MENG 344
Work Analysis and Design
The Work Environment

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Outline

• General Considerations
• Noise
• Climatic Conditions
• Health and Safety
• Working Premises
• Lighting
• Ergonomics
General Considerations

• Interdependence of productivity and working conditions.
• Conditions include health, safety, comfort.
• High indirect cost associated with bad conditions.
• Fatigue may lead to higher rejects and lower productivity.
• Ergonomics should be given better considerations.
• Worker satisfaction very important for productivity.

Noise

Check http://www.chs.ca/info/index.html
Noise and Vibration

**Noise:** Any disagreeable or undesired sound. Unit of measuring noise is Decibel (dB)

-Human ear responds to frequencies over the approximate range of 20 to 20,000 Hz

• Exposure to continuous noise levels of 90 Db or above is dangerous to hearing

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**Noise can cause various problems:** 1. It impedes sound communication

*Figure 15. Distance at which the normal voice can be heard against background noise*
Noise can cause various problems:

2. Physical Problems:
   - Sensorimotor
   - Neuro-vegetative
   - Metabolic disorder
   - Industrial fatigue
   - Irritation
   - Reduced productivity
   - Occupational accidents

   Reduction in the background noise leads to marked decrease in the number of errors and a significant improvement in production
Noise can cause various problems:

3. Permanent damage to hearing

Prolonged exposure to noise above certain levels may lead to deafness

Deafness

Temporary
- High noise intensity in short durations
  - Few seconds to few days

Permanent
- Moderate intensity noise but for years
  - May cause damage to the ears

Table 4. Duration of continuous noise exposure which should not be exceeded to ensure the prevention of occupational deafness among the majority of workers

<table>
<thead>
<tr>
<th>Daily duration of noise in hours (dBA measured “slow”)</th>
<th>Noise level in dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>8</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>95</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>1/2</td>
<td>105</td>
</tr>
<tr>
<td>1/4</td>
<td>110</td>
</tr>
<tr>
<td>1/8</td>
<td>115</td>
</tr>
</tbody>
</table>

Source: American Conference of Governmental Industrial Hygienists (ACGIH). Threshold limit values for chemical substances and physical agents in the workplace environment adopted by the ACGIH for 1997-86 (Cincinnati, Ohio).
Noise Control:
1. Reduce noise at source
2. Reduce noise transmission
3. Personal noise protection

Vibration
Vibration may cause severe health problems

1. Reduce vibration levels
   Use of vibration-absorbing mountings
   Provide heavy foundations

2. Reduce the effect of vibrations
   Use vibration-damping handles

3. Control the period of exposure
   Medical Examinations
Climatic Conditions

The objective of the control of climatic conditions is to reach thermal balance.

**Working in a hot environment**
- Examples include: furnaces, kilns, deep mines, foundries, glass work, hot rolling mills, tropical countries.
- Sweating and evaporation (good ventilation)
- Humidity hinders evaporation
Working in a cold environment

- Workers may be exposed to a cold environment even in tropical countries
- Effect of cold environment (below 10C):
  Work: uncomfortable and affects work efficiency
  Worker: Shivering, Slowing down blood circulation
- Minimizing exposure to Cold Environment
- Personal Protection: Clothes, footwear, gloves and a hat
Working in a wet environment

In hot areas:
- Humidity VS. Hot environment
- Textile industry and laundries

In Cold areas:
- Humidity VS. Cold environment
- Relative Humidity should be in the range 40-70 %

Excessive dry air also causes respiratory diseases

Control of the thermal environment

By applying one or more of the following principles:
- Regulating the workroom temperature by preventing outside heat or cold from entering
- Provision of ventilation in hot places by increasing natural ventilation
- Separation of heat sources from the working area
- Control of humidity
- Provision of adequate personal protective clothing and equipment
Control of the thermal environment

- Reduction of exposure time
- Insertion of rest pauses between work periods
- Ensuring a supply of cold drinking water in hot environments and hot drinks in cold environments

<table>
<thead>
<tr>
<th>Table 5. Control of working climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of work</td>
</tr>
<tr>
<td>Sedentary work</td>
</tr>
<tr>
<td>Light physical work in a seated position</td>
</tr>
<tr>
<td>Light work in a standing position (e.g. on machine-tools)</td>
</tr>
<tr>
<td>Moderate work in a standing position (e.g. assembly)</td>
</tr>
<tr>
<td>Heavy work in a standing position (e.g. drilling)</td>
</tr>
</tbody>
</table>

Ventilation

- Ventilation is always necessary
- Min. necessary air flow = 50 cubic meters/hour/worker
- Ventilation vs. Air circulation

Workplace ventilation:

- Disperses the heat generated by machines and people at work
- Dilutes atmospheric contamination
- Maintains the feeling of air freshness
Health and Safety

Occupational hazards

- Methods of preventing occupational hazards:
  - ensuring that the workplace is safe and without risk to workers’ health.
  - Establishment of good occupational safety and health organizations within the enterprise.
  - Encourage participation of workers in safety and health activities.
Safety and health organizations

- Workers must know the level of hazards they are exposed to while doing a task; and they have all the right to remove themselves from hazardous working situations.
- Responsibility for safety and health can’t be isolated from day to day activities.
- Training on safety and health matters should be an integral part of training activities at any enterprise.
- Training courses to be given to all personnel existing in the enterprise to ensure that each one to performing his jobs in safe way.

Occupational accidents

- Quite ordinary actions are the most common causes of accidents.
- Younger workers mostly are the ones that have accidents.
- Invisible hazards (ie, inert gases, fumes, noise) are more common and dangerous than Visible hazards (leaking chemical, unfenced scaffolds, unlocked working zone of a robot).
Occupational accidents

- Technical progress is a double edged weapon.
- An accident is a result of a combination of factors; technical, physiological, psychological, environmental, …, etc.
- In developing countries, more personal factors have a role in occurring of an accident. These include malnutrition, social changes, customs, and lack of adaptation to industrial work.

Precautions to avoid accidents:
- Elimination of potential causes, both technical and human.
- Observing technical rules and standards.
- Safety training for all workers.
Main technical safety criteria

![Diagram showing four basic methods of controlling occupational hazards](image)

- **Figure 7.** The four basic methods of controlling occupational hazards classified by decreasing order of effectiveness

   1. **Hazard → Individual → Elimination of hazard**
   2. **Hazard → Individual → Removal of the individual from exposure**
   3. **Hazard → Individual → Isolation of the hazard**
   4. **Hazard → Individual → Protection of the individual**


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Work study role in accident prevention

- 30% of accidents occur during manual handling.
- Work study can reduce these by reducing the number of handling operations and distance involved.
- Also, a large percentage can be eliminated by eliminating hazardous tasks through work study.
Prevention of industrial accidents

- Fire prevention principles:
  - designing buildings, storage facilities in a way as to limit possible combination of oxygen, fuel, and increase in temp.
  - Eliminate or reduce sources of heat or ignition as to limit the rise in temperature.

- Preparedness for fire emergencies:
  - Work place should have an emergency plane (role of each worker during an emergency)
  - Presence of at least 2 marked, unobstructed exits.
  - Presence of a way to notify workers of a need to evacuate. (alarm or public address system)
  - Providing the right types of fire extinguisher.
  - Training workers on how to use fire extinguishers.
  - Presence of automatic fire protection. (Sprinklers)
Major hazard control

- Major industrial accidents affect the environment as a whole.
- Examples of major industrial accidents: explosions, major fires, leakage of toxic chemicals.
- These kind of accident can cause major injuries and even death.

Major hazard control

- Major hazard control system:
  - Identifying major hazard installations.
    “a system to identify plants where major hazards exists.”
  - Information about the plant.
  - Action inside the plant.
    “management is responsible for operating & maintaining a safe plant”
  - Emergency planning.
Major hazard control

- Emergency planning:
  - Set up and train a fire brigade.
  - Provide alarm system direct to the public emergency forces.
  - Draw up an emergency plan.

A well structured plan is one which can be quickly and effectively employed when a major accident occur.

Exposure to toxic substances

Pollution causes include:

Toxic substances released during the work process in the form of dust, gases, vapors or mists

Control:
1. Eliminate at source
2. Reduce exposure time
3. Personal protection
Personal protective equipment

- Technical prevention and administrative arrangements may fail.
- These equipment may be expensive.
- Workers may resist their use.

Working Premises
Layout Principles

- Isolating any operation which is hazardous or constitutes a nuisance.
- Work premises should be above ground level.
- Equipped for windows having a surface area not less than 17% of floor area.
- Minimum ceiling height of 3 meters.
- Minimum of 10 cubic meters of air per each worker (more for high temperature and atmospheric pollution levels).
- Free floor of at least 2 square meters per worker to avoid accidents.

Layout Principles

- Walls and ceiling finish must:
  - prevent accumulation of dirt.
  - avoid moisture absorption.
  - reduce noise transmission (if necessary).
Layout Principles

- Floor coverings (table 1) must be:
  - non-slip.
  - non-dust forming.
  - easy to clean.
  - good electrical and thermal insulator (if necessary).

Good House Keeping Elements

- Unnecessary items.
- Arrangement.
- Marking of gang ways, passages, and toxic matter.
- Cleaning.
- Working clothes.
- Wash rooms, showers, and toilets.
Importance of Good Visibility

- Essential factor in accelerating production.
- Reduces numbers of defective products.
- Cuts down waste.
- Prevents visual fatigue and headaches.
- Reduces accidents.
Factors Affecting Visibility

- Size and color of objects.
- Distance from the eyes.
- Persistence of the image.
- Lighting intensity.
- Contrast of colors and lighting levels with background.

On What Bases Do We Control Lighting?

Table 2. Recommended minimum values of illumination for various classes of visual tasks

<table>
<thead>
<tr>
<th>Class of visual task</th>
<th>Minimum illumination of task (lux)</th>
<th>Typical examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casual seeing</td>
<td>100</td>
<td>Boilerhouse (coal and ash handling); dead storage of rough, bulky materials; locker rooms</td>
</tr>
<tr>
<td>Ordinary rough tasks</td>
<td>150</td>
<td>Rough, intermittent; bench and machine work; rough inspection and counting of stock parts; assembly of heavy machinery</td>
</tr>
<tr>
<td>Moderately critical tasks</td>
<td>300</td>
<td>Medium bench and machine work, assembly and inspection; ordinary office work such as reading, writing, filing</td>
</tr>
<tr>
<td>Critical tasks</td>
<td>700</td>
<td>Fine bench and machine work, assembly and inspection; extra-fine painting, spraying, sewing dark-coloured goods</td>
</tr>
<tr>
<td>Very critical tasks</td>
<td>1,500</td>
<td>Assembly and inspection of delicate mechanisms, tool; and die-making; gauge inspection; fine grinding work</td>
</tr>
<tr>
<td>Exceptionally difficult or important tasks</td>
<td>3,000 or more</td>
<td>Fine watchmaking and repairing</td>
</tr>
</tbody>
</table>

1 These figures refer to the mean value of illumination obtained during the life of the installation and averaged over the work plane or specific task area (i.e., the so-called “average value of illumination”).

Source: ILO, International Occupational Safety and Health Information Centre (CIS): Artificial lighting in factory and office, CIS Information Sheet No. 11 (Geneva, 1983), Table 1.
General Guides For Good Lighting

Regular cleaning and maintenance for light sources

Figure 9. Mounting of general lighting units

General lighting units should preferably be mounted as high as possible.
Source: LO, CIS, Artificial lighting..., op. cit., figure 18.

General Guides For Good Lighting

Light Should be uniformly diffused.

Figure 10. Need for general lighting

Some general lighting is always needed even when tasks are locally lit. (1) Uniform general lighting (2) Local supplementary lighting.
Source: LO, CIS, Artificial lighting..., op. cit., figure 21.
General Guides For Good Lighting

Reduce shadows.

No excessive contrasts in lighting levels between worker’s task and the general surroundings.

Table 3. Recommended maximum lighting intensity ratios

<table>
<thead>
<tr>
<th>Points involved</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between the work and the immediate environment</td>
<td>5 to 1</td>
</tr>
<tr>
<td>Between the work and distant surfaces</td>
<td>20 to 1</td>
</tr>
<tr>
<td>Between the light source or the sky and adjacent surfaces</td>
<td>40 to 1</td>
</tr>
<tr>
<td>...All points in the worker’s immediate vicinity</td>
<td>80 to 1</td>
</tr>
</tbody>
</table>
General Guides For Good Lighting

Avoid glare

Figure 12. Factors influencing the degree of glare produced by a given diffusing fitting (or a bare fluorescent lamp unit)

(1) Mounting height

Glar is worse when the mouting height of the installation is lowered, since the lighting units then approach closer to the horizontal line of sight.

This is more glaring than this

(2) Size of room

Glar is worse in large rooms than in small ones, because of the additional glare produced by the many distant units which are seen close to the horizontal line of sight.

This is more glaring than this
General Guides For Good Lighting

Avoid glare

When a substantial amount of light is emitted from the sides of a fluorescent fitting, the unit will be much more glaring when viewed broadside-on than when viewed end-on, since in the latter case the apparent area of the bright side panels (1) will be greatly diminished. This does not apply to the horizontal base panel (2), for though this panel looks a different shape, its apparent area remains the same, hence the glare produced by recessed units (and units with unit sides) is much the same regardless of whether they are viewed endwise or crosswise.

Source: E O. C.S. Artificial Lighting... op. cit., Table IV.

Use of fluorescent lighting

Figure 13. Relative cost of incandescent and fluorescent lighting

(1) Fixed capital charges
(2) Point of equal cost
--- Fluorescent lighting
--- Incandescent lighting

Source: E O. C.S. Artificial Lighting... op. cit., Figure 1.
Use of Colors

- Color selection
- Psychological
- Safety.

![Color Selection Diagram]

Control of Lighting

- Independent switches
- Avoiding using highly shiny, glossy work surfaces.
- Localized lighting.
- Cleaning lighting fixtures and following maintenance lighting schedule.
- Avoid direct eye contact with the light sources.
Control of Lighting

- For work with visual display units (VDUs):

  - general lighting level should not exceed 500 lux.
  - avoiding glare by suitable positioning of the VDU.
  - adjustable luminance and contrast of the screen and keeping sharp characters.
  - additional lighting must be adjustable to avoid glare.

Ergonomics

“science dealing with the application of information on physical and psychological characteristics to the design of systems and devices for human use”

*Encyclopedia Britannica*
Ergonomics

Ergonomics is concerned with:
- Study of the operator(s)
- Provision of data for design

Aim of ergonomics:
Enhance functional effectiveness while maintaining or improving human welfare (human welfare goes beyond safety of the operator and aims to ensure well-being of the operator)

Some Tasks of the Ergonomist:
- Develop most comfortable working conditions for workers
- Reduce physical workload
- Simplify handling of machines and controls
Ergonomics and Work Study: The Operator/Machine Interface

-A machine provides information to the operator through displays
-This process can be enhanced or degraded depending upon the quality of the displays selected
-Controls are instruments that permit the manipulation of the machine

Displays

There are three sensory channels through which displays transfer information:
-Visual (for maximum precision and agreement between operators)
-Auditory (for maximum attention)
-Kinaesthetic (movement perception; used for maximum speed and minimum attention)
C. Dial patterns

Superior design

Reasonable alternatives

Poor designs

D. Display stereotypes

Expected

Unexpected

A. Types of display

Real

Artificial

Static

Dynamic

Analogue

Digital

Pictorial

Qualitative

Quantitative

B. Scale patterns

Good designs

Poor designs

Good designs

Poor designs
Control of Operations

Two essential factors are involved in the control of the running of operations:
- Time (to exert control or react to an event)
- Space (that permits freedom of movement when exerting control)
Control of Knobs

The size and shape of a control knob can make a significant difference for a user with weak grip or for someone with cold hands. The choice of material can also affect the ease with which the knob can be gripped. The shape can help a visually impaired person select the correct knob; the shape can also be used to help the user associate the function with the key.

Working Time

- How long should employees work?
- When is the most appropriate time for working?
- How often and how long should rest pauses be?
Working Time: Hours of Work

- Case studies show that average productivity rises rapidly as excessive hours are reduced.
- Long hours of work are linked to occupational accidents.
- Exhausted workers may suffer from social life and health damage.
- The standard established by the IL conference is the 40-hour week (1962).

Working Time: Overtime

- Overtime is a form of exceeding normal hours of work.
- Overtime should minimized.
- Most countries do so by establishing a daily, weekly or monthly limit.
Working Time: Breaks and Rest Pauses

- The role of breaks during working day is to dissipate fatigue and restore the worker’s physical and nervous energy
- Most effective breaks are short and frequent
- For the same productivity and health considerations, a worker should be allowed daily and weekly rests
  - daily: 11-12 hours
  - weekly: 24-48 hours (uninterrupted)

Working Time: Night Work

- Many studies show that night work can be harmful to the health of workers due to the change in eating and sleeping habits
- Night work may also have consequences on the social life of workers
- ILO introduced measures for protecting night workers (financial compensations, rests,...)
Working Time: Flexible Arrangements

Call for less traditional working time schedules because of

- Social changes (women in the workforce,…)
- Advantages for employers (deal with seasonal fluctuations, longer operating times)

Facilitated by technological advances

Working Time: Flexible Arrangements

**Staggered Hours:**

- Staggering of arrival and departure times for workers
- Extend operation time and overcome arrival and departure time congestions
- Used when different parts of an enterprise can operate for short periods of time separately
Working Time: Flexible Arrangements

**Flexitime**

- Starting and finishing times are decided freely by employees provided that everyone is present during core time
- Advantage for recruiter, stress reduction, improved productivity
- Staffing (and supervision) problems at certain times of the day

Working Time: Flexible Arrangements

**Compressed Workweek**

- Longer working days, shorter working weeks
- Savings on overhead and starting time, longer weekends
- Decline in performance at the end of the day, accidents, scheduling problems
Working Time: Flexible Arrangements

Shift Work:
- Discontinuous (morning and afternoon, 5-6 days/week)
- Semi-continuous (24 hours/day, Week-end off)
- Continuous (24 hours/day, 7 days/week)

Working Time: Flexible Arrangements

Hours Averaging
- Working time schedule respects agreed normal hours of work *on average* (but more or fewer hours at certain times)
- Deals with seasonal fluctuations, saves on overtime, only permanent employees are used
- Great effort in time management and advance scheduling
**Work-related Welfare Facilities**

The role of these facilities is to:
- attract, retain or motivate workers
- reduce fatigue

They Include:
- Safe, cool drinking water (to decrease fatigue)
- Sanitary facilities (toilets, showers,...)
- First-aid and medical facilities (injuries and sickness)
- Rest facilities (seats, shelters,...)
- Feeding facilities (cheap, clean and nutritious food)
- Childcare facilities (for working mothers)
- Recreational facilities (libraries, sports facilities,...)
The right chair height is important for your comfort in your work area. Take the time to examine the adjustment features of your chair and experiment with them to determine what setting is most comfortable for you.

To determine the proper height of your chair, sit with your shoes flat on the floor, with shins exactly perpendicular to the floor; knees should be bent at a 90 degree angle. Measure from the hollow of the knees to the floor. Subtract 2” to 3” from the above measurements. The adjusted measurement is the recommended height of your chair seat. The backrest should be adjusted to support the small of your back (it should fit right into the curve of your back when you are seated). Your chair should not lean back too far, or too far forward.

If your feet do not rest comfortably on the floor, you may want to request a foot rest to lessen the stress on your back, feet and legs. You should sit slightly reclined, between 110 and 130.
Work comfort

The proper adjustments to the monitor are as follows:
The top of the screen should be no higher than eye level. In general, the
top of the actual screen (not the plastic portion of the monitor) should be
level with your eyes. The screen should be approximately 13 to 28 inches
from your eyes. If the screen can be tilted, the screen face should be tilted
back about 10 to 20 degrees for easier viewing. This can be adjusted for
the preference of each user, but one should never sit closer than 11 inches
or farther than arms reach (about 31 inches).

If your work requires constant looking back and forth between papers and
the screen, a document holder is recommended. The holder should be
next to the screen and as close to eye level as possible.

Some Tips On Your Computer Screen:
The top of the screen should be even with your eyes (If you wear bifocals, you
will want the screen lower).

The screen should be positioned to prevent glare.
The brightness and contrast should be comfortable to you.
The colors on the screen should be comfortable to you.
The screen should be at the proper distance from you.
The screen should be directly in front of your desk.
Your source document should be in the right place, preventing eye strain.

If You Wear Bifocals:
If you wear bifocals, you will want your screen lower to be able to see out of
the close vision portion of your glasses. This means your screen should be set
on your desk (not the CPU) and tilted backwards slightly.
**Work comfort**

**Adapt the Work Area**
There are many ways in which you can make your work area more comfortable and better suited to your specific needs. Research has provided some guidelines regarding the use and design of your work area which may prove to be very helpful.

Your work area should be designed to maximize the worksurface flow, storage capabilities and lighting requirements. This type of design allows you free flowing movement within your work area. You should be able to slide your chair under the worksurface with your legs having adequate room. On average, a desk should be 26-29 inches above the floor, unless you are especially tall.

**The Best Layout for Your Work Area**
The best layout for you depends on what you do and your individual size. For example, if you perform the same task over and over, you should arrange your equipment to allow for the uninterrupted flow of materials. Equipment and files you use frequently should be located next to you.

**How To Organize Your Work Area**
- You should not store items where your legs need to be. You do not want to obstruct your leg movement.
- The work area should not be cluttered, allowing ample room for you to do your job and have your telephone, computer, etc. on the desk.
- All worksurfaces should be installed at the same height, 29 inches. Surface heights can be adjusted depending on the task and equipment needed to perform that task.
- Storage space can be provided below and above the worksurface.