



INCORPORATION OF HUMAN FACTORS IN THE DESIGN PROCESS

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1. Introduction

Tightening demands upon product quality, efficiency and safety of process plants increase the importance of improving the reliability of operators to avoid or control critical process conditions. The consideration of Human Error to avoid mal-operations has been a common practice in nuclear and aeronautical industry for some time. Currently the term Human Error is increasingly being utilized in process industry [Iliffe, 2000]. However, standards and guidelines on Human Factors consideration in design and operation of chemical and petrochemical processes are needed.

In figure 1.1 different methods to reduce the number of accidents are shown. It can be seen that in the past the number of accidents was primary reduced by seeking Engineering and Hardware improvements. Later, it came to the conclusion, that to further decrease the number of accidents, Safety Management Systems (SMS) and procedures had to be improved. Today, integration of HF to the knowledge of hardware and procedures is aimed at further reducing the number of accidents.

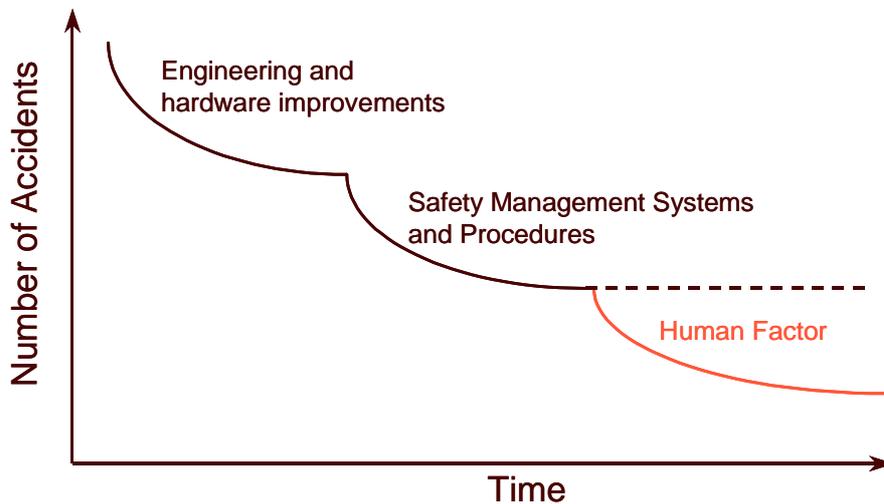


Fig. 1.1: Methods to reduce the number of accidents

Human Factor may be defined as an integration and application of scientific knowledge about the behaviour of human beings, plants and management systems (procedures, training, etc.) to improve their interactions in the workplace. See Fig 1.2.

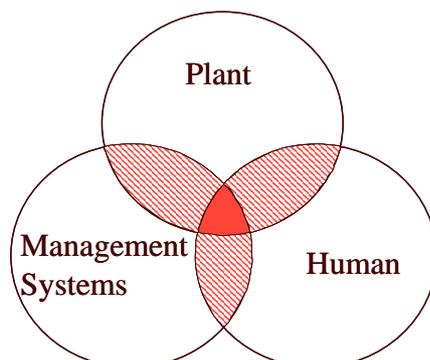


Fig 1.2: Illustration of Human Factors

Studies of the past accidents reveal that most of all process industry accidents have human error as a causal factor. Nevertheless technical defects and management faults are often the reason for the human errors. Instead of trying to adapt the human to the facility it is essential to design plants that meet the capabilities of the human.

To take human factors into account as part of the process engineering design requires design of equipment, operations, procedures and work environments in such way that they are compatible with the capabilities, limitations and needs of the human beings. This must become a vital complement to other engineering disciplines that primarily seek to optimise hardware performance and/or minimize capital costs with little or no consideration of how the equipment will actually be operated and maintained.

Consideration of HF during the engineering design process is a complex task even for simple systems. It is exponentially difficult to integrate HF in a process plant design owing to its complexity and uniqueness of each plant. Process plant is a system of systems that accommodates human multi-system requirements such as large organization structures; component-equipment-system compatibility and communication among others [Lees, 1996]. But this should not be in the least a justification to lack of HF consideration in the process industry. Other industries with relatively complex systems have made considerable efforts in this front. Today it is a requirement that nuclear, aviation, military and in some cases medical industries include HF during the design phase.

2. State-of-the-Art in The Process Industry

The first step in the task of FG 4 was to review the current practices in the process industry to get an overview of the “state-of-the-art” and to estimate the potential of improvements in HF application.

2.1 Internet Survey

2.1.1 Implementation of the Survey

A large-scale survey all over Europe was made and the analysis of the questionnaire done. It was based on a questionnaire that is divided in five sections:

- General questions
- Analysis of accidents
- Operator qualification and demands
- Consideration of human factors in the design process
- Conclusions.

At first a printed form of questionnaire was considered. The greatest disadvantage is the fact that sending the questionnaire would have eliminated its anonymity and would have introduced another task of copying all results into a database manually.

The next consideration was to email an Excel sheet as an attachment to all selected contact companies. To avoid unsystematic answers, macros were needed and this made the excel file grow to an unacceptable size. There were also concern that nobody would open an excel file containing macros.

Finally, an internet-based questionnaire was chosen. Its advantages are:

- It assured that the questionnaire is anonymous
- No macros are required
- Efficient and simple distribution to “users” was established
- The questionnaire follows a systematic approach and it is not possible to leave any questions unanswered.
- The “user” is guided through the questionnaire
- The questionnaire provides multiple choice wherever appropriate
- Statistical evaluation of large data amounts can be fully automated

The questionnaire was installed on the Internet and tested for compatibility with different hardware and software systems.

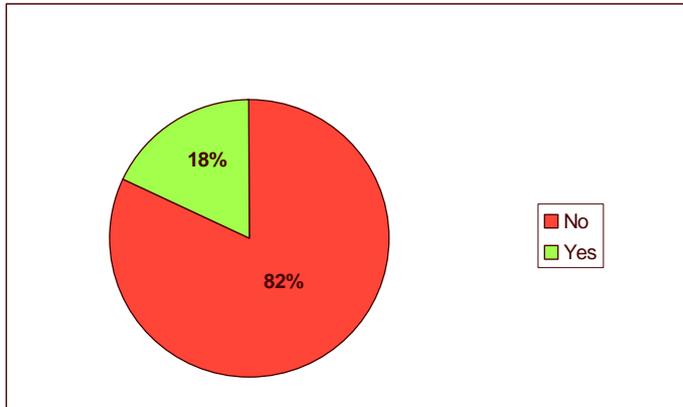
More than 70 representatives of small, medium and large enterprises from all over Europe were requested by email, telephone and in person to fill out this questionnaire.

The concluding task within the survey was the statistical evaluation and the interpretation. Although an evaluation program had been created, all written answers to questions, which did not allow multiple-choice selection, had to be analysed manually.

2.1.2 Results and Interpretation

Some of the analyses and interpretations of the survey that are presented as follows:

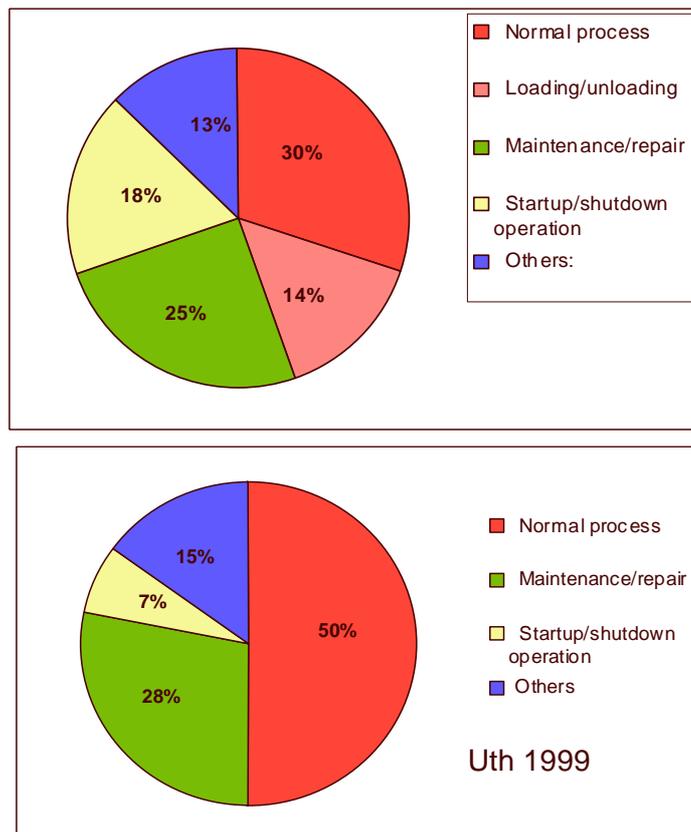
“Does your company have a skilled expert in Human Factor/Ergonomics?”



Less than 20% of the companies have an expert in Human Factors. This result may raise some questions because some of the companies could have someone having the knowledge in HF but is not necessarily referred to as a HF expert. But the degree of confidence is increased because a more familiar terminology “Ergonomics” is also used.

“The percentages of the operating states for event occurrences”

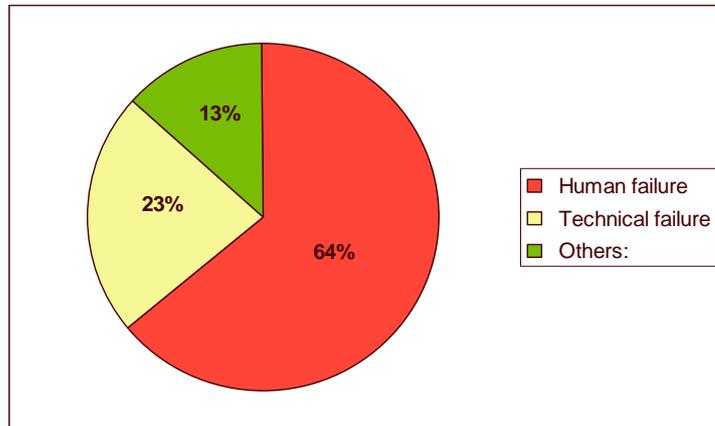
A comparison was made with results of a study by [Uth], who examined undesired events in Germany from 1993-96. Conspicuous is that 50% of the events occur in normal operations. Loading/unloading activities were not considered separately as in the FG4 survey. However, these are actually part of the *normal operations* activities of a plant. Adding them to the



normal process operation, this study yields results of undesired events that agree very well with the percentage obtained by Uth.

The next figure presents the results to the question of the main contributors to undesired events.

“The causes of the events are:”

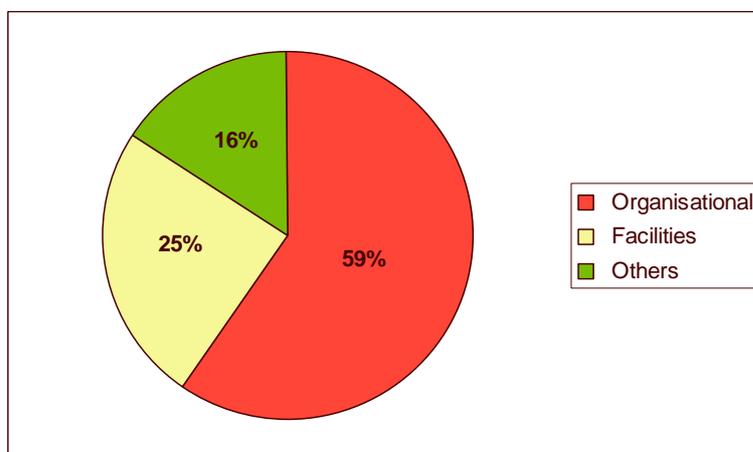


Only 13% of the events are due to technical failures. 64 % are due to human failures.

The causes given under “others” were examined for a comparison with the study carried out by McCafferty (1995). McCafferty examined the events in the USA in oil and gas companies. In his study 80% are caused by human failures. Some causes of events categorised under “others” are; work place conditions, management systems (which was mentioned more than once), systems’ failure, design and lack of knowledge of chemistry. Work place conditions and management systems Human Factor issues. From the survey, “human failure” (64%) and “others” (13%) add up to nearly the same percentage as that obtained by [McCafferty].

The causes of the human failures are:

59% human failures are contributed by the organisation and 25% by facilities.



From the survey some general conclusions can be drawn:

- A significant number companies including large ones do not have experts on Human Factors.
- Events occurring during the normal as well as non-routine operations are predominantly due to human failures.
- It was found that the operators' qualifications are lower in Small and Medium Enterprises (SME's) than in large companies and
- Non or rather no systematic methods to consider Human Factors are used in the design process.

2.2 Conventional Design Process

A conventional engineering design team is interdisciplinary comprised of engineers from the fields of chemical and process, civil, mechanical, electrical, automation and core safety just to name a few. With a good team leader the team is able to design and build a plant with reasonably high engineering strength and quality owing to the fact that much effort is invested on equipment and process reliability. Fig 2.1 outlines a typical design process.

However, this design process leaves a lot of loopholes in the issues affecting the people operating, calibrating and maintaining the plant. Only a handful of aspects concerning HF are touched during the detailed design and these do not include the actual Human Machine Interface (HMI) but rather general areas normally covered by core safety. More often than not the [task analysis](#) in the process industry is a post start-up exercise. This however may vary from organisation to the other.

Feasibility study	Basic Design	Detail Engineering	Commissioning & Start-up	Operation & Maintenance
<ul style="list-style-type: none"> -Parameters for plant location. -Basic flow diagrams. -Cost estimations. 	<ul style="list-style-type: none"> -More elaborate basic flow diagrams. -Production & ancillary buildings, approximate pipe and equipment dimensions -Investment & operating costs assessment. 	<ul style="list-style-type: none"> -Detailed design with process flow diagrams (mass, energy balances), P&I diagrams, 3-D models for plant layout. -Structural construction and assembly of equipment & machinery. -Plant safety analysis and reports. -Start-up scheduling & training on operations. 	<ul style="list-style-type: none"> -Test for conformity with P & ID. -Handing over to operations and maintenance departments. 	<ul style="list-style-type: none"> -Reviews for possible design problems for post start-up modifications -Task analysis for operation modifications.

Fig 2.1: Design Phases of a Process Plant

2.3 Obstacles in Implementation of Human Factors.

FG4 held a seminar in Frankfurt, Germany on the 16th and 17th June 2003. During the discussion participants outlined several key areas that need to be addressed. Some of them are listed here below:

- Anthropometrics in design to reduce musculo-skeletal disorders.
- Instruments and sample point's layout.
- Plant layout.
- Control room design.
- Piping arrangement.
- Alarm management.
- Design for accessibility taking into consideration the PPE.
- Loading and unloading racks.
- Automation.
- Labelling of equipments and accessories.
- Pumps installations and maintenance.
- Workspace design.
- Designing for emergency response.
- Stairways, ladders, ramps.

The list seems long and consists of areas that have been under research for many years now. The research areas keep re-emerging because of failure to implement earlier findings coupled with high rate of technological change.

Contributors during the seminar workshops gave their views on what they believe are the obstacles in the implementation of HF. These are:

- There are conflicts on where to link HF within a company structure. Most companies link it to SHE while very few have made it an independent department. Linking HF factors to SHE makes it a remote contributor during the design process because SHE has a more critical role (core safety) to play.
- The operations and maintenance departments feel excluded from HF issues. If these departments were involved in making decision associated with HF from the early stages of design they would have the ownership feeling of the whole project.
- Where HF experts are involved it is done too late. They play a role of patching up what has been missed during the main design tasks. Calling them late makes their recommendations add extra costs to the project.
- There has been little awareness creation on the importance of HF issues. Design engineers are still ignorant on the importance on the importance of HF especially in the early stages of design. They hold the onto the attitude that every safety aspect has been addressed through application of core safety techniques.
- There is lack of specific laws to address the HF issues. It has been a common practice that implementation of core safety aspects has been successful because of the requirements emanating from the authorities.
- There are no comprehensive HF guidelines available to process industry designers. They mostly apply their engineering expertise to insert the HF related issues into design.

2.4 Methods from other industries

As mentioned earlier HF consideration in the design process in nuclear, medical, military and aeronautical industries is a common practice. The guiding principles in the nuclear and medical industries are introduced briefly here below:

2.4.1 Nuclear Industry

Man Machine System Analyses (MMSA) is a tool commonly used in HF design and human reliability analysis in the nuclear power plants [Swain & Guttman, 1983]. It is both qualitative and quantitative. The steps for carrying out an MMSA are outlined:

Step 1: Characterising Human Error Environment

i. Describing the System goals and functions.

This step is aimed at identifying the points of interaction between the system and people. For each system the analyst must determine if there is a reasonable division of tasks between equipment and human beings.

ii. Describing the situational characteristics

Situational characteristics could be defined as those performance shaping factors (PSFs) that influence the performance of a task in a plant. Lighting, accessibility, noise are some of the examples.

iii. Describing of Personnel Characteristics

This step assists in identifying the capabilities of the persons to operate, calibrate and maintain the plant. These capabilities and limitations are compared with demands that the system imposes on them. Mismatch will require a change in Man Machine Interface (MMI), procedures, modification of personnel characteristics through training and/or selection.

iv. Task Analysis to identify Error Likely Situations

Task analysis focuses on specific behaviour requirement of the human component in a man-machine system. Task analysis has usually two parts. The first is the descriptive part which deals with what the performer of the task is supposed to do. The second is the analytical part and it helps to figure out what could go wrong and how it could happen.

v. Estimation of likelihood of each Potential Error and probability of error recovery

In Nuclear Power Plants (NPPs) this procedure is very important and is to a greater extent quantitative. It is expressed as probability estimates and forms the basis for the quantitative form of Human Reliability Analysis (HRA). The analyst uses the task analysis to determine the PSFs that affect the probability estimate of each subtask. Error recovery factors are used to modify the Human Error Probabilities (HEPs). Quantitative Human Reliability Analysis (QHRA) is widely used in the NPPs as a method for quantifying human error. A specific technique is Technique for Human Error Rate Prediction (THERP).

vi. Estimation of the consequences of each un-recovered error

A well designed system should be in such a way that a single uncorrected or undetected error should not cause a serious degradation of the whole system. This step makes it possible to include methods of error recovery e.g. redundancy.

Step 2. Suggest Changes to the system design

The factors to consider for a system design change are potential errors with a high probability of occurring, going undetected/uncorrected and with high consequences. The cost of modifications is also considered. Suitable design modifications are guided by the principle of reducing probability of system degradation caused by human errors. The following modifications are suggested [Chen-Wing & Davey, 1998]:

- Error occurrence elimination
- Error occurrence reduction
- Error consequence elimination and reduction

Step 3: Evaluation of suggested design changes

Each suggested modification is re-evaluated by repeating the above steps. The aim is to bring down the human error contribution to system degradation to an acceptable level.

This method though highly applicable has its inherent limitations. The requirement to undertake a QHRA faces some obstacles. One of them being the scarcity of data on which to base the probability estimates. This is already a drawback to exploitation of its full potential in the NPPs. It also does not indicate which phases of design this should take place. Another point is that the operation requirements for NPPs is different from that of the process plants.

2.4.2 Medical Industry

In the USA the Food and Drug Administration (FDA) and the Centre for Devices and Radiology Health (CDRH) proposes that user characteristics be considered while designing a medical device. Other countries have not wholly recognised HF although it is attracting much interest across Europe (Andersson & Reis, 1999). The model “ Designing in the user” developed by FDA is illustrated in Fig 2.

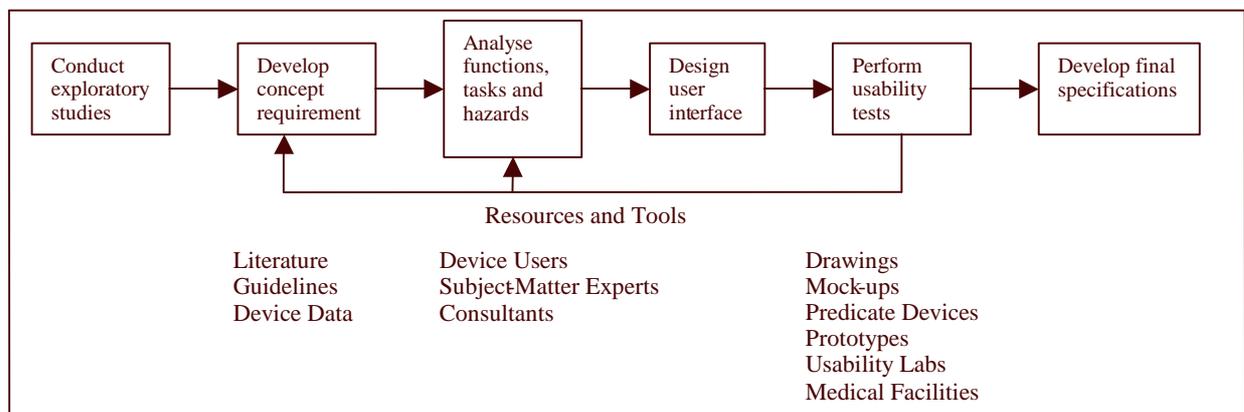


Fig 2: FDA Human Factors Engineering Plan

The design and development stage is divided into three broad steps:

Step 1: Exploratory Studies

This step is used to obtain first hand information from the users by observations done in a medical facility, interviews with the users, supervisors, trainers and maintenance personnel or physical measurements of work environment for parameters like noise levels, light intensity among others.

Step 2: Analysis

Analysis is done throughout the design phase. This includes function allocation and task analysis, hazard analysis and workload analysis.

Step 3: Usability Testing

Testing for operation, installation and maintenance is an important final step for HF design for medical devices. It involves development of prototypes, selecting of test participants and developing of scenarios. This is simulated in a 'real environment'.

Process plants are system of systems but most medical devices are simple devices or systems. It is possible to interact with the operators and use them as test persons. Its is also possible to built a complete model that will be the basis for mass production. This is not possible in the process plants.

3. Systematic Approach to incorporate HF in Process Plant Design

3.1 Developing HF Program

The guiding principle to the design team is that people just like hardware and software are a part of the system being designed. However, they are the weakest link in any engineering system [Turner, 1978]. This is due to the fact that all engineering systems rely on human intervention in some respect. Expert systems to handle a wide variety of situations without operator interventions have been on a continuous development. This will though take a long time before they can be totally relied upon.

Some of the tasks that require continuous operator intervention or participation include sequential control, starting of pumps, motors, mainly in batch processes; monitoring the proper operation e.g. watching a filling process; alarm response and diagnosis of unusual system condition [Kandel & Avni, 1988].

Going by the above fact it would only be prudent to identify the capabilities and limitations of the people interacting with the plant. A HF team require to be included in the design team at the outset of the project to make sure that all human related aspects have been analysed, reviewed and integrated at all phases of the design process. This approach otherwise referred to as concurrent engineering strives to eliminate, where possible, or minimise characteristics of a facility (part of the plant or whole plant) that require extensive cognitive, physical or sensory skills or those that may require extensive training or may lead to frequent error, health hazards or property loss through accidents. The role of HF in design is illustrated graphically in fig 3.1.

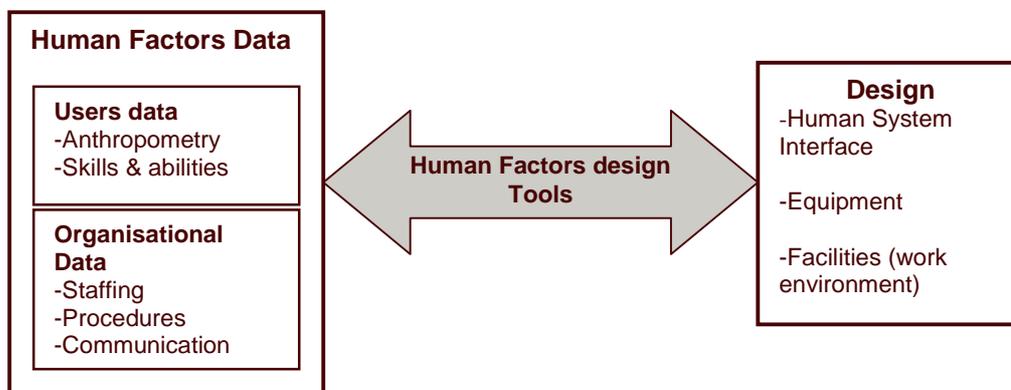


Fig 3.1: Role of HF in Design

A first step in developing a HF program is the initial assessment of the project to determine the level of support activities required of HF specialists. This is done parallel to the concept development of the project. Some of the factors to take into consideration are population from which the operators/maintainers will be selected from, skills of the personnel, lesson learnt from similar plants already in operation, operating environment (e.g. hazardous material). After the assessment, a plan for human factors deliverables is outlined.

3.2 Composition of HF Design Team

The composition of a typical design team for concurrent engineering is as illustrated in fig 3.2. The group of engineers come from departments of mechanical, electrical, automation,

chemical & process, production, system safety engineering but this list is not exhaustive. The composition of the engineers is also influenced by the type and requirements of the plant. In fact, this is the composition of a traditional design team. Definition of HF requires consideration and involvement of user in the design. In a process plant the end user are the departments of operations while maintenance department will often be interacting with the plant. Therefore these two departments require representation in the design team.

It is notable that today many companies are trimming their engineering strength in favour of engineering contractors. This is purely for economic reasons. The contractors simply keep their hands off after the commissioning and handover process. They are not in a position to get the right feedback to improve the life-cycle operations, maintenance and other problems. By involving contractors in the design process this loophole is sealed. They are able to get the feedback at the right time and therefore able to rectify any misfits that maybe found during the early phases of design.[Löwe and Kariuki, 2004]

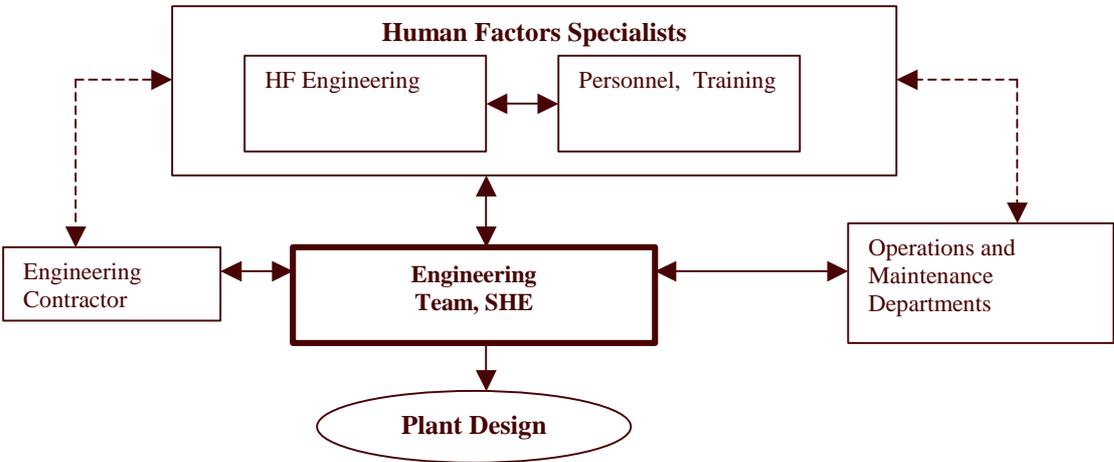


Fig 3.2: Composition of a HF Design Team

Human factors specialists as stated earlier ensure that all human related issues are identified, reviewed and accommodated throughout the design process. They ensure that all data required to support design activity is available during analysis. Human factors specialists are composed of HF engineers or engineers trained in HF and those from personnel and training. The two need constant interaction because personnel and training constraints limit design of hardware, software and tasks while the design place demands on personnel and training resources. Human Factors engineer may suggest design that would reduce pressure on personnel and training resources [MIL-HDBK-46855A].

Coordination, cooperation and communication between all members of the design team are paramount because it brings about the sense of ownership of the ideas and inputs. Computer Aided Design (CAD) is a powerful tool that could be used to achieve this goal. A technical project manager should oversee all the activities of the project.

3.3 HF Implementation

The best way to achieve the desired results in a design process is by systematically integrating HF efforts in the plant design process. HF efforts are divided into four broad categories namely HF planning & analyses, HF design, HF evaluation & validation and HF monitoring. Fig 3.3 shows how these activities are mapped on the plant lifecycle.

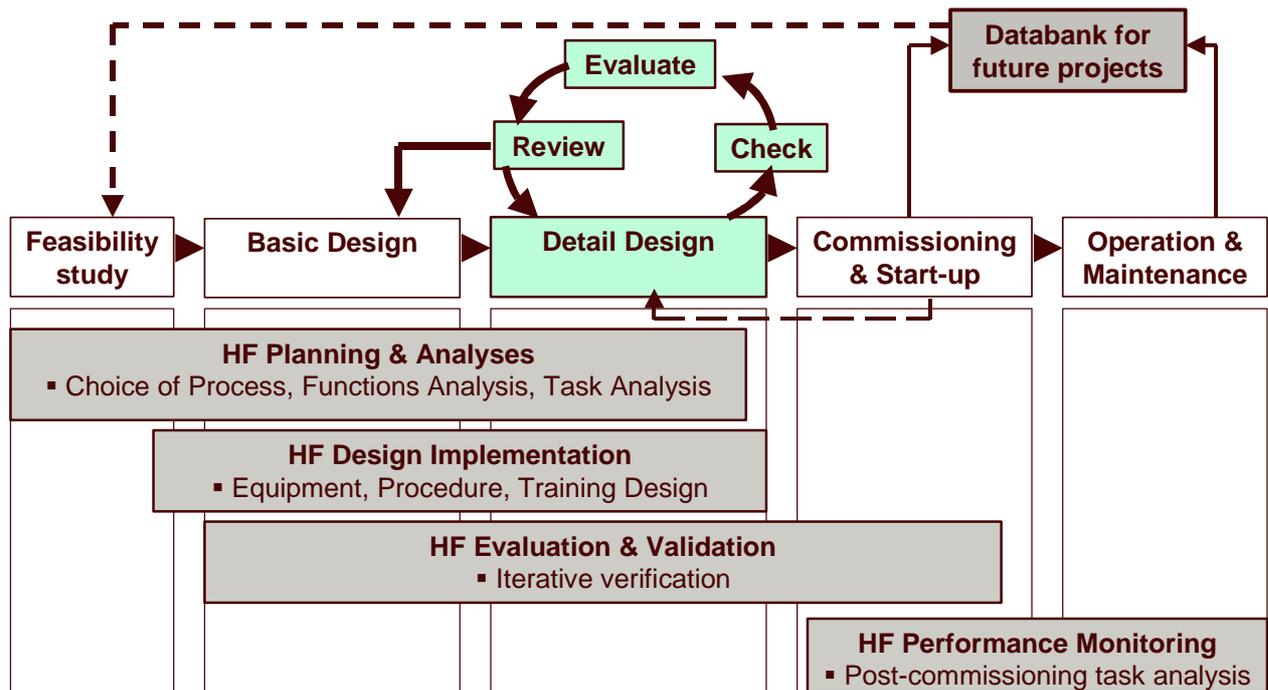


Fig 3.3: Human Factors Activities in the Design Process

3.3.1 Human Factors Planning & Analyses

It should commence together with the feasibility studies phase of the design. An important source of data is similar plants that are already in operation and this shall be provided by maintenance and operation teams.

Deliverables of this activity are:

- ▶ Functional analysis and functions allocation.
- ▶ Task and work Analysis.

3.3.1.1 Functional Analysis and Function Allocation

The functions to be performed to achieve the overall plant objective are identified. They should then be analysed to determine which would best be performed by human alone (manual), hardware/software (automatic) or combination thereof (semi-automatic). Function allocation is the responsibility of engineers, specifically systems engineer but HF specialist should be assigned the role to assist determine whether a function should be performed and controlled by the either of the mean mentioned above. Fig 3.4 graphically expresses how function allocation is done.

Helpful tools are functional flow diagrams, operational sequence diagrams and functional allocation trades. Functions to be performed are screened, the effectiveness of using either man or hardware/software (machine) is analysed and potential risks for each option listed. “Trade-off Table” (See table 1) could be used when to evaluate when to best use man or machine.

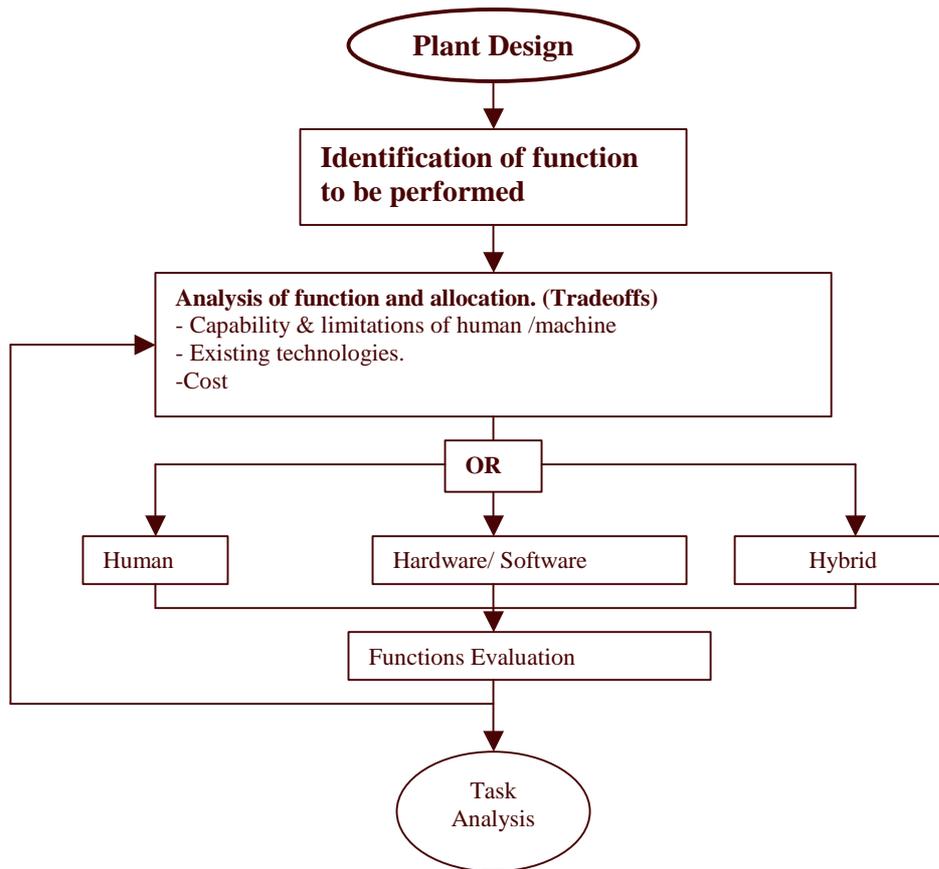


Fig 3.4: Function Allocation Process

<u>HUMANS EXCEL IN</u>	<u>MACHINES EXCEL IN</u>
<ul style="list-style-type: none"> • Detection of certain forms of very low energy • Sensitivity to an extremely wide variety of stimuli • Perceiving patterns and making generalisation about them • Ability to store large amounts of information for long periods – and recalling relevant facts at appropriate moments • Ability to exercise judgement where events cannot be completely defined • Improvising and adopting flexible procedures • Ability to react to unexpected low-probability events • Applying originality in solving problems, i.e, alternative solutions • Ability to profit from experience and alter course of action • Ability to perform fine manipulations, especially where misalignment appears unexpected. • Ability to continue to perform when overloaded • Ability to reason inductively 	<ul style="list-style-type: none"> • Monitoring (both people and machines) • Performing routine, repetitive, or very precise operations • Responding very quickly to control signals • Storing and recalling large amount of information in short time-periods • Performing complex and rapid computations with high accuracy • Sensitivity to stimuli beyond the range of human sensitivity (infrared, radio waves) • Doing many things at one time • Exerting large amounts of force smoothly and precisely • Insensitivity to extraneous factors • Ability to repeat operations very rapidly, continuously, and precisely the same way over a long period • Operating in environments which are hostile and beyond human tolerance • Deductive process.

Table 1: Human Machine Tradeoffs

3.3.1.2 Task and Work load analyses

Safe operation of a plant depends on the successful performance of tasks by human operator. Some of these tasks may have adverse effect on overall safety, reliability of a unit or the environment [Attwood]. Based on this background task analysis is a very critical step in the design process. The technique could be used for existing tasks as well as those tasks that do not exist. It should be aimed at:

- i. Identifying human factor issues associated with each task and find effective solution for each issue.
- ii. Identifying tasks that are performed under abnormal conditions and those that have critical consequences if not correctly performed.
- iii. Developing procedures for operations and maintenance and develop training needs.

It starts by dissecting a function into specific tasks and subtasks that fulfils that function. For each particular task the associated human performances parameters should be identified. For instance the environmental conditions that these tasks have to be performed and any related risks are analysed. Task analysis process is complex and time consuming therefore could be expensive. It should thus be done only to human related functions and these are selected on perceived criticality e.g. consequences caused by an error. Human factors specialist should analyse the tasks systematically to determine the operators needs to complete a particular task.

Task analysis for a new project will depend on the analysis team knowledge of the facility the operator will work in and equipment to be used; the operating environment; and the activity the operator is to perform. Important source of information is the existing similar plants and this is the reason operation and maintenance departments presence in the design team is significant.

Task analysis should best be divided into two. Simple and direct tasks that involve obvious physical steps are tabulated indicating the task steps, description of the steps, possible errors and consequences of each error. Examples of methods that are applicable are link analysis and adjacency tables.

Cognitive Task Analysis goes a step further by trying to capture and relay information related to mental processes. It focuses on difficult decisions, judgments and perceptual skills that play an important role on the task performance [MIL-HDBK-46855A]. This being a very complex method should be focused on the critical and frequent tasks that are difficult to learn, carried out in a complex/difficult environment and involve many subtasks that should be carried out simultaneously. [Hall, Gott and Porkony, 1995]

Fig 3.5 represents a simplified loop diagram of the cognitive behaviour underlying performance of a certain task.

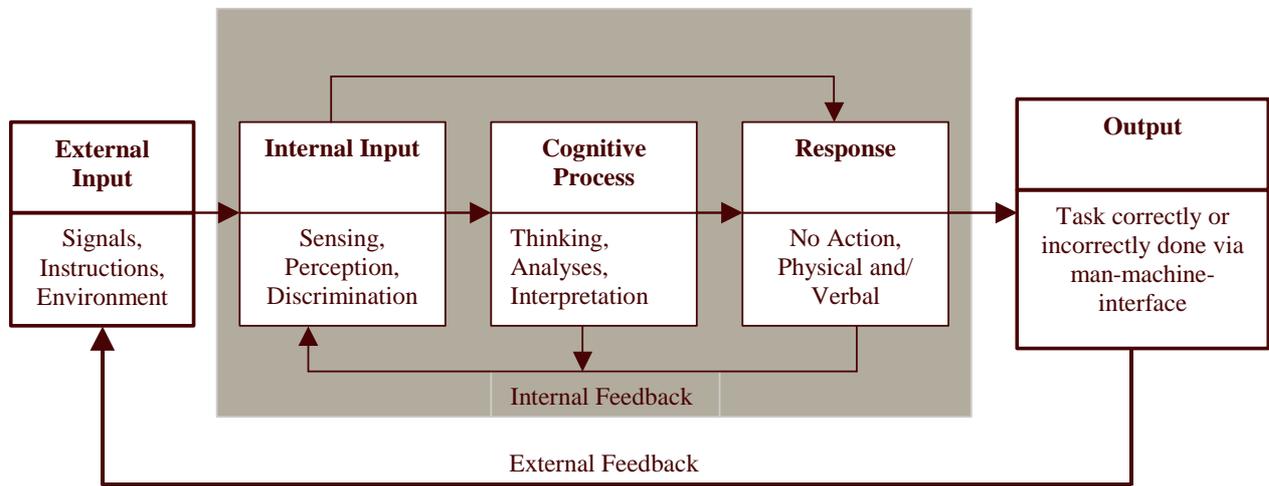


Fig 3.5: A Simplified Model of human as a Process Component. [Adapted from Swain & Guttman]

Human operator receives information from external source e.g. displays or instructions. According to the way this information is perceived, sensed or discriminated it is interpreted and analysed before the response action is carried out. Therefore the speed and accuracy at which the operator responds to a particular task depends on the quality with which associated information is presented to him and his cognitive capability to make the right decision. At times the operator response is almost automatic and thus the internal process does not have to undergo all the three steps. This would be described as a skilled-based behaviour. The operator acts almost sub-consciously based on experience. In case of more complex unfamiliar tasks the operator has to use personal perception that is at times based on ability and experience to make a decision. This is referred to as knowledge-based behaviour. A third type of behaviour described by [Rasmussen, 1981] is rule-based which relies on a set of pre-defined rules.

Task analysts should aim at identifying the task parameters associated with each task. Some of task parameters are listed here below:

- i. Input parameters – Information required versus information available
- ii. Mental processing parameters – Evaluation process, job knowledge required
- iii. Response parameters – Actions taken, Control & display locations
- iv. Feedback Parameters – Feedback required versus feedback available
- v. Workload - Cognitive and physical
- vi. Task Support requirements – Protective Clothing, Tools and Equipments
- vii. Work environment parameters – Noise, climate, lighting

In general, task analysis (for critical tasks) shall entail the following steps:

- i. Identification/ description of task
- ii. Ranking of tasks according criticality
- iii. Analysis of the task

Workload analyses helps to identify the demands imposed on the operator by the task assigned to him in comparison with the time and resources available. Too much workload exerts a lot of pressure and this increases the possibility of making an error. The same fact applies when the workload is too low because this induces boredom and slackness. An optimal balance has to be struck. The analysis usually influences the number of operators to undertake a particular task. Work Load Analysis tools are available in the market.

3.3.2 HF Design Implementation

The requirements obtained during the analyses stage are translated into design. Fig 3.6 shows the progression from task analysis into the design stage. HF is a discipline that affects all the others in one way or the other. Therefore, HF specialist working in an integrated team with other engineering disciplines ensures that their design incorporates HF design criteria.

This activity is tied within the basic engineering and detailed engineering phases. Human factors concerns should be addressed at a greater extent during basic engineering to avoid costly modifications at later stages.

Deliverables:

- ▶ Man-Machine Interface (MMI) Design
- ▶ Procedures Design
- ▶ Training Development

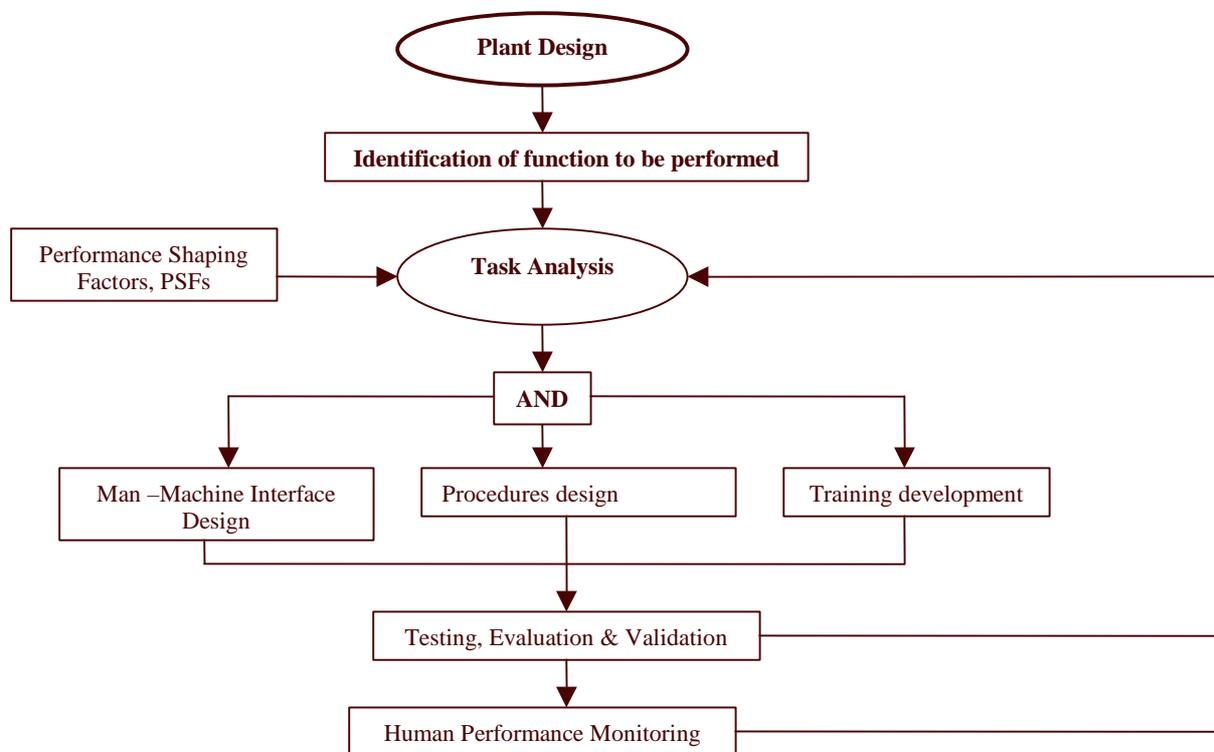


Fig 3.6: Design Components after Task Analysis

MMI encompasses any interaction that the system within the plant makes with the human operator, calibrator or maintainer. The design of these interfaces should thus take into consideration the capabilities and limitations of those interacting with them. The broad categories of what the plant design should consider is listed here below:

- a. Maintainability and operability
Accessibility of workstations, design of ladders and stairs, location of valves
- b. Control Monitoring and instrumentation
Field control panels, display design, alarms

- c. Automation and Control Design
Fault management and false alarms, control room design/ layout
- d. Work Environment
Lighting, noise, heat stress
- e. Plant Labelling and Signing
Information transmission, visibility and legibility, label location

These areas are further elaborated in the “PRISM Human Factors Design Guideline”. Apart from guideline and checklists computer models, electronic mock-ups are good tools to achieve good results.

Procedures design and training are being handled by other PRISM focus groups and therefore will not be covered in further details.

3.3.3 HF Evaluation & Validation

Evaluation and validation is a continuous process that should ensure that the plant can be effectively and safely operated and maintained by the targeted people within the intended environment to achieve both operational and safety goals. The activity should start as early as the basic design but most benefits are achieved during detailed design when all the plant parameters have been defined but before any fabrication/construction starts. It is used to verify that the task requirements for the personnel are defined and that the design accommodates the human capabilities and limitations. The HF specialist reviews the drawings and the tasks that have been assigned and suggests any modification that may be needed. Computer simulation plays an important role here. An MMI may be simulated to identify any HF deficiencies.

After the assembly of system components e.g. pump-sets or compressors the HF specialist should evaluate if they fulfil the HF design criteria before they are installed for operations. It would be easier and cheaper to make modifications at this point than when they are already in operation. The evaluation activity proceeds through to the maintenance and operation.

3.3.4 Human performance monitoring

All HF related problems cannot be eliminated during the evaluation and validation stage. From the start-up of the plant a strategy to make observations to evaluate the success of HF implementation in the plant design is set. Some modifications may still be needed at the early and later life of the plant through a supplementary task analysis. Care should be taken that any changes made do not lead to a further degradation of the plant. Lessons learned should form a useful databank for future projects.

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