

Core Principle

Engineers and designers must design construction projects that can be built, used, maintained and eventually demolished in a manner that does not cause harm to construction personnel, end users, maintenance operatives, demolition specialists, and others who may come into contact with the project. On the interface between client, designer, engineer and contractor this requires the acceptance of project objectives that include tasks/ activities being completed on time and in a manner that does not cause harm to the employees, customers, other non-employees, or the company.

Some hazards can be eliminated or contained through good engineering design solutions and others, inherent in the process, have to be worked around. In all cases it is essential to identify at the earliest opportunity what hazards exist, the harm that can result and how it does so.

Fundamentally this necessitates a full analysis of the design safety issues and the development of appropriate controls to ensure that work operations during the construction phase proceed in a manner that make certain that people, plant and property are protected from harm prior to, during and after the work operation, regardless of the nature of the hazards faced.

The design safety analysis and control process (below), derived from the OAC model integrates all aspects of the project process including those associated with the design elements in construction. Underpinning this approach to safety is the elimination of risk through the absolute control of all stages of the process.

The model suits the requirements of European Council Directive 92/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites with particular reference to project preparation.

There are three stages to the design analysis and control model as follows

Stage 1 –Analyse the Design

Hazard identification must commence when the project is first proposed. The ideas of the client, the location chosen (if already done so) and the financial resources that he makes available represent the beginning of the process and all of the parameters set at this point impact upon the construction and whole life safety of the project. A preliminary assessment of client requirements against project resources at this stage will identify any hazards that may render the project not viable or that need to be adjusted in order to make the project feasible.

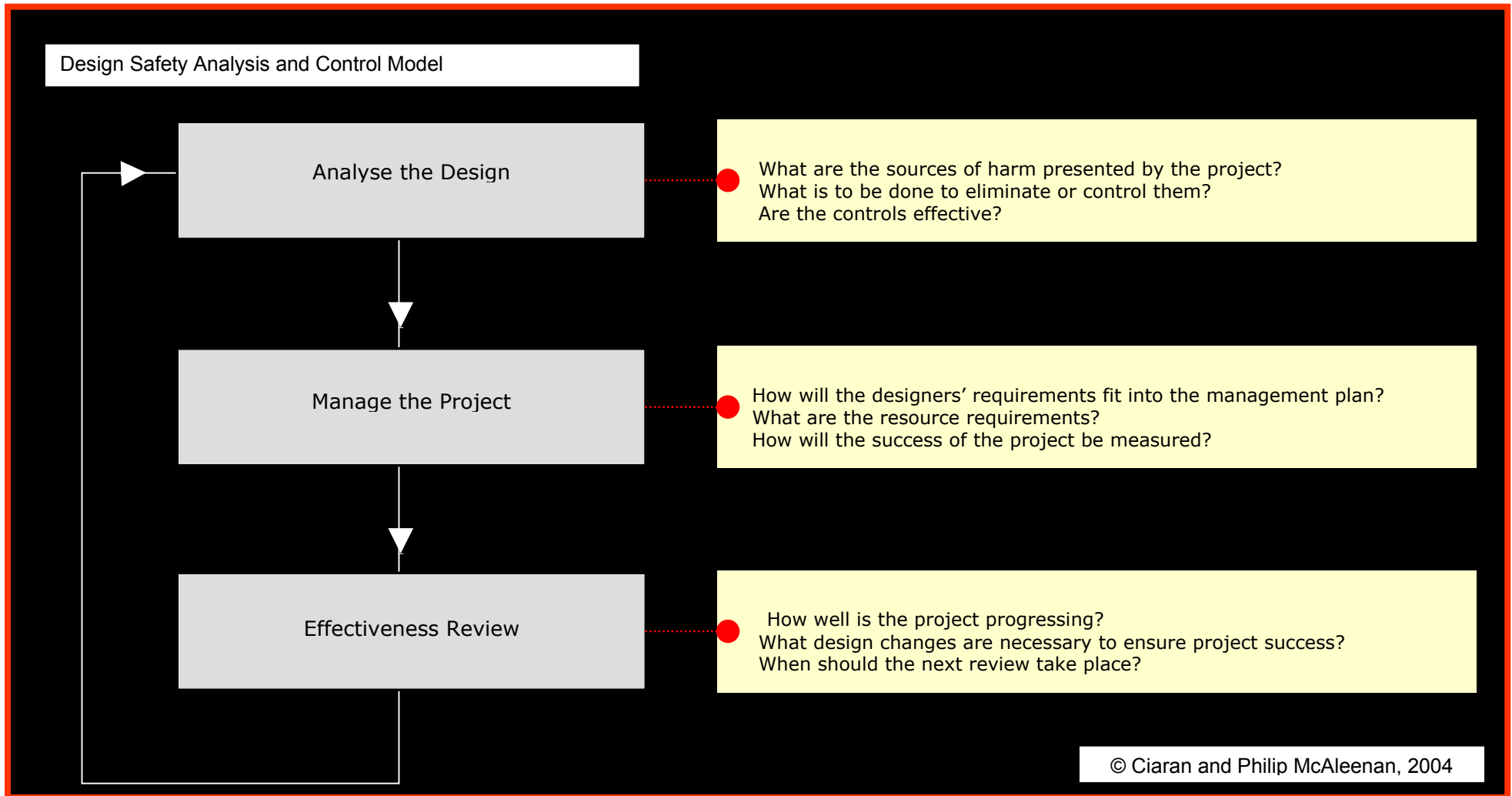


Figure 1: Design Safety Analysis and Control (DSAC) Model ¹

¹ The Singapore inquiry has recommended that 18 similar on-going projects undergo a comprehensive engineering review of the design and safety measures (NCE 23 September 2004, p.6)

It is the designers' and the engineers' tasks to identify what hazards are presented by the design, the location, the environment and the materials to be used for any factors in the design that can cause harm. As the project develops and the design is modified, other factors become relevant such as methods of construction, the workforce, the plant and the equipment.

In each of the different phases in the building's life, from construction, to occupation/maintenance and finally to the demolition phase, there are hazards with the potential for harm. Good design principles apply at all stages from the initial building design to the design and erection of scaffolding by contracted in firms.

Critically the process of assessing what hazards exist is not concerned with reducing the risk posed by them rather it is focused on the elimination of the risk through robust and appropriate control systems. Having identified the sources of harm presented by the project design the key players must consider what has to be done at each stage of the project to prevent harm occurring.

Since elimination is the first objective it may be necessary to go back and review the designs. If the hazard cannot be eliminated, then consideration is to be given to all the available alternative control measures necessary to prevent the harm from being realized. Whatever measures are selected they must be sufficient to eliminate or control the hazards described.

Table 1 below illustrates examples of the hazards and design solutions that may be appropriate.

At the design stage, and before embarking on the work operation, it is important to consider whether enough has been done to prevent harm.

There are limitations to the knowledge of any one individual and it is imperative that specialist advice and where necessary crosschecking is sought. Sources of specialist advice include the project coordinator, other designers and architects, contractors, manufacturers and suppliers of materials, plant and equipment, OSHA, trade or professional associations or other safety professionals. In this way the designer and the client can be assured that national and/ or international design standards are being applied.

UK Roads and Bridges

The Design Manual for Roads and Bridges, used throughout the UK, includes the provision for a technical approval process.

This process requires independent engineering checks that all standards have been applied. These checks include buildability, constructability and safety.

Table 2 – Sample Designers Checklist (Apply appropriate National or International Standards)

Phase	Hazards / Harm	Design Solution (Note whether it eliminates, contains or controls the hazard)	Information required for construction safety plan and/or client safety file ²
Construction	<ul style="list-style-type: none"> • Bridge construction, working at heights 	<ul style="list-style-type: none"> • Pre-assemble spans and raise to position (eliminates a substantial amount of work at heights) 	<ul style="list-style-type: none"> • Construction safety plan
Occupation & maintenance	<ul style="list-style-type: none"> • Painting exposed steelwork (e.g. bridges). 	<ul style="list-style-type: none"> • Use weathering steel (eliminates need for painting). 	<ul style="list-style-type: none"> • Construction safety plan.
	<ul style="list-style-type: none"> • Pipe and cable maintenance or replacement. 	<ul style="list-style-type: none"> • Lay pipes and cables along accessible routes (eliminates need for heights). 	<ul style="list-style-type: none"> • Construction safety plan and client safety file.
	<ul style="list-style-type: none"> • Fragile roof 	<ul style="list-style-type: none"> • Construct and mark permanent walkways, erection of barriers, warning signs (contains) 	<ul style="list-style-type: none"> • Construction safety plan and client safety file.
Demolition	<ul style="list-style-type: none"> • Pre-stressed concrete supports 	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • Construction safety plan and demolition sequence in the client safety file

Note: This table is simplified, incomplete and is included as an example to illustrate the DSAC process

² Construction Safety Plans are dynamic documents that describe the measures necessary for ensuring safety at all stages of construction. Client Safety Files are files developed throughout the life of the project and presented to the client/ owner at the end of the construction phase. They are intended for client use during the occupation, maintenance and demolition phases of the project.

Things can go wrong and it important to try and anticipate what they may be as early as possible. Designers in determining whether the controls they have established are effective must ask themselves;

- What could go wrong?
- How could it happen?
- Will the controls be sufficient to prevent harm if things do go wrong?

Asking the questions at the outset focuses the mind and ensures that all the foreseeable incidents have been considered and planned for at the project preparation stage. These questions also prompt consideration of emergency preparedness plans that should be in place prior to starting any particular operation.

Stage 2 – Manage the Project

Having carried out the design safety analysis a list of what has to be done to ensure a safe outcome to the construction, use, maintenance and demolition of the building must be drawn up. For example;

- How are the designers' requirements to be integrated into the project management plan?
- Has the client, the project coordinator and contractors been made aware of what can cause harm and what they must do?
- What resources are needed? (Material, technical, human, financial).
- Is it known what specialist skills are needed during the different phases in the life of the building?
- Does everyone know who is responsible and for what?
- How will the success of the project be measured?
- Are the occupational safety and health objectives clearly identified and measurable?

It is important that the resources, once identified are made available. To be effective the controls and the resources necessary for their implementation must be built into the budget and business plan.

It is worth considering some of the issues here.

Material and Technological

Some resources will be needed well in advance of any work operation. Others will need to be ordered well in advance of them being needed, for example, custom designed tunnel boring equipment that may take a year and more to be designed, manufactured and tested before delivery to the construction site.

All materials, plant and equipment that are to be used in the construction or the occupation phases must be selected and acquired with care. They must

be suitable for their intended purpose, meet any applicable national or international standards and be safe in their normal use.

Human

Human resources in any project, from the appointment of the initial designer to the employment of site labourers, must be engaged on the basis of their competence (or agreement to undertake appropriate training) to do their job.

The term "Competent Person" is used in many national standards and documents. As a general rule, the term is not specifically defined, though in a broad sense, a competent person is an individual who, by way of training and/or experience, is knowledgeable of applicable standards, is capable of identifying workplace hazards relating to the specific operation, is designated by the employer, and has authority to take appropriate actions. Some standards add additional specific requirements that must be met by the competent person.

Knowledgeable and authorized to act are the key components of competence, and there is no doubt that these are important indicators to a person's likely competence, but as a definition of competence they are inadequate, and as a measure, not sufficient in themselves. A more appropriate definition of competence (at whatever level that may be within the company) would be "*the consistent skilful application of skills and knowledge to any specified work operation*", were the use of the term skilful implies conducting the operation to the highest standards within the field.

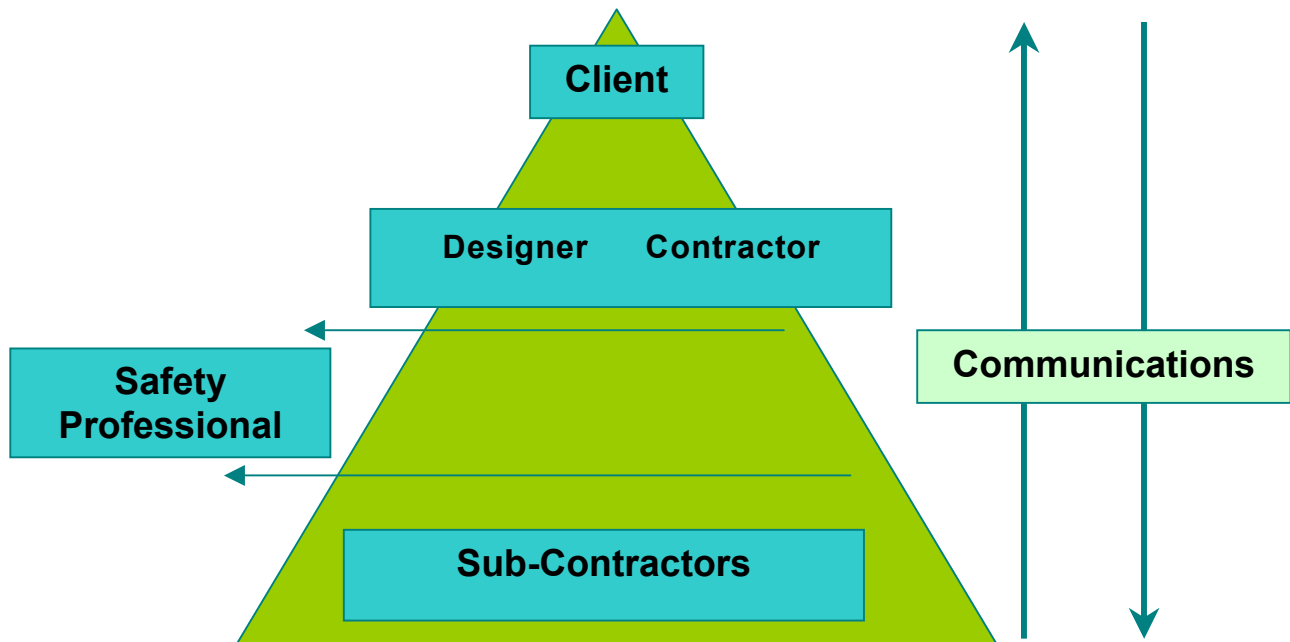
In this respect a competent designer is one who consistently produces structural designs that can be built, used, maintained and demolished without causing harm (in its widest sense) or hurt to construction workers, maintenance workers and end users. Integral to this concept of competence is the notion that, having regard to the designer's age, experience and skill they will know of the hazards and apply the controls necessarily associated with the work.³

Importantly, the thread of competence extends throughout a company; executives, managers, supervisors and subordinates with each level skillfully applying their knowledge and skills to the successful completion of their particular work areas (Figure 3, below). Ultimately, in the design process, competence begins with the client who must ensure, through reasonable enquiry and by seeking advice, that the designers and engineers he engages are themselves competent to assess his project and to advise him accordingly on the health and safety issues. The client must also be assured the people he engages are well enough resourced to undertake the duties he requires of them, that they can demonstrate a successful track record in similar work and that they can and will act in compliance with their legal duties for health and safety.

³ See Dalton v Frendo (1977), Irish Supreme Court.

Where it is necessary and appropriate to do so, a competent professional may be engaged to advise on aspects of health and safety in the construction of the project⁴. Sometimes referred to as a planning/ project supervisor⁵ or safety and health coordinator the task is to ensure that all the safety issues have been considered and adequately dealt with by the managers and supervisors at each level. Competent engineers/ designers are well placed to fulfill the safety and health coordinator's role, given the requirements for experience, knowledge and qualifications. It may be that on occasions input from a particular specialist safety professional(s) is called for to assist with the design safety analysis and control process. However a clear delineation must be made between the safety professional's role as an advisor and the project managers' responsibilities to manage safety and ensure that they and their subordinates are compliant.

Figure 2: Relationships Model



⁴ It is important that professionals engaged to advise on aspects of construction safety and health have a sound working knowledge of safety and health in construction work, a thorough knowledge of the design process and experience of the site processes likely to be involved in the project and in future maintenance, refurbishment or demolition.

⁵ EU Council Directive 92/57/EEC on the implementation of minimum safety and health requirements at mobile construction sites refers to the requirement to appoint coordinators for safety and health matters and specifies duties to be complied with at the project preparation [design] stage and the project execution [construction] stage.

Safety of the project commences at the strategic level and develops throughout the design process to the specific safety and health plan implemented at all levels.

Each player in the process has clear roles and responsibilities. The relationship between client, designers and engineers and contractors is a cyclical one where the exchange of information and advice between one party and the next is crucial to the development of the safety plan and the successful outcome of the project. In respect of safety their roles can be summarised as follows;

Thus the process of identifying and selecting on the basis of task requirements and competence applies throughout the project whether selecting designers and engineers, or contractors and employees. It applies to all parties in the process and requires a sufficient degree of managerial competence itself to make it successful. Anything less will introduce hazards to the project and the further along the process it occurs the greater the likelihood and degree of harm caused to the project.

Stage 3 – Effectiveness Review

Designs need to be reviewed since believing that a design is safe is a sure way of ensuring that it is not. Designs, like workplace safety measures need to be assessed, managed and improved, as necessary. It is important therefore that time is set for reviewing the effectiveness of the designed safety controls. A review could be triggered;

- When new processes or new equipment are introduced to the operation.
- When new techniques have been developed.
- When statutory obligations require it.
- When resources inputs are set to change.
- When an accident or incident occurs.
- When the site is handed over.
- When maintenance, renovation, demolition is planned.
- At regular intervals (determined by the nature and complexity of the hazards present).

Note: The above list is not exhaustive. An effectiveness review should be carried out at any other time, if it is warranted.

Potentially there are many design issues involved in each phase of the life of the building. The designer of the project has a responsibility to consider how these design issues will evolve after the client assumes ownership. It is important to ensure that these progress as planned, and here a project coordinator plays a vital role. Designs change, as does the use of the building. Designers and engineers need to be aware of the effects of any change and try to anticipate how they will need to be dealt with. Consider the following questions;

- How well is the project progressing, when measured against the projects safety objectives?
- What design changes are needed to ensure project success?
- What effect will they have on the project (timing and/ or resources)?
- How will they be dealt with?
- When should the next review take place?

If nothing has changed then it may be sufficient to note that the review has taken place and set the next review date. If design changes are necessary, they should be itemized in the designer's checklist (see Table 2 above) and consideration given to what information needs to be added to the safety plan and the safety file.

Following an effectiveness review any improvement actions should be listed, an action plan developed, resource implications identified, persons responsible for completing the actions nominated and the timescales for completion drawn up.

Remember that the effectiveness review process is the starting point for learning transfer. Solutions developed in one design are normally capable of transfer to new designs for other projects, either with or without modification. The concept of foreseeability is an intellectual skill in the direct application of or deduction from knowledge from prior design or construction experiences to future situations. If we can draw on past experiences on what can go wrong, likewise we should be equally adept at drawing on past successes in preventing injury and harm.

Summary

The design safety analysis and control process is concerned with the identification of hazards in construction projects and the development of sufficient control measures that will ensure that no harm comes to anyone effected by the project, whether employee, end user or member of the public. It is within the gift of the talented engineer to inject enthusiasm for safety and health issues into the design and throughout the whole life of the project. Recognition that hazards exist is the commencement point. What has to be achieved is the identification of the harm that can result and to develop effective controls to prevent that harm from being realized. These controls constitute the safety barrier between the hazards and the construction operator or end-user.

This barrier is the development and use of a variety of suitable and sufficient mechanisms that may include one or more of the following;

- Eliminate the hazard
- Reduce the hazard impact potential
- Control and residual hazards by alternative means
- Information to operators and Safe Working Procedures

The outputs of the DSAC process are a Designers Checklist and an effective health and safety plan that ensure a safe and healthful work environment. The core and guiding principle is that engineers and designers must design construction projects that can be built, used, maintained and eventually demolished in a manner that does not cause harm.

Engineering is the art of the possible and this is just good engineering practice, after all.

By

Philip McAleenan
MSSC FInstLM Cert Law
Member ASSE

Ciaran McAleenan
MPhil CEng MICE MIOSH RSP
Professional Member ASSE

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