasks can be divided into work elements that consist of logical groupings of motions performed by the worker.
- \* Cycle time  $(T_c)$ : the sum of the work element times:  $\Rightarrow T_c = \sum_{k=1}^{\infty} T_{ek}$  • k: work element: •  $n_c$ : # of work elements

\* it is important to design the work cycle to minimize the time required to perform it.

\* the actual time taken for a given manual cycle is a variable.

\* variability is inherent in any repetetive human activity & it is manifested in the activity time.

\* Reasons for variations in cycle time:
 1. differences in performance
 2. variations in motion.
 3. differences in cognitive attributes of workers
 4. variations in methods.

\* Performance: the pace of a worker doing a task.

\* as performance increases, the time of the work cycle decreases.

\*normal performance: a pace of working that can be maintained by a properly trained average worker throughout a shift without deleterious short-term or long term effects on the worker's health

\* a work-shift is usually eight hours.

\* when a worker works at a normal performance level, they are working at 100 % performance. \* normal time the time taken to perform a task at 100% . Te : actual time If the actual time to perform the work cycle  $\rightarrow T_c = T_n$   $T_n$  normal time  $P_1$   $P_2$   $P_3$   $P_4$   $P_2$   $P_3$   $P_4$   $P_2$   $P_3$   $P_4$   $P_3$   $P_4$   $P_3$   $P_4$   $P_4$ \* Workers are allowed periodic rest breaks because it has been found that overall productivity is greater if breaks are provided. \* Allowane: the time added to the normal time to account for breaks • To : normal time • Appl : allowance factor (decimal) \* Standard time: Tstd = Tn (1 + Appl) \* Inequiliar Work elements: elements performed with a frequency of less than once per cycle, also accounted for in the regular cycle time.  $G T_n = T_n + \frac{IWE}{* \sigma_F uple*}$ \* Standard Hours: the work actually accomplished by a worker during a given period. G Hstd = QTstd \* Worker Efficiency: Hold Hoh wentber of shift hours. \* efficiency & performance level can be equal only when: 1) + of hours worked is exactly consistent with allowance factor 2) the entire work cycle consists of manual Labor.

\* worker performance is hard to compute because the amount of time worked varies from day to day.

\* the effect of worker performance is reduced when machine time is included in the cycle.

4 Worker Machine System: one or more workers operating one or more pieces of powered equipment.
4 construction worker operating a backhoe.
a factory worker loading parts at a machine tool.
a crew operating a rolling mill.
4) a secretary using a personal computer.
5) an I.E. using CAD to create a design layout.

\* forwared Machinery is distinguished from hand tools be it's powered by a source other than human or animal power like electric, pneumotic, hydraulic, & fossil fuel motors. (4) portable power tools: portable drills, sours, electric hedge trimmers. 2) Mabile powered equipment: Otransportation equipment like ears, buses, trains, planes, otc. 2) Mabile powered equipment: Otransportation equipment like ears, buses, trains, planes, otc. 2) Mabile powered equipment: Otransportation equipment like ears, buses, trains, planes, otc. 3) Mabile powered equipment: Otransportation equipment like ears, buses, trains, planes, otc. 3) Mabile powered equipment: Otransportable & mobile during operation: can move under its own power 10 like construction, agricultural & 10 material handling equipment. 3) Stationary powered machines: stationary while operating & not operating, power source is electricity. 10 uachine tools: stationary power-driven machine that shapes & forms parts. 20 office equipment: personal computers, photocopiers, fax machines, etc.

© other machinery like furnaces, each registers, sewing machines, etc.

\* another method to dassify worker-machine systems is how many workers & machines there are.

\* another classification method is the level of attention required from workers.

\* according to uple time analysis: 1) systems in which the machine time depends on operator control
 ⇒ can be repetetive or nonrepetetive, \$ nonrepetetive situations do not consist of a regular work cycle that is repeated.
 e) systems where the machine time is constant \$ independent of operator control, \$ work cycle is repetetive only.

# usually Am = 30 %

\* Am = O => worker is idle during machine cycle.

\* when the cycle includes a constant machine cycle the worker performance has no

4 external work elements : performed sequentially.

+ internal work elements: performed simultaneously.

\* when internal elements are present, nc have to find whether Trn or Sum of worker's internal elements takes longer.
 Trn = Trnw + Max (Trnwi, Trn) \* Trnwi: workers ext. elements.
 ⇒ Trn = Trnw + Max (Trnwi, Trn) \* Trnwi: workers int. elements.
 ⇒ Tstd = Trnw (1+Appd) + Max (Trnwi (1+Appd)), Trn (1+Am)).
 ⇒ Tc = Trnw + Max (Trnwi, Trn)

\* Automation: the technology by which a process is accomplished without human assistance using a program of instructions combined with a control system that requires power.

\* Semiautomated machine: performs a portion of the work cycle under program control & a human tends to the machine for the remainder of the cycle, & the worker must attend during ench cycle.

\* fully automated machine operates for extended periods of time (longer than one cycle) with no human attention or periodic attention with regular servicing. • may require one or more workers to be present to monitor the operation, workers don't actively participate in pocess except for adjustments, maintenance, # to spring to action if needed.

\* if the number of setups is unknown, each system must be set up at the beginning of its production run but we don't know how many machines there will be, so we express the total work load for setup time as a junction of the # of machines.
⇒ WL = <u>ATstd</u> + Tsot • N → unknown variable
⇒ AT = Hsh A
⇒ n = <u>WL</u> ⇒ find n & round up.

- 2) Machine To is the same for all machines.
- 3) machines that a worker services are close to each other.
- 4) work rules of the plant permit a worker to service more
  - than one machine

\* repositioning time  $(T_r)$ : the time lost due to worker walking from one machine to another.  $\Rightarrow$   $T_3 = T_3 + T_r$ ,  $T_n = n(T_3 + T_r)$ service time if one machine n machines.

$$\xi$$
 the selection of  $n_1$  or  $n_2$  is based on whichever case results in lower  $C_{pc}$ .

★ if servicing is required at random # unpredictable intervals by each machine then there will be periods when several machines require servicing at the same time, which is above the capabilities of the human worker, & other times no machine will require servicing & worker will be idle.

\* production rate:  $R_p = \frac{actual time}{cycle time} = \frac{n \cdot 60}{actual time}$ 

\* Machine It : To - AT

9 - Charting & Diagramming Techniques \* used to graphically display relationships. \* Objectives: D to permit work processes to be communicated & comprehended. 2) to allow the use of algorithms designed for the particular diagramming technique 3) to divide a given work process into its elements for analysis. 4) to provide a structure in the search for improvements 5) to represent a proposed work process or method. \* ways an analyst creates a chart: 1) they are intimately familiar with the process 2) they observe & record information about the process. 3) one on one / group interviews of those familiar with the process. \$ how to analyze chart algorithmic → checklists ----> brainstorning -> separating value-added \$ non-value added operations. \* improvements due to charts include: reducing cycle time & cost, eliminating unnecessary steps, mitigating safety harards, & improving product quality \* 4 types of charting techniques •) Operation charts 2) process charts 3) flow diagrams 4) activity charts. \* Orantt chart: a charting tool associated with traditional IE, used in production control & project scheduling

- \* Operation chart a symbolic / graphical representation of the operations used to produce a product.
   → 1) processing & assembly operations
   → 2) inspection operations.
- \* operation charts consist of a series of vertical stems, each depicting the sequence of operations \$ inspections performed on a given component.
- \* it uses only two symbols, for operation & inspection. ○-operation □-inspection

\* the focus of the operation ohart is on the materials of a product and the operations performed on them.

- \* steps of operation chart: 1) developing a list of operations a) examinating by questioning the procedure. 3) developing proposals based on the result of questioning.
- \* Process chart: a graphical & symbolic representation of the process, consisting of a vertical list of the steps performed.

three types: 1) flow process chart: analyzing a material/workpiece being processed.
 a) worker process chart: analyzing a worker performing a process.
 3) form process chart: analyzing the processing of paperwork forms.

**¥** frow and worker process symbols: O - operation D - delay
□ - inspection ∇ - storage.
→ - move D - operation & inspection.

| * form process sumbols: @ - creatio | n D-delay        |  |
|-------------------------------------|------------------|--|
| O - merati                          | AN J- Storage.   |  |
| U - incorchi                        | en X - disorsal. |  |
| → - morian                          | mt               |  |

- ★ a flow diagram is a drowing of the facility lowout but with added lines to represent movement of materials/workers to specific locations in the facility with arrows to show direction, often used with a process chart.
- \* it also reveals problems in the work flow often not shown in the process chart, like excessive trowel, traffic congestion, inefficient layout of workstations & other delays.
- \* an activity chart is a list of the work activities of one or more subjects plotted against a time scale to indicate graphically how much time is spent on each activity to provide brief descriptions.
- \* they may have one or more time scale, called multiple activity chart, used to analyze now workload is coordinated.

Chart types: 1) worker-marchine activity chart.
 a) worker-multimachine activity chart.
 3) gang activity chart.

#### 12 - Intro to Work Measurement

\* time is important because of its economic significance. \* the labor content to produce a product is a mayor determinant of the cost.

\* Work measurement: a set of four techniques evaluating how much time needed for the overage human worker for a task. 1) direct time study 2) predetermined motion - time systems 3) standard data systems Gwork sampling where statistical measures are determined about how workers allocate their time among work activities

\* the objective of work measurement is to find the standard time of a task. \* time study all the ways in which time is investigated in work situations.

\* learning curve phenomenon a learner's efficiency in a task improves as the learner repeates the task

\* stanard time includes the allowance, so it's also called allowed time.

\* time standards are beneficial because of: 3) ong production runs 5) short cycle times. 1) low productivity 2) repeated orders 4) repetetive work cycles

accomplish a task (usually divided into work elements which are timed separately.

\* performance rating: an evaluation of the worker's pace.

\* normal time: observed time x performance.  $\Rightarrow$  Tn = Toos (PR)



may be measuring machine utilization & determining Appl.

advantages: capable to add multiple subjects in study.

\* standard method: the optimum method procedure (one best method).

\* std. method includes: 1) procedure used by worker a) tools 3) equipment 4) workplace layout 5) irregular work elements. 6) working conditions. 7) Setup. # the time required to accomplish a task also depends on the condition of the work element. \* companies address allowance by: 1) scheduled break periods 2) a pfol allowance. \* scheduled breaks planned periods set aside during the shift as break time from work (5-15 min). ♦ personal time allowance is usually 5%

the fatigue allowance is determined by the rest formulas & negotiation between labor & management.
 \* usually 5% for fatigue but for heavy work could be 20% or more.



## 13 - Direct Time Study

\* Direct time study: involves direct & continuous observation of a task using a also "stopwatch time study" stopwatch or another time-keeping device to record the time needed for a task.

# alts is most appropriate for tasks that involve a repetetive work cycle.

\* dts steps for a standard: 1) define & decument the std method. a) divide task into work elements. 3) find Tobs. of work elements by timing them together (4) evaluate pace & find performance rating to find Th 5) add an allowance to Th to find Tstd.

\* once the standard method is defined, it is impossible/very difficult to make further improvements.

# thorough documentation of the std method is very important, because:
 (1) batch production.
 (2) methods improvement by operator.
 (3) disputes about method.
 (4) data for standard data system.

twork element a series of motion activities that are grouped together because they have the same purpose.

\* each element should be timed over several cycles to find a vehiable average.

standard performance.

\* reasons work element times vary 3 variations in body motions, placement of tools, \$ quality of the starting work units. @ mistakes by the operator. 3 errors in timing. l variations in worker pale. (sperformance rating compensates for this.

| 16-Work Sampling   |
|--|
|  |
| * Work sampling: statistical technique for determining proportions of time spent<br>by subjects in various activities. |
|  |
| * a large number of observations is made over an extended period of time.  |
| * to be accurate, observations must be taken at random times.  |
| * work situations that are good. for work, sampling:   |
| a sufficient time anoilable to perform study   |
| a multiple subjects  |
| Contractor di anti-  |
| ong cycle times  |
| (4) non repetetive work cycles   |
| * other names: activity sampling, occurrence sampling, ratio delay study, snap<br>reading method                       |
| Kumpk equaling ran be used for:  |
| a machine utilization  |
| a worken white at the  |
| allowing to the standards  |
| 3 dawwines for line standards  |
| 4 average unit time  |
| 5 time standards   |
|  |
| * the basis of work sampling is binomial distribution which is   |
| approximated by normal distribution because n is very large so   |
| its not too different.   |

\* 
$$\mu = n\rho$$
  $\oint \sigma^2 = \frac{\rho(1-\rho)}{n}$   
\* biased estimate: an estimate that consistently differs from the true  
value, because:  $\widehat{P}$  estimating method is flowed  
(a) variable being estimated is influenced by  
observation.  
\* low variance  $\Rightarrow$  measured values are close together:  
 $\Rightarrow \sigma + \text{ when n } \uparrow$   
\*  $P(-z_{a_2} < \frac{\widehat{p} - p}{\widehat{\sigma_p}} < z_{a_{22}}) = 1 - a$   
\*  $\widehat{P} + estimated proportion$   
\*  $p \rightarrow \text{ true proportion}$   
\*  $P(\widehat{P} - z_{a_{22}} < \widehat{p} < p < \widehat{\rho} + z_{a_{22}} < \widehat{\sigma_p}) = 1 - a$   
\*  $P(\widehat{P} - z_{a_{22}} < \widehat{\sigma_p} < p < \widehat{\rho} + z_{a_{22}} < \widehat{\sigma_p}) = 1 - a$   
\*  $a_{3} n + timits of CI + (neurorower)$   
\*  $CI \Rightarrow p \pm C$   
\*  $C : desired acceptable deviation from p.$   
\*  $C = z_{a_{22}} < \widehat{\sigma_p}$   
\*  $n = \frac{\widehat{\rho}(1-\widehat{\rho})}{\widehat{\sigma_p}^2} = \frac{(z_{a_{22}})^2 \widehat{\rho}(1-\widehat{\rho})}{c^2}$   
\* standards determined by work sampling are not appropriate for wage incentive plans.

\* when the purpose of the study is to set a standard, observer must rate worker performance while identifying the activity category which is difficult because the observer has a brief moment to do it.

C Keypunching

writing
filing
felephone
walking

#### \* advantages of work sampling:

? operations that are impractical / costly can be measured by W.S. @ multiple subjects can be included. 3 needs less time / lower cost than ets. obser (4) reduced risk of short-time aborrations & techniques to identify the aberrations. 😉 training requirements are less than other study methods. © less tedious & tiresome than ets observation 🔁 being a subject is less demanding ★ disadvantages of work sampling : ( not very accurate in setting time standards @ not practical/economical for studying a single subject 3 if the subjects are far from each other, observer spends too much time walking between them & workers may alert each other & there will be biers. @ provides less detailed information about the work elements E since it averages multiple subjects' activities the differences in individual activities are overlooked 6 workers may not understand the statistical theories of the study so acceptance of results may be a problem. The worker methods so if they change the study results will be invalid. (2) the behavior of subjects may be influenced by being observed so there will be bias.

### All Rules to be used

C Chapter 2  

$$T_{c} = \Sigma T_{k} \qquad \text{ and down the set of equation of the set of the set of equation of the set of t$$

