



# Part 1

## Analysis

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# 1 The Framework for Understanding

This opening chapter outlines a framework to help develop an understanding of what has to be known in order to take decisions on how we should build. The framework suggests a way of going about selecting construction and identifies the knowledge that is required to make the choice. It is the framework that will be developed and used throughout the book.

## Process and knowledge

This book provides examples of construction, showing how we currently build, and provides an introduction to the understanding necessary to explain how the construction works. These two types of knowledge are both vital to making decisions as to how we should create and maintain buildings in the future. This book sets this knowledge in the context of the process of making choices for the construction. In practice, a great deal of knowledge exists of the types of construction we might use and the materials and details that might be specified. There is, however, the need for any proposed construction works to answer the questions 'Will it fail?' and 'Can it be built?' Clearly it requires the answer to these two questions to be 'No, it will not fail' and 'Yes, it can be built'. These categorical no and yes answers may be difficult to give in practice. There often needs to be some analysis to develop a level of confidence with which to make the choice. The amount of analysis required determines the level of understanding and experience needed to provide the evaluation of the suggested solution before the decision is taken to put the final proposal into practice.

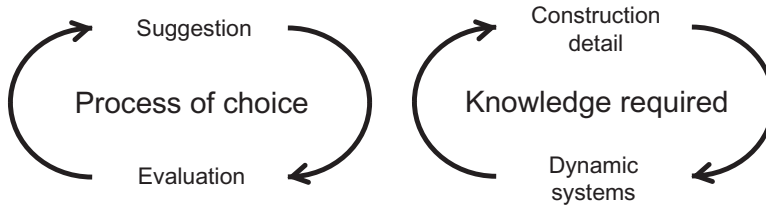
It is this basic ability to make a suggestion of how a building might be constructed and then to carry out an evaluation asking the questions whether it will fail and whether it can be built

that is developed in this book. The evaluation points to changes in the suggestion, which after re-evaluation will lead, through a series of refinements, to the specification and details to be adopted.

This requires knowledge of what potential solutions might look like, with current practice and precedent as the major sources for an initial suggestion. It requires an understanding of what is necessary to be specified in order to describe the proposed construction in sufficient detail to carry out the evaluation. The ability to carry out the evaluation, on the other hand, is dependent on an ability to 'see' the proposal working in the dynamic systems of the physical and social conditions in which the building is to be built.

This process of choice and the way it leads to the identification of the knowledge required is shown in Figure 1.1.

It will be shown later that the process of choice is not just an analysis of the behaviour of physical performance. This evaluation of a proposal's response to the dynamic physical, chemical and biological systems of nature is vital, but building also takes place in a social and cultural context. There will be an imperative to ensure that the resources and know-how are available to manufacture and assemble the construction. This will require knowledge of the available industrial systems. Further, it will be necessary to ensure that the cost of the solution



**Figure 1.1** Relationship of process of choice to knowledge required.

is monitored and that its social and environmental impact is audited. These will demand an understanding of both the economic and social systems in which the building is to be created.

### The initial suggestion

If the process is suggestion and evaluation, and the starting point is suggestion, it is necessary to know how we make the initial suggestion. How do we make that first best guess?

In most cases the suggestion is informed by precedents. It is necessary to have knowledge of current solutions and how they perform in practice. Something, somewhere, has been done before that gives clues as to how the new solutions might be formulated. In times where change is limited the particular circumstances will have been faced a number of times in the past and successful solutions will have evolved. The well-tried and tested solution needs only to be suggested and, with some evaluation to ensure the circumstances have not materially changed, can be immediately adopted. If the circumstances are changing, current solutions may still be the best starting point. They represent not only a sound basis in performance but also an existing base of resources and know-how to manufacture and produce the materials and details. Evaluation may modify but not fundamentally change the solution. This, over time, gives rise to a number of general forms from which specific solutions can be derived.

In some cases, perhaps where there are increasing user demands, or the structure of industrial practice is changing, then similar or

related practice may have to be investigated. On the rare occasions where suggestions have to be derived from little or no existing previous work, a more fundamental understanding of the behaviour of the construction will have to be applied.

While experts approach making suggestions based on their knowledge and experience, it is, in many ways, not necessary to know much at all to make suggestions. It is the evaluation that requires the expertise. Novices or casual observers may make suggestions that may be hailed as brilliant observation, but in truth they have no way of knowing whether that particular suggestion is workable or not. It will take the expert to spot its potential and prove its worth through evaluation.

The power of the expert to spot potential is probably associated with the ability to carry out a rapid, approximate evaluation before subjecting the suggestion to more rigorous and explicit analysis.

### Carrying out the evaluation

The heart of the success of the process of technological choice lies in the ability to be able to carry out an evaluation. The need to carry out a series of analytical exercises determines the knowledge required and manner of its application. It requires a level of understanding to answer the question 'What if we built the building as proposed?'

While the suggestion and the ultimate solution describe the construction in what appears to be a static detail, the evaluation of the suggested construction has to describe a dynamic

system of behaviour ('Will it fail?') and a production process ('Can it be built?').

The process starts with the client's brief, the design then being devised from the requirements of those who commission the works, and as a response to the social and physical context in which the building is to be built. It is against these criteria that failure will be judged. There will be many possible ways to construct a building to achieve performance expressed in the client's brief. The criteria for choice of the technical solution come from the identification of the function of the parts and how they contribute to the function of the building as a whole.

The dynamic behaviour of the construction responding to changing conditions has to be understood, anticipating the modes of failure. Some specification of performance has to be established and then the suggestion has to be tested in the mind to assess the risk of failure within agreed design conditions.

It is easy to see technology as only the final construction, an assembly of components and materials, the building as a static object. However, making the choice of what construction should be adopted has to be rooted in an understanding of the construction as a dynamic system responding to changes in conditions and open to a failure to perform.

It is necessary to be able to visualise not only the physical construction but also its behaviour under the conditions it will have to endure in its working life. Both of these are of equal importance. If the suggestion is not visualised correctly, its behaviour under analysis may be misinterpreted. If the dynamic system of behaviour is not visualised correctly, a flawed proposal may be adopted. Visualising the building as a dynamic system will involve identifying the flows and transfers that take place both within the building and through the construction itself. These ideas are explained in Chapter 7.

Technological choice demands skills in these areas of visualising the object and the systems, and then the conceptual manipulation of the systems acting on the construction to predict behaviour and assess the risk of failure.

If the two basic questions to ask of a proposed solution are whether it will fail and whether it can be built, the criteria for choice come from an understanding not only of the potential dynamic flows and transfers when the building is in operation but also of the resources available. The performance of construction can only be realised if the resources are available to construct the building. This relies on the manufacturing and assembly possibilities but will also include the existence of design expertise and the options for maintenance and disposal. Knowledge of available techniques and know-how for production is crucial to the choice of the final construction if it is to be successful in reality as well as on paper.

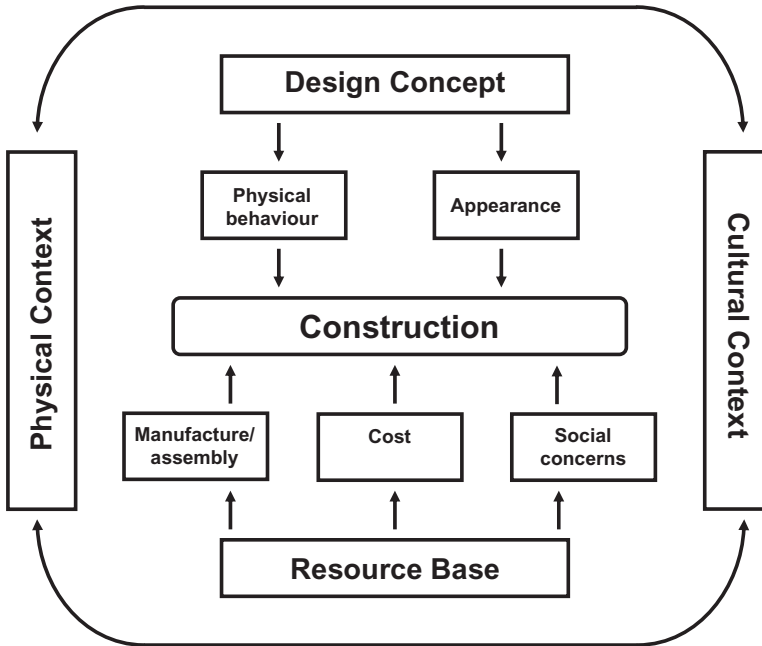
As a design concept emerges, it is necessary to question what construction solutions may be used to fulfil the design requirements. It is then necessary to question whether this solution is available with current technology and resources within any environmental, cost or time requirements. The resources available make the design a reality. Technology stands between the design of the building and the management of the resources.

Choices can be made that may extend current production and design knowledge, but this must be recognised, and any costs involved in prototypes or training and the risks involved must be accepted before the final choice is made.

The design and resources available condition the choice. These two areas are shown in Figure 1.2. These are the two areas that have to be understood before any analysis can be started leading to the final choice of construction.

## Physical and social context

Figure 1.2 also indicates that before any choice for a specific building can be made it is necessary to understand something of the context in which it will be constructed. There needs to be some knowledge of the conditions that exist when and where the building is to be built, possibly with some assessment of how conditions may change in the future.



**Figure 1.2** Framework of analysis.

Construction takes place within, and has an impact on, the world in which it is undertaken. Some description of this world is necessary for both technical and socio-economic analyses. The world can be represented as a series of contexts, both physical and cultural. The physical context includes nature and climate. These exert forces that act on the building; they provide the raw resources and may be adversely affected by the construction and operation of buildings. The physical context includes the surrounding development and the need for the design to respond to existing buildings and spaces.

People and their social, economic and political systems create the cultural context. It needs a response to local, national and even global needs based on beliefs and fundamental world views of the relationship between individuals and between society and the other components of the natural world.

The interaction between these two sets of contexts has been brought into focus at the beginning of the twenty-first century by the movement for sustainable development. The realisation that development cannot continue without

consideration of its impact on the natural environment as well as established economic and social considerations calls for new knowledge associated with materials choice, energy use and waste disposal aspects of our chosen construction.

There are, therefore, dangers in seeing these two sets of contexts as separate. However, it is still useful to consider them as having different dynamics, as, generally, in order to resolve technical questions, it is necessary to have an understanding of the physical context, while to evaluate the chance of a solution being successfully applied requires an understanding of society, its economic and political systems.

### The basis of analysis

Having identified the design concept and the resource base as providing the criteria for choice and having recognised the need to understand the physical and social context in which we build, it is possible to identify five areas of analysis as shown in Figure 1.2.

The design concept is the translation of the physical and social needs for the operation of the whole building into a scheme that identifies the function and performance of each of the parts. In order to achieve this, the design concept has to articulate both the arrangement and appearance of the spaces and the technical contribution each part of the construction will make to the creation and maintenance of the internal conditions.

Two tests indicated in Figure 1.2 have to be applied to a suggestion to see if it complies with the design concept:

- Does the *physical behaviour* of the construction provide a building fulfilling its functions to the required performance level?
- Does it provide the right attributes of *appearance*?

The test for physical behaviour involves three separate areas of analysis:

- Creating environments
- Under load
- Over time

Three tests indicated in Figure 1.2 have to be applied to a suggestion to see if it is achievable with available resources:

- Can it be produced, including *its manufacture and assembly* and the subsequent processes of maintenance and disposal, with existing skills and know-how in a reasonable time and at the required quality?
- Are the resources available at reasonable *cost*?
- Will it be compatible with the *social concerns* that currently exist?

These resources are both natural (from the environment) and social, so both aspects have to be part of the evaluation. It is only possible to use resources that nature has provided. However, the level of economic development in a society will provide the capacity to process materials, develop the skills and machinery to work them, the intellectual capacity to undertake design and the provision of capital to invest in the enterprise of the construction itself. Both the technical properties of materials and the exist-

ence of the knowledge to exploit them plus any environmental impact of their use must be analysed in evaluating a suggested form of construction.

These seven areas of analysis (physical behaviour being three) that have to be undertaken are, by and large, unrelated to each other and each needs its own tools of analysis and knowledge base to be successfully applied. Carrying out one analysis may indicate the need for a change in the suggestion, but the change that is chosen may make the analysis of a previous aspect invalid. It is not until all the relevant areas of analysis are shown to be satisfactory that the suggestions can be adopted as the solution.

These seven areas of analysis have potentially to be undertaken for all aspects of the construction, from the overall structural system to the finest detail such as the screw that fixes the final fitting to a wall. The work in this is clearly overwhelming if it has to be carried out for every building that is constructed. Current practice can inform much of the process of choice. One of the most important decisions that experts take is, of all the thousands of choices that have to be made to fully specify the construction, which of the areas of analysis for which parts of the building are significant. Where, if analysis is not thought through, is the greatest risk of failure?

It is not clear how experts make this judgement. One possible explanation is that while looking at a suggestion they make many rapid checks against the seven criteria. From their knowledge and experience they take a view on what is well within failure limits and where the risks of failure are higher.

### Knowledge needed for choice

It is now possible to start to identify the knowledge that is required and the areas of understanding that have to be developed in order to carry out a full evaluation. Although used in various combinations in the different areas of analysis, it is possible to put forward a tentative list of types of knowledge that will be required:

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- Setting the performance levels as the criteria against which the evaluation will be made.
- Defining the conditions under which performance has to be achieved.
- Determining the fundamental behaviour of the construction that would lead to failure to meet performance requirements.
- Identifying the materials' properties that will govern the behaviour that could lead to failure.
- Thinking through the behaviour of the particular combination of materials and details under the conditions envisaged.
- Identifying the process of manufacture and assembly together with the resources required to produce the building within quality, time, cost and safety limits.
- The cost in economic, social and environmental terms of using a particular form of construction.

The process of evaluation requires the building to be conceptualised in a number of ways. While the final building will be seen as a physical construction, 'bricks and mortar', it is necessary to perceive the building in a number of other ways when carrying out the evaluation. Initially, the construction has to be seen as fulfilling a set of functions with associated performance levels. For evaluation, the building has to be viewed as a series of physical systems responding dynamically to changing conditions. The building then has to be seen as a series of production operations with the resources required for the realisation of the design. All these will have economic, environmental and social implications that have to be understood. When all these can be mastered, choices can be made associated with an assessment of risk and with some confidence of a successful building.

### Summary

1. The process of choice is one of suggestions and evaluation that requires knowledge of the physical construction and the dynamic systems in which it will be built and will operate.
2. How a suggestion is generated, and the extent to which a formal evaluation has to be undertaken, depends on the scale and nature of any changes from current practice required by either the design or the resources available.
3. When there is a changing demand for buildings and rapidly developing technical knowledge, the role of experience changes from predominantly reproducing known solutions to the integration of experience into a process of analysis to explore the possibilities of failure in the modified or new solutions before they are built.
4. The design and the resource availability define the criteria for the evaluation. This has to be set within a physical and cultural context.
5. The suggestion will probably be based on precedent and this leads to general forms from which specific solutions can be derived.
6. The evaluation needs to be carried out through seven areas of analysis: appearance, behaviour creating environments, behaviour under load, behaviour over time, manufacture and assembly, cost and social concerns.
7. This will involve constant reference to both production and design. The concern is for what will not fail and can be built.