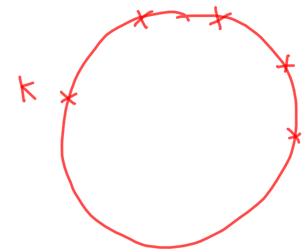
Chapter 2

Manual Work and Worker-Machine Systems

Cycle Time Analysis

- **Cycle time T_c**



$$T_c = \sum_{k=1}^{n_e} T_{ek}$$

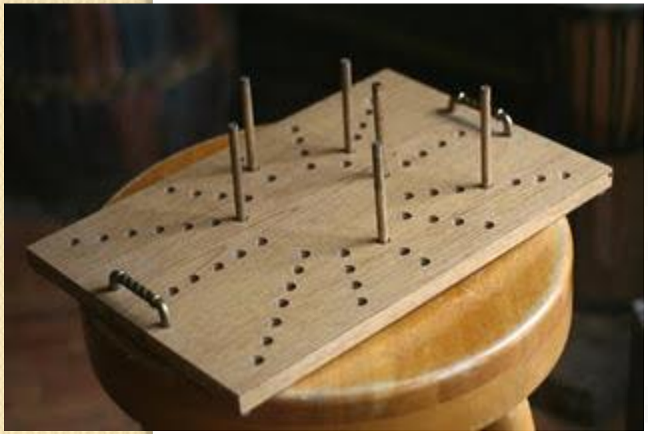
where

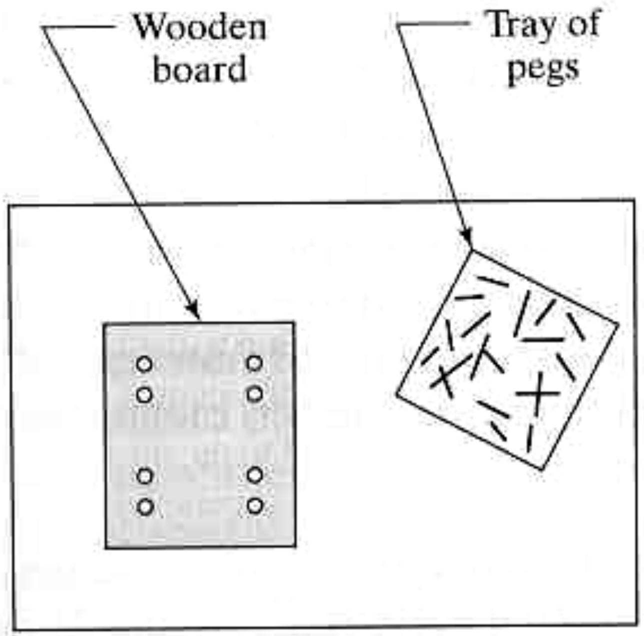
T_{ek} = time of work element k, where k is used to identify the work elements (min)

n_e = number of work elements into which a cycle is divided.

Example1: A repetitive Manual Task

- **Current method:** An assembly worker performs a **repetitive** task consisting of inserting 8 pegs أوتاد into 8 holes in a board. A slightly interference fit is involved in each insertion. The worker holds the board in one hand and picks up the pegs from a tray with other hand and inserts them into the holes, one peg at a time.



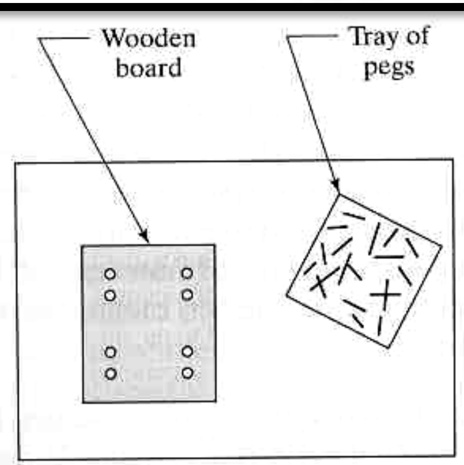


(a)

Example 1: A repetitive Manual Task

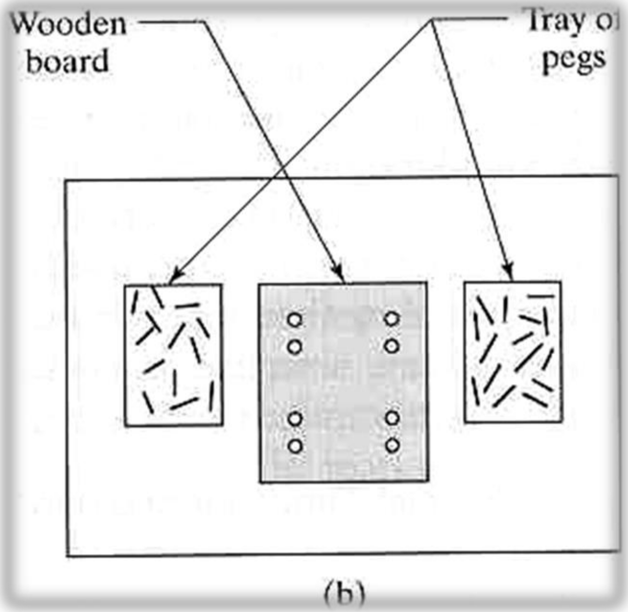
- **Current method and current layout:**

Sequence	Work Element Description	Work Element Time, T_{ek} (min)
1	Worker picks up board with one hand and holds it.	0.08
2	Worker picks peg from tray and inserts it into hole in board.	0.06
3	Worker picks second peg and inserts it into hole in board.	0.06
4	Worker picks third peg and inserts it into hole in board.	0.06
5	Worker picks fourth peg and inserts it into hole in board.	0.06
6	Worker picks fifth peg and inserts it into hole in board.	0.06
7	Worker picks sixth peg and inserts it into hole in board.	0.06
8	Worker picks seventh peg and inserts it into hole in board.	0.06
9	Worker picks eighth peg and inserts it into hole in board.	0.06
10	Worker lays assembled board into tote pan.	0.06
Total work cycle time		0.62



A repetitive Manual Task

- **Improved method and improved layout:**
  - Use a work-holding device to hold and position the board while the worker uses both hands simultaneously to insert pegs.
  - Instead of picking one peg at a time, each hand will grab أمسك ب four pegs to minimize the number of times the worker's hands must reach the trays.



A repetitive Manual Task

- **Improved method**

Sequence	Work Element Description	Work Element Time, T_{ek} (min)
1	Worker picks up board and positions it in workholder.	0.12
2	Worker picks 4 pegs each with both hands from 2 trays and inserts them into 8 holes in board.	0.15
3	Worker removes board from workholder and places in tote pan.	0.10
Total work cycle time		0.37

- The cycle time is reduced from 0.62 min to 0.37 min.

- % cycle time reduction= $(CT_{Current} - CT_{Improved}) / CT_{Current}$

$= (0.62 - 0.37)/0.62 = 40\%$

A repetitive Manual Task

- Production rate$_{current}$= $1/0.62$ min $= 1.61$ units/min
- Production rate$_{improved}$= $1/0.37$ min $= 2.7$ units/min
- % increase in R = $(R_{Improved} - R_{Current}) / R_{Current}$

$$= \frac{2.7 - 1.61}{1.61} = 68\%$$

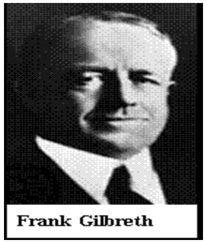
- It is important to design the work cycle so as to **minimize** the time required to perform it.
- Of course there are many alterantive ways to perform a given task. Our focus is on the **best** one.

One Best Method Principle

Before you standardize the method and time, determine the best method for a task

- Of all the possible methods that can be used to perform a given task, there is one optimal method that minimizes the time and effort required to accomplish it

  (Attributed to ***Frank Gilbreth)***



- A primary objective of work design is to determine the best method for a task, and then standardize its use
- This one best refers to an average worker with a moderate level of skill, operating under normal working conditions with nominal material quality and tool/equipment availability

Definitions

Important

Actual, Normal and Standard times

- **Actual time (cycle time)** T_c

  The time a particular employee actually takes to perform a particular operation (working at his own pace).

  No allowed time

- **Normal time** T_n

  100 % efficiency

  The time needed to complete an operation by an employee working at normal/average pace and at 100% efficiency (no delays and no time allowances).

  100 % eff

- **Standard time (Allowed time)**

  allowed time

  The time needed to complete an operation by an employee working at 100% efficiency with the consideration of PFD (with time allowance).

  PFD: Personnel, Fatigue, Delay

Is the actual work time fixed? Or it differs from a worker to another?

Cycle Time\Actual Time Variations

- Once the method has been standardized, the actual time to perform the task is variable because of the following:
  - Differences in worker performance
  - Variations in hand and body motions
  - Mistakes by worker
  - Variations in starting work units
  - The learning curve phenomenon
  - Extra elements not performed every cycle

Normal Performance

Tn
100 % efficiency

- A **pace** (steady and consistent speed) of working that can be maintained by a properly trained ***average*** worker throughout an entire work shift without harmful short-term or long-term effects on the worker's health or physical well-being.
- Normal performance = 100% performance.
- Common benchmark of normal performance
  - Example: Walking at 3 mi/hr

Worker Performance

pace
relative speed

- Defined as the pace or relative speed of working
- As worker performance increases, cycle time decreases.
- From the employer's viewpoint, it is desirable for worker performance to be high.

What is the reasonable pace/speed to expect from a worker?.

Cycle Time (Actual time)

$$\text{Velocity} = \frac{D}{T}$$

$$T_c = \frac{T_n}{P_w}$$

$$V_n = \frac{D}{T_n}$$

$$V_c = \frac{D}{T_c}$$

$$P_w = \frac{T_n}{T_c}$$

or

$$P_w = \frac{V_c}{V_n}$$

where

T_c = cycle time (actual time)

T_n = normal time (Time required to complete a task when working at normal performance/normal pace)

P_w = worker performance or pace

Actual time to perform a cycle depends on worker's performance (Pw)

Example: Normal Performance

Given: A woman walks in the early morning for health and fitness. Her usual route is 1.85 miles and she travels this distance in a typical time of 30 min. The benchmark of normal performance is 3 mi/hr.

D, T_c, V_n

Determine:

(a) how long the route would take at normal performance

(b) the woman's performance when she completes the route in 30 min.

(a) $V_n = \frac{D}{T_n}$

$T_n = \frac{D}{V_n} = \frac{1.85}{3} = 37$ Min

(b) $P_w = \frac{T_n}{T_c} = \frac{37}{30} = 123.3\ \%$

Standard Performance

100% efficiency → allowed time

- Same as normal performance, but acknowledges that periodic rest breaks must be taken by the worker
- Periodic rest breaks are allowed during the work shift
  - Federal law (USA) requires employer to pay the worker during these breaks
- Other interruptions and delays also occur during the shift

How to take these factors into consideration when calculating the time?

(What is PFD Allowance?)
Personal, Fatigue and delay Allowance

To account for the delays due to:

- **Personal time (P)**
  - Bathroom breaks, personal phone calls
- **Fatigue (F)**
  - Rest breaks are intended to deal with fatigue

- **Delays (D)**
  - Interruptions, equipment breakdowns

The allowance time also depends on the work environment as well as the nature of work.

Standard Time (or Allowed Time)

Defined as the normal time but with an "allowance taken into account" for losses due to personal time, fatigue, and delays

$$T_{std} = T_n(1 + A_{PFD})$$

where T_{std} = standard time, T_n = normal time, and A_{PFD} = PFD allowance factor

Hence , the standard time is the amount of time that should be allowed for an average worker to process one work unit using the standard method and working at normal pace.

Irregular Work Elements

Elements that are performed with a frequency of less than once per cycle. In other words, it is performed every ***n*** number of cycles where ***n*** is greater than 1.

- Examples:
  - Changing a tool
  - Exchanging tote pans of parts
- Irregular elements are prorated (distributed) into the regular cycle according to their frequency

Standard Hours and Worker Efficiency

Two common measures of worker productivity are used in industry:

(a) Standard Hours and (b) Worker's Efficiency.

(a) **Standard Hours** – represents the amount of work actually accomplished

$$H_{std} = Q\,T_{std}$$

Where H_{std} : is the Standard Hours, and Q: is the actual quantity produced during the standard hours.

(b) **Worker's efficiency (E_w)** – work accomplished as a proportion of shift hours

$$E_w = \frac{H_{std}}{H_{sh}}$$

Where H_{std} is the standard hours and H_{sh} is number of hours per shift (e.g. 8 hr)

Note: H_{std} should be calculated based on the Q produced in one shift (measure =H_{sh})

Actual Worked Time and The Quantity produced

(a) Actual Worked Time

Lost time = Shift time − Actual-worked time

Shift time = Actual worked time x $(1 + A_{PFd})$

(b) The quantity produced (Q)

$$Q = \frac{\text{Actual Worked time}}{T_c}$$

$$T_c = \frac{T_n}{P_w}$$

* $P_w = \frac{T_n}{T_c}$

* $T_{std} = T_n (1 + A_{PFD})$

* $H_{std} = Q \, T_{std}$

* $Q = \frac{\text{Actual time worked}}{T_c}$

* $E_w = \frac{H_{std}}{H_{sh}}$

* shift time = Actual time worked × $(1 + A_{PFd})$

* lost time = shift time − actual time worked

Example: if the shift time is 8 hours and the PFD allowance is 15%, determine the actual worked time by a worker.

* Shift time = Actual time worked × $(1 + A_{PFd})$

$8 = \text{Actual time worked} \times (1 + 0.15)$

Actual time worked = 6.956 hrs

Example: The normal time to manufacture a part is 3 hours (T_n) and the worker's performance if 90% (P_w). Calculate the quantity produced in one 8 hours shift, given that the PFD allowance is 15%

* $P_w = \frac{T_n}{T_c}$

$T_c = T_n / P_w = \frac{3}{0.9} = 3.33$ hrs

* Actual time worked = 6.956 hrs

$Q = \frac{6.956}{3.33} = 2.08$ Parts/Unit

Example: Determination of The Standard Time

Given: The normal time to perform the regular work cycle is 3.23 min. In addition, an irregular work element with a normal time of 1.25 min is performed every 5 cycles. The PFD allowance factor is 15%.

Determine:

a) The standard time

b) The number of work units produced during an 8-hr shift, if the worker's pace is consistent with standard performance. $T_n = T_c$

c) Determine the anticipated amount of time lost per 8-hour shift.

d) Determine the production rate when worker performance is 125%.

(a) $T_n = 3.23 + \frac{1.25}{5} = 3.48$ Mints

$T_{std} = T_n (1 + A_{PFd})$

$= 3.48 (1 + 0.15) = 4$ Min

(b) $Q = \frac{\text{time worked}}{T_{std}} = \frac{8 * 60}{4}$

$= 120$ units

Or

Total shift time = actual time worked $(1 + A_{PFd})$

$8 = \text{actual time worked} (1 + 0.15)$

actual time worked $= \frac{8}{1.15} = 6.956$ hr

$Q = \frac{6.956 * 60}{3.48} = 120$ units

(c) loss time $= 8 - 6.956 = 1.044$ hr

(d) $T_n = 3.48 \Rightarrow P_w = \frac{T_n}{T_c}$

$T_c = T_n / P_w = \frac{3.48}{1.25} = 2.78$ min

$R_p = Q_{New} = \frac{6.956 * 60}{2.78} = 150$ work units

100 % Performance $\Longrightarrow$ 120 Units / 8-hr shift

125 % Performance $\Longrightarrow$ Q = ? ? !

$$Q = \frac{120 * 125}{100} = 150 \text{ Units}$$

Example: Standard Hours and Worker's Efficiency

Given: In the previous example, T_{std} = 4 minutes and the worker's performance during the shift is 125%,

Determine: (a) H_{std} , (b) E_w.

Standard Time	$T_{std} = T_n (1 + A_{PFD})$
Quantity	Q= Actual time worked/Tc

(a) $H_{std} = Q \; T_{std} = 150 * 4$

$= 600 \text{ Mints} = 10 \text{ hrs}$

(b) $E_w = \frac{H_{std}}{H_{sh}} = \frac{10}{8} = 125\%$

E_w is equal to the worker's performance for two reasons:

- The number of hours actually worked is consistent with 15% allowance factor.
- The entire work cycle consists of manual labor.
  - So, worker efficiency = worker performance (rate)

Example: Standard Hours and Worker's Efficiency

In the previous example, assume that the actual worked hours is 7.42 hr, determine

(a) The number of units produced

(b) Number of standard hours accomplished

(c) Worker efficiency

(a) $T_n = 3.48$

$T_c = \frac{T_n}{wp} = \frac{3.48}{1.25} = 2.78$ Mints

$Q = \frac{7.42 * 60}{2.78} = 160$ units

(b) $H_{std} = Q\, T_{std}$

$= 160\,(4) = 640$ Mints

$= 10.67$ hrs

(c) $E_w = \frac{H_{std}}{H_{sh}} = \frac{10.67}{8}$

$= 1.333 = 133.3\ \%$

Standard hours and worker efficiency as affected by hours actually worked

- Note that in this example worker efficiency, E_w, and worker pace, P_w, are not equivalent.

- The reason for that
  - Actual work hours of that labor (7.42–given in the example) is greater than the allowed time (or anticipated work time, which is found to be 6.956 hr)
  - That is, on that specific day, the worker delays (8-7.42=0.58hr) and the rest breaks are less than the anticipated time loss due to PDF allowances (1.044hr).

Important Note:

When a worker works at a performance level greater than 100% and his or her actual time worked during the shift is consistent with or greater than what is provided by the allowance factor, then the number of standard hours accomplished will be greater than the number of hours in the shift.

Problem 2.3

- The normal time to perform a certain manual work cycle is 3.47 min. In addition, an irregular work element whose normal time is 3.70 min must be performed every 10 cycles. One work unit is produced each cycle. The PFD allowance factor is 14%. Determine (a) the standard time per piece and (b) how many work units are produced during an 8-hour shift at 100% performance, and the worker works exactly 7.018 hr, which corresponds to the 14% allowance factor. (c) If the worker's pace is 120% and he works 7.2 hours during the regular shift, how many units are produced?

(a) $T_n = 3.47 + \frac{3.7}{10} = 3.84$ min

$T_{std} = T_n(1 + A_{pfd})$

$= 3.84(1 + 0.14) = 4.378$ Min

(b) @ 100 % $T_n = T_c = 3.84$

$Q = \frac{\text{actual work hours}}{T_c} = \frac{7.018 * 60}{3.84}$

$Q = 109$ units

(c) $T_n = 3.84$ Min

$P_w = 120$ %

actual work hours $= 7.2$ hrs

$T_c = \frac{T_n}{P_w} = \frac{3.84}{1.2} = 3.2$ Mins

$Q = \frac{7.2 * 60}{3.2} = 135$ units

* $P_w = \frac{T_n}{T_c}$

* $T_{std} = T_n (1 + A_{PFD})$

* $H_{std} = Q \, T_{std}$

* $Q = \text{Actual time worked} / T_c$

* $E_w = \frac{H_{std}}{H_{sh}}$

* Shift time = Actual time worked x $(1 + A_{PFd})$

* lost time = Shift time − actual time worked

Worker-Machine Systems

- A worker operating a piece of powered equipment
- Examples:
  - Machinist operating a milling machine
  - Construction worker operating a backhoe
  - Truck driver driving an 18-wheeler
  - Worker crew operating a rolling mill
  - Clerical worker entering data into a PC



Relative Strengths

Humans:

1. Sense unexpected stimuli
2. Solve problems
3. Cope with abstract problems
4. Adapt to changes
5. Generalize from observations
6. Make decisions on incomplete data

Machines

1. Perform repetitive operations consistently
2. Store large amounts of information
3. Retrieve data from memory reliably
4. Apply high forces and power
5. Make routine decisions quickly

Classifications of Worker-Machine systems

- Types of Powered Equipment
- Numbers of Workers and Machines
- Level of Operator Attention

Types of Powered Equipment

1. Portable power tools
   - Portable power drills, chain saws, electric hedge trimmers
2. Mobile powered equipment
   - Transportation equipment, back hoes, forklift trucks, electric power generator at construction site
3. Stationary powered machines
   - Machine tools, office equipment, cash registers, heat treatment furnaces

Classification of Powered Machinery

- Powered machinery
  - Portable power tools
    - Portable power drills, chain saws, electric hedge trimmers

  - Mobile powered equipment
    - Transportation equipment
      - Cars, buses, trucks, airplanes
    - Transportable and mobile
      - Tractor, bulldozers, backhoes, forklifts
    - Transportable and stationary
      - Electric power generators

  - Stationary powered machines
    - Machine tools
      - Turning, drilling, milling
    - Office equipment
      - PCs, photocopiers, telephones
    - Other machinery
      - Ovens, cash register

Numbers of Workers and Machines

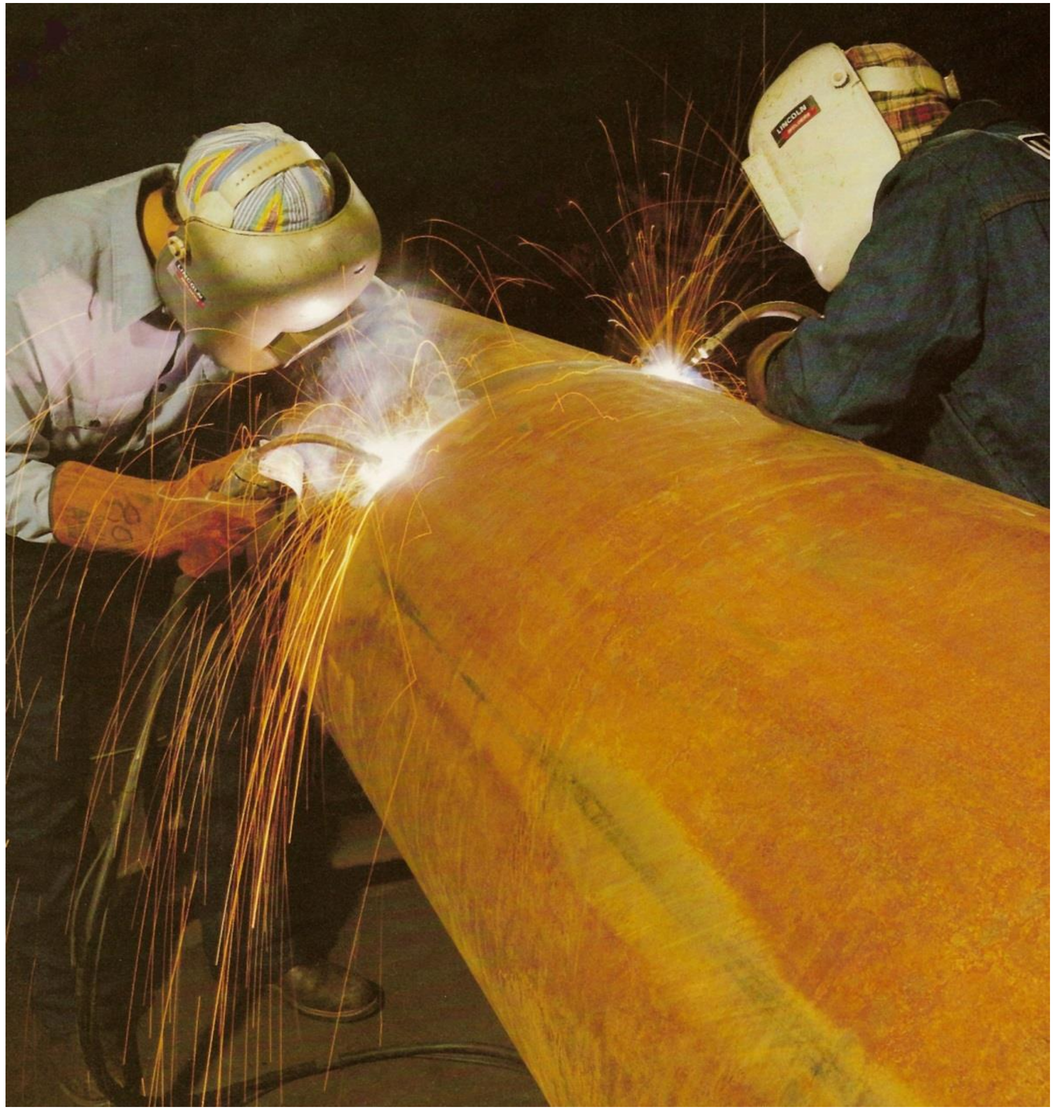
- One worker and One machine
  - Taxicab driver and taxi
- Multiple workers and One machine
  - Ship's crew

- One worker and Multiple machines
  - Machine cluster
- Multiple workers and Multiple machines
  - Emergency repair crew responding to machine breakdowns

Level of Operator Attention

1. Full-time attention
   - Welders performing arc welding
2. Part-time attention during each work cycle
   - Worker loading and unloading a production machine on a semi-automatic cycle (longer than periodic attention)
3. Periodic* attention with regular servicing
   - Crane operator in a steel mill *(at known time intervals)*
4. Periodic attention with random servicing
   - Firefighters responding to alarms *(at unknown time intervals)*

*Periodic means happening or occurring at intervals



Two welders performing arc welding on pipe - requires full-time attention of workers (photo courtesy of Lincoln Electric Co.)

Cycle Time Analysis

Two categories of worker-machine systems in terms of cycle time analysis

- ***(a) Systems in which the machine time depends on operator control***
  - Carpenter using power saw to cut lumber
  - Cycle time analysis is same as for manual work cycle
- ***(b) Systems in which machine time is constant and independent of operator control***
  - Operator loading semi-automatic production machine

Workers and Machines – Internal & External Work Elements

- Some worker elements are performed while a machine is working:
  - Internal work elements are performed simultaneously with machine cycle (overlap between elements)
  - External work elements are performed sequentially with machine cycle (no overlap)
- Desirable to design the work cycle with internal rather than external work elements

Worker and Machine – External work elements (No overlap – sequential)

- Worker elements and machine elements are sequential
  - While worker is busy, machine is idle
  - While machine is busy, worker is idle
- Normal Cycle time (T_n)

$$T_n = T_{nw} + T_M$$

- Standard Cycle time (T_{std})

$$T_{std} = T_{nw}(1 + A_{pfd}) + T_M(1 + A_M)$$

Where T_{nw} is normal time for the worker, T_m is machine cycle time and A_m is machine allowance factor (The machine allowance is added to the basic time to compensate for the operator having to temporarily stop work to do small maintenance tasks)

Example: Worker-Machine Systems

Solve it yourself

- On a semiautomatic machine, the normal time of manual work is 1.0 min and the machine time is constant and equal to 2.0 min. The A_{pfd} is equal to 15%.
- (a) Estimate the cycle standard time when: $A_m = 0.0$ and $A_m = 30\%$.

  $T_{std} = T_{nw}(1 + A_{pfd}) + T_m(1 + A_m)$
- (b) Estimate the worker's efficiency with $A_m = 0.0$ when 150 units are produced in 8-hour shift.
- (c) Estimate the worker's efficiency with $A_m = 30\%$ when 150 units are produced in 8-hour shift.

(a) $T_{std} = T_{nw}(1 + A_{PFd}) + T_M(1 + A_M)$

when $A_M = 0$

$T_{std} = 1(1 + 0.15) + 2(1 + 0)$

$= 3.15$ Min

when $A_M = 30\%$

$T_{std} = 1(1 + 0.15) + 2(1 + 0.3)$

$= 3.75$ Min

(b) $A_M = 0$ $T_{std} = 3.15$ Min

$Q = 150$ units

$T_{sh} = 8$ hrs

$E_w = \frac{H_{std}}{H_{sh}}$

$H_{std} = Q\,T_{std} = 150 * 3.15 = 472.5$ Min

$= 7.875$ hr

$E_w = \frac{7.875}{8} = 98.4\%$

$A_M = 30\%$ $T_{std} = 3.75$ min

$Q = 150$ units

$H_{std} = Q\,T_{std} = 150 * 3.75 = 562.5$ Min

$= 9.375$ hr

$E_w = \frac{9.375}{8} = 117.2\%$

Example: External Work Elements (sequential)

Sequence	Work Element Description	Worker Time (min)	Machine Time (min)
1	Worker walks to tote pan containing raw stock	0.13	(idle)
2	Worker picks up raw workpart and transports to machine	0.23	(idle)
3	Worker loads part into machine and engages machine semiautomatic cycle	0.12	(idle)
4	Machine semiautomatic cycle	(idle)	0.75
5	Worker unloads finished part from machine	0.10	(idle)
6	Worker transports finished part and deposits into tote pan	0.15	(idle)
Totals		0.73	0.75

For these external work elements (sequential), the cycle time is:

$T_c = 0.73 + 0.75 = 1.48$ Min

Normal Time and Standard Time for Worker-Machine Systems – Internal Work System (Simultaneous)

- Normal time

$$T_n = T_{nw} + Max\left(T_{nw_{ci}}, T_M\right)$$

nw: normal worker time , m: machine cycle time, A: allowance, nwi: sum of the worker times needed for (i) elements simultaneous with machining

- Standard time

$$T_{std} = T_{nw}(1 + A_{PFd}) + Max\left(T_{nw_{c}}(1 + A_{PFd}), T_M(1 + A_M)\right)$$

- Actual cycle time (manual work is based on worker's performance)

$$T_C = \frac{T_{nw}}{P_w} + Max\left(\frac{T_{nw_{ci}}}{P_w}, T_M\right)$$

Example: Improved method (internal work elements –simultaneous tasks)

Sequence	Work Element Description	Worker Time (min)	Machine Time (min)
1	Worker unloads finished part from machine	0.10	(idle)
2	Worker loads part into machine and engages semiautomatic machine cycle	0.12	(idle)
3	Machine semiautomatic cycle		0.75
4	Worker transports finished part and deposits it into tote pan, walks to tote pan containing raw stock, and picks up raw workpart and transports it to machine. (This element is internal to the machine semiautomatic cycle.)	0.15 + 0.13 + 0.23 = 0.51	
Totals		0.73	0.75

- Re-arrange (no combination as it is difficult to reduce the number of tasks) the tasks and perform the first three tasks (1-3) simultaneously to the machine cycle (worker task 4 is simultaneous with machine task 3).

$$T_n = T_{nw} + \text{Max}\{T_{nwi}, T_m\}$$

For parallel elements only

$$Tc = T_{nw} / P_w \text{ (or } T_{cw}) + \text{Max}\{T_{nwi}/P_w \text{ (or } T_{cw}), T_m\}$$

Task 4 (Tnwi)

Task 3 (Tm)

$$T_c = 0.1 + 0.12 + \text{Max}(\underbrace{0.15 + 0.13 + 0.23}_{0.51}, 0.75)$$

$$= 0.1 + 0.12 + 0.75$$

$$T_c = 0.97 \text{ Min}$$

Formula summary

Standard Time $T_{std} = T_n (1 + A_{PFD})$

Quantity $Q = \text{Actual time worked}/T_c$

Standard Hours $H_{std} = Q\, T_{std}$

Worker Efficiency $E_w = H_{std} / H_{shift}$

Worker Performance $P_w = T_n / T_c$

N.B:

The worker's performance measure does not consider time allowances and waste of time between cycles, but the worker's efficiency does.

Problem

- The work cycle in a worker-machine system consists of (1) external manual work elements with a total normal time of 0.42 min, (2) a machine cycle with machine time of 1.12 min, and (3) internal manual elements with a total normal time of 1.04 min.
- (a) Determine the standard time for the cycle, using a PFD allowance factor of 15%, and a machine allowance factor of 30%.
- (b) How many work units are produced daily (8-hour shift) at standard performance?

(a) $T_{std} = T_{nw}(1 + A_{PFd}) + \max\begin{pmatrix} T_{nwi}(1 + A_{PFd}) \\ T_M(1 + A) \end{pmatrix}$

$= 0.42(1 + 0.15) + \max\begin{pmatrix} 1.04(1 + 0.15) \\ 1.12(1 + 0.3) \end{pmatrix}$

$= 0.42(1.15) + \max(1.196, 1.456)$

$T_{std} = 1.939$

(b) $Q_{std} = \frac{8 * 60}{1.939} = 247.6$ PC

≈ 247 PC

Problem 2.6

A worker performs a repetitive assembly task at a workbench to assemble products. Each product consists of 25 components. Various hand tools are used in the task. The standard time for the work cycle is 7.45 min, based on using a PFD allowance factor of 15%. If the worker completes 75 product units during an 8-hour shift, determine (a) the number of standard hours accomplished and (b) worker efficiency. (c) If the worker took only one rest break, lasting 13 min, and experienced no other interruptions during the 8 hours of shift time, determine her worker performance.

$T_{std} = 7.45$ Min

$A_{pfd} = 15\%$

$Q = 75$ units – 8 hr shift

(a) $H_{std} = Q\,T_{std} = 75 * 7.45/60$

$= 9.313$ hr

(b) $E_w = \frac{H_{std}}{H_{sh}} = \frac{9.313}{8} = 1.164 = 116.4\%$

(c) actual time worked $= 480 - 13 = 467$ Min

(480 = 8 * 60; 13 = Mints)

$Q = 75$ units

$T_c = \frac{\text{Actual time worked}}{Q}$

$= \frac{467}{75} = 6.227$ Min/pc

$T_{std} = T_n (1 + A_{pfd})$

$T_n = \frac{7.45}{1+0.15} = 6.478$ Min/PC

$P_w = \frac{T_n}{T_c} = \frac{6.478}{6.227} = 1.04$

$= 104\%$

Problem 2.7

The normal time of the work cycle in a worker-machine system is 5.39 min. The operator-controlled portion of the cycle is 0.84 min. One work unit is produced each cycle. The machine cycle time is constant. (a) Using a PFD allowance factor of 16% and a machine allowance factor of 30%, determine the standard time for the work cycle. (b) If a worker assigned to this task completes 85 units during an 8-hour shift, what is the worker's efficiency? (c) If it is known that a total of 42 min was lost during the 8-hour clock time due to personal needs and delays, what was the worker's performance on the portion of the cycle he controlled?

$T_{nw} = 0.84$ Min

$T_M = 5.39 - 0.84 = 4.55$ Min

$T_n = 5.39$

(a) $T_{Std} = T_{nw}(1 + A_{PFd}) + T_M(1 + A)$

$= 0.84(1 + 0.16) + 4.55(1 + 0.3)$

$= 6.889$ Min

(b) $Q = 85$ units   8-hr shift

$H_{Std} = Q\,T_{Std}$

$= 85 * 6.889/60 = 9.76$ hr

$E_w = \frac{H_{std}}{H_{sh}} = \frac{9.76}{8} = 1.22 = 122\%$

(c) Time worked $= 480 - 42 = 438$ Min

total Machine time $= 4.55 * 85 = 386.75$ Min

total operator time (actual) $= 438 - 386.75 = 51.25$ Min

$T_c = \frac{\text{Actual time worked}}{Q}$

T_{cw} (operator) $= \frac{51.25}{85} = 0.6$

$P_w = \frac{T_{nw}}{T_{cw}} = \frac{0.84}{0.6} = 1.393\%$

$= 139.3\%$

Problem 2.11

The normal time for a work cycle in a worker-machine system is 6.27 min. For setting the standard time, the PFD allowance factor is 12%, and the machine allowance factor is 25%. The work cycle includes manual elements totaling a normal time of 5.92 min, all but 0.65 min of which are performed as internal elements. Determine (a) the standard time for the cycle and (b) the daily output at standard performance. (c) During an 8-hour shift, the worker lost 39 min due to personal time, rest breaks, and delays, and she produced 72 pieces. What was the worker's pace on the operator-controlled portion of the shift?

(a) $T_{nw} = 0.65$

$T_M = 6.27 - 0.65 = 5.62$ Min

$T_{nw_i} = 5.92 - 0.65 = 5.27$ Min

$T_{std} = T_{nw}(1 + A_{PFd}) + Max\left(T_{nw_i}(1 + A_{PFd}),\ T_M(1 + A_M)\right)$

$= 0.65(1.12) + Max\left(5.27(1.12),\ 5.62(1.25)\right)$

$= 0.728 + 7.025 = 7.753$ Min

(b) $Q_{std} = \dfrac{T_{sh}}{T_{std}} = \dfrac{8 * 60}{7.753}$

$= 61.9$ PC $\simeq 62$ PC

(c) Time Worked $= 480 - 39 = 441$ Min

$Q = 72$ PC

Total Machine time $= 72 * 5.62 = 404.64$ Min

Total Worker Controlled time $= 441 - 404.64$

$= 36.36$ Min

$T_{cw} = \dfrac{\text{Actual time worked}}{Q} = \dfrac{36.36}{72}$

$= 0.505$

$T_{nw} = 0.65$

$P_w = \dfrac{T_{nw}}{T_{cw}} = \dfrac{0.65}{0.505} = 1.287$

$= 128.7\ \%$

End of Ch (2)