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HEALTH, SAFETY AND ENVIRONMENT

HUMAN FACTORS

(GUIDELINE)

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SUMMARY

The purpose of this document is to provide the reader with knowledge relating to the background and philosophy of Human Factors (HF), the associated techniques of HF, when to use them and applications within PETRONAS.

This guide describes the approach of Human Factors Analysis, a generalised methodology aimed at assessing and improving human performance in technical systems. It:

- a) defines what Human Factors (HF) is
- b) explains why it represents an important consideration in Engineering Design and Health, Safety and Environment management
- c) describes how HF can be incorporated into the planning and review of assets and activities according to the EP business model
- d) describes the generalised approach (the HF Process), its techniques, and when to use them
- e) relates these HF tools to other parts of the Hazard and Effects Management Process (HEMP)

The objectives of using human factors are to protect people and assets from hazards caused by human error, and to enhance efficiency and usability of systems. Nine of the major techniques of HF, which are viewed as being valuable additions to PETRONAS's HEMP tools, are each summarised in the Appendix 1 Overview of HF Techniques.

1. SCOPE OF HUMAN FACTORS

Human Factors (HF) and Ergonomics have evolved to occupy the same field of study. Although Human Factors engineers and ergonomists use the same techniques, the origins of the two fields differ. Human factors emerged from the military, concentrating on human performance, while the focus of ergonomics has been on worker safety and comfort. Human factors are the term used predominantly in the United States and a few other countries. The term ergonomics, although used in the United States, is more prevalent in Europe and the rest of the World. Some people have tried to distinguish between the two, but the distinctions are arbitrary and for all practical purposes, the terms are synonymous.

The approach of Human Factors (HF) is the systematic application of relevant information about human capabilities, limitations, characteristics, behaviour and motivation to the design of equipment and procedures used by people and the environments in which they use them. This involves scientific investigations to discover relevant information about humans and their responses to stimuli in their environments. This information serves as the basis for making design recommendations and for predicting the probable effects of various design alternatives. The human factors approach also involves the evaluation of the products of design to ensure that these satisfy their intended objectives.

The objectives of Human Factors are fourfold:

- To protect the users' safety and health (integrity)
- To prevent human errors and/or its consequences (reliability)
- To enhance productivity by optimising human efforts (efficiency)
- To enforce ease and comfort of operations (usability).

Including provision of benefits to the individual worker as well as to system performance.

Although no short catch phrase can adequately characterise the scope of the human factors field, such expressions as *designing for human use* and *optimising the environment in which we perform* give a partial impression of what Human Factors is about. The definition below combines the essential elements of the objectives and approach discussed above:

"A multidisciplinary field of science and its application that considers the integrated knowledge of human capabilities, limitations and needs, in the interaction between human - technology-environment for the design of work systems, workplaces and products".

The benefits are measured in terms of system safety, reliability and life cycle cost savings.

It would be remiss not to mention what human factors are not. The following are four things human factors are not.

- 1) *Human factors is not just applying checklists and guidelines.* To ensure consistent input, human factors engineers develop checklists and guidelines; however these are only aids to the human factors analysts. There is not a checklist or guideline in existence today that, if it were blindly applied, would ensure a good human factors product. Trade-offs, considerations of the specific application, judgment, and user feedback are things that cannot be captured by a checklist or guideline but are all important in designing for human use.
- 2) *Human factors is not using oneself as the model for designing things.* Just because a set of instructions makes sense to an engineer, there is no guarantee others will understand them. Just because a designer can reach all the controls on the machine, is no guarantee that everyone else will be able to do so. Human factors recognise individual differences and the need to consider the range of characteristics of user populations in designing objects for their use.
- 3) *Human factors is not just common sense.* To some extent, use of common sense would improve a design, but human factors are more than just that. Knowing how large to make letters on a sign to-be read at a specific distance, or selecting an audible warning that can be heard and distinguished from other alarms, is not determined by common sense. Knowing how long it will take operators to respond to a warning light or buzzer is also not just common sense. Whilst human factors recognise that certain visual relationships have an instinctive element, for example in the siting of displays with respect to controls, these relationships have to be carefully analysed and rule sets derived before they can be relied upon.
- 4) *Human factors is not the same as human issues.* Quite often people say that attention should be given to 'human factors' when they mean to say 'human issues'. Human factors is an *academic field of study as well as a structured approach* in design for applying tools and techniques for optimising work systems. In contrast, human issues may embody practically everything which has to do with 'humans' and is not always the direct concern for the designer/human factors engineer e.g. accounting for an operator's dysfunctional family life in the design of a system. Engineers/ designers need to be given the tools to understand human performance and the role it plays in the system's functioning. Engineers do not need to be able to predict human performance but they need to understand the range of possibilities and effects the human can exert on a system and then safeguard the system to protect it. The term human factors were not meant to be used to incorporate any issue which has to do with humans which is difficult to handle.

Human factors are primarily based on and including the human in the concept or loop of a "system".

1.1 MODEL OF THE HUMAN - MACHINE SYSTEM

A central and fundamental concept in human factors is the system. A system is an entity that exists to carry out some purpose. A system is composed of humans, machines, materials and the work environment which work together to accomplish some goal (i.e. these same components could not produce independently). Humans have the ability of being able to make judgements, act in changing environments and make decisions based on induction. Machines are not able to adapt and operate in a changing environment nor can they reason as humans can. However, within a human/machine system, the component with the most variability and potential for failure is the human.

Therefore, to properly address the issue of system reliability, we must optimise the integration and compatibility of the human and machine components within that system.

A human-machine system is a combination of one or more human beings and one or more technical components interacting to bring about, from given inputs, some desired output. In this frame of reference, the common concept of machine is too restricted, and should consist of virtually any type of physical object, device, equipment, facility, or thing, which is used to carry out some purpose. In a relatively simple form, a system could be a hammer and a person. Going up the scale of complexity, a system could be a lawn mower, or a paper copier. More complex systems include an aircraft, or a semi automated gas plant along with its personnel. The essential nature of people's involvement in a system is an active one, interacting with the system to fulfil the function for which the system is designed.

The typical type of interaction between a person and a machine is illustrated in Figure 1. This shows how the displays of a machine serve as stimuli for an operator, trigger some type of information processing on the part of the operator (including decision making), which in turn results in some action (pressing a button) that controls the operation of the machine.

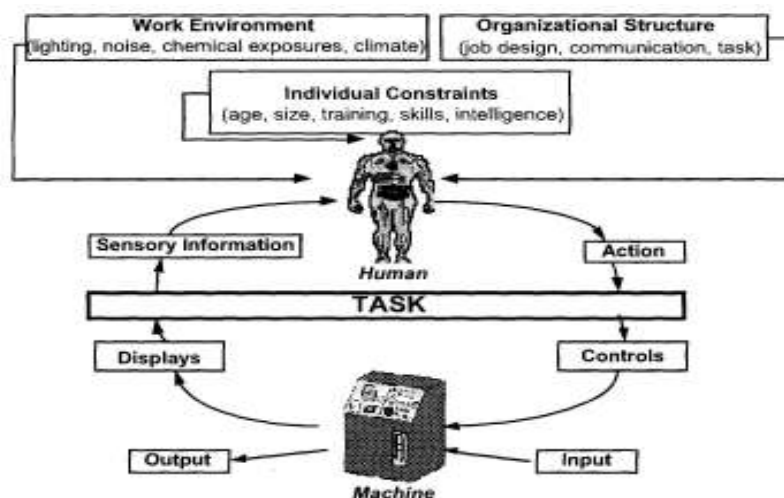


Figure 1: SCHEMATIC REPRESENTATION OF A HUMAN – MACHINE SYSTEM

1.2 HUMAN FACTORS IN SYSTEM DESIGN

Over the years, HF has developed many techniques for understanding how the components of the human - machine system, especially the human component (perception of stimuli, processing of information, responsiveness), actually function. Techniques, which accomplish these lie in the psychological realm.

HF also includes techniques for analysing the "hardware" or physical layout of systems. Techniques utilised for analysing the physical layout and design of the system are more engineering than psychological yet still are considered HF techniques because of the effects caused to and by the human operator.

Many HF techniques involve breaking down the operator's task into its smaller components, which can be modelled by the human-machine system portrayed in Figure 1. Models are often used to better describe or simplify the interaction between the human and the technical part of the system.

Without using these techniques, it would be difficult for the HF analyst to know clearly when the human input is playing a role on system performance even when the human input is not directly involved in one of the system tasks.

When the human is excluded from performing system sub tasks (perhaps in the case of allocating complex computations to the computer, or performing a physical function which exceeds the capabilities of the operator), careful attention needs to be given when bringing the operator back into the system loop.

Certain HF techniques are designed for the purpose of task allocation while other techniques are used for analysing systems. Each technique has its own purpose(s) and limitations on when it should be employed. The HF analyst plays a major role, in deciding where, when and how the techniques should be employed.

2. **HUMAN FACTORS TECHNIQUES**

This section gives an outline and a short description of the main HF techniques. The three most frequently used HF techniques (numbers 1, 2 and 3 below) are explained in detail using case scenarios provided in Section 4. Appendix A details for each technique: what the technique is, when and how it should be used, what kind of competence and experience is needed to implement it, and what the strengths and weaknesses are.

To familiarise the reader with the HF tools, nine techniques are listed below with a short description:

- 1) Hierarchical Task Analysis (HTA) - A general technique for systematically describing a task by breaking down the task into smaller task components. Each task component (sub-task) has an associated goal which must be reached
- 2) Link Analysis - A technique which is used to identify relations between an individual and one or more parts of the system. Here, a part of the system can be either a physical part of a machine or communication with other individuals
- 3) Human Error/Reliability Analysis - Qualitative and quantitative techniques for considering the errors identified in the decomposition analysis (HTA) and determines their likely consequences, means of error recovery (if any), and potential error reduction measures.
- 4) Walk/talk - Through Analysis - Walk-through require personnel to perform some sort of demonstration of a task in realistic surroundings, without necessarily undertaking that task. Thus in a large system walk-through, subjects would probably walk around the plant pointing in turn to the controls and displays which they would use for successive steps, and explaining how and why each of these would be used. A talk-through is very similar, but it is undertaken more remotely from the normal task location so that the tasks are verbalised rather than demonstrated (Meister, 1986).
- 5) Task Allocation - This technique is concerned with the distribution of system functions between system equipment and human operators, as some tasks are best performed by machines and others by people
- 6) Ergonomic Checklists - These checklists can be used to see how good a system satisfies certain ergonomic demands/requirements.
 - a) Generic checklists - a list of points for checking the absence or presence of general ergonomic requirements.
 - b) Specialised checklists - a list of points for checking special items/subjects e.g. VDU workstations, manual handling etc.
- 7) Simulations - Artificial situations set up to mimic the actual working environment. These approaches are aimed at compiling data on human interaction with the system to create a more dynamic model of what actually happens during the execution of a task:

- a) Mock ups - a physical representation of the system with a high or low level of system functioning used to test layout and identifying links between system attributes.
 - b) Simulator trials - used for determining training needs, identifying places where system deviates from specifications and determining the difficulties in the human - machine interface.
- 8) Ergonomic Standards - Standards have been developed from empirical and laboratory research as well as best practice in industry which incorporate ergonomics data to facilitate workplace layout or task execution. These standards are aimed at improving individual safety or system performance. A list of relevant ergonomic ISO standards is given in the References section.
- 9) Job Hazard Analysis - Job Hazard Analysis (JHA) is the application of the hazards and effects management process at the task level, identifying and assessing the hazards of each element of the task and defining appropriate controls and recovery measures. The methodology is derived from the work study technique known as Task Analysis, and is known variously as Job Safety Analysis (JSA), Work Safety and Health Analysis, Activity Risk Assessment (ARA).

2.1 SELECTION OF HUMAN FACTORS TECHNIQUES ACCORDING TO OBJECTIVES

How does one know when to use a particular HF tool? What should one do if several HF techniques are applicable at the same stage in the asset lifecycle? A good solution to these questions is mapping each technique to one or more HF objectives. If one objective is being focused on in a project, the choice of techniques can be narrowed down.

As discussed in Section 1.1, the philosophy and main objectives of Human Factors, is fourfold:

- To protect the users' safety and health (integrity)
- To prevent human errors and/or its consequences (reliability)
- To enhance productivity by optimising human efforts (efficiency)
- To enforce ease and comfort of operations (usability).

As an organisation becomes more advanced with its system performance objectives, it will start to analyse not only the hardware and process in its facility (the basic minimum for operation), but also begin to look towards achieving higher system goals, (Figure 2). HEMP tools have demonstrated a side effect of eliminating hazards in a facility in higher profits directly a result of reducing losses). An organisation's performance can be raised even more by fulfilling these higher order objectives. HF objectives range from eliminating hazards to increasing the usability or efficiency of a system. Although the degree of analysis is also more detailed at higher levels in the triangle, the results can be quite profitable.

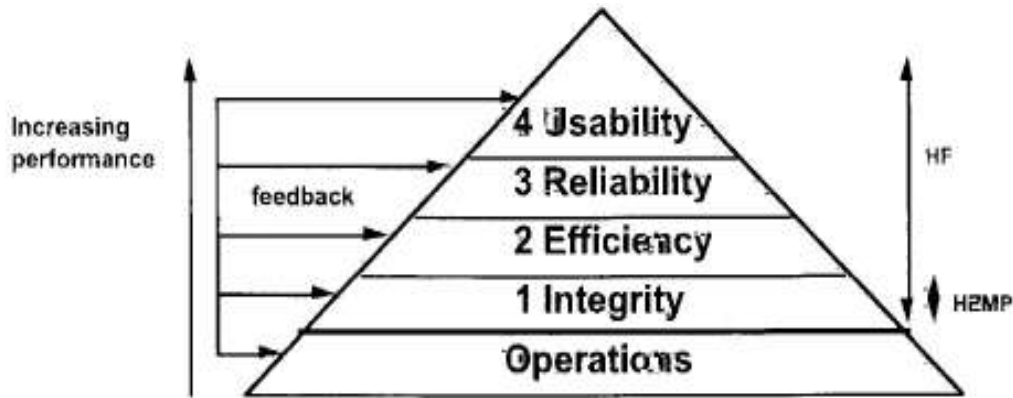


Figure 2: SYSTEM PERFORMANCE OBJECTIVES OF HF

These objectives are difficult to achieve simultaneously. Each objective has several associated HF techniques to facilitate realisation of the goal. For example, if safety is the primary concern for a study, HF techniques, which focus on the safety of the plant operations, should be used. If efficiency of the system is the primary concern, HF techniques which focus on evaluating the work flow of operations are used. If both of these objectives are desired, then most of the HF techniques are employed to ensure that the operator and the tasks surrounding the work environment are properly studied. These HF techniques or derivatives of them should be utilised when considering the user in a design. Good designs require these analyses as a minimum standard.

Table 1 map four HF objectives listed above to their associated HF techniques. (The faces indicate that the technique corresponds to that objective along with its level of importance). The user should determine which techniques satisfies the current objective(s) and then narrow down the choices (if necessary) by applying some of the other criteria listed in the descriptions in the Appendix (advantages of the particular technique, required effort, expertise needed and drawbacks of using a technique).

Alternatively, one can narrow down the choices of HF techniques by combining particular objectives together. For example, if one wanted to minimise the number of HF techniques performed but wanted to use the technique for different objectives, then a versatile technique should be selected. However, if the technique is used for multiple purposes, it might be necessary to modify it slightly to fit the situation.

Table 1: HF OBJECTIVES AND THEIR ASSOCIATED TECHNIQUES

HF Techniques/Objectives	Integrity	Reliability	Efficiency	Usability
1) Hierarchical Task Analysis	☺☺	☺☺	☺☺	☺
2) Link analysis	☺	☺	☺☺	☺
3) Human Error/Reliability Analysis	☺	☺☺	☺☺	☺☺
4) Task allocation	☺☺	☺☺	☺	☺
5) Ergonomic Checklists	☺	☺	☐	☺
6a) Simulation - Mock up	☺	☺☺	☺	☺☺
6b) Simulation - Training	☺	☺☺	☺	☺☺
7) Ergonomic Standards	☺☺	☐	☐	☺
8) Walk/Talk Through	☺	☺	☺	☺
9) Job Hazard Analysis	☺☺	☺☺		

☺☺ = Most applicable

☺ = Applicable

☐ = Not applicable

3. THE ROLE OF HUMAN FACTORS IN ASSETS AND ACTIVITIES MANAGEMENT

Human Factors input varies within Assets and Activities Management. Before an installation is built, there is an opportunity to design the installation to facilitate good operability, accessibility, maintainability and usability for the operator. Utilising several HF techniques at various design phases should help a designer analyse the critical aspects of the facility and design around the known potential bottlenecks. Over the span of the entire lifecycle of an asset, operating costs should be greatly reduced when employing human factors techniques in the design, yielding larger profits while still maintaining attention to HSE issues.

Within the management of existing assets via its activities, practically all of the design decisions and equipment selection has already been taken, and operators are quite often forced to "make do" with the current system design configuration. During Activities Management, Human Factors is not used to a large extent for redesigning things which should have been accounted for before the installation was built but rather for making smaller changes, to procedures, training or physical additions to equipment to aid the operator in his daily activities. Although improvements to procedures are not as effective in ensuring safe conditions for the worker as having a good design, it is usually not cost effective to go back and modify hardware after it has been built. Therefore, procedures are used as a second defence to help manage design deficiencies.

3.1 PLANNING AND REVIEW OF ASSETS

Planning for the entire lifecycle of an asset takes considerable analysis not only in minimising the CAPEX but also the OPEX. The results of implementing human factors tend to influence OPEX to a greater degree than CAPEX. The failure to implement HF studies at the right time in the design sequence can result in costly modifications when commissioning an asset.

3.1.1 Specific HF tools for the asset lifecycle phases

During the initial phases of the asset lifecycle, less information is known about the asset as then when the asset is being constructed. When the asset is in its conceptual stages, Human Factors and other HEMP tools are used to help designer's better picture the future design of the facility. Most HF tools are intended to provide a clearer picture for the designer of how operators will function in the work environment. If problems are discovered with the human/machine interface as a result of performing an analysis, solutions can be found and implemented before the project progresses to a stage where implementation becomes too costly. Therefore HF tools which help early on in the asset lifecycle are usually the most effective. The figure below shows the phases in the asset lifecycle where the relevant HF tools are most effective.

It has recently been recognised that some HF techniques are more appropriate for different stages in a project's development. The next section explains how to use human factors techniques within the EP project management lifecycle business model. Table 2 illustrates when a HF tool should be called up for execution in a particular phase in the asset lifecycle. The alphanumeric code in the title of each section heading corresponds to the number of the executed activity from the

(PETRONAS equivalent insert here)

Table 2: HF TOOLS IN ASSET LIFECYCLE PHASES OF THE EP BUSINESS MODEL (amend to reflect equivalent process step)

Project phase	HTA	HF Link Analysis	Tools Human Error/Reliable Analysis	Task Allocation	Check-lists	Simulations	Standards	Walls/talk through	Job Hazard Analysis
Prepare conceptual design (A-12.01)		○							
Define preliminary facility layouts (A-12.01.10)	●	●							
Finalise HSE requirements (A-12.01.11)	●			●					
Finalise Operating requirements (A-12.01.12)	●		●	●	●		●		○
Compile project specifications (A-12.01.13)									
Prepare detailed layout and construction design (A-12.02.09)		●			○	●	○		○
Prepare detailed HSE assessment (A-12.02.10)	●		●						
Compile approved for construction (APC) package (A-12.02.12)			○			●		●	
Erect facilities and prepare as-built drawings (A-12.03.02)					○			●	●
Precommission facilities (A-12.03.03)								●	●
Commission facilities (A-12.04.01)						○			●

● = Most applicable
○ = Valuable

3.1.1.1 Prepare conceptual design (insert equivalent)

During the conceptual design phase, technical integrity and coarse layout of the asset is considered. Input to the conceptual design should consist of designers having an idea about not only of the system process, but also the major activities performed on the system by the operators. Once these major activities are known, they can be accounted for in the layout of the facility. As soon as there is an involvement of humans interacting with the system, HF tools should be utilised. However, traditionally, at the conceptual design phase the added value of input from previous designs and operator experience was not considered enough and the designs were mainly process and hardware related. Yet the placement of major components in a facility can be moderated by the added knowledge of the major activities in operations the facility will support. Using this knowledge can make a facility more efficient and safer.

For example, if after performing an analysis of the operator's daily activities, it is realised that the operator must check the level of oil in the storage tanks 6 times a day and in order to do that, he needs to walk initially to the control room to contact the supervisor, then to the supply area to get the calibrated measuring device and then to the storage tanks to take the readings, this accounts for 50% of the operator's time over the course of a shift. Perhaps these distances can be minimised between the various areas in order to make the operator's task more efficient and hence utilise the operator for another task. However, the conceptual design phase is the perfect time in the asset lifecycle to perform these cursory analyses. The HF tool used to examine this layout based on the operator's task is the *link analysis*.

3.1.1.2 Define Preliminary Facility Layouts (insert equivalent)

The link analysis example above is essential during this stage of the conceptual design. It is important that the operator's major tasks are reflected here in the gross layout of the facility. Furthermore, in order to plan the escape routes, it is important to understand the possible places the operator is likely to be situated at during both normal and critical operations. Combined with the results of the *link analysis*, *task analysis* would adequately address the issue of operator location.

3.1.1.3 Finalise HSE Requirements (insert equivalent)

In this stage of the asset lifecycle, risk control and HSE philosophies are prepared. Furthermore, CAPEX and OPEX estimates are also prepared. During this stage, ergonomic requirements such as philosophies regarding manual handling, physical and mental workload, hazards in the work environment, alarm management and reducing the effects of human error in relation to safe guarding systems should be considered along with their estimated costs. Using an *ergonomic cost benefit tool* especially designed for justifying both tangible and intangible benefits obtained from implementing ergonomics provides insight into relative costs for fulfilling these ergonomics philosophies. Furthermore, *task analysis* should be used to help setup manual handling philosophies. If a lifting task is to be repeated frequently over the course of a shift or if the weight to be lifted is heavy and/or awkward, *task allocation* will help determine this and hence consequently develop the manual handling policy.

3.1.1.4 Finalise Operating Requirements (insert equivalent)

Besides all of the regulatory operational requirements defined in this stage, the operations to be performed are also specified. To a large extent, operations to be performed are based on the internal production process and the associated tasks which need to accommodate the functioning of the physical part of the system. However coinciding with the Human/Machine Model of a system in Figure 1, there is no clear specification for whether the machine or human should be the primary caretaker of the task and which role should be the supporting function.

If a reference facility and its operations is used as a baseline without questioning the premises which comprised it, *task allocation* (or functional allocation as some refer to it) becomes irrelevant because all of the decisions, regarding who will be performing each task, is taken over from the reference facility. Consequently, there can be major problems in safety and efficiency of a new facility if old philosophies such as whether to automate or not are taken on without careful analysis.