Human factors engineering in petrochemical projects: Part II

Among the subjects in this second article on the place of human factors in project planning, the project business is analysed – discussing how ergonomic princples should be integrated – and the framework of a warranted quality system, including management monitoring tools and system auditing

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Although the man-machine interface in petrochemical manufacturing projects has always been considered to be an integral part of a sound engineering design, many ergonomic misfits in operability and maintainability have been experienced after implementation. Based on that experience a vision and policy was formulated, which resulted in a human factors engineering strategy integrated in the front end loading (the early development phases) of the business process of project preparation and execution.

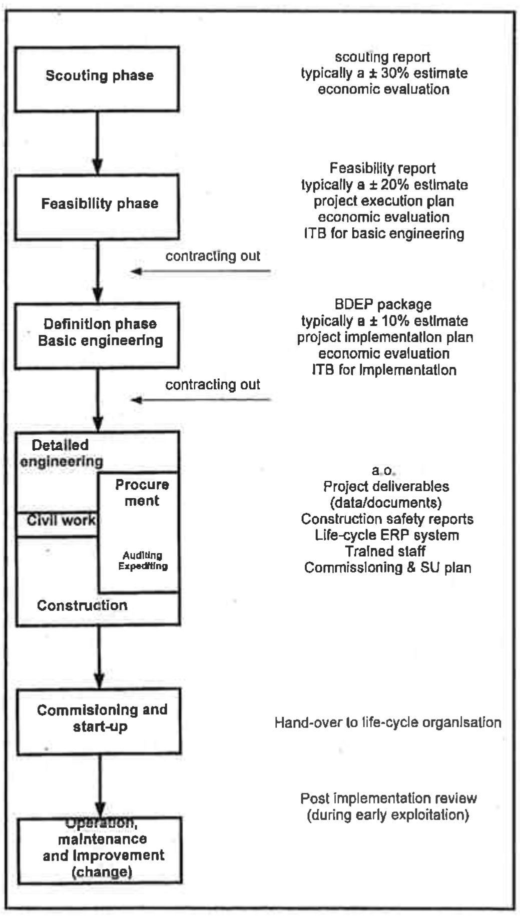

***Figure 1** Typical high level business process description: "Project preparation and execution instruction"*

The benefits of this strategy are identified both in business terms (economics) and in working conditions; like improvement in Health, Safety and Environmental (HSE) aspects. Based on historical data it is now identified that for a typical $400 million petrochemical project the strategy can result in a reduction of: 0.25 per cent of capital expenditure (Capex), 1 per cent of the total engineering hours, and 3 to 6 per cent of operational and maintenance life-cycle costs of facilities (Opex).

Part I of this article, published in the Summer 1998 issue of *PTQ*, described the development of the strategy starting with creating awareness within an organisation up to the general approach based on a developed vision and policy. Part 2 gives the reader insight in the actual project management and quality assurance of human factors engineering in petrochemical projects.

The statements that human factors and ergonomic principles are not sufficiently anchored in the design process is not worldshaking. However, especially for projects in the petrochemical industry, a clear recipe cannot been found in literature – much has been written but an incorporated control system has not been found.

Design process

After the birth of an idea to invest in a petrochemical plant, either for economic or other reasons, a conceptual design is made, on the basis of existing, improved or new technology. The conceptual design is normally followed by a study into the feasibility of the project and an early (economic) evaluation will indicate whether to proceed with the basic engineering study, during which the project is further defined in terms of scope, implementation and financing. The so-called basic engineering and design package (BDEP) or project specification (PS) contains enough information to make an accurate cost estimate (accuracy normally plus or minus 10 per cent).

At this point business premises and forecasts are frozen and an economic evaluation, including technical and financial risks and sensitivities, is performed. In most petrochemical companies this evaluation is the basis for approval of the project. During this front end engineering phase typically some 5 per cent of the capital is spent. After approval of the project the implementation phase is started, including the detail engineering, during which the equipment and material specifications are described in requisitions, being the starting point for the procurement.

During detailed engineering, drawings (now usually based on data) are produced to enable the constructors to build the petrochemical facility. Two dimensional computer techniques have been increasingly used and during the past decade graphic oriented 3D computer imaging has been used, while today 2D and 3D design is integrated on the basis of object oriented design and engineering. Virtual reality is commonly used on the construction side as well after construction of the new facility is tested and started up.

This process, as described, can be shown schematically in relation with time, showing the deliverables of each process step, as shown on the right hand side in Figure 1.

Input of engineering disciplines in the design process

During the process of design, engineering, procurement and construction, many engineering disciplines are involved, such as process technologists/engineers, mechanical, electrical, civil and instrumentation engineers. Cultural, strategic, and logistic considerations give a continuous input during the design process, resulting in decisions mostly influenced by conflicting arguments or constraints. Often the capital investment must be incorporated into existing infrastructure and, especially in recent years, much capital investment is spent in retrofitting and debottlenecking existing units.

Good engineering is considered when all disciplines mentioned are working integrally and where mutual empathetic behaviour is shown. Although it is sometimes said that this is the project manager's role, we have noticed that the system (organisation and availability of the correct procedures and culture) in which the responsible project manager has to work is of determining influence to success.

Budget constraints (foreseen or unexpected) are a handicap in good integration between the disciplines as it is often thought that this is in conflict with proper engineering, procurement and construction.

It should be noted that many petrochemical companies have slimmed down their engineering strength, relying more and more on the aid of engineering contractors. Although this is attractive from a staffing point of view there are some penalties.

Engineering contractors do not operate the plant so do not obtain enough feedback, as a company engineer would, to improve the level of engineering skills with respect to anticipating life-cycle operations, maintenance and other risks. Therefore, and depending on the type of contract, ECs are not always too interested in the plant's life after construction has finished.

These constraints definitely influence the quality of the projects.

Lack of user participation in design

Some important participants in the project have not been mentioned yet. This important group of potential contributors to the design are often not involved during the design process, or come in too late or only in order to submit comment. Yet they are the very ones who have to operate and maintain the plant for many years to come.

Of course, these end users were always recognised as participants in a project, but more in the sense of giving comments on a design or a document. Seldom have they been recognised as really contributing to the design as a demand defining participant.

From interviews with designers, engineers, constructors and project managers as well as operators and maintenance workers it can be concluded that there is a difference in attitude between the two groups, in that the first group is motivated to deliver a product that fulfils the basis of design and who concentrate on those issues and the end-users who are motivated to operate and maintain the plant in an efficient and effective way and are more concerned with the life-cycle.

The attitude of the engineer can be generally summed up as: "As long as it's working I did a fine job". Operators and maintenance workers, on the other hand, complain that they need more effort to do their job during the exploitation as a result of user unfriendly designs. They also claim that this increases exploitation costs. The fact is that if end-users, as the representatives of the operator/ owner, are insufficiently involved during the design and construction phases, this results in a negative influencing factor – what is generally identified as limited "client commitment level" (CCL).

However, a new dilemma exists in view of the availability of operational and maintenance staff during the design, and methods should therefore be developed to overcome this.

Problem definition

Ergonomics or human factors engineering is easily forgotten during all phases of a project (refer to Part 1 of this article). This leads to many disadvantages, among others, extra costs during the

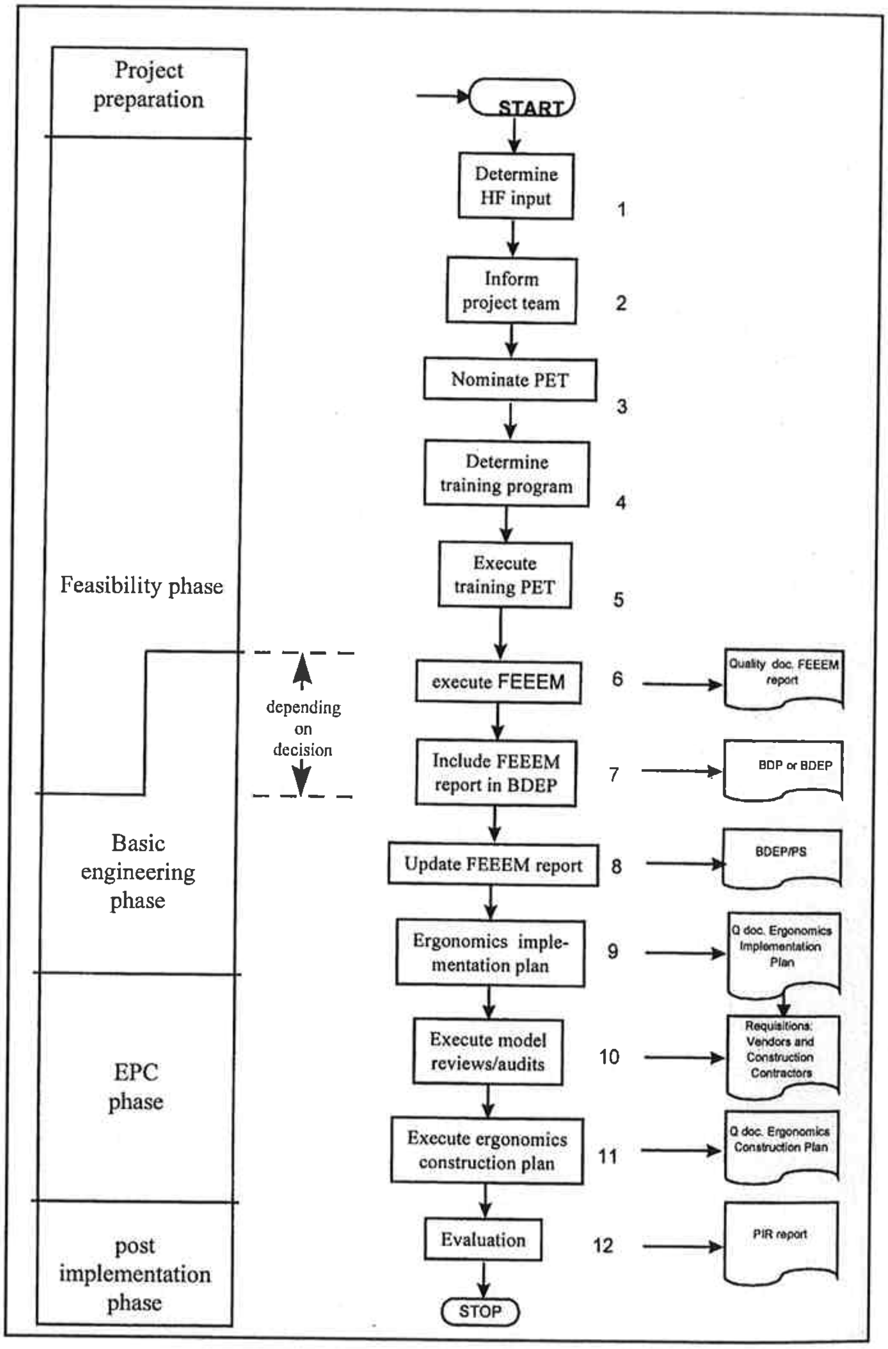

Figure 2 Business process flow diagram

further life-cycle of the plant for operations and maintenance, and additional health and safety risks. Furthermore, those who might contribute to avoid ergonomic misfits are not often consulted.

Not enough emphasis is paid to the many tasks which have to be done when the plant is in operation and has to be maintained. It can be concluded that the design process should have incorporated more means to ensure the knowledge of ergonomics, human factors engineering, and task analysis, of which the results have influence on the design and user participation.

Too many ergonomic misfits exist in petrochemical plants, even those recently built after making use of graphic but static oriented 3D computer programs.

This is due to the fact that project and design organisations and their engineering contractors have not the appropriate business controls in place to make sure the defect is addressed properly. Furthermore, those who might contribute to avoid ergonomic misfits – the end-users of a work system – are not often consulted.

This can best be achieved by an ergonomic awareness programme for all those involved in projects, through organisation and management procedures and, last but not least, by showing the economic and non-economic benefits of human factors engineering in projects. The application of new simulation tools based on data-centric and object oriented, and thus 2D/3D integrated (dynamic) engineering systems – which have a proven history in the automobile, aircraft and shipbuilding sectors – will lead to simple and early 3D simulation of the plant under design. This leads to better understanding of an early "designing out" of ergonomic misfits as well as optimised life-cycle oriented designs.

Procedure to follow

In this procedure, the human factors engineering activities, as experienced in a number of recent projects, are described in relation to the project phases. On the left hand side of Figure 1 the status of the project is given, ranging from the feasibility phase, through the definition (basic engineering) phase into the detailed design, procurement and construction phase. It may be noted that, early in the design, ergonomic demands have to be specified, the main reasons being:

—It is in this phase that inside battery limit (IBL) operational and maintenance philosophies are being defined

—The design is still flexible in its scope definition, so that ergonomic demands, especially on IBL philosophy level, can easily and at no cost be integrated in the design

—Demands and scope ergonomic categorisation can be set for use in the basic and detailed engineering phases.

The business process flow diagram, shown in the centre part of Figure 2, indicates the scope, purpose, organisation and management of human factors engineering in projects. Keywords in this procedure are: Plant Layout, Human Machine Interface design, Control Room and Human Computer Interface Design, Ergonomics, User Participation, Client Commitment Level, Operability, Maintainability and System Reliability.

The purpose of this procedure is to integrate the user's requirements into the design of a system at the right time, well in balance with the technical and economical constraints, with respect to project investment as well as life-cycle cost savings and occupational health and safety benefits. In doing so, the design will also reflect the way the future operators and maintenance people will utilise their system effectively while at the same time understanding that impossible demands are not implemented.

The procedure in general leads to lower capital expenditure as well as lower life cycle costs of installations and costs of plant change [Managing human factors engineering in projects procedure; doc ID EMIS PMQ.01, Shell International, The Hague].

Executing a human factors task analysis in basic design and/or definition phase is crucial for catching the technical/usability requirements of the human machine interfaces early. After these requirements are identified and recorded, there is a standard approach to follow during the succeeding phases.

This procedure is applicable for new grassroots projects as well as for brown fielders and debottlenecking or major retrofitting. The procedure demands cooperation between operations/maintenance, process engineering, project management, construction management and the engineering contractor. Discipline engineers normally do not participate during the analysis or audits but are consulted along the road.

The policy with respect to human factors engineering is geared towards achieving an optimal human machine interface for installations, control rooms, work places, laboratories, and offices. It is essential that the persons who are ultimately responsible for ensuring a user friendly design are the designers, engineers and project managers executing the project; they need the input of life-cycle users in time to avoid later changes during detailed engineering or, even worse, during construction.

A good quality control is guaranteed when there is proof in the form of deliverables, sometimes integrated in general reports, like BDEP packages or project specifications. The type of deliverables is indicated on the right hand side of Figure 2.

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Identify necessary human factors engineering input

The person responsible for putting together the Basic Process Design Package (BDP, often called BOD) and/or the Basic Design and Engineering Package (BDEP) – frequently the process engineer or the project co-ordinator/manager – should discuss and evaluate the necessary effort for the project with the human factors engineer.

Inform project team/manager/kick-off meeting

The process engineer informs the project team leader or manager about the proposed strategy, including the initial costs (it is assumed that the project team leader or manager is an experienced professional and relates the initial costs to the benefits to be acquired later, although, many times, the challenge from the project team leader indicates differently. The agreed human factors engineering plan of action is then part of the agenda of the project kick-off meeting. Within larger projects (above $50 million) the human factors engineer often plays a coordinating role

Nominate the Project Ergonomics Team (PET)

The person responsible for drafting the BDP and/or BDEP should nominate (in consultation with the appropriate discipline managers) the participants of the PET. The Project Ergonomic Team normally consists of a (lead) process engineer, participants experienced in operations and maintenance, sometimes specialists (mechanical, instrumentation) depending on the type of project,