Taking account of human and organisational factors in planning and designing a high risk system

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Abstract

Title Taking account of human and organisational factors in planning and designing a high-risk system

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A Human and Organisational Factors (HOF) approach to project planning and design aims to improve decisions by anticipating the consequences of technical and organisational choices on the human activity that will take place in future operations. To foster efficient and safe work, the HOF approach is based on in-depth analysis of human activity in existing situations combined with simulation of probable activity in future operations, based on planned technical and organisational choices.

The approach requires project owners to express their requirements clearly, good coordination with design and engineering contractors, and participation of various stakeholders, in particular from operations. The integration of a HOF approach should start at Front End Engineering and continue until the final project review.

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Foreword

To manage industrial risks, over many years companies have developed measures focusing on the continuous improvement of the reliability of installations and the establishment of safety management systems. While maintaining their commitment in these two areas, today they consider human and organisational factors to be an additional driver of progress.

The Institute for an Industrial Safety Culture (ICSI) and the Foundation for an Industrial Safety Culture (FonCSI) have made the consideration of human and organisational factors one of the major strands of their joint strategy for the development of safety culture. A first stage consisted of proposing a renewed vision of safety through a synthesis of scientific knowledge, borrowed from the human and social sciences in particular. It took the form of the publication of the *Cahier* entitled 'Facteurs humains et organisationnels de la sécurité industrielle, un état de l'art' [Daniellou *et al.* 2011] followed, in 2012, by the *Cahier* entitled 'Facteurs humains et organisationnels de la sécurité industrielle, des questions pour progresser' [Daniellou 2012].

This third *cahier* complements this vision by addressing a specific field of action: installation design/modification projects.

There are many examples of projects that are costly to implement or failing, of changes that are difficult to introduce, etc. Some organisations have even found themselves at risk due to their inability to successfully complete a technical and/or organisational development project. To address this issue, this *cahier* calls on all project and safety stakeholders (employees and their representatives, managers and senior management of companies, safety experts, etc.) to anticipate the impact of technical and organisational choices on future working conditions.

In view of the fact that improving decision-making will foster efficient and safe work, it encourages project owners to express their requirements clearly, good coordination with design and engineering contractors, and participation of various stakeholders starting at Front End Engineering and continuing until the final project review.

This *cahier* is the outcome of a now well-established process that has involved numerous stakeholders:

1. First of all, the FonCSI selected François Daniellou, whose research stands as a reference, and funded his laboratory in the context of its call for proposals on 'Technical, human and organisational vulnerabilities and striving for safety'.
2. Representatives and members of the ICSI, from diverse backgrounds (industrial managers, trade union representatives, specialists from research or specialist institutes, etc.), met in an ICSI Working Group on human and organisational factors in projects[1].
3. The author has produced a document based on his expertise and experience.

1. Working Group drawn from the ICSI's 'Human and Organisational Factors of Safety' Discussion Group.

This new *cahier* ultimately raises key issues but also points for attention and proposes good practices; in short, concrete benchmarks to be integrated into project management by all those who believe that the improvement of safety culture also requires greater consideration of the human and organisational dimensions.

Toulouse, 30 June 2013
Myriam PROME-VISINONI, ICSI

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Summary

A company plans to invest to build or modify a production installation which is known to present potential risks to the employees, the environment and the general public. Industrial safety will therefore be a constant concern in the design of this installation, which will be punctuated by hazard studies, risk analyses and safety reviews.

But what kind of safety? Too often, the approach is limited to identifying the undesirable physical and chemical phenomena that can be predicted through calculation, and to guarding against them through installation design, automated systems and the drawing up of procedures.

But safety is at stake in day-to-day operations, in the activity of the women and men who are the production and maintenance teams and managers, whether they are in-house employees or from contractor companies, who will supervise, run, control and maintain the installation. They will have to manage situations that have been foreseen and governed by procedures, but also many others that have not been specifically anticipated. To do this, it will be necessary for them to seek information, diagnose, take action on systems, coordinate, and monitor the outcome of their actions.

If this activity has not been fostered from the design phase, the operators will of course 'adapt': they will undoubtedly do their best to ensure that such a system, designed without consideration for human activity, is fit for production; but at what cost, at what level of efficiency and with what risks? Industrial safety may be diminished, occupational health and safety undermined and productivity jeopardised.

The system that will be designed is not a technical system, but **a sociotechnical system**, the effective operation of which will be based on coordination between individual and collective human activity and the technical processes. In fact, what is at issue is **a comprehensive vision of the system's future performance**, which, in addition to economic and technical criteria, incorporates the various other determining factors that can contribute to the sustainable effective operation of the installation and to its control by the women and men who manage it and spend their working lives there, under normal circumstances and in crisis situations.

The consideration of human and organisational factors in a project is intended to support the designing of a system that can be operated efficiently and safely, both from an industrial safety perspective and from an occupational health and safety one. Doing this involves **anticipating the future human activity**, which will be determined by the technical and organisational choices made at every stage of design, assessing the likely difficulties, and fine-tuning design decisions.

This advance consideration of the activity is not simply an 'ergonomics review' at the end of the detailed design phase. Certain choices that define the human activity are made very early on in the project, and quickly become irreversible. In fact, the consideration of the future activity should take place throughout the design cycle.

In order to structure this integration of human factors into projects, large organisations have published good practice guidelines, for example the International Association of Oil and Gas Producers (OGP)[1], the Federal Aviation Administration (FAA)[2], ASTM International[3], the US Nuclear Regulatory Commission[4], etc. Some large companies also have their own standards for the consideration of human factors in projects[5].

The purpose of this document is to provide all project stakeholders with a concrete description of the requirements for the establishment of a 'human and organisational factors' (HOF) approach in design. It is based on the results of thirty years of international research on the sociotechnical management of investments and on the experience of the members of the ICSI's 'HOF in Project Management' Working Group[6].

1. See [IOGP 2011].
2. See: [FAA 2003].
3. See: [ASTM 2007].
4. See: [NUREG 2012]
5. By way of example, the approach put in place in a large oil company is the subject of an interesting article [Seet and McLeod 2012].
6. Working Group drawn from the ICSI's 'Human and Organisational Factors of Safety' Discussion Group.

Definition

What is a HOF approach in design?

It is a question of improving design decisions, by anticipating the consequences of technical and organisational choices on the **human activity** that will take place under future operating conditions. To foster efficient and safe work, the HOF approach is based on in-depth analysis of human activity in existing situations combined with simulation of probable activity in future operations, based on planned technical and organisational choices.

The consideration of human factors in design does not challenge the general methodology for the implementation of a project; it complements this methodology at every stage and it could be said that they are developed alongside each other. In general, no changes are made to the main characteristics of a process or to the intrinsic features of equipment or of an installation: there is collective reflection and a desire to define, step-by-step, from the general to the particular *'how will people work in the installation?'*, by identifying the normal situations, but also the plausible variations that the operators will be required to manage. This thorough anticipation will often help to limit technical deviations and the subsequent adaptations or transformations that are commonplace, and which are rarely taken into account in the overall cost of the project.

However, this approach significantly changes the position and the role of the various stakeholders. On the one hand – because not just the technology, but also the individual and collective human activity of the system is addressed – when using this approach, it is important to ensure that the project owner possesses the **necessary competencies**. It is also important for the sociotechnical considerations defended by the project owner to override, when necessary, the technical arguments raised by the engineering contractor. On the other hand, this approach is based on the idea that nobody has all of the required skills: an exchange of points of view should be organised. This means identifying the required skills, taking the time needed to define and examine together the issues to be addressed and to build reasonable compromises. But in order for to prevent this enhanced consideration from affecting the overall planning of the project, the approach must be carefully phased, with identified milestones at which multi-criteria assessments are carried out.

The document comprises three parts:

1. The first part focuses on **the organisation of the stakeholders**: broadening perspectives, identifying the required skills, involving the stakeholders, structuring the relationship between the project owner and project contractors – to move away from the 'specifications' approach and towards an approach of continuous interaction throughout the project –, and ensuring the conditions for the success of the HOF approach and planning it.

2. The second concerns **the human and organisational factors approach**: enhancing the quality of design by anticipating future operating situations and the activities that they will require; developing the skills of the women and men who will operate the installation; supporting the establishment of a learning organisation for future operations.

3. The third concerns **the preparation of the site and of start-up** and the lessons that can be learned for future projects.

Introduction

This document focuses on the consideration of human and organisational factors (HOF) in the investment projects of high-risk industries. It follows two other *Cahiers de la sécurité industrielle*:

- Human and organizational factors of safety: state of the art [Daniellou et al. 2011];
- Facteurs humains et organisationnels de la sécurité industrielle: des questions pour progresser [Daniellou 2012].

It refers to several aspects from these two earlier *Cahiers*. Unlike the previous ones, here we use the expression *human and organisational factors* (HOF) and not *human and organisational factors of industrial safety* (HOFS): the consideration of the future activity at all stages of design makes a significant contribution to industrial safety, but it also has many other effects, such as the improvement of working conditions, the reduction of arduousness, the improvement of social relations, efficiency and production quality, etc.

The purpose of this document is to facilitate the integration of human and organisational factors into a design project for a high-risk installation located in Europe or on another continent[7]. It is primarily intended for a project with all of the following characteristics:

- it involves an investment to build and/or modify an industrial installation that has technical and organisational dimensions;
- it concerns a single site[8];
- there are known industrial risks, which have been assessed;
- the investment is in the order of tens to hundreds of millions of euros.

Some of the elements presented here may be relevant for other projects:

- a greenfield investment project on undeveloped land, with the building of a new site;
- a brownfield investment project on land polluted by a previous installation;
- project to move a production site;
- multisite project;
- organisational change project without investment in heavy equipment;
- project relating to localised equipment changes;
- hospital investment project;
- etc.

It will then be for the project stakeholders to assess and adapt the information in this document that remains relevant in their case.

The project stakeholders, for whom this document is intended, are:

- the senior management and central department staff who define the project management guidelines;
- the members of the site management and of the project management;
- the project managers;

7. The legislative references are French, and should be changed in the case of an international project.
8. And the project team works in proximity to it.

- ▹ the operations managers[9] of the future installation;
- ▹ the human resources managers;
- ▹ the HSE managers and those who manage the relationships with residents and the local authorities;
- ▹ the officials of the supervisory authorities (e.g. the Regional Directorate of the Environment, Planning and Housing, DREAL);
- ▹ the members of the staff representative bodies.

This document may also be useful to people who are studying human factors.

It is intended for companies in which the HOF dimension of investment projects is not yet well developed. In other companies, many of the points mentioned here correspond to practices that are already in common use. In this case, the stakeholders concerned will easily be able to 'translate' the terms, names and methods used here to those to which they are accustomed.

The objectives of the consideration of HOF in projects

What we wish to support

- ▹ efficient and safe future operation;
- ▹ a future system that is resilient (capable of anticipating, preventing and positively managing deviations from nominal operating conditions);
- ▹ the adaptability of the system to changes in environmental constraints, throughout its life cycle;
- ▹ satisfactory working conditions for the construction, production and maintenance teams;
- ▹ the best possible occupational health and safety performance (prevention of workplace accidents and occupational illnesses) during the construction works and operation;
- ▹ career and skills management both for the start-up of the installation and throughout its life cycle;
- ▹ the acceptability of the project to the employees, residents, public opinion and the local authorities;
- ▹ high-quality social relations with the staff and the representative bodies, during the project, at start-up, and in future operation;
- ▹ an improved dialogue with the supervisory authorities;
- ▹ compliance with the schedule and the budget, in particular through an efficient start-up on the scheduled date.

What we wish to avoid: a few common pitfalls

- ▹ start-up delayed by last-minute changes, with associated budgetary slippage;
- ▹ a system struggling to achieve nominal operation;
- ▹ a significant number of serious accidents and/or shortcomings during the construction works;
- ▹ difficulties in the management of the installation by the production and maintenance teams (sub-optimal operation, risks of error);
- ▹ day-to-day or critical operations made difficult or dangerous due to installation design, giving rising to higher than forecast operating costs[10];
- ▹ organisation preventing the safe shutting down of installations if necessary;

9. In this document, the term operations encompasses production + maintenance + materials and product management.

10. The OGP Human factors engineering in projects document referred to above [IOGP 2011] provides, in Annex 1, numerous examples of typical design flaws leading to operating difficulties and, in Annex 2, several industrial accidents resulting from a lack of consideration of HOF.

- ▷ the apperance of 'demographic barriers' (insufficient training time planned in order to have an empowered workforce by the intended date, large-scale and unanticipated retirements shortly after start-up);
- ▷ social tensions and strikes during the project and at start-up. Insufficient information and interaction with employees – and their representatives – makes it difficult to envisage the future system, what will be expected of them, the support that they will receive, and ultimately their ability to perform their future roles. This psychological destabilisation enhances other possible concerns relating to employment, status, etc.

Analysis of numerous industrial projects shows that **these typical difficulties are generally due to project management shortcomings**. Although these failures and the desirable approaches have been very clearly identified by international research[11], these references are still largely unknown in some companies.

The consideration of HOF is not therefore only about the content of the specifications: it is the **structuring of the project** itself that will help or hinder this approach. It is about consistently and visibly fostering interactions between the project teams and the various stakeholders involved in the project, whether directly (future operators) or indirectly (other units that have to in fact integrate the introduction of the new installation).

Common project management shortcomings

Projects that result in a challenging start-up often have several of the following characteristics:

- ▷ The *project management function of the project* is not clearly defined or does not bring together the necessary skills.
- ▷ The project owner defines initial objectives that are purely technical and economic, without considering the activity of the end-users.
- ▷ It entrusts project management to the project contractors (engineering) and then leaves them to it. The project management function is poorly identified and represented during the design phase.
- ▷ The project is then managed only on the basis of technical and financial issues alone; the issues relating to the organisation, recruitment and preparation of the future operators are dealt with at a late stage, as an outcome of the technical approaches adopted.
- ▷ The activity carried out in existing installations or in industrial pilot projects by the operations teams and the difficulties and incidents that are encountered there are not fully analysed and taken into consideration by the engineering teams.
- ▷ 'Human factors' specifications do not feature significantly in the general specifications.
- ▷ The coexistence of the construction project and the units in operation (phasing) is examined at a late stage of the technical definition of the new units.
- ▷ The future operations managers are appointed at a late stage and/or have little involvement in the project.
- ▷ Staff representative bodies are informed at a late stage and in an incomplete manner. Social discussion primarily concerns statutory and pay issues.
- ▷ The future production and maintenance teams become aware of the procedures and installations when the project is almost set in stone. The establishment of teams and training is carried out at a late stage of the project.
- ▷ Hazard studies and risk analyses are primarily conducted from the perspective of 'regulated safety': putting in place of safeguards such as automated systems and procedures. Little consideration is given to the issue of 'managed safety' (the availability at all times of skills in the field to deal with an unforeseen situation)[12]. The high-risk situations are identified and the procedures for dealing with them are written by the project experts, without interaction with the operations teams. These documents

11. The sociotechnical approach to project management has undergone numerous developments since 1985. The publications from the period include in particular: [Laplace et Regnaud 1986; Riboud 1987; du Roy 1989; Daniellou 1987].
12. For the discussion on 'regulated safety/managed safety', see the preamble and chapter 7 of the State of the art *Cahier* [Daniellou et al. 2011].

therefore sometimes reflect scenarios of standardised situations and trained operator behaviours, which do not correspond to the likely reality of operation.

To contribute to a more favourable structuring of project management, this document comprises the following chapters:

▷ **Part 1: the structuring of the project, a prerequisite for integrating HOF**

- Chapter 1: The establishment of project management and the definition of project objectives.
- Chapter 2: Project owner/project contractor coordination at the different stages of the project.
- Chapter 3: The conditions for the success of the HOF approach.

▷ **Part 2: the HOF approach**

- Chapter 4: From current activity to future activity: the HOF stages in design. Overview of the approach.
- Chapter 5: The methods of an HOF intervention.
- Chapter 6: Training.

▷ **Part 3: The construction project and start-up**

- Chapter 7: The preparation of the construction project and of start-up.
- Chapter 8: Start-up, the evaluation of the project and the transition to ordinary operations.

Part 1

The structuring of the project: a prerequisite for integrating HOF

1

The establishment of project management and the project objectives

Summary

The initial structuring of the project is a prerequisite for improving design choices. Chapter 1 stresses the importance of robust project management, representing the various approaches that are vital to the success of the project. It describes the establishment of broad objectives, reflecting the project owner's wishes for future operation and incorporating the human and organisational dimensions.

The project owner (PO) is the body on behalf of which the project is executed. This definition too often results in the PO primarily being considered in its role of *payer* or even to it being limited to the role of *client*. However, a couple that are having their house built are not just the architect's *clients*. The couple have a responsibility to question the architect to ensure that the house is not merely a reflection of the contractors' aesthetic or technical biases, but rather that it offers living conditions that are in line with the owners' wishes. In fact, it is the PO's responsibility to **define an intention regarding the future, to translate it into objectives** in several areas**, to supply the appropriate resources**, **to make the trade-offs** required throughout the project between objectives and resources, and to **evaluate the end product**.

In an industrial project, it is therefore important to distinguish between:

- ▹ strategic project management, i.e. the decision-making level – generally at the headquarters – that can release the funding (often considerable) for the investment, with a view to the achievement of technical and economic objectives:
- ▹ and **operational project management**, which will be responsible for representing the company in order to embody the intention that gave rise to project, until its completion. In what follows, we will primarily consider this operational project management, which has to provide the project's policy leadership, by being accountable and seeking the assessment of the strategic project management on key issues.

1.1 Establishing a project management group

Through the establishment of the operational project management group, a company organises itself in order to deal with the major issues that will determine the success or failure of the project:

- ▹ the overall performance of the system, throughout its life cycle: the requirements for its design, the construction project, its operation, its development and its final decommissioning;
- ▹ compliance with objectives, deadlines and the budget;
- ▹ the technical and cultural compatibility of the solutions adopted with whatever already exists on the site;
- ▹ organisational choices;
- ▹ the management of human resources, recruitment and training;
- ▹ the quality of the products produced and their alignment with customer demands;

- industrial safety and occupational safety;
- respect for the environment;
- acceptability to supervisory authorities, residents and local authorities;
- the interface with staff representative bodies and social negotiations.

The composition of the project management group should reflect the diversity of these issues, by involving (specifically depending on the case):

- the management of the site concerned;
- one or more operations managers (production and maintenance);
- one or more representatives of the 'installation user', when the installations will be operated by a company other than the one that owns it[1];
- the quality function: occasionally the function providing independent inspection of the technical integrity of the installations;
- the HSE function – both the industrial safety aspect, in particular SMS, and the occupational health and safety aspect;
- the interface with the supervisory authorities, residents, associations and local authorities;
- the 'protection against malicious acts, intrusion and terrorism' function, referred to as security in the chemicals and airport industries, and site protection in the nuclear industry;
- a technical function capable of providing the PO's interface with the engineering teams (see chapter 2);
- the human resources function;
- occasionally the marketing function or the function providing the interface with clients;
- occasionally the legal function;
- the HOF approach coordinator (see chapter 3);
- etc.

This diversity helps to represent all of the approaches that should be taken into account in the objectives of the project.

Given this necessary plurality, it is likely (and desirable[2]) that contradictions will arise during the project between the different issues represented in this way. It is therefore important that the establishment of a project management group involves the appointment of **the mediator** for this group, who will often be the site director.

1.2 Technical planning of the project

To facilitate the identification of the PO's tasks at every stage of the project, we present the typical stages here. The organisation of the coordination between the project owner and the project contractors will be set out in chapter 2.

1.2.1 A typical project

A major investment project spans several years. The organisation, phasing and naming of the design stages differ depending on the company. Figure 1.1 presents fairly typical planning, which will serve as a point of reference in the remainder of the document. The names and the content of the stages are to be adapted to each specific case. The technical stages are presented here and the introduction of the consideration of human factor dimensions in planning will be described in chapter 3.

1. A common situation in the port and airport industries.
2. Management involves holding together approaches that are partially contradictory, through mediated compromises following investigation of the various issues. The censure of divergent points of view prior to mediation is a major source of risk.

PRELIMINARY DESIGN	Intention Front end engineering and design Initial costing of the project Feasibility assessment Establishment of the operational PO Definition of the detailed objectives Functional programme Selection of the project contractors
CORE DESIGN	Refinement of the costing Confirmation of the financing Selection of the technical options Drafting of the specifications
DETAILED DESIGN	Definition of solutions Plans and specifications Consultation of companies Selection of companies
CONSTRUCTION PROJECT	Tests Acceptance
START-UP	Nominal
OPERATION	

The order here may vary depending on whether the project is the design phase or the design/construction phase.

See comments in chapter 2.

FIGURE 1.1 - *Typical project planning*

The **preliminary design phase** is generally carried out at the request of the strategic project owner. Its purpose is to consider the feasibility and potential profitability of a planned investment. The potential major technical options are the subject of front end engineering and design (FEED)[3]. An initial feasibility and impact assessment is carried out, concerning in particular:

- the industrial risks;
- in the case of international projects, the compatibility with the geography, climate, culture and local institutions;
- the environmental impact and its remediation[4];
- any impacts on heritage (areas of historical and archaeological interest);
- the characteristics of the available workforce;
- the acceptability of the installation to the general public, communities and the authorities.

3. FEED (Front-End Engineering and Design).

4. Requirement to mitigate the damage done to the environment (the biodiversity of flora and fauna, etc.) throughout the life cycle of the installation, including its decommissioning.

If the assessments are positive, the project owner will draw up the objectives of the project in the form of a 'functional programme'[5]. It is desirable that the operational project management group described above be established at this stage, so as to effectively supplement the initial objectives. The engineering programme will be used either to launch a call for tenders to external engineering companies, or to establish the foundations for the work of an internal contractor (see chapter 2).

Midler's curve

The cost of the preliminary design phase represents a small share of the total investment amount. The experts who manage it have to make assumptions (e.g. regarding the workforce) in order to estimate the profitability of the system. These assumptions are, at this stage, developed with very little information; but, due to the fact that they affect the economic calculations, they will be difficult to revisit later on.

This is represented by Christopher Midler's well known 'scissor curve' [Midler 1993]:

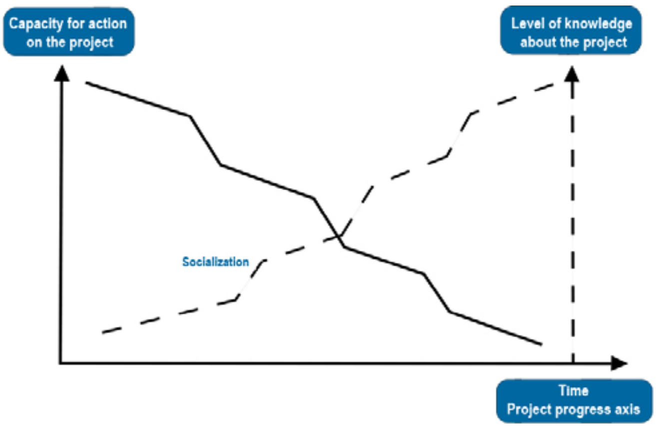

FIGURE 1.2 - *Midler's scissor curve*

At the start of the project, the level of knowledge is low and there is wide scope for action (*'we can do a lot but we do not know very much'*). At the end of the project, the level of knowledge is high, while the scope for action is very limited (*'we know everything but we can no longer do very much'*). One means of limiting the effects of this contradiction is to **increase the level of information with supplementary analysis prior to the completion of the preliminary costing**.

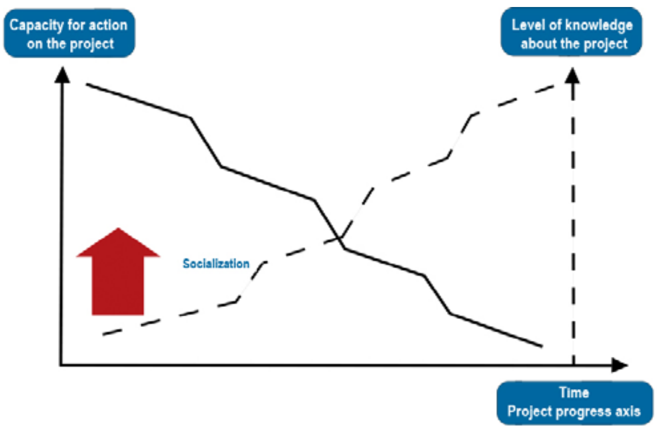

FIGURE 1.3 - *Supplementing the initial assumptions*

5. Here we use the term 'programme' for this document from the project owner intended for the engineering team, to distinguish it from the 'specifications' that will then be drawn up by the project contractors.

The selection of the project contractors marks the transition from the preliminary design phase to the core design phase.

The **core design phase** is managed by the project contractors (chapter 2). On the basis of the functional programme issued by the PO, the project contractors will examine several technical options, so as to offer refined costing. The impact and hazard studies are conducted in a more detailed manner. The major technical and location choices are decided at this time, and the financing for the project is confirmed.

By way of example, the core design phase may cost approximately 3% of the total investment amount.

The **detailed design phase** defines all of the elements of the system with a level of detail that enables their construction. Many specialists from various disciplines work in parallel. They generate an enormous amount of information (plans, technical specifications, etc.). This is the most critical phase, in which the risk of the loss of technical coherence between the system's different components is highest if there is fragile project coordination.

The detailed design phase is very costly (e.g. approximately 8% of the total investment amount), and the further it progresses, the more choices become near-irreversible. At the end of the detailed design phase, the construction specifications are established and the consultation and selection of the executing companies are carried out.

The **construction project** comprises two components: works, first of all civil engineering works, take place on the site. At the same time, technical sub-assemblies are assembled on the suppliers' premises, to then be assembled on-site. There is a significant difference between the 'civil engineering' component and the 'mechanical engineering' component. The mechanical assembly works generally build the elements described by the plans with precise tolerances. However, during a civil engineering project, difficulties in the field can lead to sometimes fairly significant 'adjustments' to the plans. The tolerances are not of the same order.

In general, this phase requires the use of a large number of participants, which results in significant concurrent activity. The preparation and coordination of the construction project should contribute to preventing the corresponding risks (chapter 7, page 59).

The purpose of the **trials and tests** is to test the different parts of the installation, without the intention of going into production: for example, the operation of the pumps and the watertightness of the circuits will be water-tested. These tests in particular contribute to the acceptance of installations, which is a condition for the payment of the suppliers[6].

Start-up begins on the date on which there is an intention of going into production for the first time. It lasts until such time as the installation's production complies with the **nominal** quantity and quality levels provided for in the initial programme. The installation is then in operation, until the next significant modification.

The duration of start-up is a key indicator of the success of the project: when a long period of adjustments and fine-tuning is required to achieve nominal levels, the profitability of the project is affected, and all the more so when the 'return on investment' time was shorter.

1.2.2 The typical project does not exist

Of course, no project runs smoothly from the initial intention to stabilised operation.

On the one hand, a real project consists of various sub-projects (e.g. civil engineering, process engineering), which progress at a different pace and may be subject to different delays: one may still be in the core design phase while the detailed design phase for another is at an advanced stage.

On the other hand, given the duration of a large-scale project, external events (raw materials prices, market or regulatory developments, economic crisis, technical difficulties, appearance of additional costs, etc.) may cause the management of a company to change the initial objectives along the way. Many projects are subject to 'turns of events' like this as they progress. In this case, the design phase cannot be continued by simply changing the parameters concerned. It is often necessary to revisit the initial assumptions.

6. Acceptance contractually combines the verification of the conformity of the structures and materials, the trials and tests, the lifting of reservations, and the documented verification of the effective operation and nominal performance of the installation. Acceptance is thus a condition for the payment of suppliers in full and the taking 'ownership' of the installation.

The appearance of a real project often resembles figure 1.4, which shows the coexistence of several sub-projects, each affected by turns of events.

PRELIMINARY DESIGN	
CORE DESIGN	Confirmation of the financing Drafting of the specifications
DETAILED DESIGN	Selection of suppliers Detailed definition of all of the components
CONSTRUCTION PROJECT	Tests Acceptance or acceptance testing
START-UP	Nominal
OPERATION	

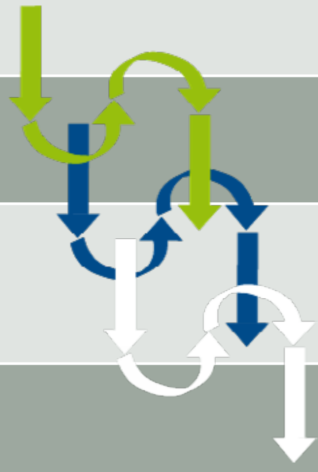

FIGURE 1.4 - *Example of the actual course of a project*

The coordination of the project becomes even more critical for maintaining the substance and the coherence of the project when such disruptions occur.

The regularly updated overall plan should be shared by the project owner, the project contractors and the operators.

Following this overall presentation of the project plan, we will consider the tasks of the project owner.

1.3 Supplementing the project objectives

The project is a technical investment, intended to produce a target amount of products or service (transport industry) at an established level of quality and with target profitability. But there is more to it than that. It will result in a **sociotechnical transformation**[7] **of the site**, which cannot be simply a by-product of the technical design.

Furthermore, a major investment represents a financial input that can 'in passing' help to resolve some of the site's recurring problems (for example as regards flows, risk factors, etc.). Any project can thus be an opportunity to 'do some housekeeping' on some long-standing issues that are unresolved due to a lack of resources.

The initial objectives of the project, which will provide a framework for its entire execution, cannot only be the quantitative objectives for production and profitability. The preliminary **supplementation of the initial objectives of the project** is the focus of in-depth work by the project management group, prepared in each area by the relevant managers. It is essential that each of the functions represented in project management hear and discuss the constraints presented by the other functions. The specific contribution of the HOF approach will be presented in detail on page 29.

7. It is not only the technical systems that will be changed, but also the interactions between the technical systems and human society represented by an organisation, as well as the relationships between individuals and between groups within it.

1.3.1 The objectives for the improvement of existing installations

A thorough assessment[8] of the existing installations enables the identification of the current strengths, which have to be safeguarded by the project[9], and the identification of the known difficulties that are likely to be dealt with during the project:

- ▷ HSE issues (general traffic plan, local accidentology, high-noise areas, physico-chemical risks, access for emergency services, pollution generated by the site, etc.);
- ▷ issues relating to the prevention of intrusion or malicious acts;
- ▷ issues relating to working and living conditions[10] (catering, changing rooms, etc.);
- ▷ human resources issues (available population, demographics, career and age management, the wish to bring more women or men into certain professions, etc.)[11];
- ▷ identification of trade groups that are in difficulty or in crisis;
- ▷ identification of suppliers or contractors that are in difficulty or in crisis;
- ▷ organisational structures that have been deficient in certain critical situations;
- ▷ client dissatisfaction regarding packaging, delivery issues, etc.;
- ▷ tensions with residents, local authorities, government departments or the supervisory authority;
- ▷ social tensions;
- ▷ etc.

The project owner may decide that the handling of some of these issues is an integral part of the key objectives of the project.

1.3.2 Compatibility with other projects

It is not uncommon for several projects to be launched in parallel on the same site. Their management in parallel often gives rise to uncontrolled interference. The initial project scope should help to identify all of the other projects with which it may interfere. If necessary, a master plan ensuring inter-project coherence should be put in place.

1.3.3 Product-related objectives

The installation to be built will operate for many years. It is frequently the case that industrial installations are designed only on the basis of client requirements as expressed at the start of the project. Insufficient anticipation of the likely developments, which are nevertheless known to marketing teams, often leads to costly modifications soon after start-up.

Product-related objectives (type, quantity, quality, packaging, delivery flows, etc.) should incorporate forward-thinking, both in marketing terms and in regulatory terms.

1.3.4 Environmental objectives, public opinion and local authorities

The environmental objectives of a project may be a pure reflection of the regulations and of foreseeable changes to them in the coming years. But, in some cases, a company may also wish to manage the project in such a way as to increase its acceptability in environmental and societal terms, and to improve its relationships

8. In some companies, the high quality of the technical lessons learned process enables it to be used as a starting point for this assessment. In others, the lessons learned process has not been sufficiently formalised to be used as a basis for the assessment, which has to be repeated in full.

9. Indeed, it is necessary to guard against the illusion that innovation is always better than techniques and organisational methods that have developed over the long term.

10. In particular in relation to data on occupational health and the work carried out to assess and prevent arduousness.

11. In some projects in which a site is established in an isolated area, it is also necessary to consider the consequences in terms of transport, or even urbanisation (sanitation, children's schooling, health care system, etc.).

with associations and local authorities. In these cases, the management of the environmental footprint and integration into the local social fabric are key dimensions of certain investments[12].

This involves identifying the key external stakeholders and resources[13]: explaining the planned choices and involving these stakeholders fosters the acceptability of the installation, greater involvement in the local employment pool, and helps to develop environmental offset measures that are acceptable to all.

1.3.5 The ‘people and organisations’ report: a prerequisite

Any major investment involves prior consideration of the target population and organisations. Some companies require that a ‘people and organisations’ report be included in the functional programme. Whether this is the case or not, undertaking this consideration is essential in order to identify the human and organisational factors that should be taken into account, but also to establish guiding principles for future operation (automation levels, organisational choices).

The constraints resulting from existing installations

- Age profile, distribution of genders, of the available trades and skills, and of length of service[14]. Three and five-year projections for these distributions.
- Review of the medical fitness requirements and the employment of people with disabilities. Three and five-year projections.
- Analysis of the arduousness, absenteeism and accidentology in the existing installation.
- Identification of the trade groups and their ‘state of health’, identification of the required changes to the trades.
- Diagnosis of the strengths and weaknesses of the current organisational structure and of the safety culture of the site, and of its subcontractors.

The ‘innovation delta’

Some investments may take the form of a slight change in the technologies and procedures in use on the site. Other projects, even though more limited, may introduce a major technological advance and have a cultural impact. Some trades may disappear while others emerge. The project management team will have to assess this ‘innovation delta’ in order to define the HR objectives of the project and the change management policy.

Objectives for the project

- Planned staffing range by trade and category of skills.
- Objectives regarding the development of trades, skills and qualifications.
- Objectives for the use of the local workforce.
- Objectives regarding the employment of older people, young people, women and men, people with disabilities or with limited medical fitness.
- Objectives for the improvement of working conditions and the reduction of arduousness.
- Objectives in the area of organisation (e.g. increase in the scope of action of certain professional categories, organisation of shift work, etc.).
- Industrial policy objectives (scope of subcontracting) for the management of the construction project and in operation.

12. We refer to the numerous *Cahiers de la sécurité industrielle* on the subject, which are available on the websites of the ICSI and of the FonCSI.
13. For example, a university research team deeply involved in the local fabric.
14. In particular, using the discussions undertaken with social partners on the forward planning of jobs, trades and skills, on gender equality and on the employment of older people.

1.3.6 The challenges of phasing

The coexistence of the construction project and the installations in operation, the connection of the new installations to the old ones and the switch-over from some installations to others can be complex. In some projects, these challenges are so significant that they can be expressed as design-critical objectives from the start of the project.

1.3.7 Project management objectives

The project management team must learn lessons from the strengths and weaknesses of previous projects[15], in order to define a more effective form of project structure:

- ▷ Structuring of the project owner/technical project contractor interface (see chapter 2).
- ▷ Timely appointment and professional stabilisation of the key managers throughout the project. The unconsidered turnover of key stakeholders is one of the causes of the difficulties encountered in many projects.
- ▷ Definition and planning of the key stages and points for validation.
- ▷ Representation of the operators in the project.
- ▷ Provision of information to/consultation of the staff representative bodies.
- ▷ Integration of human and organisational factors at every stage (see chapters 3 and 4).
- ▷ Formalisation, with respect to the project contractor, of requirements relating to the consideration of HOF.
- ▷ Definition in advance of the forms of start-up evaluation (see chapter 8).

1.4 Ensuring the continuous presence of the project owner in the project

The project management group has been established to represent all of the approaches that are vital to the success of the project. This group of managers will not be able to be involved in the detail of the project on a day-to-day basis. It is therefore important that the project owner ensure it is embodied by a **project manager** who will represent it on a day-to-day basis in all of the design stages, and call for the project management group to meet when appropriate to ensure the necessary trade-offs.

The function of the project manager representing the project owner differs from that of the contractor's project manager: the project owner's project manager represents the vision for the future established by the project owner, and ensures it is fulfilled through the solutions developed by the project contractor.

1.4.1 Substance and coherence of the project

The project comprises at least the following dimensions:

- ▷ the overall establishment of the project's main components;
- ▷ the design of civil engineering operations;
- ▷ the definition of physical infrastructure;
- ▷ the definition of an information system, and IT hardware and software[16];
- ▷ consideration of the future organisational structure;
- ▷ the preparation of the future operators (recruitment, training, accreditation);
- ▷ the writing of the procedures;

15. This requires a lessons learned process for projects that is not limited to technology but also concerns project organisation itself.
16. Information systems are increasingly based on integrated management software packages, which coordinate production management, commercial management, logistics, human resources, accounting, management control, etc.

- the management of the provision of information to and/or consultation and/or negotiation with external partners (associations, residents, local authorities, supervisory authorities) and internal ones (employees and staff representative bodies);
- the organisation of the phasing between current operation, the organisation of the construction project and future operation.

A successful project is one in which **all** of these aspects have been comprehensively and coherently dealt with. The relative failure of a project may be the result of the inadequate handling of **just one** of these components. The **substance** of the project is the comprehensive consideration of these different issues. The **coherence** of the project is the compatibility between the decisions taken in the different areas, which involves providing interfaces between them, and a cross-cutting approach.

The substance and coherence of the project define the scope of the mission of the project owner's project manager.

1.4.2 The profile of the project owner's project manager

Given the transversal nature of the mission of the project owner's project manager, it would not be appropriate for him or her to have the profile of a technical expert, like that of a project contractor. He or she should have operations experience.

A good solution is to appoint the future operations manager of the new unit in advance, and to make him or her the project owner's project manager: this person will have a vested interest in all of the technical, human and organisational dimensions being coherently dealt with at every stage of the project. Nevertheless, it is necessary to guard against him or her seeking to have the technical and organisational solutions that he or she is most familiar with reproduced: this is the challenge of the interactions with the multidisciplinary project management group and its trade-offs.

In a major project, the function of the project owner's project manager requires a full-time employee. In a more limited project, it can be a part-time function.

1.5 Provision of information to/consultation of the staff representative bodies

The provision of information to/consultation of the staff representative bodies is a component of project management, and therefore within the remit of operational project management, regardless of the person who will provide this interface in practice afterwards.

In France, the works council is informed and consulted on the employer's projects and decisions concerning

> *The working conditions resulting from the organisation of work, technology, employment conditions, the organisation of working time, qualifications and methods of remuneration.*

The health, safety and working conditions committee (CHSCT)

> *Shall be consulted prior to any significant planning decision changing the health and safety conditions or the working conditions and, in particular, prior to any significant change to jobs arising from the modification of tooling, a change in product or in the organisation of work, prior to any change in productivity rates and standards whether or not linked to the remuneration of work [Labour Code].*

These two bodies must therefore be consulted on any investment project[17].

Some companies have a tradition of the limited or late provision of information to staff representative bodies, so as not to create social movements that may disrupt the execution of the project. Apart from the fact that this position is contrary to the regulations, it regularly produces the opposite of the expected effect, with an accumulation of social problems during the project and at the time of the construction project and start-up. Grey areas will only give rise to comments, rumours and fears, which have an inevitable impact on the project and its implementation.

17. Particularly in the case of categorised obligations, in which the opinion of the health, safety and working conditions committee should feature in the operating permit application package.

Other companies prefer to ensure the early and regular provision of information to the staff representative bodies. If the works council or the health, safety and working conditions committee decide, as they are permitted to by law, to have an expert evaluation carried out, it may be included in the overall timetable for the project. One of the difficulties identified by some company heads is the risk that if they announce information that is not yet final, they will later be accused of hindrance if developments in the project lead to a change to these decisions. But there is no reason not to present **scenarios that are being examined** to the representative bodies particularly in the area of organisation, by clearly explaining that they are *scenarios* that will be subject to further examination and simulations (chapters 3 and 4). This way of working is necessary to be able to implement a participative approach that involves the staff. It also makes it possible to take the response from the bodies into account during subsequent examination of organisational scenarios.

Experience of human factor interventions in major projects shows that company heads who were initially reluctant to circulate information that was not final, discovered the benefits of this practice at the time of an investment, and then made it a general practice: social negotiation progresses more smoothly, the participation of the teams concerned is encouraged and there is potentially less of an impact on the timetable of the project.

Relationships with staff representative bodies: some key points

This enrichment of the social dialogue surrounding a project involves a learning process on both sides. At each stage, it is necessary to ensure the examination of the proposed solutions, discussion of their advantages and disadvantages to enable trade-offs when this is possible, but also the acknowledgement that some constraints are non-negotiable.

The following qualities in elected staff representatives and representatives of trade union organisations can be leveraged:

- they have good knowledge of the site;
- they know the employees on the site but also managers in the group, which facilitates interactions;
- they are a powerful channel for communication;
- they can bring an additional perspective to the project;
- inter-branch organisations have members who work for subcontractors and can more easily highlight problems or improve interfaces.

Consultation will be even more effective if the partners have defined common issues, common objectives and methods of interaction. A process of dialogue can be initiated in line with the obligations for the provision of information to and consultation of staff representative bodies, in particular by deciding on tasks on specific subjects that are jointly defined, or by calling joint meetings when necessary on specific subjects, such as professional advancement, career development, changes to working hours and working patterns, etc.

It is therefore advisable for the project owner to have a qualified person to manage the interface with the staff representative bodies throughout the project.

1.6 Planning all of the dimensions of the project

The planning of the technical design stages is always carried out in a precise manner. In particular, in the case of an installation that is to be connected to the existing units, the works are often scheduled to coincide with a major shut-down for maintenance of the latter.

However, other dimensions of the project are sometimes much less specifically anticipated. It would be advisable for the following aspects to be included **in the scheduling of the project from the outset**:

- hazard studies, risk analysis (HAZOP analyses or what-if reviews), preparation of the operating permit application;
- implementation of the environmental offset measures identified during the preliminary design phase;
- preparation and submission of the operating permit application;
- provision of information to and consultation of staff representative bodies, social negotiation of the future organisational structure, which may include the carrying out of an expert evaluation requested by the works council and/or the health, safety and working conditions committee;
- human factor analyses and simulations concerning the future operation of the installation (HOF framework, see chapter 4);

- development and simulation of the organisational assumptions (see chapters 4 and 5);
- early recruitment of the future teams and managers, undertaking of training and accreditations;
- pre-site project review;
- pre-start-up project review (see chapter 7).

2

Coordination between the project owner and the project contractors

Summary

The project contractors are responsible for implementing the intention expressed by the project owner, by seeking solutions that are compatible with the constraints and resources established by the latter. The smooth running of the project requires coordination at every stage between the project owner and the project contractor, to enable the design problem to be gradually and collectively fleshed out. The quality of this interface rests in particular on the appointment of a project manager to represent the project owner, who surrounds himself or herself with a dedicated project team.

The detailed examination of technical solutions will be assigned to a project contractor, which may be internal (e.g. engineering teams in the group[1]) or external (engineering company). The project contractor manages the design phase and coordinates execution on the project owner's behalf.

The structuring of the project should help to ensure that **the activity of the project contractor supports the intention expressed by the project owner**. A project contractor that becomes autonomous due to weakness on the part of the project owner is the main cause of project risks.

2.1 The intention-feasibility dynamic

The design process is often represented in a sequential form in a 'specifications'-focused approach:

FIGURE 2.1 - *The classic model of design*

According to this model, the project owner would exhaustively define its objectives and needs at the start of the project, which would enable the project contractor to examine solutions that meet all of the constraints established in this way. This model, which provides the structure of the Public Procurement Code for example, does not reflect the reality of the execution of design processes, or the way in which the stakeholders think.

1. It is important to ensure that it is not under the hierarchical authority of the project owner, which would make difficult the effective coordination of the points of view of the project owner and the project contractor, as described in this chapter.

In reality, after the initial definition of the objectives by the project owner, the project contractor will begin to examine their feasibility and to search for potential solutions. This initial examination will enable it to identify grey areas, contradictions or discrepancies between the objectives set and the objectives assigned. It will then have to **go back to the project owner** to obtain clarifications and trade-offs:

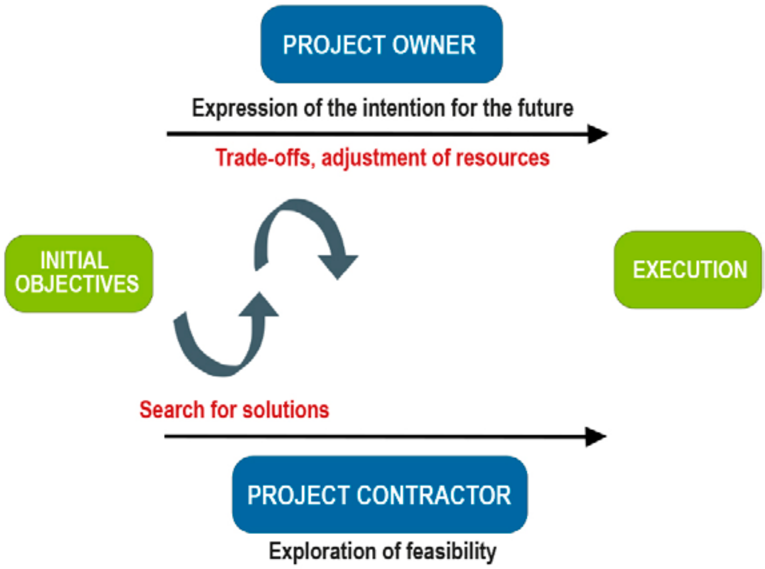

FIGURE 2.2 - *The initial project owner/project contractor interactions*

The project owner can clarify its intention, remove objectives that are unachievable with the resources planned or allocate new resources to support the objectives. This cycle will continue throughout the design process, until final execution:

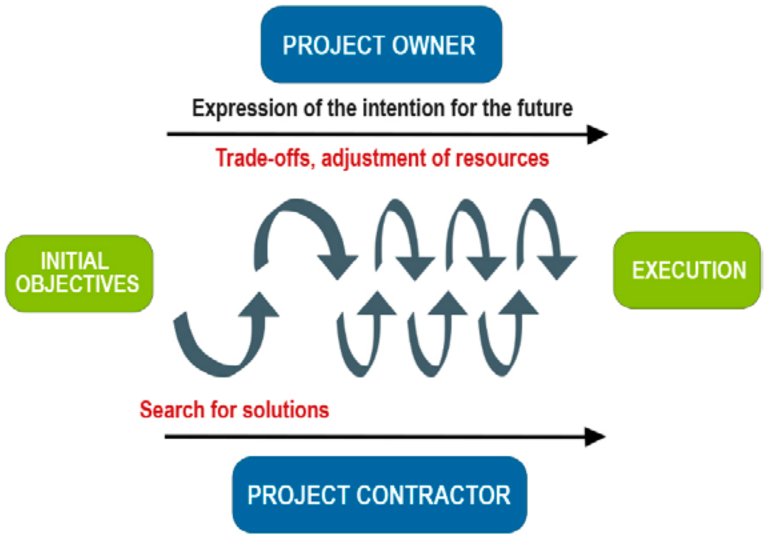

FIGURE 2.3 - *The project owner/project contractor dynamic*

It is the examination of solutions that raises new issues, makes it necessary to have objectives explained, to remove contradictions between them and to make trade-offs between objectives and resources.

For example

Example

A technical solution may be rejected by the projector manager because it results in excessive arduousness, and the retention of ageing workers is one of its priorities (which it perhaps had not expressed in the initial objectives). Or, a solution that appears very satisfactory in all respects requires additional resources, which the project owner may or may not decide to allocate based on the issues.

The 'design problem' cannot be exhaustively defined initially and is gradually fleshed out, combining the search by the project contractor for feasible solutions and the refinement of the project owner's intention[2].

When the project manager is forceful and well represented it makes the necessary trade-offs between intention and feasibility. If the project owner is not involved, it is the project contractor that answers the questions that it itself has raised: it will often do so based on purely technical expertise, at the risk of underestimating the sociotechnical challenges of the solutions adopted.

2.2 The tasks of the project contractor

The project owner has a choice between two forms of the use of project contractors:

- ▹ a design contract: the project contractor is appointed to carry out the design phase, and the project owner will enter into a contract directly with the executing companies;
- ▹ much more frequently, an EPC (engineering, procurement and construction) contract: the project contractor is appointed to carry out the design phase, select the executing companies and complete the construction project; it is the project contractor that will enter into a contract with the executing companies.

The distribution of the design work between the project contractor and supplier companies may take place in two different ways, depending on the type of provision:

- ▹ in some cases, the engineering teams will write the specifications for the consultation of the supplier companies (physical installations, process computing, etc.) at the end of the core design phase, and the companies selected will manage the detailed design phase. In this situation, the design power of the supplier companies is widely used;
- ▹ in other cases, if the engineering teams have design expertise in all of the processes concerned, it is the project contractor that will manage the detailed design phase; the latter will result in the specifications for the companies that will manage the construction project. In this situation, the design power is concentrated within the project contractor's organisational structure;
- ▹ a combination of these two situations, depending on the type of provision, is frequently encountered.

The formalisation of the project contractor's responsibilities relating to the HOF approach is discussed on page 30.

2.3 The quality of the project owner/project contractor interface

As noted in the previous chapter, the primary requirement for the smooth functioning of this project owner/ project contractor interface is the existence of an identified and available **project manager to represent the project owner**, who is a permanent discussion partner for the project contractor. He or she will seek the assessment of the project management group at milestones planned in advance, and when necessary.

2.3.1 A project team

In order to carry out its functions, the project owner's project manager may call upon the company's various departments (e.g. HR department, HSE, purchasing, etc.). But he or she will generally also require a **dedicated project team**. This team will include at least:

- ▹ technical specialists capable of analysing the project contractor's proposals, their compatibility with the established objectives and their costing;

2. According to [Martin 2000].

- ▷ operating expertise making it possible to anticipate the actual operating requirements of the installations, **prepare the organisational assumptions**, prepare the training plans, coordinate the writing of the procedures, *etc.*;
- ▷ cost planning and control expertise;
- ▷ environmental and human factors expertise (see chapter 3).

The skills required in this project team and their gradual development will be planned from the outset. It will be necessary to ensure the stability of employees throughout the project.

The project owner may be geographically distant from the site in question. However, it is essential that the project manager representing the project owner and the project team be located **on the site** where the new unit will be located. This geographic proximity is critical for the interface with the operators, the quality of the preparation and supervision of the construction project, and the execution of start-up. It may be necessary to put temporary facilities in place.

2.3.2 Other support

Depending on the characteristics of the project, the project owner may use different types of internal or external consultants, to assist it with aspects relating to energy, the environment, regulations, human factors, etc. It is essential that the project owner's project manager have an overview of the contribution of each consultant.

2.4 In summary: the overall structuring of the project

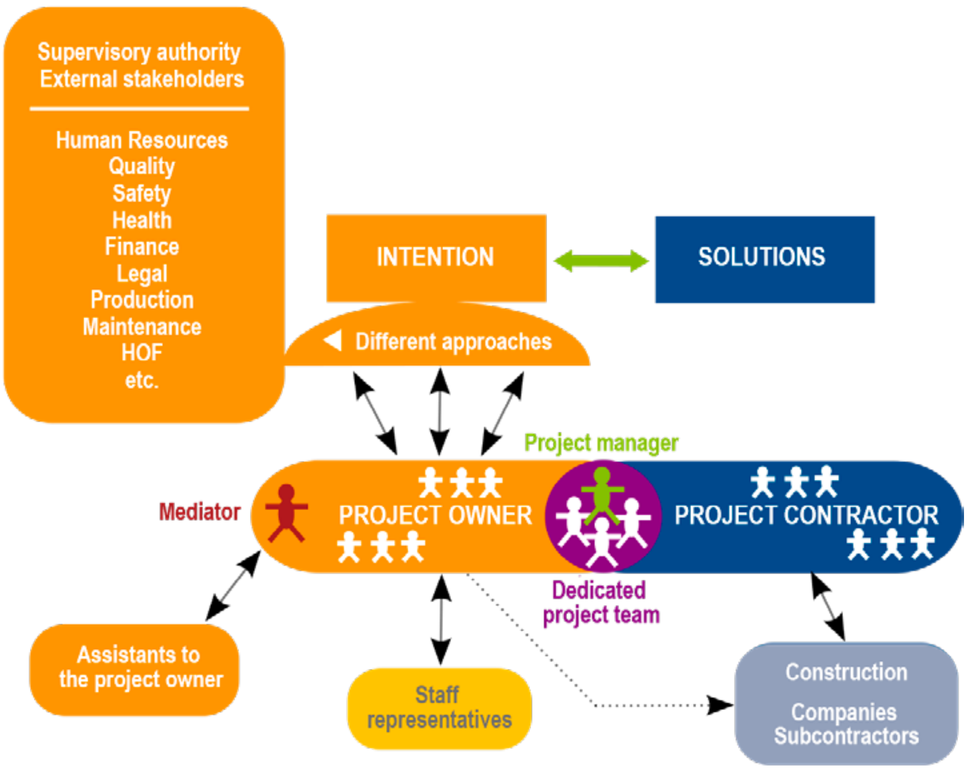

FIGURE 2.4 - *The overall structuring of the project, according to* [JACKSON 1998].

In summary, the structuring of the project has the following characteristics:

- ▷ all of the project's key issues (relating to internal and external stakeholders) are reflected within the **project management group**, which represents the vision concerning the future operation of the system, and in particular provides the interface with the external and internal partners (staff representative bodies);

- ▷ possibly assistants to the project owner;
- ▷ a '**mediator**' who is capable of establishing the compromises between the different approaches;
- ▷ a **project manager to represent the project owner**, ensuring continuous representation of the project owner alongside the project contractor and requesting project management meetings when necessary;
- ▷ a **dedicated project management team** that assists the project owner's project manager;
- ▷ a **project contractor** tasked with designing and possibly implementing solutions compatible with the project owner's objectives.

3

The expected benefits and the conditions for the success of the HOF approach

Summary

The establishment of a HOF approach in the project helps to contribute to the improvement of the overall sociotechnical system, the reduction of uncertainty regarding industrial safety, the improved circulation of information and the convergence of efforts. The HOF approach should be planned from the start of the project for it to be harmoniously integrated into the design stages and provide the necessary information and validations in a timely manner. In the case of an EPC contract, the HOF approach is formalised with the project contractor. The conditions for the involvement of the operators in the project should also be defined early.

Before describing the possible contributions of a HOF approach to the management of an investment project in chapter 4, we will consider its expected benefits and the conditions for its success.

3.1 The benefits expected by the project owner and in particular the site management

The establishment of a HOF approach requires project structuring that gives pre-eminence to the project owner over the project contractor, and that fosters coordination between the two (see chapter 2).

The primary requirement for the success of a HOF approach in an industrial project is therefore the conviction of the project owner and in particular of the site management. They can expect it to deliver the benefits described below.

3.1.1 The reliability of the overall sociotechnical system

The HOF approach will enable:

- ▷ more interaction between the different project and operations stakeholders;
- ▷ greater consideration of the future use throughout the design process.

Normal operating situations or incidents that are likely to arise in the future are thus more likely to be considered from the design phase and corrected in planning rather than being discovered during operation.

The early involvement of the operations managers and teams increases operators' control and their ability to deal with foreseen and unforeseen situations.

3.1.2 Improved control of start-up and the budget

In the absence of a HOF approach, a strain is often placed on the budget by the appearance of numerous risks during the design phase (comments from the operator coming at a late stage), and by a problematic start-up that requires modifications and results in an operating loss.

Unfortunately, these significant costs are often not fully analysed, due to the lack of an approach that considers the overall budget of the project.

When a HOF approach is established, its cost is that of the HOF participants, the time for meetings and the participative approach. The results of simulations lead to changes to the project at the planning stage. These changes are offset by **the reduction of the risks discovered at a late stage** in design. In most cases, start-up takes place on schedule with minor modifications. There is no significant operating loss. The outcome is therefore improved design, not only as a result of the presence of HOF specialists but of all of the interactions between stakeholders encouraged by the approach.

3.1.3 The reduction of uncertainty regarding industrial safety

A project in a high-risk industry always comprises a measure of uncertainty, in particular regarding the ability of the organisational structure to deal with potential incidents. Will we be able to safely shut down the installation under any circumstances? The setting up of simulations of the future activity contributes to reducing this uncertainty:

- ▹ it enables early improvement of installation design, organisational arrangements and procedures;
- ▹ it enhances the ability of the teams and the managers to manage the installations and to deal with rare incidents, thus improving preparedness.

3.1.4 Improved information flow

One of the frequent problems in projects is the gap between the levels of information possessed by the different stakeholders. The human factors approach is driven by interactions with numerous project stakeholders. It generates 'intermediate tools' (reports, schedules, mock-ups, etc.) that can be shared by all. It gives rise to meetings bringing together different types of stakeholders. As a result, it contributes to the flow of information regarding the progress of the project and to the alignment of the opinions on all sides. In particular, it supports the provision of information to the operations managers regarding the solutions adopted by the project team.

3.1.5 The convergence of efforts

Remote engineering contractors are often perceived by site-level staff as being outsiders who are not familiar with the local traditions and way of operating, and projects that they manage may be mistrusted and rejected as a result. Conversely, project management that involves the local stakeholders in the anticipation of future operation and in the development of the solutions proposed fosters the acceptability of the project and the convergence of the different efforts: project team, operations managers, local managers, operations teams. Senior operators have fewer concerns about their ability to undertake new training and to obtain new accreditations.

If the requirements for the provision of information to and consultation of the staff representative bodies (chapter) are met, the HOF approach can also support the improvement of social dialogue.

3.1.6 The reduction of arduousness and the frequency of accidents

Installation design that incorporates the requirements of human activity at an early stage can contribute to a reduction of the arduousness of the execution of operations, lower exclusion of ageing workers, the lowering of certain fitness requirements, and contribute to lowering the frequency of accidents. However, it is necessary to ensure that the reduction of physical stresses is not accompanied by an increase in constraints on work rate or an increase in the information processing load.

3.2 The organisation of the HOF approach

3.2.1 The expertise required

The implementation of a HOF approach throughout a project requires the expertise of ergonomists (or of human factors specialists[1]). For a major investment, simply making a technical manager aware of human factors will not be sufficient to ensure the coherent consideration of all of the aspects at issue.

1. The term 'ergonomist' is associated with European culture, including British culture. The term 'human factors specialist' is traditionally linked to US culture. Convergence of these two terms is taking place at the international level, in view of the fact that the *Human Factors Society* in the US has become the *Human Factors and Ergonomics Society* and that the *Ergonomics Society* in the UK has become the *Institute for Ergonomics and Human Factors.*

A coordinator of the HOF approach should be appointed. Depending on the size of the project, he or she may be accompanied by several qualified participants, perhaps with different areas of expertise (e.g. ergonomist specialising in HMI, organisational specialist, etc.).

The HOF participants in a project will bring to bear expertise based on:

- knowledge of the functioning (physical, cognitive, psychological) of human beings and of organisations, making it possible assess the human cost[2] of an activity and the different associated risks (risk of errors, risks to health);
- methods for the analysis of activity in existing situations;
- methods for the simulation of the future activity and the assessment of the HOF of the planned system;
- methods for the integration of HOF aspects at every stage of the project, in collaboration with the stakeholders concerned.

They may be employees of the company or external consultants[3]. For major projects, it is preferable that they be employees of the company, for example, made available to the project by the central departments for example.

3.2.2 The positioning of the HOF participants

Some companies have chosen to position HOF expertise in the organisational structure of the project contractor, by requiring that it have an ergonomist. The latter can then participate in the technical aspects of design; but, if HOF expertise is positioned there alone, the project owner deprives itself of a human factors contribution in the definition of the project objectives, the organisational assumptions, the preparation of training, the writing of the procedures, etc.

In order to give full scope to a HOF approach, it is advisable that the person taking the lead on it be positioned in the organisational structure of the project owner[4]. A good solution can be to **assign him or her to support the project owner's project manager**, within the project team. This position ensures the legitimacy of the HOF approach, proximity to the information flows and design stakeholders, and enables a cross-cutting perspective. The HOF lead can be invited to the meetings of the project management group when necessary. He or she will participate in the pre-validation of the major design choices at different milestones in the project.

3.2.3 The framework of the HOF approach

The scale of the HOF approach[5] should make it possible to make all of the contributions set out in chapters and 5. Ideally, it should therefore be planned throughout the project, from the definition of the objectives to the evaluation of start-up. An HOF lead should therefore be identified from the preliminary design phase[6], in order to contribute to the framing of the approach. The use of additional HOF participants can take place for an amount of time that is variable depending on the stage of the project.

The **framing of the HOF approach** in the preliminary design phase consists of:

- determining before or during the preliminary design phase the specific issues, opportunities and risks of the project with regard to human and organisational factors: characteristics of the population,

2. The human cost of an activity relates to its negative effects on people:
   - in the short term: significant stress, uncomfortable postures, pain, significant fatigue, injury, tension, conflicts in a group, etc.
   - in the longer term, due to the repetition of certain situations: health effects, limited fitness or exclusion from functions, anxiety, depression, deterioration of interpersonal relationships, etc.
3. A company that requires a guarantee of a participant's expertise can ensure that he or she has a master's degree in human factors and/or the European Ergonomist® credential. This certification, established by all of the European ergonomics societies, is based on the assessment of training, professional experience and skills maintenance. The US equivalent is called *Certified Professional Ergonomist* or *Certified Human Factors Professional*.
4. Incidentally, this is still possible in the case of an ergonomist with the team of the project contractor, in particular when the latter has a design and build mandate.
5. Standards in English-speaking countries refer to HFE (human factors engineering) screening: this term describes the early identification of all HOF needs, which results in the definition of an overall HOF strategy and the planning of the approach. See in particular the article by Seet & McLeod mentioned in the initial summary of this document [Seet and McLeod 2012].
6. This HOF lead brought into the preliminary design phase very early on will sometimes not be the person who will actually monitor the project in the subsequent design phase.

identification of known problems in existing situations, degree of innovation, technological risks, complexity of the interfaces, social or even societal issues, etc.;

- enhancing the information used to establish the initial assumptions, as regards staffing or organisational structure for example[7];
- encouraging and informing the definition by the project owner of the sociotechnical objectives relating to these different issues and **their expression in the functional programme** (chapter 1);
- producing the 'people and organisations report' in the functional programme in collaboration with HR department teams (page 16);
- identifying the company's other approaches or procedures that are likely to interfere with the human factors approach;
- determining the overall human and organisational factors approach for the project as a whole, and defining what it requires from each of the project's stakeholders (**HOF integration plan**);
- contributing to structuring of the project that enables continuous interaction between the project owner and the project contractor, and introducing the corresponding requirements into the formalisation of the project contractor's role (chapter 2);
- translating the overall HOF strategy into methodological steps, negotiating the corresponding resources and incorporating the HOF steps into the overall project schedule.

3.2.4 The allocation of resources

The HOF approach is not an 'expense', but a part of the investment. As such, it should be budgeted for from the start of the project. Of course, the sum to be provided for depends on the nature of the project, its degree of innovation, the level of industrial risk and the overall HOF strategy put in place (in particular the distribution of the HOF tasks between the internal project team and the project contractor).

Although the budget structure of projects can vary greatly, some real examples[8] are a basis for the suggestion of the following scales:

- cost of the human factors participants: 0.10 to 0.25% of the investment total;
- internal cost of the human factors approach (time of the management, project team, managers and operators): 0.5 to 1.5% of the investment total[9];
- the budget allocation to incorporate the outcomes of the human factors approach into design (equipment contributing to enhancing safety and to preventing arduousness, correction of design errors identified in this way, etc.): 1 to 4% of the investment total.

3.3 The formalisation of HOF in the project contractor's role

The establishment of a HOF approach is for the project owner to decide. If an overall HOF approach is established, the project contractor's specific responsibilities in this area should be set out in the functional programme and in its contract with the project owner. The following will be specified in this way:

- the presence of a HOF contact or even a HOF specialist in the project coordinator's team;
- the conditions for the participation of the project contractor in the hazard studies and risk analyses;
- the nature and the planning of the HOF information that will be supplied by the project owner and are to be considered by the project contractor, in particular the benchmarks for design and the results of the simulations;
- the nature and planning of the information, materials and resources that are to be supplied by the project contractor to enable the execution of the HOF approach (e.g. type of plans or mock-ups, presence of a representative of the project contractor in the working groups carrying out the simulations, intermediate version of the management procedures or documents, etc.);

7. When the project concerns the modernisation, expansion or relocation of an existing installation, the execution of the above tasks may require the HOF specialist to carry out a detailed analysis, starting in this phase, of its current operation and the difficulties encountered (see chapter 5).
8. Examples from the chemicals and petrochemicals sectors.
9. Since these salaries are paid in any case, the allocations made for the HOF approach are rarely specifically identified.

- ▹ the methods of interaction between the project contractor and the project owner (regular meetings in particular) at every stage of the project;
- ▹ the nature and the date of the HOF validation milestones of each of the stages of design;
- ▹ the HOF requirements that the project contractor is to incorporate into the specifications and into the process for the selection of companies;
- ▹ the project contractor's expected contribution to the training of the operators;
- ▹ the contractual forms for the participation of the operations teams in commissioning when it is carried out by the project contractor;
- ▹ the HOF requirements relating to preparation of the construction project, and the requirements for the coordination of the construction project between the project contractor and future operations managers;
- ▹ the forms of project contractor's presence in the start-up stage;
- ▹ the requirement for a usage evaluation a few months after start-up;
- ▹ etc.

3.4 The involvement of the operators

The presence of operators **(production and maintenance)** in the project is a prerequisite for its success and it takes several forms.

3.4.1 The presence of experienced operators in the project team

It is common for operations staff (operators, shift managers, maintenance team managers, production engineers, etc.) to be assigned to the project team. This presence is very helpful for fostering the consideration of operating constraints in the design decisions.

Nevertheless, it should not be understated that after several months in a design team, experienced operators gradually and partly take on the way of thinking of their designer colleagues. It may be necessary to allow them to periodically return to working in operations.

The way in which assigned operators are involved in the project should not place them in the position of merely being endorsers of the rest of the project team: their contribution should therefore be coordinated with the whole of the HOF approach.

Furthermore, their presence is not a substitute for the regular provision of information to the current operations managers on the progress of the project.

3.4.2 The involvement of the current operations managers

The ownership of the project by the entity that will receive the installation is a key issue. The current operations managers are often marginalised in the execution of the project, in particular due to their day-to-day workload. Occasionally, this lack of involvement has serious consequences:

- ▹ the local managers have difficulty answering questions from the teams about the project;
- ▹ it is difficult for them to anticipate the effects of the new installation on the operation of the other units, and therefore make little contribution to the consideration of the organisational assumptions;
- ▹ they are likely, in the existing units, to take decisions that will be challenged by the project.

In fact, the operations managers should be involved from the start of the project, for example during a kick-off meeting, in which they will contribute to the surveying of the risks and opportunities relating to the project.

The regular provision of information to the current operations managers should be organised by the project manager representing the project owner, for example in the form of a monthly meeting. A certain number of project tasks should specifically involve them, such as the identification of the operating situations (see page 41).

3.4.3 The involvement of the future operators

The establishment of a human factors approach requires the participation of future operators (local operators and managers) from the detailed design phase[10]. Moreover, the training required for the management and the maintenance of the new installation and the writing of the procedures should also start at this stage.

It is therefore essential that the **future operators** of the new installation be **identified early on**, whether this involves recruitment or transfers from other units on the site or from other sites. While it is not always possible to appoint all of the members of the future teams very long in advance, a gradual build-up is advisable[11]:

- appointment of the future operations manager for the unit from the start of the project, if possible in the function of the project manager representing the project owner;
- appointment of the local managers and a proportion of the senior operators 18 months to one year before the start of the construction project, to enable their participation at the end of the detailed design phase and the preparation of training (which does not require that they be available for the project full-time, but can be a part-time assignment away from the previous functions);
- future teams fully established no later than the start of the construction project, to enable the completion of training, participation in the tests and the completion of accreditations.

3.4.4 The requirements of a participative approach

A participative approach to human factors does not consist of gathering the 'opinions' of employees on technical and organisational directions.

It aims to involve them in the joint assessment or even selection of these solutions, based on the questions ***'How will we work in the future system? What issues are we likely to encounter? Which solution directions can focus on?'***, applied to various operating situations.

This direct participation by operators is viewed differently from the participation by their elected representatives in the staff representative bodies. The latter have the function of representing the interests of all of the employees over a wide range of areas (employment, status, qualification, remuneration, working conditions, working hours and patterns, training, social benefits, etc.). Operators who get involved in the assessment and development of solutions are representing their own professional expertise.

These two forms of representation should therefore be combined: it is impossible to establish a participative approach if the staff representative bodies are not being specifically informed and consulted beforehand on its objectives, stages, and the arrangements for the establishment of the working groups. If the staff representatives support the project management put in place, this will foster the trust and engagement of employees. Staff representative bodies should also be regularly kept informed of the outcomes of the approach.

10. This training should start from the core design phase in the case of the modification of an existing installation. If the future operators have not been specifically identified, it is possible to involve in the project operators with the skills that will serve as a basis for the future appointments.

11. Examples from the chemicals and petrochemicals sectors.

Part two

The HOF approach

4

From current activity to future activity: the HOF stages in design

Summary

The HOF approach aims to anticipate the future activity that will take place in the new installation. It interfaces with the design process at every stage of the project. One of its first key contributions is the definition of the future normal or adverse situations that will have to be managed for the operation of the new system.

The future unit will be operated by women and men whose activity will determine the performance and safety of the installation, as well as the health and safety of the people concerned. This activity must therefore be supported by the **technical and organisational design** of the entire system.

4.1 Different dimensions of a HOF approach

Consideration of human activity in the design of a system has several dimensions[1].

- The best known dimension concerns the **adaptation of working methods** to the physical and perceptive characteristics of the users (in their diversity): making valves accessible to operators of any height; avoiding excessive strain; preventing exposure to harmful ambient factors; displaying information in a clear form contributing to the quick and accurate understanding of a situation, and therefore the taking of appropriate decisions; designing controls in accordance with good practice; sizing furniture, etc. This vital consideration is often lacking in industrial design projects[2]. It can be significantly improved simply through compliance with design standards.
  But this necessary adaptation of working methods to human physiology is insufficient if we do not consider **the actual activity**. Installations are very often primarily designed for operation that is meant to be normal. When the operating conditions deviate from the design assumptions, for example during start-up, an incident, maintenance, etc., the operators may have to manage situations not foreseen in design. In that case, the operating conditions may be problematic with regard to working conditions, safety, but also industrial performance.
- The second major contribution of a human factors-ergonomics approach therefore consists of identifying the **situations** that the operators will have to manage in the future installation, and considering the activity that it will be possible to carry out in these situations, using **simulations**, which will be described later. The technical and organisational assumptions can be tested with these simulations, and be corrected at the design stage if necessary.
- The third contribution of a human factors approach consists of promoting the **development** of the system and people beyond the initial situation that will follow start-up. An industrial system that is not advancing is a system that is moving backwards, particularly given the ageing of installations. We will focus here on the organisational conditions that will drive the continuous improvement of safety, the development of skills, the management of career paths, social dialogue, etc., in day-to-day operations.

1. See for example [Béguin 2004].
2. Annex 1 of the OGP 454 guide mentioned in the summary of this document [IOGP 2011] provides examples of illustrations of what should be avoided.

4.2 The stages of a HOF contribution in the project

This section presents an overview of the HOF contribution possible at each stage of the project. The corresponding methods will be set out in detail in chapter 5.

4.2.1 Preliminary design phase

The HOF contribution during the preliminary design phase was described above in the 'framework of the HOF approach' paragraph, on page 29.

4.2.2 Core design phase

During the **core design phase**, depending on the major technical options that are outlined, the work of the HOF specialist will largely concern the identification **of the likely future operating situations**, of the main characteristics and of the requirements for the project arising from them. It is a question of defining, as specifically as possible, production and maintenance situations that the operators may have to manage in the future, not only in normal operation, but during start-up, incidents and shut-downs (placing a specific emphasis on **critical tasks** from a safety standpoint). This identification should enable design to take account of all operating situations, and not only situations of normal operation.

For example

Example

The emptying of a catalyst bin into a reactor is a 'simple' operation. However, all of the following operations have to be possible:

- identifying the correct catalyst bin in a storage area
- transporting the bin to the location for emptying
- **opening the bin** (tool?) and **setting down the lid and the tool**
- obtaining permission from the control room to carry out the operation
- opening a hatch (reactor in operation)
- positioning and tipping the bin
- **being able to determine that the bin is empty**
- **removing the remaining catalyst stuck to the bottom of the bin**
- removing and closing the bin, putting the tool away
- informing the control room of the completion of the operation
- **cleaning up any product that fell on the floor**
- removing the bin to a storage area for empty containers.

These operations have to be possible **during the day, at night and when it is raining or snowing**. They may be carried out by an operator who is tall or short, young or older, a wearer of corrective glasses, etc. The urgency of the operation and the timing margins should be specified. The solutions selected should take account of the fact that the catalyst is highly toxic (operator with disposable overalls over his or her work overalls, mask, protective goggles, gloves, etc.).

This identification of the operating situations will be based on three sources:

- familiarity with the technical options being examined;
- the analysis of the current situations on the site concerned by the project (see details in chapter 5);
- the analysis of situations existing on sites with solutions that are similar to those being examined.

The corresponding methods are set out in detail on page 41.

The definition of the operating situations will help to produce 'benchmarks for design' (page 41) that will supplement the specifications. It will then serve to develop the simulation scenarios that will be used to test the technical and organisational assumptions.

These operating situations will also be used during risk analysis.

An initial series of simulations may take place during the core design phase to inform the selection of the major technical or organisational options. The majority will take place during the detailed design phase to test the solutions proposed and to have them corrected before their implementation if necessary.

4.2.3 Detailed design phase

As technical solutions are proposed by the designers, and the organisational assumptions take shape, it is possible to set up **simulations** of the human activity that will be necessary to make them function or maintain them, detect likely problems and enable their correction at the planning stage.

The carrying out of these simulations requires the participation of operators and operations managers. It contributes to their learning about the future installation and therefore to their training. The process will be set out in detail in chapter 5.

During this phase, the HOF participants will also contribute to the preparation of the construction project and start-up.

4.2.4 Construction project

As the new installations are built, it is possible to carry out full-scale simulations (equipment in idle mode) of the execution of certain operations. These simulations enable the adjustment of certain configurations (addition of platforms, walkways, handles, labels, etc.). They also contribute to the operators' learning about the installations and the training. Visits to manufacturers can assist familiarisation with certain key sub-assemblies.

4.2.5 Trials and tests

The participation of the operators in the trials and tests contributes to their knowledge of the installation. It may require contractual provisions with respect to the supplier who has legal responsibility for commissioning.

4.2.6 Start-up, evaluation of the project and transition to ordinary operations

Chapter 8 will stress the importance of an HOF presence at start-up and will cover the evaluation of the project and the management of the transition from project mode to normal operating mode.

Table 4.1 summarises the main HOF contributions possible throughout the project.

Technical stages	HOF contribution
Preliminary design phase	Supplementation of the objectives Identification of the issues Definition of the guiding operating concepts and principles Framing of the HOF approach Incorporation of HOF into the functional programme
Core design phase	Analysis of existing situations: • definition of the future operating situations Provision of benchmarks for design
Detailed design phase	Technical and organisational simulations Provision of benchmarks for design Preparation of the construction project
Construction project	Full-scale simulations Preparation of start-up
Start-up Nominal	Evaluation of start-up
Operation	Usage evaluation Lesson learned from the project

TABLE 4.1 - *The HOF contributions at the different stages*

Chapter 5 will now set out in detail the methods that it is possible to implement at each of these stages.

5

The methods of an HOF intervention in a project

Summary

The HOF approach is based on the combination of two key methods:

- ▷ the in-depth analysis of the work carried out in existing situations that are relevant to the project;
- ▷ the simulation of the future human activity that is likely to result from the design choices.

The HOF specialists will provide the designers with 'benchmarks' to improve the design, in line with the design decisions that are taken at each stage.

The entire HOF approach in design converges towards the carrying out of simulations of the future activity. The steps to be followed during the intervention consist of gathering enough information on current activity in existing units and on the technical and organisational solutions being designed to be able to anticipate the future activity, identifying the likely problems, and to influence design on this basis.

5.1 Knowledge of the project

The first task of any HOF participant in a design project is to become specifically acquainted with its organisational structure:

- ▷ objectives of the project;
- ▷ general framing of the HOF approach;
- ▷ structure established between the project owner and the project contractor, organisation of the project team;
- ▷ scheduling and progress;
- ▷ progress of the design solutions;
- ▷ tools and materials used (e.g., schematics, comprehensive plans, dimensional drawings, PID diagrams, 3D representations, etc.).

A HOF participant who does not have basic technical training must give himself or herself the means to understand the procedures and technologies at issue, without however becoming a technical expert.

5.2 Analysis of the existing situations

The foundation of any human factors approach is the fact that human activity can never be described as merely the execution of prescribed procedures[1]:

- ▹ the operators have to manage numerous forms of variability, numerous disparities between the actual situation and that which was anticipated by the procedures;
- ▹ they do so by making use of their bodies, their intelligence, their experience and that of the groups to which they belong;
- ▹ the performance obtained is not indicative of the human cost that was necessary to achieve it.

The learning of lessons from and the analysis of the existing situations aims to identify these dimensions of the activity, which are not apparent just from reading the job descriptions or the procedures.

5.2.1 Several types of 'reference situations'

In the case of a design project, it may be helpful to analyse several 'reference'[2] situations:

- ▹ the current units, which the project aims to modernise, group together, expand or relocate;
- ▹ other units, possibly on other sites, that have similar characteristics to those that the project is aiming to introduce.

In general, the first case does not present any access issues. The second set of situations may concern another site in the same group, an industrial pilot[3], or installations of another company, to which there is open access in the context of industrial trade or through a supplier. The analyses possible in this latter case will obviously be more limited.

In all cases, the HOF participant will present his or her mission to the managers and to the teams concerned, and will obtain their agreement prior to the observations.

5.2.2 The understanding of the prescribed activity and the analysis of the operation patterns through lessons learned

The meetings with the unit's managers are an opportunity to learn about the process and the organisation of the sector, and to discuss critical stages of its operation. They will be supplemented by documentary analysis to understand the prescribed tasks, through the process drawings, organisation charts, organisation notes and job descriptions. Analysis of the characteristics of the population (in particular age and length of service, qualifications) will also be carried out.

It will be followed by the analysis of documents concerning the unit's operating conditions: production (volume and quality) and maintenance reports, incident reports, accidentology and first aid, absenteeism, issues raised by the staff representatives, etc.

The purpose of this documentary analysis (lessons learned) is to identify sets of situations in which the planned performance is not achieved, or is achieved at a high human cost.

This stage does not require in-depth ergonomics-human factors expertise and can be shared within the project team.

5.2.3 The understanding of the actual activity

The main method of HOF analysis is based on the observation of the activity. The HOF participant will, over sufficiently long periods of time, observe the activity of the different categories of operators[4] in the control room and in the field. The purpose of this analysis of the activity is not to assess its compliance with the

1. See the 'State of the art' Cahier [Daniellou et al. 2011].
2. This term does not mean that these are references that it is desirable to emulate, but rather situations to which reference is made in order to gather information. The approach in terms of 'reference situations' differs from certain benchmark approaches aimed at identifying interesting solutions elsewhere, and incorporating them into the project, without considering the differences in contexts that may result in the failure of this transposition.
3. Or even in certain cases part of an experimentally reconstructed installation.
4. It will be necessary for the HOF participant to have the required accreditations.

prescribed procedures, but to understand the variabilities that the operators have to manage, the development of their operating methods, the collaborations between operators, and any sources of human costs. It is in particular a question of identifying the factors that determine the efficiency of the operations, those that generate human costs, risks of error, performance impairments, etc. Observation is supplemented by meetings with the people concerned, which may focus on the situations observed and on others that occur more rarely. The conclusions are validated with the people observed. These methods require specific expertise in the ergonomic analysis of activity.

5.3 The identification of the 'operating situations'

Based on the observations in the existing situations mentioned above and on the knowledge of the technical and organisational solutions being examined, and by involving the operations managers and members of the project team, it is possible to establish an initial definition of the main 'operating situations' observed in the existing situations and that are likely to occur in the future system:

- ▹ interventions in normal operation, including the surveillance strategies, the organisation of the tours or patrols, the supply of raw materials, the sampling for testing or analysis, the transfers and the removal of products, regular cleaning, waste management;
- ▹ transitional operations (start-ups, product change, shut-down, product transfers, etc.);
- ▹ handling of frequent or critical incidents (tripping, fluid system losses), operations requiring the presence of several operators;
- ▹ synchronisation and coordination between the members of the operating team in the control room and in the field, with maintenance, with other units;
- ▹ tagout/lockout prior to maintenance;
- ▹ frequent or critical maintenance operations; management of the interface with the contractors (work requests, works permits, acceptance of the works, etc.);
- ▹ etc.

The factors influencing the execution of the tasks in these situations are also mentioned: daytime or night-time operation, bad weather, influence of the condition of the rest of the installations, etc. It is a question of identifying the invariant elements of the handling of these situations, but also their variation factors.

This surveying of situations should be discussed with the operations managers and the project team.

Key point

The start-stop modes

It is in particular essential that there be an agreement between the project team and the operations, automated systems and instrumentation managers on the identification of the critical equipment and on the strategies that will be implemented to carry out the start-up, shut-down, load-shedding of this equipment or to deal with their non-availability.

The selection of the safety positions of the valves (opening or closure in the event of instrument air failure, for example) may also result from this identification.

The tagout or lockout modes of the systems will also be reviewed.

From these situations, those that are critical for industrial safety will be identified ('critical tasks').

Following validation, this identification will become a common reference, which will serve as a basis for consideration of the solutions envisaged.

5.4 The HOF benchmarks for technical design

On the basis of the information on the project and of the analysis of the existing situations, it becomes possible to draw up 'HOF benchmarks for design', which will feed into the thinking of the project contractor and/or the specifications.

Some of these HOF benchmarks for design have fairly general validity (e.g. sizing standards, certain HMI design specifications), while others are specifically linked to the nature of the operating situation that have been identified.

Three main types of information can in this way be forwarded to the project contractor (after validation by the project owner's project manager).

5.4.1 The definition of the operating situations

The list of the operating situations and of their characteristics that has been drawn up should be forwarded to all of the designers: at the time of the design of each part of the installation, consideration can thus be given to all of the operations carried out in the area. From the outset, the designers will be able to consider the accessibility for each operation and solutions that limit arduousness and support the safe execution of the tasks.

The situations identified in this way will be the normal recurring operating situations, degraded operating modes and critical situations. Some of these situations may be generic (e.g. all of the sampling) and others specific (a specific incident).

The information forwarded alerts the designers to the need to consider operations other than normal operation and to ask a series of questions for each one (text box below).

Situations that are critical for safety will be identified as such, in particular as regards the operation of sensitive systems (e.g. prioritisation of the valves).

This information on the operating situations to be considered **in no way prejudges solutions** that the designers will find to support them.

Example

For each operation to be carried out

General characteristics of the operation

- Objectives?
- Time constraints of the operation?
- Geographic location, nature of the environment, available space, bad weather

Physical aspects of the operation

- Fittings (type, weight)
- Need to install fittings during the operation
- Clothing worn by the operator (PPE)
- What effort is to be exerted? What are the advisable postures given the nature of the operation? What movements are required?
- Precision requirements

Cognitive and collective aspects

- How can the system concerned be identified with certainty?
- What needs to be seen? What needs to be achieved, reached, activated?
- Who needs to be communicated with? What information needs to be received? What information should be forwarded to whom? In what form?
- What needs to be kept as stored information?
- What collaborations are required? Synchronisation with others?
- How can the result of the operation be monitored?
- What incidents may occur? How can they be identified? How can they be resolved?

Risks

- What risks are there? Toxic, noise, heat, process risks, etc.

5.4.2 The ergonomic specifications

On certain issues, there is sufficient specific expertise to be able to set normative objective for the designers. These are for example:

- anthropometric specifications (dimensions of the human body) and their consequences for the sizing of systems, staircases, etc.;
- maximum effort for the operation of a control or the handling of loads;

- lighting technology;
- permissible noise levels;
- exposure to physico-chemical risk factors;
- certain characteristics of HMI, in particular the presentation of the information on the condition on the installation;
- design objects for which there are company standards, industry standards, etc. (e.g. walkways, ladders, valves, etc.)[5];
- etc.

Other specifications can aim to ensure homogeneity with the rest of the existing installation: standards for designation or numbering, use of colours, labelling, etc.

On certain issues, the specification not only imposes criteria to be met, but also a set of questions to be considered.

Example

Example: for each valve

- Location on the unit, distance from the system supplied
- Usage (Regular? Increasing or on/off?). Grease valve? Acid valve?
- Environment (heat, projections)
- Special clothing?
- Identification, graduation
- Urgency of the operation? Duration of the operation?
- Position and direction of the wheel? Type and diameter of the wheel? Rotation effort?
- Position of the gauges showing the result of the operation?
- Communication needs during the operation
- Posture during the operation (feet, eyes)
- Accessibility for upkeep and maintenance, greasing, disassembly
- Tagout/lockout method.

The purpose of such analytical frameworks is to promote HOF vigilance across the whole design team: if, when locating each valve, the designer spends a few minutes considering these questions, the problems raised during the simulations will be much less numerous and easier to resolve.

5.4.3 Anticipating the future requirements of the HOF approach

When the specifications are written, it is important to notify the suppliers of the provisions that will expected from them in the future for the requirements of the HOF approach. These may be for example:

- regular interactions between the designers and the HOF participants, to ensure the design benchmarks are fully taken into account;
- the supply of plans or mock-ups;
- the supplier's presence at certain meetings;
- user manuals for certain equipment (specifying the language);
- visits to the supplier at the time of the assembly of equipment;
- the supplier's participation in certain training sessions;
- HOF requirements for the preparation of the construction project;
- the forms of its presence at the time of start-up;
- etc.

5. The operators will be involved in the determination of the tapping and sampling required.

All of the provisions that are indicated in the specifications are included in the supply price submitted during the call for tenders. However, if, for the requirements of the HOF approach, some of these requirements are expressed at a late stage, it is likely that the supplier will invoice them for a different amount. Therefore, it is advisable to anticipate all of the steps of the HOF at the call for tenders stage.

5.5 The simulations of the future activity

The HOF approach in design is based on the combination of two structured processes: the analysis of the activity in the existing situations on the one hand and the simulations of the future activity on the other.

> The purpose of the latter is to test the planned technical and organisational solutions, starting from the questions *'If these solutions are adopted, how will we carry out the operating activities? What problems can this cause? What solution directions can we consider?'.*

These simulations should obviously be planned according to the technical design timetable.

5.5.1 Different levels of investigation

The setting up of extensive simulations of the operating situations is a relatively demanding operation, that should be carefully planned with respect to the technical design phase, for the latter to be able to incorporate the results of the simulations without this delaying the progress of design.

In fact, several levels of investigation can be used to ensure that the solutions designed will be usable:

- *'What if'* reviews involving the project team, operations and automated systems managers, etc., and the HOF specialist, which are not simulations of the human activity, but make it possible to compare the planned solutions and the operating strategies possible for the key critical situations: *'if both main pumps stop working, do we carry on with the emergency pump or do we shut down?'.* These reviews make it possible to establish operating strategies that are accepted by all, to identify the need to add automated systems or to modify certain equipment, to identify the importance of training or of specific procedures, etc.;
- Expert 'error correction' pre-simulations involving the designers concerned, a HOF specialist and an operator: the designer explain the planned operation, and the investigation by the HOF specialist and the operator make it possible to identify and correct significant deficiencies;
- Detailed simulations of the future activity that will now be described.

5.5.2 Progressive and iterative simulations

During the core design phase and at the start of the detailed design phase, the simulations concern major technical or organisational options: composition of the teams and distribution of the functions, location of the key equipment, product and waste flows, circulation of people and vehicles, location and configuration of the control room, etc.

As the detailed design phase progresses, the simulations will focus on more specific aspects, such as the accessibility and the detailed design of certain areas or certain equipment, the presentation of the information on the screen views or the remote control panels, etc.

When a simulation highlights problems that require the reworking of designs, the new solution will be subject to a new simulation, in particular to ensure that the handling of one issue has not generated the secondary effect of additional difficulties elsewhere.

If significant design options are modified in the design phase, the overall coherence should again be verified by going back to more comprehensive simulations.

5.5.3 The two main types of simulations

There are two main types of simulations of the future activity.

Full-scale experimental simulations

In certain cases, there is full-scale prefiguration of part of the installation: full-scale wooden or cardboard mock-up, prototype, full-scale simulator. These may in particular include an industrial pilot, or a simulator of management methods (control room, etc.). In that case, simulation consists of 'running' the chosen scenarios on this system, and observing and analysing the activity implemented in this way: real workers engage in a real activity on a 'near-real' system. This method is for example used in the design of the control rooms of nuclear plants, and the driver's cabs of transport equipment. It is currently rare in the chemicals or petrochemicals industry.

Key point

The use of a full-scale simulator

A full-scale simulator can be a means of testing the distribution of tasks, the organisation of the operations and the layout of the space in an area (crisis unit, control room, backup control room, etc.), with the full-scale reconstruction of the main features of the room. The associated technical resources (IT, means of communication) can be more or less similar to the target version. The simulator should be designed for the ambient conditions to be similar to the future reality (lighting, no interference noise) and in particular for it to be possible to position the observers outside the work areas.

The preparation of the simulation requires the recruitment and training of operators who are representative of the future population, by trainers with a good understanding of the future system. Draft documentation should be drawn up.

The scenarios are prepared with close attention to detail. During the running of the simulation, an instructor 'injects' contextual elements in real-time (a new alert, a meteorological change, etc.).

The information gathered during experimentation concern the activity of the operators in real-time, but also the experience (questionnaires or individual interviews, collective review meeting). It is examined in order to assess:

- the effectiveness of the simulated system (its ability to achieve the objectives);
- its efficiency (the resources that had to be committed to achieve the objectives and the forms of associated human and economic costs);
- the weaknesses (misunderstandings, risk of errors, etc.).
- etc.

Narrated simulations on a reduced-scale tool

In the absence of a full-scale simulation, the future activity should be discussed on the basis of reduced-scale tools: plans, mock-ups. In this case, the simulation consists of verbally describing the future activity of the operators, represented in the tool by 'avatars', (e.g. scale figures), which carry out different scenarios [VanBelleghem 2012][6]. The HOF participant should possess sufficient expertise to be able to verify the plausibility of the narrative constructed in this way.

5.5.4 The 'ingredients' for the setting up of simulations

To be able to set up simulations of the future activity, four 'ingredients' have to be assembled.

A social agreement

It is not possible to have operators participate in simulation meetings without the entire approach first being presented to the staff representative bodies, the managers and the teams in the area concerned.

The participants

Three types of expertise are required among the participants in the simulation:

- an ability to describe the future system as it is currently envisaged, provided by one or more members of the design team (project team, project contractor, supplier);
- experience of operating situations similar to those that will take place in the future system: this is provided by operations staff (operators and local managers);

6. The purpose of representing the operators using avatars is for them to be able to carry out the simulation in the first person: *'I am doing this'* instead of using an impersonal form (*'this must be done'*).

- ▷ in certain projects, expertise relating to the specific risks and to their prevention;
- ▷ an ability to conduct the simulation, provided by the HOF participant in the project, who is the custodian of the method, one of the holders of knowledge on the existing situations, with the ability to be alert, to analyse and to report on the running of the simulation.

Regarding the representation of the operators, several situations may arise:

- ▷ Sometimes, at the start of the project, the project owner is not very confident of the viability of the initial organisational assumptions that it is considering. It may want a preliminary series of 'groundwork' simulations to take place just with the operations managers, to then be able to carry out more in-depth simulations with the teams on 'presentable' scenarios.
- ▷ If – as is advisable – the future operations teams and the local managers of the future unit, or at least some of them, have already been identified, it is with them that the simulations should be carried out: indeed, the simulations will make a powerful contribution to their learning about the future installation and to their training. If this is not the case, operators with skills similar to those that will be required in the future unit will be selected..
- ▷ The selection of the operators takes place in two stages:
  - the definition of the skills profiles required (e.g. a control room operator, an external operator accredited on that type of installation, a shift manager, a maintenance manager, etc.);
  - a call for volunteers after the provision of information to the teams about the approach.

Each working group may not consist of more than eight to ten people. Several working groups can be tasked with examining several aspects of design in parallel, provided that common members ensure overall coordination.

It is necessary to plan the simulation sessions well in advance to enable the management of the replacement of the shift workers concerned but also precise coordination with the design deadlines.

The simulation tools

It is only possible to carry out simulations of the future activity if the technical and organisational dimensions of the future system are represented.

- ▷ The future organisational structure is represented in the form of organisational assumptions (organisation chart and definition of the functions planned).
- ▷ The technical system can be represented by different types of tools that do not have the same characteristics for the simulation of the future activity.
  - Comprehensive plans are required for the identification of the locations of the different equipment. They are sometimes very difficult to read for people who are not design specialists.
  - 3D views[7] enable a better understanding by the operators of the configuration of the installations. They are therefore very helpful, but often difficult to use as a simulation tool in that it is difficult to place the 'avatars' representing the operators and tools in them. Some CAD software programmes make it possible to include human models in the representation, but it is in particular necessary to be wary of the extreme flexibility of the joints and of the spinal column of these computer models, which execute feats of contortion that are not recommended for operations teams! Furthermore, changes to CAD data in real-time are not easy, and require that the participants' suggestions go through a skilled technician in order to be introduced into the programme.
  - Virtual reality representations are used occasionally. They are also an effective tool for understanding, but it is necessary to be very careful when using them as a simulation tool. In the majority of software, the detection of interference and of elements passing through each other[8] is still approximate.

7. In the case of the modification of existing installations, the practice of carefully overlaying views of the existing installations and diagrams in CAD is particularly useful.

8. Situation in virtual reality in which one object passes through another (without being detected).

- Reduced-scale physical mock-ups are an excellent simulation tool. They are easy to produce for the control room[9], or for a particular area of the installation presenting specific issues. For large production installations, a detailed physical mock-up of the whole is a complex and costly undertaking. It would only be usable for the HOF approach if it had already been produced, for other purposes, for the design team or for training needs.
- Full-scale mock-ups may be required for the development of a specific area that is very complex. The mock-up does not need to be sophisticated: a simple affair strung together from cardboard, wood and a few pieces of piping is often sufficient to detect problems that would be difficult to identify on engineering drawings, or to convince people that the planned arrangement will work.
- A prototype can be produced when special equipment will be widely used.
- Computer mock-ups (content of the screen views) can be produced before the programming is done.

Of course, this list of tools is not exhaustive and the choice of tool should be appropriate for the phase of design and the objective of the simulation.

In addition to the main simulation tool, it is necessary to provide 'avatars' representing the operators, vehicles and certain work tools or objects (e.g. a bin, mobile machinery) to scale.

The simulation scenarios

Of course, it is not possible simulate all of the situations that are likely to arise in the future installation. A limited number of scenarios, which are considered to be design-critical, should be selected following discussion within the working group.

Regarding the examination of the major technical and operational options, several types of scenarios are generally required:

- ▷ scenarios relating to the basic day-to-day operations (e.g. carrying out of patrols or tours, signature of the works permits, etc.);
- ▷ scenarios relating to periodic operations presenting some difficulties (start-up, product change, periodic maintenance interventions, etc.);
- ▷ scenarios relating to frequent or critical incidents;
- ▷ very infrequent scenarios (heavy maintenance, changes to equipment or to product storage devices, upgrading of automated systems, etc.) that would not have been experienced by the teams but are proposed by the experts.

Regarding the detailed development of an area or equipment, the scenarios will concern the main operations carried out in this area.

The scenarios are of course drawn from the identification of the 'operating situations' carried out previously. But, to enable its staging, the script for a scenario is more specific than the description of the operating situation.

For example

Example

If we consider the 'steam system loss' operating situation, the scenario can be described as follows: 'Let us imagine that it is a Saturday, it is 5.30 a.m., the status of the installation is x with product type y, the steam system is triggered.' This wording will immediately 'speak' to the different participants, who may envisage a specific situation and not a category of situations. Moreover, it is likely that they will propose further defining the situation with aggravating factors: 'it could be said that the wind is blowing from the South-East and therefore that any discharges would go over the city.'

5.5.5 The running of the simulation

In the case of a full-scale experimental simulation, operators will 'run' the scenario and their activity will be observed. In the case of a narrated simulation, it will be a question of describing all of the activities that are likely to take place in terms of time and space.

9. For the HOF approach, a good mock-up is not a beautiful mock-up, like those sometimes produced by architects: the latter are totally fixed, and do not allow for the dynamics of simulation (*'and what if we moved this?'*). A foam board mock-up with equipment represented in polyurethane foam will be less aesthetically-pleasing, but much more flexible.

The representation of the sequence over time

Time	9:10	9:15	9:20	9:25	9:30	9:35	9:40
Operator 1	Valve A	Pump D		Valves L, M			Valve A
Operator 2	Pump B		Valves E and F		Pump B	Valve N	Valve E
Operator 3	Valve C		Pump G	Valves H, I, J, K			Valve C

TABLE 5.1 - *Simulation of the temporal sequence of an activity.*

Table 5.1 represents an example of the sequence of an operation involving three operators, who at a given time have to all be available to carry out an operation together on valve N.

Before being entered into a spreadsheet, a temporal sequence like this one can easily be represented on a white board, using magnets or sticky notes.

The estimation of the temporal sequence is based on the technical process data, on the estimation of the travel time based on the plans, and the consideration of the arduousness of certain operations (valves requiring significant effort, etc.). The communication time, which is sometimes substantial, has to be included.

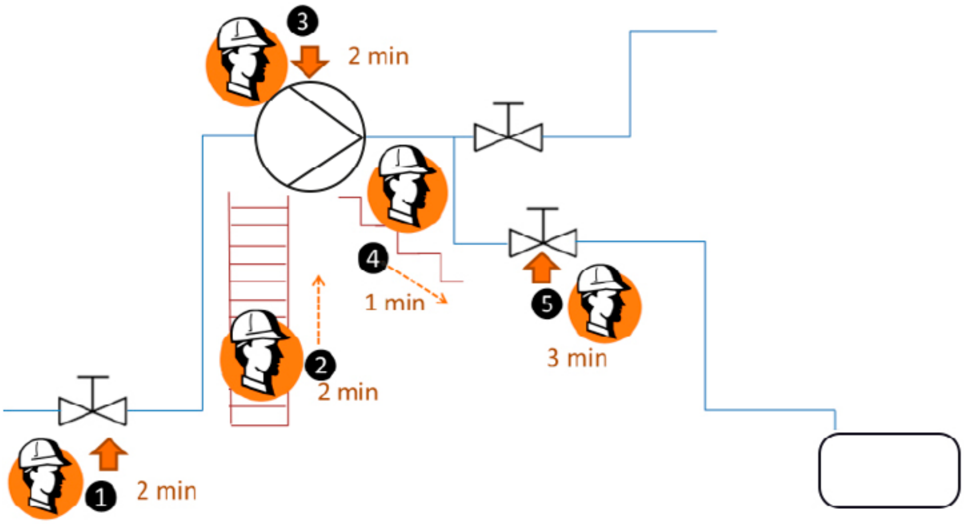

FIGURE 5.2 - *Estimation of the duration of an operation*

The spatial representation of the sequence

In certain cases, the activity is static (e.g. in front of the screens in the control room): the purpose of spatial simulation is to check sizing and the postures. But, in other cases, the carrying out of the activity requires the operator to move, represented by the movement of an 'avatar' on the plan or the mock-up. It is helpful in this case for the avatar to be moved by the actual operator representing the simulated function, and for him or her to progressively describe the sequence of the operation (*'I check the pressure; I close the valve; I go upstairs; I stop the pump, etc.'*).

The plausibility checking of the narrative

As the operation is described, a four-fold check of its plausibility is carried out by the different participants:

- **the continuity in space and it time:** if the description is *'I do this in A and then I do that in B'*, it is necessary to consider the movement between A and B; if an operator says he or she *'takes the valve key'*, it is necessary to verify its planned location; if the operator states *'I close the discharge valve again'*, one of the participants will perhaps note *'wait, you never told us that you were opening it'*;
- **the compatibility with the operating rules:** *'no, this pump cannot be started up before...'*;
- **the taking into account of all of the information processing operations:** for example, checking a level before operating a valve, checking the result of an action;
- the plausibility in relation to **human perceptive and physiological characteristics**: two operators cannot exchange oral information when they are two metres apart in a noisy environment that requires

the wearing of ear plugs, an operator cannot read letters that are 15 millimetres high on a display that is 5 metres away, etc.

The points for attention

As the narrative of the operation sequence progresses, specific attention is paid to several aspects:

- **the availability of information:** how does the operator know that he or she has to start an operation? That it has ended? For example, if *'when the tank is full, the operator closes the valve'*, how does he or she know that the tank is full? Is the information available in proximity to the valve? Does he or she have to call the control room?
- **the ambiguities and the risk of errors:** when similar systems or tanks are located close to each other, with similar designations, what are the error prevention measures? When a system of pipes and valves makes it possible to establish a large number of different connections, what indicators make it possible to verify their proper alignment?
- **arduousness and exposure to hazards:** going up and down ladders or stairs multiple times for a single operation, the operation of heavy valves, the handling of loads, prolonged retention in an area requiring the wearing of uncomfortable PPE, the prolonged isolation of an employee, presence in very dirty areas, etc.
- **the potential consequences of the occurrence of foreseeable risks**, and in particular of the unavailability of critical equipment: if the safety of an operation is entirely dependent on radio contact, what happens in the event of a defective radio? The reasoning here is similar to that of the *what-if reviews*.

Quite often, as the simulation clarifies the sequence of the human activity, the process specialists present identify technical issues: in the event of instrument air failure, should the valve remain closed or open? If a sensor is defective, is there a means of detecting this?

5.5.6 The results of the simulation

The purpose of the simulation is to identify any difficulties at a stage of design in which the changes can be made on the plans, prior to construction. It can have several types of results:

- in some cases, it confirms that the solutions planned should enable the smooth execution of the operation;
- in others, it highlights potential difficulties, but simple solutions are found, they appear acceptable to the designers concerned, and do not result in significant additional cost (limited widening of a platform, relocation of a staircase, addition of fail-safe devices, etc.): they can then be immediately validated, without requiring the approval of higher authorities;
- sometimes, the solutions are found, but they are likely to result in additional cost: validation, for example by the project owner's project manager, will be necessary;
- finally, in some cases, the simulations raise a serious issue, which requires the reworking of designs. A new simulation will take place at a later stage, after modification of the solution.

The communication of the results

The summarised results of the simulations will be quickly communicated:

- to all of the participants in the working group;
- to the project manager;
- to the project owner, at least when trade-offs are required;
- to the designers concerned;
- to the operations managers.

Summaries of the progression of the solutions will be periodically presented to the staff representative bodies and to the teams concerned.

Key point

The traceability of the simulation results

It is important to keep records of the successive stages of the simulations and of their results to:

- to verify proper subsequent incorporation into the design choices;
- to feed into the subsequent iteration of simulation after modification of the plans;
- but also to be able to support the responses to subsequent requests from the supervisory authority.

We will now present an example simulation concerning the testing of organisational scenarios. Two other examples are described in the annexes: control room design (Annex A), control view design (Annex B).

5.5.7 An example: the testing of organisational scenarios

Organisational assumptions are put forward for the new unit, but the project owner wishes to make certain that they ensure safe operation, and in particular that it is possible to safely shut down the installation under any circumstances.

In that case, it is possible, as shown above, to carry out organisational simulations.

- The participants will first of all most likely be the local managers and members of the project team. When the preliminary 'groundwork' has been carried out, the simulations can be refined with operators.
- Two types of tools are required:
  - a description of the planned organisational structure (staffing, scope of functions, level of qualification, type of accreditations, etc.);
  - a representation of the future unit, making it possible to estimate in particular the time for the operations to be carried out.
- The initial scenarios used will concern ordinary day-to-day operation (organisation of the tours or patrols) and some design-critical incidents. If the organisational assumption envisaged successfully passes this first test, it can be tested against more diverse scenarios.
- An emphasis will be placed on the temporal sequence of the collective activity: as in Table 5.1, the various operations carried out by the different operators to manage the simulated situation will be represented temporally. This representation makes it possible to verify whether, with the organisational structure planned, it is possible to carry out all of the required operations within a timeframe compatible with safety. It also shows whether the operations requiring the presence of several operators can be carried out[10], whether opportunities for team coordination are possible, etc.
- A specific point for attention will focus on not having the same operator 'work' in two places at the same time. A typical example is that, in fire management simulations, an operator is counted once as a volunteer firefighter holding the fire hose nozzle, and once as an operator closing the valves.
- The simulation can lead to different results:
  - the organisational assumption has successfully passed all of the tests to which it was subjected: this does not guarantee that an unexpected pattern cannot arise that is likely to challenge the organisational structure; but the current assumption can serve as a basis for social negotiation, the development of training plans and be subjected to full-scale testing for start-up;
  - the simulation highlights difficulties for the carrying out of certain operations, but it appears that these can be dealt with using technical solutions (motorisation of valves, remote display or control, additional of walkways, modification of the sampling system, etc.). the organisational assumption appears viable, subject to the carrying out of these modifications;
  - the organisational assumption is challenged by realistic operating scenarios. In this case, it has to be reviewed: modification of the distribution of tasks, increase in the scope of responsibility and accreditation of certain operators, necessary increase in staffing, etc. A new series of simulations will take place with a modified assumption.

10. This requires that the different operators concerned have the necessary accreditations, that they be available at the same time, etc.

5.5.8 Other simulation outcomes

The preliminary outcome of the simulations of the future activity is assessing the viability of the technical and organisational solutions planned[11], identifying potential problems, and enabling their correction at the design stage, without having to wait for start-up to take place.

But the simulation of the future activity produces many other outcomes [Barcellini et al. 2013]:

- ▹ it enables early learning about the installations and procedures by the operators who participate in it, thus contributing to their training and to their knowledge of the unit;
- ▹ likewise, the simulation contributes to the provision of information to the operations managers on the project, and supports their consideration of the integration of the new unit;
- ▹ the discussions between operators and process experts can result in the definition of an operating method that is more relevant than that which was envisaged;
- ▹ the designers discover constraints of the activities that they had not considered, and that they can now directly take into account in the other solutions that they will design;
- ▹ the contribution of each of the stakeholders present enables a better mutual understanding and a mutual recognition of each other's skills; this cross-learning often contributes to the improvement of social relations;
- ▹ the involvement of the operators and of the managers in the project can serve as a basis for the development of a directive-participative management style[12], particularly with regard to industrial safety, in the future installation.

Another set of indirect effects concerns the preparation of the training plans, and the writing of the procedures.

5.5.9 The effects on training

We will go into further detail in chapter on the preparation of the training plans. But we note here that **the simulation of the operating activities is a very powerful training tool**: indeed it is based not on passive learning, but on an active examination, by the operators, of the technical data that is provided to them, and on the search for an appropriate response to the situation.

However, it is rare for all of the future operations teams to participate in the simulation sessions set up in the context of the design project. There is therefore a risk that those who have participated in them will acquire a much better knowledge of the future system than those who were absent from them. There would then be a risk of seeing more rapid career progression occur for the 'volunteers' of the working groups than for the others, which is not the intended objective.

To avoid this pitfall, it is possible to use the same simulation techniques as an educational tool in the training sessions involving all of the teams. Rather than the lecture-style relaying of the prescribed operating methods, the trainers can promote the active pursuit of the correct operating method, based on the technical data, in order to successfully complete an operation. Its sequence can, here too, be described in terms of time and space.

5.5.10 The effects on the writing of the procedures

When the carrying out of an operation has been executed from start to finish, by involving process experts, the managers and the operations teams, the corresponding procedure is as good as written.

The same method can then be used for the writing of the other procedures, based on a spatio-temporal description of the execution of the operations. This approach contributes to the realism of the procedures and avoids, for example, asking without realising, for an operator to go up and down several ladders in order to carry out a series of operations, which could have just as well be carried out in a different order (systems that are close on the process drawings are not necessarily geographically close).

11. It is common for organisational simulations to highlight the need for technical modifications for the organisational structure to be viable, addition of walkways, automated systems, etc.
12. See 'State of the art' *Cahier*, section 9.2 [Daniellou et al. 2011], and 'Des questions pour progresser' *Cahier*, chapter 4 [Daniellou 2012].

6

Training

Summary

The training needs of the future operators should be anticipated to enable the effective appropriation of the new unit. The purpose of training is to develop operating skills, which requires the introduction into the teaching of 'learning by doing' methods. The training of the most experienced workers should be given particular thought.

In this chapter, we will discuss the training of the future production and maintenance operators, and their appropriation of the new installation.

6.1 Preparing for future situations

The preparation of a training programme requires that three questions be answered:

- ▷ what are the initial skills of the people to be trained?
- ▷ what are the target skills that they have to be able to acquire?
- ▷ what teaching methods are required to progress from the initial state to the target state?

The key concept here is that of skills and not of knowledge.

Definition

Skill

A skill is the **ability to manage a set of situations**, by making use of various resources: knowledge, physical abilities, perceptive abilities, collaborations with others, *etc.*

A training programme is not defined on the basis of the question *'what should the operators know to perform their new functions?'*, but by asking *'what sets of situations should be they be able to manage?'*.

However, in the approach that has been proposed thus far, this surveying of the situations is already widely carried out, because the project stakeholders have identified the future operating situations (chapter 5). It is easy to determine, for each category of operators, those situations that concern each function, and thus to draw up a list of target situations by function.

The next question consists of identifying, in each of these situations, *'what should the operators be able to do?'* (identifying a situation, executing an operation, checking a result, writing a report, reporting an anomaly, etc.).

It is then possible to identify the different **resources** that the training should offer, for example:

- ▷ information on the project objectives and the challenges (economic, technical, environmental) for the smooth operation of the unit;
- ▷ knowledge on the physico-chemical process, which is helpful for identifying a situation or deciding on the action to be taken;
- ▷ tools to develop an accurate representation of the layout of the future installation, based on up-to-date information on the progress of the solutions;

- knowledge on the hazards and risks, but also precautionary know-how for the execution of certain operations;
- the opportunity to learn the execution of operating activities that are not already known through previous experience;
- facilitation of the acquisition of reporting skills, risk reporting skills, etc.;
- etc.

6.2 Planning the training actions

It is not advisable for the entire training process to be concentrated at the end of the design stage and during the implementation of the construction project. The progressive organisation of training, from the detailed design phase, will facilitate better interaction between the skills acquired in training and those that come from the information on the progress of the project and possible participation in the working groups set up. This kind of organisation dispels a significant amount of concern and reluctance, fosters the acceptability of the project, boosts operators' confidence in their abilities, and contributes to the establishment of trade groups.

The different resources that the training will provide to support the acquisition of the target skills can in this way be spread over **several modules**, planned a long time in advance. Each of these modules will be developed with a view to the acquisition of certain skills, here too asking the question *'what should the operators be able to do at end of this module?'*

6.3 Learning by doing

Skills are not 'in the head', they are 'in the body'. It is the whole body that has to learn to deal with the future operating situations. It is impossible to develop intervention skills solely on the basis of documents shown on a projector and discussed by the trainer. Learning requires doing. But it is often not possible to 'do' real operations on the actual system, either because it is not ready, or because certain situations are rare and high-risk, and because there is no question of causing them in a full-scale manner for training purposes (e.g. a distillation column fire).

The team of trainers will therefore work on coming up with smallerscale teaching situations, which make it possible to gradually develop the required skills, by taking action on objects that are less complex than the system as a whole. For example, these can include:

- school construction projects, reconstructing part of the installation for the learning of difficult or critical operations;
- simulations on a reduced-scale mock-up (see chapter). In certain cases, the production of the mock-up can also be a component of the training;
- simulations on a computer mock-up;
- the active examination of the internal plans for a system, and the production of a simple mock-up based on these plans;
- assembly/disassembly tasks at the workbench;
- full-scale simulations on installations in the process of assembly (idle unit);
- etc.

This requirement for *learning by doing* does not concern the acquisition of the physical skills for intervention on the installations. It is equally important for the development of theoretical skills, for example physico-chemical skills. Let us imagine for example that it is necessary to teach that *'water boils at 100°C at normal atmospheric pressure, at a lower temperature if the pressure is lower, and at a higher temperature if the pressure is higher than that value'.* The fact that a participant in the training is able to say or write this sentence from memory in no way proves that this knowledge will be used in a real work situation in which it would be useful. Knowledge is mainly used when the current circumstances are similar to the circumstances in which it was acquired. If this knowledge is to 'kick-in' in a work situation, it is necessary to create circumstances in training for the acquisition of the knowledge that are similar to the circumstances in which the knowledge should be useful. For example, the use of a transparent pressure cooker with the valve removed can help to predict that a tank will boil when its pressure suddenly drops.

6.4 Selection and accreditation

Senior operators whose school education is far behind them may view the requirement to undertake extensive training and to obtain new accreditations with concern. If a selection is planned at the end of the training, it is typical to observe a gradual loss of composure in some people as the date (*'the gallows'*) approaches.

To avoid this effect, it is advisable for the selection to take place prior to the training, and for the learning agreement to be that every effort will be made for each person to obtain his or her accreditation. This requires that the trainers be able if necessary to provide greater support to operators that they identify as experiencing difficulties. It is also necessary that the first accreditation test take place sufficiently in advance of start-up for additional training to enable some operators to retake the test under appropriate conditions.

Part three

The construction project and start-up

7

The preparation and the execution of the construction project

Summary

The carrying out of the activities during the construction project should be anticipated as much as possible during the design stage. The strong involvement of a human factors specialist or a safety and health protection coordinator should make it possible to influence the phasing and the organisational structure planned in a timely manner. The early appointment of the construction project coordinator and the resources that are provided to him or her, are important issues for safety.

The execution of the construction project represents a three-fold challenge for safety:

- the prevention of accidents during the construction of the installations;
- the construction by the companies of installations that comply with the design requirements;
- the approval of the new installations by the future operators prior to start-up.

The execution of the construction project has to be anticipated as much as possible during the design stage.

7.1 Design and organisational structure of the construction project

7.1.1 Safety and the working conditions on the construction site

Experience shows that safety and the working conditions on the construction site depend to a large extent on the **resources provided to the construction project coordinator** to prepare it[1]. Construction project stages that are thoroughly examined in advance are safer than those where the operating methods are thought up in real time and with the resources at hand. The worst situation is one in which the forwarding of the plans from the project owner to the executing company takes place at a late stage, and in which the preparation of the construction project is minimal so as not to delay its start. The preparation of the construction project includes the fire safety and first aid assessment.

If the project contractor has a design and build mandate, it is advisable for the construction project coordinator to be appointed early on in the design stage, and as the technical solutions are defined, for him or her to be able to examine (with the qualified experts) the conditions for their assembly, and perhaps suggest changes to facilitate it. The simulation techniques that were described in chapter 5 are fully applicable for simulating the various critical operations for the transport of systems and their assembly. Unfortunately, it is rare for an ergonomics-human factors specialist to be assigned to the preparation of the construction project, as well as one to lead the consideration of the future operation activity. It is difficult for the same person to perform both functions.

When the project contractor only has the mandate for design, the same function for the anticipation of assembly constraints should be assigned at an early stage to a safety and health protection coordinator with experience in the type of industry concerned, without waiting for the executing company to be selected.

1. See the research of F. Six on works supervisors [Six 1999].

7.1.2 The preparation and communication of phasing

The preparation and the execution of the construction project will impact the rest of the site[2]: areas will be sealed off and roads will be closed; a large number of heavy vehicles will take routes that are usually quiet; certain networks will be temporarily cut off; an unusual influx of workers is to be expected, etc.

It is difficult for the project manager and the construction project coordinator alone to conceive of all the consequences of these disruptions for all of the services on the site (circulation of the internal shuttle bus, laboratory's sampling round, fire brigade and emergency service access to all areas, access routes to the canteen, consequences in the event of general evacuation, use of the outdoor car parks, etc.). It is therefore very helpful for the relevant information to be gathered as early as possible and circulated so that the different categories of site users can express their specific constraints. An effective communication method is the creation of a **phasing chart**: this has a comic strip-type format that shows week-by-week (or any other appropriate division) the plan of the site with the sealed-off areas, the closed or re-routed roads, etc. Each department can then check the conditions for the execution of its own activity at each stage, and provide its comments. Following consideration of these comments, a final phasing chart is then disseminated.

The same type of chart, but this time in three dimensions, can be used to communicate the progress of the site itself, the construction of the structures and the gradual assembly of the different systems.

7.1.3 The reception of the construction and assembly companies

A large number of employees from external companies will work on the site. It is generally acknowledged that the quality of the reception provided by the client company determines the quality of the service provided by the subcontractors.

We refer to the 'Des questions à se poser' *Cahier*, sections 6.4 and 6.5 for a set of relevant questions for preparing this reception and the organisation of the construction site [Daniellou 2012].

Key Point

The specifications and the pre-site reviews

The requirements relating to safety and, in particular to concurrent activity, should be set out in the specifications and be included in the criteria for the selection of companies. Several safety reviews with all of the companies concerned are required prior to the start of the construction project. An incident reporting system will be established.

Specific precautions should be taken when the operators undertaking the construction do not speak the same language as the operations teams, to ensure the possibility of interaction at all times.

7.1.4 The coordination of the construction site

One of the known problems on constructions sites is that each participant is only aware of his or her task of the day: he or she does not have much of a picture of what is happening elsewhere at the same time and of what will happen the following day in the same place. This limited view often leads to undesirable actions (disassembly of scaffolding that will be required the following day) and to hazardous interference (concurrent activity).

The improvement of the safety and quality of the construction site therefore requires **the better sharing of information** on the **ongoing and upcoming** tasks in a given geographic area. If the phasing board is sufficiently detailed and up-to-date, it can serve as a tool for this information sharing in the daily site coordination meetings. These meetings should at least bring together, with the construction site coordinator, the team managers for the different trades, as well as of course the safety and health protection coordinator and the prevention managers.

In addition to this coordination function, the site meetings also serve to determine the response to problems encountered during construction. *'We are having difficulty getting a pump to the intended spot, can we place it one metre away?'*. Providing an appropriate answer to this type of question requires the presence of members of the project team and operations expertise. The alternating presence of the future shift managers and maintenance supervisors at the site meeting is an important means of developing their detailed knowledge of the new installation.

2. See [Beaujouan et al. 2011].

7.1.5 Site visits

Visits to the site by the future operators have a training purpose but also serve to identify likely problems. They should be organised for the future operators on a regular basis and be followed by a debriefing.

7.1.6 The trials and tests

Although the project coordinator generally has a commissioning mandate, it is essential that the future operators be able to participate in the trials and testing of the new equipment. This may require contractual definition of the limits of liability.

7.2 The pre-start-up reviews

It is fairly common for a pre-start-up review to involve the project manager, the construction site coordinator, an HSE manager, the fire brigade, the production and maintenance managers, *etc.* All of the operations required for start-up are executed and the diversity of expertise present helps to ensure that all of the prerequisites have been met or will be. *What-if safety review*-type methods make it possible to consider various risks, and to anticipate the action to be taken.

It is very helpful for the same type of exercise to take place within the operations teams and with the maintenance managers (e.g. one week prior to start-up), so that all of the stakeholders have an overview of the planned execution, and for each person to identify his or her role in the overall process.

These reviews will in particular ensure that up-to-date documentation is available for start-up.

A dedicated start-up team is set up with strengthened functions: management, maintenance, instrumentation, *etc.*

7.3 The inauguration risks

The inauguration of the new installation is often a cause for celebration and speeches.

When the new unit is replacing another one that was obsolete, it is not uncommon for the official speeches to emphasise the negative aspects of the previous unit, in order to promote the qualities of the new one. This type of communication is very difficult to hear for the operators who for years had painstakingly made the ageing equipment work. There is no need to erase the past. On the contrary, it is advisable for the site management to highlight the work done in the old installations and the investment of this operations experience in the thinking for the new project.

8

Start-up, the evaluation of the project and the transition to ordinary operations

Summary

The HOF approach should continue during start-up, to contribute to the finishing touches and to participate in process of learning lessons from the project.

Unlike the tests, the purpose of which are to test parts of the installation without the intention of going into production, start-up begins on the date on which there is an intention of going into production, and lasts until such time as there is nominal operation, i.e. in accordance with the initial programme.

8.1 A presence at start-up

If a human factors approach was established during the project, it is important for it to continue during the start-up period.

8.1.1 Overcoming negative evaluations

Irrespective of the care taken by everyone during the project, there are always some unsatisfactory aspects that remain at start-up, which were overlooked. The higher the quality of the overall design, the more obvious they are!

It is therefore common for the initial spontaneous evaluation of start-up by members of the operations teams to be negative: *'it was not worth the effort to do all that for...'*. This feeling will soon disappear if the problems encountered are identified quickly and the teams are immediately informed of the action taken:

- ▹ some problems can be resolved in a few days, thanks to the presence of the project contractor and the supplier companies or by the maintenance department;
- ▹ others require the minor reworking of designs and will be dealt with within a few weeks;
- ▹ finally, other modifications may not be possible in the short term, but the problem encountered can be dealt with by changing the organisational structure or the procedures, etc.

This form of the presence of the project and operations managers, and this attention to the detail of start-up, to the handling of problems and to the provision of information to the teams contribute to continuing the 'human factors momentum' introduced during the project.

8.1.2 Errors of youth

It is common that 'errors' made by the operators during start-up are attributed to the learning process and considered 'errors of youth'. However, cognitive psychology shows that errors made in the learning process are also those that will occur when one is overwhelmed or in a moment of great tension.

The errors made during start-up, like all errors, are often linked to characteristics of the situation that makes them more likely[1]: ambiguity of the presentation of information, communication difficulty, contradictory

1. See the State of the art *Cahier*, chapter 7 [Daniellou et al. 2011].

instructions, *etc.* They have to be analysed, their determining factors highlighted and corrected, to reduce the likelihood of them being repeated later in an incident.

8.2 Completing start-up

Very often, the increasing of the installation's level of activity and the transition to ordinary operation take place gradually, without start-up being officially ended.

However, start-up is a special stage with the strong presence of the project team, the project contractor and the suppliers, and the sharing of responsibilities with the operators. There must be a clear end to this period and full handover of authority to the operations managers.

In the best case scenario, start-up ends when nominal operation is achieved (operation that complies with the quantity and quality levels in the initial specifications).

In some projects, it takes some time to achieve nominal operation. It is not however possible to remain 'in start-up' indefinitely. Clear communication of the situation and the allocation of roles has be established by the site management.

8.3 Evaluating the project

The project is finished and the installation is running. The constraints of industrial life will quickly take over.

However, it is important to take the time to **formally carry out an evaluation of the project (lessons learned from the project)**, to capitalise on certain lessons and enhance future projects. An effective evaluation always involves several voices (site management, project manager, operations managers and teams, staff representative bodies, etc.). This is a 'broad-band evaluation' and not a 'narro-wband' evaluation carried out by just a few experts.

The evaluation partially concerns the achievement of the established objectives. Certain objectives are quantifiable and can be numerically audited. Others are tied to criteria (obtaining a certification) and their achievement can be easily verified. But numerous phenomena have occurred during the project that are more difficult to quantify (change in the relationships between departments, change in social relations, appearance of new groups, involvement of new stakeholders, etc.), which can be evaluated positively (and therefore fostered in a future project) or evaluated negatively (and that should therefore be avoided). The various stakeholders may have differing opinions on the positive or negative nature of certain events (e.g. the training was longer than planned). It is important to carry out this broad information-gathering.

As regards the human and organisational factors approach, the evaluation will in particular concern:

- ▷ the management of start-up (duration, difficulties, etc.);
- ▷ the ultimate quality of the working conditions and the difficulties that remain;
- ▷ the perception of the project by the operations managers and teams;
- ▷ developments in the relationship between managers and teams;
- ▷ the perception of the project by the staff representative bodies, developments in social relations;
- ▷ the organisation and the content of training;
- ▷ the organisation, the scope and the results of the simulations and their consideration in design[2];
- ▷ the structuring of the project, project owner/project contractor coordination;
- ▷ the position and the resources allocated to the HOF approach;
- ▷ etc.

8.4 Continuing the HOF momentum

This document describes the establishment of a participative approach during the design process. The intelligence of the operations teams and their experience have been acknowledged and used to ensure the project's success.

2. It is important to distinguish between the difficulties that had not been anticipated by the simulations and the difficulties that had been anticipated but were not considered in the technical and organisational design.

If, after this period, the operations managers establish a purely directive style, it is likely that this will result in disappointment and demotivation of the teams. In contrast, it is possible to continue the momentum initiated, in particular with respect to industrial security issues. The '*Des questions pour progresser*' Cahier [Daniellou 2012] identifies several themes making it possible to combine the engagement of the managers and that of the operators, in particular with respect to industrial security issues. For example, these include the forms of management presence in the field; the attention paid not only to the achievement of performance but also to the human cost in achieving it; the continuous improvement of the lesson learned from incidents or accidents; the establishment and the handling of safety alerts; the participative modification of procedures (in particular for critical tasks); the forms of the running of safety meetings; the collective consideration of future modifications; consideration, in conjunction with the HR department teams, of the development of trade activities, etc.

If the unit managers have the desire and the resources to maintain this momentum, it can contribute to both the continuous improvement of system resilience, and to people development.

A

Annex 1
An example: the control room architecture

Designing for all usage situations

The design of the control room provides solutions to numerous constraints (e.g. protection against a potential explosion). As regards human and organisational factors, it must be designed so as to support all of the activities that take place within it. The situations and constraints below in particular should be considered in the programme provided to the architect[1].

The activity of outdoor operators

- ▷ numerous entrances/exits (analysis of flows);
- ▷ in units with specific risks, a safety shower may be required in front of the entrance;
- ▷ customised storage of coats, helmets, gloves in close proximity to the exterior door;
- ▷ storage of SCBA and other safety equipment, pharmacy;
- ▷ storage and recharging of radios and small equipment (lamps, oxygen meters, H2S detectors, etc.);
- ▷ easy access to toilets with dirty shoes, without having to cross 'clean zones'.

The activity of the maintenance teams and contractor companies

- ▷ large work force likely to be waiting for works permits, in particular during shut-downs. The waiting area should provide seating and have a beverage dispenser and toilet access. If mobile telephones are prohibited, a public telephone will be provided;
- ▷ issuance of works permits or fire permits without it being necessary to enter the control room (type of 'counter' to be defined);
- ▷ signs for contractors should be able to be displayed from the office and be visible from the outside.

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1. Various constraints for control room design are described in the following standards:

- NF EN ISO 11064-1 (FA049452) Ergonomic design of control centres, Part 1: Principles for the design of control centres;
- NF EN ISO 11064-2 (FA049678) Ergonomic design of control centres, Part 2: Principles for the arrangement of control suites;
- NF EN ISO 11064-3 (FA045295) Ergonomic design of control centres, Part 3: Control room layout;
- NF EN ISO 11064-4 (FA102538) Ergonomic design of control centres, Part 4: Layout and dimensions of workstations;
- NF EN ISO 11064-5 (FA102539) Ergonomic design of control centres, Part 5: Displays and controls;
- NF EN ISO 11064-6 (FA102540) Ergonomic design of control centres, Part 6: Environmental requirements for control centres;
- NF EN ISO 11064-7 (FA102541) Ergonomic design of control centres, Part 7: Principles for the evaluation of control centres.

The activity of the shift manager and the day managers

- ▷ the office of the shift manager (or equivalent) is usually a handover area (day managers, maintenance managers, lockout managers, etc.). It should therefore be easily accessible without 'visitors' having to cross the control room, but also adjoining it;
- ▷ the shift manager must often have several types of IT equipment (administration, maintenance, process, sometimes with different printers). The appropriate space should be provided for;
- ▷ the same applies for the storage of documentation and the numerous noticeboards required;
- ▷ depending on the company's organisational structure, a lockout or permit issuance office may be required, which is separate from the shift manager's office;
- ▷ if the company's organisational structure provides for the establishment of a crisis centre in the event of a serious incident, and if it is supposed to be within the control room building, its connection to the shift manager's office should be planned.

The control room activities

- ▷ when functionally-related units are controlled from the same room, the location of the control panels should enable both the independence of the activities relating to the separate units and the coordination between operators when a common operation is in progress;
- ▷ activity relating to the screens of the digital command-control system (DCCS) is not only that of management, but also of IT maintenance; the equipment to be maintained should be easily accessible (e.g. changing of a screen);
- ▷ it should be possible to move to another workstation in the event of a failure;
- ▷ the design of the management control panels should, for each workstation, enable the presence of two seated people rather than one (shift changes, training periods, critical operations, etc.). The furniture should enable the use of the IT equipment and the control buttons, the means of communication with the patrollers, the plant's departments and the outside (including the fire line), but also of written documents (diagrams, reports, forms, etc.);
- ▷ the controls for emergency installation shut-down, horns and rotating beacons should be present at the workstation or in close proximity;
- ▷ it is often necessary for monitors linked to cameras to make it possible to view outdoor systems (chimney, flare, furnace, etc.) to compensate for the lack of a direct view;
- ▷ if the process views have to be consulted by people other than the control panel operators (e.g. maintenance manager, chemist, etc.), one or more additional screen will be installed in an area that does not interfere with the management activity (of course, only certain actions are possible using these screens);
- ▷ the documentation is likely to be voluminous. The displaying of the plans, production instructions and by-passed safety features, and the filing of the instrumentation diagrams and procedures is are to be provided for in the design of the space;
- ▷ the outdoor operators should have space to write the round reports;
- ▷ the control room is the team assembly point. Have a coffee or snack together is not just an enjoyable tradition for shift workers, but an important time for collective debriefing, exchanging information and the synchronisation of representations between the outdoor operators and control panel operators. The control room should have a table that can seat the whole team and from which the alarm screens remain visible;
- ▷ the operators should be able to access computer application stations other than the DCCS, for example to schedule their leave or access company information;
- ▷ if it is the company's communication policy to show the control room to visitors, the design should ensure that these visitors do to disrupt activity;
- ▷ when the control room is windowless for safety reasons, the lighting should be carefully considered, given the 3x8 shift working pattern. The use of a lighting technician will be necessary to ensure high

illumination levels, low luminance of the sources (prevention of glare), a 'daylight' colour temperature and dynamic lighting adjustment according to time of day;

- the acoustic treatment (absorbent) of the walls of the room is important for maintain a peaceful environment despite conversations, radio calls, etc.
- the air-conditioning should be quiet, adjustable and have accessible filters. It should be possible to turn it off from the control room in the event of a toxic leak outside.
- cleaning should be facilitated by the furniture design.

Changing rooms and living area

Shift workers spend the night and weekends in the workplace. The design of the premises should provide good living and nutrition conditions (the possibility of having hot and balanced meals is particularly important for the health of shift workers):

- sufficient space for the changing rooms, showers and toilets;
- possibility to wash work overalls (depending on the organisation of the company);
- kitchen/meal area enabling the storage of food and dish washing, the preparation and consumption of hot meals, dishwasher;
- waste storage and disposal;
- quiet relaxation area, enabling a rest break during the night shift.

Other collective activities

- containment areas for the team in the event of a gas alert is provided for;
- one or more meeting rooms should be provided for training activities, collective work on procedures, safety meetings, working groups, etc.
- storage of training equipment (e.g. first aid equipment).

Cleaning supplies room

Given the large number of people who go in and out of the building, floor care is an important issue. The storage of the cleaning equipment and the water inlets and outlets should be provided for.

In response to the architect's proposals

Based on the programme provided to the architect, he or she will submit a preliminary design (PD), which only includes the position of the partition walls and exits. It is very helpful to set up a simulation of the main situations that will take place in the control, on the basis of this document. It will involve representatives of the different professional categories that will have to work there. This simulation will make it possible to request local modifications, superficial modifications, etc., at an early stage of plan design.

A new simulation can take place when the architect has produced the final design (FD), with all of the details of the door and window frames, electrical and plumbing installations, etc.

B

Annex 2
An example: control and alarm view design

The adaptation of control views[1] to operational needs is not only dependent on the quality of the design of each view.

It is a question of controlling an industrial installation, not a computer

The expression 'human-machine interface' (HMI) can be misleading. People are often primarily interested in the interface between the operator and the computer of the command-control system. However, the operator's task is not to control the DCCS, but rather the industrial process. The means of control is an interface between the operator and the industrial installation, and has to be designed to support the control activity.

Furthermore, it is necessary to ensure that the control operator is released, as much as possible, from secondary computer system management tasks, to allow him or her to focus his or her attention on the execution of the process.

Promoting an overview

Unlike the old charts, which provided an overview of the installation, control on screens can lead to seeing the process with 'keyhole vision' [Guy and Meyer 1995; Lejon 1991]. To avoid this phenomenon, certain precautions should be taken:

- **a sufficient number of screens** per operator for him or her to be able to separately display one or more supervision views, an active alarm view, and the view on which he or she is currently working. The minimum number of screens per person is often three, but in order to support control by two operators in certain critical phases, at least four screens per workstation (the placement of the information on the screens is programmable) are required. In certain cases, it is necessary to also provide one or more screens for the shift manager, the maintenance department, etc.
- **display flexibility** enabling the operator to set up 'customised' views with the values, logs or trend curves corresponding to the needs of a specific operation not foreseen in design.
- **control view design** supporting the gathering in the same view of the key **parameters required to manage an operation or an incident**. Indeed, when the information required for an operation is dispersed over several views (figure B.1), they are viewed in quick succession, there is an increase in the operator's mental load, and a loss of overview of the situation.

1. Screen views of the digital command-control system (DCCS).

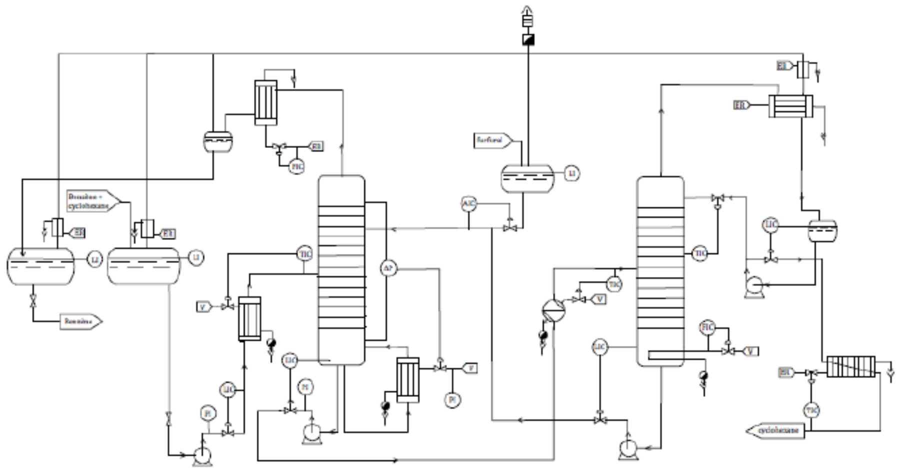

FIGURE B.1 - *Display by system does not provide an overview*

Control view design should not therefore be considered system-by-system, but rather situation-by-situation: start-up, product change, different types of incidents. All of **the information required for a phase of activity will be grouped together** in the same view, it being understood that certain information will be duplicated in other views.

The specifications for view design

It is common for the screen views to be programmed by the DCCS supplier, based on the specifications that are provided to it. The latter should consist of two parts:

- on the one hand, design principles, a standard establishing a sort of 'grammar' for the presentation of the information (graphic charter, layout rules, library of graphical objects);
- on the other hand, the list of views and the identification of the parameters to be displayed on each one.

A presentation standard

The standards for the presentation of information on the control views that will be imposed on the supplier are based on international scientific work on the one hand, and on the company's practices on the other. Certain DCCS manufacturers have undertaken significant work with their clients and their own ergonomists to achieve satisfactory standards[2]. These may have to be adapted to take account of the company's previous practices.

Some examples of principles used in some companies are present in the text box below.

2. For example, see: [ASM 2009]. See also: [NUREG 2002].

Example

Example of principles used in a company

The permanent background is understated

- ▷ No colour for permanent information (drawing of the systems and pipes)
- ▷ Displaying of details on request
- ▷ The control wiring is only displayed if it is essential or on request
- ▷ The size of the apparatus is based on their importance
- ▷ Gravity positions are respected
- ▷ Consistency of symbols and codes (in accordance with the company rules)

'Lights off, all is well'

- ▷ Colours are used to attract attention to non-permanent information
- ▷ No change in colour from green to red without a change in shape (colour-blindness)
- ▷ Yellow and red for alarms only
- ▷ Animations only for safety information requiring immediate action
- ▷ Acknowledged alarms are lighter

Displaying of trends (temporary or sustained) on request

- ▷ Option of modifying trend configuration
- ▷ Option of creating 'customised' view bring together the values and trends relating to an operation

Option of displaying equipment tagout or lockout

Changes to alarm thresholds or PID 'actions' are stored and can be consulted

The content of views

Some supervision views present the main parameters making it possible to identify the status of the technical process.

Detailed views are designed based on the **situations** that they make it possible to deal with. The first stage of their design is therefore the identification of the main control situations (starting up of apparatus, adjustments, triggering, product change, shut-down, etc.). If a HOF approach has been established, this list has mostly already been drawn up (see 'identification of the operating situations', chapter 5. Having it explained by the operations teams is an important contribution to their training.

After having identified the key operating situations, so as to be able to create a view for each one, the measures and controls that should feature in it are identified to minimise the switching of views mid-operation.

View design is normally undertaken by the supplier, based on the process drawings and the list of views and parameters that was provided to it. It is important that prior to undertaking their final programming, it forwards the mock-ups of the screen view design produced in this way.

It will then be possible to carry out a simulation, on these mock-ups, of the execution of some operation or incident scenarios, to verify the relevance and the completeness of the grouping together of parameters, to identify any ambiguities, *etc*. The mock-ups will have to be validated prior to final programming by the supplier.

Alarms

Alarms have several functions[3]:

- ▷ enabling the overall supervision of the process, and the gathering of information on its status, in particular at shift change;
- ▷ drawing attention to an event that is abnormal or requires urgent action;
- ▷ provision of timely information to enable a human response prior to the triggering of an automated system;

3. See: reference document OGP 454 mentioned above [IOGP 2011, p.66]; [HSE 2000]; International Standard of the International Electrotechnical Commission [IEC 2004]; [Daniellou 1986].

- ▷ provision of information on the failure of an automated safety system;
- ▷ etc.

The triggering of certain alarms is new information for the operator, while others are the expected result of an action that he or she carried out voluntarily.

Consideration of the structure of an alarm system should enable:

- ▷ the limiting of the number of alarms to what is appropriate;
- ▷ the visibility of the alarm, the clarify of its description, the identification of the level of priority and status (acknowledged or not);
- ▷ the displaying of the alarm both in a structured context facilitating its handling (control view) and in a chronological list[4] making it possible to go back;
- ▷ further than what is displayed or active;
- ▷ support for the identification of 'alarm structures' (significant combination facilitating diagnosis) and access to 'alarm notes' (identifying the possible causes);
- ▷ the filtering of alarms normally associated with an installation status or with the locking out of certain equipment;
- ▷ the immediate identification of disabled alarms;
- ▷ the prevention of repeated alarms when a parameter fluctuates around the limit value, with the appropriate selection of the 'dead band' (hysteresis) between the appearance threshold and the disappearance threshold;
- ▷ the operator to easily identify the primary fault when the same incident results in a flurry of alarms;
- ▷ the operator to 'store' a copy of the alarm in 'boxes' (lists structured by him or her);
- ▷ a distinction to be made between a high value that remains stable and a high value that continues to rise;
- ▷ the operator to programme 'alerts' or pre-alarms that differ from the alarms that reduce his or her mental load in supervision by signalling that an objective has been achieved (e.g. the nearly high level during the filling of a balloon).

The notification of the occurrence of an alarm normally consists of an audible signal and a light signal[5]. Several separate audible signals can be selected, either based on the part of the unit concerned[6], or based on the level of urgency.

The acknowledgement system should make it possible to separate the immediate deactivation of the audible signal and the deactivation of the visual signal when the operator has identified the parameter concerned. It should be possible to execute these acknowledgements without the operator having to move.

Provision should be made for the inspection of the proper operation of the alarms (indicator testing, etc.) and intervention by the maintenance department.

4. This chronological list can be used for the purposes of real-time control, but should also be stored for future operational and analysis needs.

5. The tone of the audible signal should be selected so as to be audible even by people with the onset of age or occupation-related hearing problems (choose frequencies below 2000 Hz). Light signals should be visible in any lighting conditions (reflections).

6. It is in particular essential to choose different tones when the control panels for several units are placed together in the same room.

List of abbreviations

FD	Final design
PD	Preliminary design
SCBA	Self-contained breather apparatus
CHSCT	Comité d'hygiène, de sécurité et des conditions de travail (Committee of Hygiene, Safety and Working Conditions)
DREAL	Direction régionale de l'environnement, de l'aménagement et du logement (Regional Directorate of the Environment, Planning and Housing)
EPC	Engineering, procurement and construction contract
PPE	Personal protective equipment
FEED	Front end engineering and design
HOF	Human and organisational factors
HOFS	Human and organisational factors of industrial safety
HFE	Human factor engineering
HSE	Health, safety, environment
HMI	Human-machine interface
PO	Project owner
PID	Piping and instrumentation diagram
REX	Retour d'expérience (Lessons learned)
HR	Human Resources
SMS	Safety Management System
DCCS	Digital command-control system

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