

Introduction to the book and the author

This book is about how to model the behaviour of complex projects. It isn't about how to manage projects—although you'll be expected to know the basics of project management—and reading this won't make you into a better project manager. This book is written for analysts and workers in project management who find themselves needing to model how a project behaves. This could be at any point in the project life-cycle—from feasibility studies before the project proper begins (when the modeller might be helping to advise and inform senior management about project strategies and risks) to project post-mortems after the project is completed (when the modeller might be helping a project team understand what happened in the project to learn lessons for the next project, or might be involved in preparing legal claims) and, of course, all points in between. The modeller can be fulfilling any of a number of roles: independent auditor, advisor to a project manager, part of a project support office, expert witness for a legal claim, consultant to a project client, and so on.

The book doesn't offer one particular point of view or technique. It collects together techniques that have been found useful by the author in his practice as a project modeller over the past 15 years. So perhaps a brief introduction to that experience would be useful here. The author is an operational researcher (“OR”-er) at heart, starting his career with a few years' lecturing in OR. He then moved to work in OR in an engineering and naval consultancy. There he quickly became interested in modelling some of the big defence projects, particularly looking at their risk before the projects began, and developing prototype project risk analysis computer tools. This field of work was given added emphasis at the time as there were political moves to pass risk from government to private industry—so, for example, industry had to be sure that it was not taking on too much risk, while government had to be satisfied that it wasn't being charged too much

in terms of risk premium for having risk taken away from it. But the work was at that point given a particular incentive by the mandating of formal project risk analysis and management by the Ministry of Defence (MoD)'s Chief Scientific Adviser (CSA, in MoD jargon—he has a crucial role on MoD's Equipment Acquisition Committee). This was largely a consequence of the Nimrod project, a story which is well told by Humphries (1989), then Assistant CSA. But as well as pre-project risk analysis, the author was also involved in mid-project reviews, then, when the consultancy was taken over by a major defence contractor, acted as risk manager on major multi-company defence contracts. After nine years with this company, the author rejoined Strathclyde University's internationally known Department of Management Science, to research and carry out independent consultancy in project modelling and risk analysis (and also in his spare time to look after an MSc class in OR!). There he immediately got involved in the other end of project modelling: post-project claims for litigation. His first project was the building of the wagons for *Le Shuttle* in the Channel Tunnel (described in more detail in the list of projects below): a project which had significantly overspent for reasons which were at that point not particularly clear, and difficult to prove were the fault of the project client. A team led by Professor Colin Eden, with Dr Fran Ackermann (both well-known in eliciting information from groups and analysing the structure of causality to gain understanding of the dynamics in “messy” situations) and the author, built up models and evaluated the extent to which the overspend and time overrun was due to “disruption and delay” caused by the project client. This supported a large claim to this project client. This work has led to work on other disruption and delay claims by the same team (later joined by Susan Howick), and some of these will be referred to in this book. It also led to research and teaching within the manufacturer to learn lessons from the project. Carrying out project post-mortems is a very good source of knowledge and experience to help carry out risk analysis and risk monitoring—it is surprising how often, in practice, risk analysis is carried out by “risk analysts” while post-mortems are carried out by claims consultants, with little communication between them, instead of each being informed by the other.

Coming back to this book, as an introduction we'll look at why the book has been written, and why the subject is becoming of increasing importance; then the structure of the book will be briefly described and, finally, you will find out what you need to know about already to be able to read this book.

Why is there a need for this book?

In the next chapter, we'll describe what we mean by a "project" for the purposes of this book. Taking for now the common usage of the word, projects have always been important in the development of the environment in which the human race lives. This is true in two common senses of the word "project"—construction projects with a tangible output (the Pyramids; Stonehenge; the Great Wall of China) and projects which bring about a change in the organisation of society (the biblical bringing the Israelites out of Egypt, claimed by Martin Barnes as the first recorded major project; Columbus' setting out and discovering America). While it is true that society has always tried to improve incrementally the way it operates and produces goods, projects have through history formed the major stepping stones for step-changes. This continues to be true today, and indeed projects are becoming more important to industrial life. The preface to Turner (1993) extrapolates from statements by British Telecom to suggest that the annual spend on projects in the UK would be around £250mn.

A whole field of endeavour has therefore arisen to try to manage projects better. "Project management" had its origins in the chemical industry as far back as the 1930s, but really became well-defined and developed in the 1950s: the key point at which it became a discipline in its own right was in the Atlas and Polaris programmes. Gradually, methods were formulated and codified. Professional societies were developed: the US Society became the Project Management Institute (PMI); European nations' national societies joined in a society initially called "Internet" then later (as something else with this name became widespread!) this was renamed the International Project Management Association (IPMA). Degree courses (generally at Masters level) are offered at many universities around the world. PMI also has a widely recognised accreditation scheme, and many IPMA member societies have their own accreditation schemes.

But the nature of projects has been changing in recent years. One change has seen the continued rise of extremely large projects. While we have already mentioned a few giant projects that occurred before the mid-twentieth century, and of course many other major construction projects can be included, such projects are becoming more common. Kharbanda and Pinto (1996), for example, list over 40 projects underway in the mid-1990s in India, China and south-east Asia alone, each forecast to cost over \$1bn. These are mainly construction projects, but engineering projects are also becoming larger in some industries as the investment needed to

develop new products increases—the break-even point of an aircraft development programme is generally held to be at least 300 units, and the development cost of a new model can approach the sales equivalent of the order of 100 units. But, along with their size, it is generally held that the complexity of projects is also increasing: “Construction projects are invariably complex and since World War II have become progressively more so” (Baccarini 1996). What complexity is, and why it is increasing, is explored in more detail in Chapter 4. But it is worth noting two compounding causes for projects increasing in complexity (from Williams 1995c). The first is that products being developed today are increasingly complex themselves, which leads to more complex projects. The second is that projects have tended to become more time-constrained, and the ability to deliver a project quickly is becoming an increasingly important element in winning a bid; and furthermore, there is an increasing emphasis on tight contracts, using prime contractorship to pass time-risk on to the contractor, frequently with heavy liquidated damages for lateness. Chapter 4 will look further into how this compounds increasing project complexity, and Chapters 8 and 9 will look at how to understand and model this compounding.

The last four decades of project management are characterised according to Laufer *et al.* (1996) by an evolution of models appropriate to changing dominant project characteristics: they characterise the 1960s by scheduling (control), for simple, certain projects; the 1970s by teamwork (integration) and the 1980s for reducing uncertainty (flexibility), both for complex, uncertain projects, and the 1990s by simultaneity (dynamism) for complex, uncertain and quick projects. These latter are precisely the challenges we will face in this book, and it is the increase in such projects that has given rise to the need for models to support the projects, and has led to a need for this book.

One aspect of the future is obvious: all new undertakings will be accomplished in an increasingly complex technical, economic, political and social environment. Thus project management must learn to deal with a much broader range of issues, requirements and problems in directing their projects to successful conclusions. Certainly, project management in every field will be called upon to address complexities and risks beyond anything experienced in the past (Tuman, 1986).

So how successful have projects been in the past? If we have been successful at bringing projects in, then perhaps new methods aren't needed. Some anecdotal evidence is available: for example, Cleland and King (1988b) cite half a dozen American examples, including Forbes magazine's comments on the US nuclear power programme, and the well-known case of the \$8bn Trans-Alaskan Pipeline, of which the State of Alaska claimed

that an \$1.6bn spend was “imprudent”. This evidence is not sufficient to draw firm conclusions. However, there has been a certain amount of work collecting data on historical project out-turns, beginning with work such as Marshall and Meckling (1959), who collected data to try to predict overruns. Let us look first at four studies done in the late 1980s.

- The key text in summarising the historical evidence, at least up to 1987, is Morris and Hough (1987). They list 33 references containing databases of project out-turns, and the reader is strongly recommended to read the beginning of this book to study the conclusions drawn. Morris and Hough’s preface to their list of databases states that:

Curiously, despite the enormous attention project management and analysis have received over the years, the track record of projects is fundamentally poor, particularly for the larger and more difficult ones. Overruns are common. Many projects appear as failures . . . particularly in the public view. Projects are often completed late or over budget, do not perform in the way expected, involve severe strain on participating institutions, or are cancelled prior to their completion after the expenditure of considerable sums of money.

In summarising their database, they state that, “There are hardly any reports showing underruns. . . . In all the other cases, representing some 3500 projects drawn from all over the world in several different industries, overruns are the norm, being typically between 40 and 200 per cent, although greater percentage overruns are found in a number of groupings, particularly certain defence projects and in the US nuclear industry.” (This last figure relates to cost overruns.)

It should be noted, however, that Morris and Hough also give a number of caveats to their cost overruns which are worth considering, as we will need to bear these in mind when we look at our example projects in the next section. First, some of the “overruns” relate to customer-requested changes. Some of these are simply increased order quantities (indicating a successful rather than an unsuccessful project). Regulatory changes, such as in the US nuclear industry, causing “a substantial proportion of the cost growth in this industry”, are also included in this category. However, this is perhaps too simplistic—for semi-public or mixed private/public projects, which increasingly make up mega-projects, regulation changes are possibly the major risk, and will feature in the discussion of systemic effects in Chapters 8 and 9. The second most important caveat is the treatment of escalation. Many government projects specifically exclude any allowance for inflation in the tender price, and escalate payments in accordance with some accepted index;

an example quoted in Morris and Hough is that the “Central Electricity Generating Board (CEGB) discounts all costs back to the project’s budget base dates. This makes comparison of overruns on UK nuclear power plants with those experienced by the US nuclear plants, for example, almost impossible to make accurately—US plant costs include not only inflation but generally the finance charges for funds used during construction”. Third, the treatment of contingencies differs from datum to datum: quoting again, “The Apollo programme, for example, came in at \$21 billion, only \$1 billion over its original estimate. Few know that the initial estimate included \$8 billion of contingencies . . . Very few public projects have even semiformal contingency budgets”. Finally, of course, cost- and time- out-turns are not the only measures of project success, a subject which will be considered further in Chapter 2.

- A major study carried out since Morris and Hough is Merrow (1988). This is an analysis carried out with RAND on a database of 52 projects, all worth over \$500mn. Analysis showed that many projects met their time-target—the average slippage was 17%—but there was a clear overrun on cost—the average overspend was 88%, although the caveats made by Morris and Hough must be made here, since it is not clear what the original budgets contained for the projects. The main problem causing overrun was again found to be regulatory problems, and we will revisit this question of regulatory problems later in the book, in particular, in the naval ship life extension example in Chapters 7–9.
- One database quoted by Morris and Hough that is perhaps worth mentioning, as it has in the past been an important source of world data, is the World Bank Tenth Annual review of project performance audit results (World Bank 1985). The results show a gradual decline over time in performance, with cost overruns shown up to 560%, cost often being contained at the expense of scope (although their overrun figure includes inflation (see discussion above) and the effects of the oil crisis); time overruns average 61%.
- In the UK, one of the key clients for large and complex projects is the Ministry of Defence (MoD). The MoD’s key auditors on expenditure are the National Audit Office, whose report on the control and management of the development of major equipments (National Audit Office 1986) examined 12 projects, and found real increases of almost £1bn (91%) after the project staff requirement was approved. In the US, a survey of 246 US army programmes by Arbogast and Womer (1988) showed cost overruns of –21% to +437% (mean 15%) and time overruns of –8 to +74 weeks (mean 7 weeks).

Studies done in the 1990s have generally found similar results, although with less easily quoted statistics. Most collections have been to study particular aspects of overruns (e.g. Chan and Kumaraswamy, (1997), which analyses varying causes of overruns in construction projects). The inescapable conclusion is that our history over the past few decades of managing projects is not particularly good, and many of the example projects described in the next section will show this.

Furthermore, this book will outline why the changes in project characteristics described above imply that classical ways of analysing projects within the canon of project management, which are based on breaking down a project into its constituent parts, are becoming less appropriate for modern projects. This book explains where the use of modelling can help to estimate, monitor, control and analyse projects, and thus help their successful implementation—for any project, but especially for today's large, complex, uncertain and fast projects.

The structure of this book

The title of this book is *Modelling Complex Projects*; so the book begins with three chapters that take each of these three words and deconstruct them.

- Chapter 2 discusses what a *project* is, and the type of projects we will be discussing here, giving references and thumbnail sketches for the case studies.
- Then Chapter 3 discusses what we mean by *modelling*: Why do we model? What is modelling? How does modelling work in practice? How can we validate our models?
- Chapter 4 moves on to the adjective *complex*, and discusses what constitutes project complexity, and what it is that makes a project complex.

While these might appear at first glance to be simply introductory flannel, they do highlight many of the issues that form the book's *raison d'être*—the reasons behind the inadequacies of classical project management decomposition techniques for complex projects, the types of modelling we will be using, and why, and so on.

The heart of the book concentrates on the models, using the dimensions of complexity outlined in Chapter 4.

- Chapters 5–6 look at individual and discrete probabilistic effects within projects, and the use of simulation to understand how these affect projects. This adds the complexity effects of uncertainty into the models. Chapters 5–6 deal mainly with identifiable physical events; however, there are many “softer” elements that have a major—often crucial—impact on projects. Chapter 7 looks at modelling these effects, including perceptual issues and the role of information flows.
- The effects generated by the elements on Chapters 5–7 are systemic, and can set up portfolio effects, dynamics and feedbacks. Chapter 8 considers these, and discusses both qualitative and quantitative ways of modelling.
- A natural way of modelling the systemic effects of Chapter 8 is by a method known as *System Dynamics* (SD). Chapter 9 looks at how SD can be used to model these effects, and how it demonstrates the compounding of effects so commonly seen in projects (sometimes referred to as “ $2 + 2 = 5$ ”). Again, questions of data collection and validation are discussed, since it is important that these methods are seen in the context of their use in practice. Chapters 8–9 include the complexity effects defined in Chapter 2 as *structural complexity*.
- We have now looked at probabilistic methods, which analyse the operational level of the project, and at deterministic methods which analyse a project’s systemic effects at a more strategic level. Chapter 10 looks into a variety of hybrid and mixed methods to bring together the benefits of these methods, and suggests this as a way forward.

To complete the book, Chapter 11 looks at the role of the modeller. After introducing different roles within project management, the chapter looks at where and how modelling should be used at the start of a project (for example, during estimation and risk analysis), during the execution of a project (monitoring and replanning) and after a project has ended (carrying out post-mortem analysis and claims preparation). It looks briefly at the role of models in programmes of projects, and at where a modeller fits in to the project management team.

Chapter 12 ends the book.

What do I need to know before I read this book?

Since this is a book about modelling projects, it’s not surprising that some basic knowledge will be assumed of two areas: projects and modelling.

As far as projects are concerned, you will need to be aware of two areas. First, you will need to be aware of how projects work in general. This would ideally be by personal experience if you really want to relate to the problems this book is trying to address—it is only by personal experience that you can relate to the feel of project life: the suspension of everyday life for a year or two, the working away from home, the gearing of effort to a single temporary end. Failing this, however, Turner (1995) gives a good description of the commercial environment in which projects are undertaken. In particular, you will need to understand the following:

- The idea of *project life-cycles* and *project phases*. Terms used differ between engineering, construction and IT projects, but typically a project might consist of: proposals being formulated and feasibility established in a “feasibility” phase; task identification, initial estimates and plans, and sometimes initial design drawn up in a “definition” or “project definition” (PD) phase; the work carried out in an “execution” or “design and initial production” phase; then (depending on the context) perhaps a “full production” phase, or a “commission” phase; then close-out. In addition, we shall discuss moves towards concurrency (some overlapping of the phases, in particular the design and manufacture phases, to shorten the project duration—see Syan and Menon 1994).
- The idea of the *legal contract as the basis of the project*. Most of the projects discussed (although not all) were carried out for a client or owner (who initiates the project, specifies the requirement, supplies the finance, and owns the final product) by a contractor (who controls the resources to carry out the project, and who executes the project). You should be familiar with the ideas of contract clauses (ideas such as “Force Majeure” might be helpful, too).
- Still in the area of the contract, you should be aware of *penalty clauses* and *liquidated damages* (the costs a contractor must pay if he does not meet all of the project requirements, in particular the due date). You should be aware of the issues behind different contract payment types, such as “Cost Plus”, or more properly Cost Plus Percentage Fee, and Cost Plus Fixed Fee; at the other end of the spectrum Firm Fixed Price; and typical positions between the two, such as Cost Plus Incentive Fee, where there is a percentage fee payable, which can vary within set upper and lower limits in accordance with a formula tied to allowable actual costs (with a sharing formula by which costs are shared between the two parties). (For more information, see In’t Veld and Peeters 1989).
- *Typical management structures* generated to manage projects, in particular

the idea of *matrix management*. Functional organisational structures (which divide the people in a company into groups of similar specialisation) have problems when faced with large projects. They cannot cope with the dynamic changes and complexities; they do not allow the clear line of authority from a project manager that is a prerequisite for good project management; and they cannot cope with industries where design, procurement and manufacture overlap in time. Therefore, the matrix organisation was developed in the 1980s (see Cleland (1984)'s handbook), where workers have a responsibility both to their functional superior and to the project manager(s). Surveys (such as Larson and Gobelli 1989 and Gray *et al.* 1990) have shown this to be a superior management structure for multi-project-oriented companies, although the mid-1990s has seen a move towards flatter structures, and the impact this will have on project management is not yet clear.

As well as being aware of how projects work in general, you will be expected to understand the basic tools and techniques of project management. A summary of all of these elements from a US viewpoint is given in the Project Management Institute's *Project Management Book of Knowledge*, or "PMBOK". A good project management textbook will describe the basics. There are lots of good textbooks: Lock (1994) is a good overall handbook; Cleland and King provide an excellent handbook for engineering projects; the American Management Association also have their own handbook (Dinsmore 1993); and my favourite, and a book which has become a recognised classic, is Turner (1993), which describes management by projects in a generic way. Many of these techniques are based on the idea of decomposing the project into its constituent parts in an orderly, structured way. You should be familiar with:

- How the scope of work is defined, decomposed and controlled, in particular the ideas of *specifications*, the *Work Breakdown Structure (WBS)* and *configuration control*.
- How time is defined, decomposed and controlled, in particular the ideas of network scheduling (the use of activity-on-the-node and activity-on-the-arrow networks, also called Critical Path Method, or CPM, and developed into the Project Evaluation and Review Technique, or PERT) and the use of *Gantt charts*.
- How costs are defined, decomposed and controlled, in particular the ideas of *cost-breakdown structures* (more advanced readers will be aware of how estimates are built up from the cost-control cube, which relates the WBS, Organisational Breakdown Structure and Cost Breakdown

Structure, as in *C/SCSC*) and *earned-value analysis* (analysing budgeted, committed, incurred and forecast costs).

- How *project estimates* are drawn up: Turner, (1995), for example, lists methods including step-counting, exponential and parametric methods, elemental, empirical and bill-of-quantity methods and (for the IT industry) analogy, top-down and bottom-up, COCOMO-type (CO-structive COst MOdel) models, and function-point analysis.

Finally, you will need some basic mathematical modelling skills—the books referenced in Chapter 3 give some useful background here. You will need to be familiar with using equations to represent real situations, basic probability and the use of simulation; and later chapters will introduce the technique of System Dynamics, for which references will be given. But you won't really need any ideas more advanced than the idea of statistical "correlation". Key here, though, is a sympathy with the idea of building a mathematical or analytical model of a real situation and interrogating the model to learn about the real world.

Conclusion

No more needs to be said, other than I trust that you will join me on this journey. I have found that the modelling of projects both gives me excitement and makes a real contribution to the projects in which I've been involved—I hope you do too!

