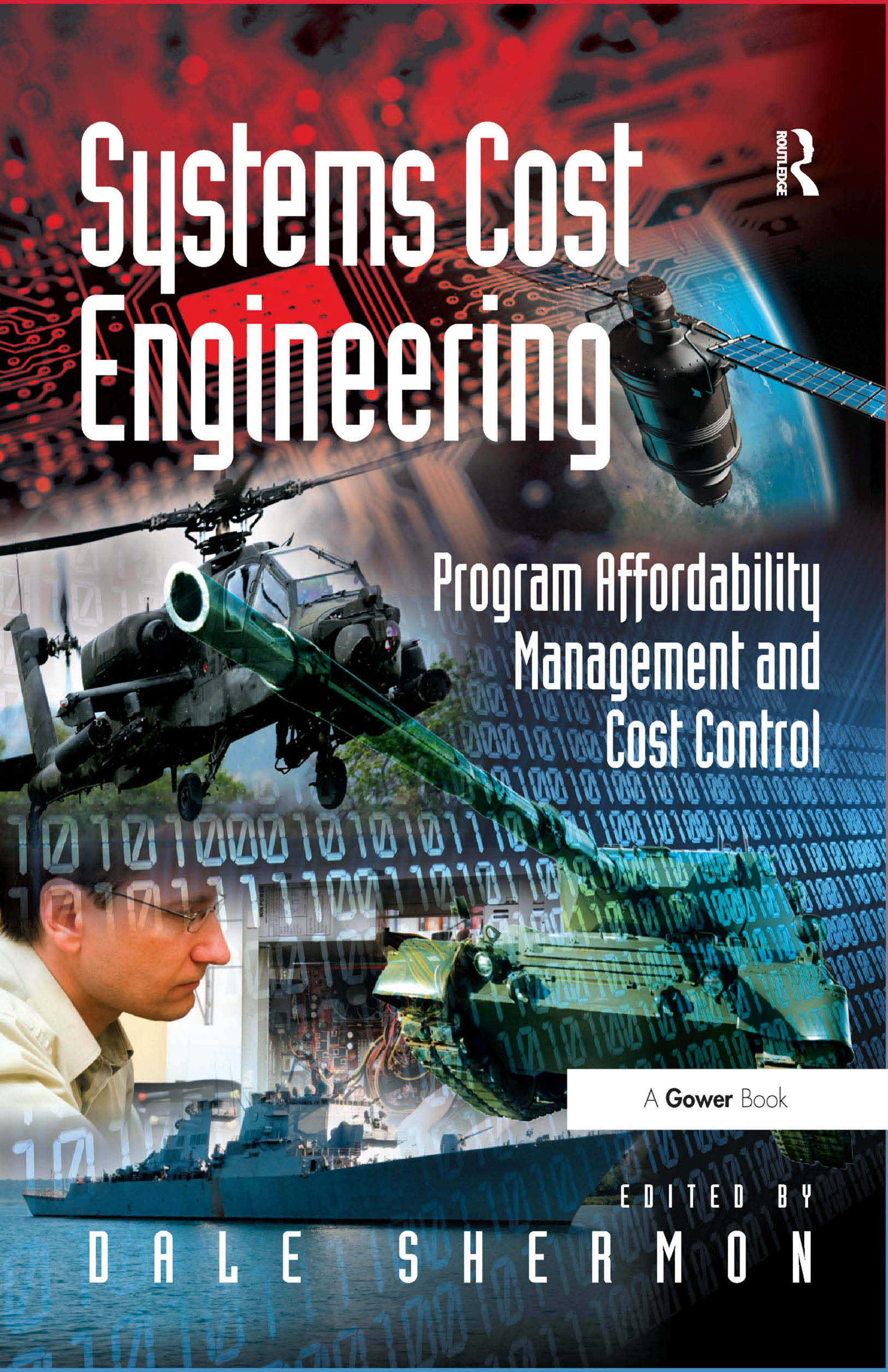
Systems Cost Engineering

Program Affordability Management and Cost Control



ROUTLEDGE

A Gower Book

EDITED BY
DALE SHERMON

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Program Affordability Management and Cost Control

DALE SHERMON

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Contents

List of Figures

List of Tables

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Foreword

By Tony DeMarco

President, PRICE Systems

I am an entrepreneur, but my academic training was in mathematics and computer science, not business or accounting. One day I sat down with a pencil and a blue-lined paper pad (I could not find my graph paper) to craft a formula to determine the amount of near liquid cash we had to meet our operating needs. I laboured over income statements and balance sheets for a day before I found an equation that I knew would work. Proud of my accomplishment, I showed this financial revelation to our accountant. He promptly told me that it was the formula for Working Capital found in every beginners accounting text book. I learnt; there were better ways to have spent my day.

Program Affordability Management is the set of coordinated activities that determine whether or not an organization will be able to bear the cost of a program over the course of its life. It takes leadership, discipline and people armed with effective methods and tools to practise Program Affordability Management successfully. Great tools alone will not keep programs affordable. Tools must be applied as part of a credible process if estimates and analyses are to be accepted. We want people to be successful with the tools and solutions they use, so this book is a collection of methods with proven success.

Consider the needs of your organization and challenge people 'why are we not performing these activities?' Don't reinvent the wheel or accounting equations, learn from others. Familiarize yourself with this book's contents and keep it by your side. Your days will be more productive.

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Acknowledgements

This book was inspired during work on more than 25 years of conference and symposium papers written by customers and consultants on the applications of parametric cost models.

The inspiration to compile a book came from Dale Shermon, but the contents have been gathered from the team of consultants at PRICE Systems with a collective Cost Engineering practical knowledge in excess of 300 years.

Therefore, acknowledgement is extended to the following team who assisted in writing this book:

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'The team is greater than the sum of its parts.'

Glossary

Calibration	The process of tuning a commercial parametric model to an individual organization by producing the productivity metrics of historical projects.
Commercial Off the Shelf (COTS)	Referring to items which are purchased or built to licence or to the design of a customer. They can be either software or hardware items.
Manufacturing Complexity	An empirical factor comprising the technology implicit in a product and the productivity of its manufacturer. Most easily perceived as a normalized cost density in a hardware parametric model.
Organizational Breakdown Structure (OBS)	This is a formal arrangement of resources (labour and non-labour) which will need to be consumed or used to ensure successful completion of the project.
Organizational Productivity	The calibration factor for a software parametric model which represented the efficiency or productivity of an organization in software projects.

Product Breakdown Structure (PBS)	This is a formal arrangement of technologies or software which will need to be acquired or built to ensure successful completion of the project.
Program	An alternative description of a project taking into account all its facets including the budget and schedule.
Programme	A software code used to make computers perform a useful function.
Work Breakdown Structure (WBS)	This is a formal arrangement of activities or tasks which will need to be conducted to ensure successful completion of the project.

1

Introduction

Cost Engineering requires the fusion of three elements: processes, cost models and skilled people. When these three elements are combined efficiently, a capability is achieved that will profoundly influence the projects that an organization embarks upon. When these elements are realized in the organization, then cost estimating naturally leads to project control, which enables the development of corporate knowledge and the re-use of what has been learned in the cost estimates of the future.

Program Affordability Management (PAM) (see Figure 1.1) is a seamless union of these elements that results in what we call True Program Success. How do we know when we have achieved True Program Success? When we can confidently say, no program will ever:

- be conceived without a credible analysis of alternatives;
- be initiated with insufficient funding because of inaccurate initial estimates and inaccurate quantification of the risks;
- be deterred from its mission because of lack of credible cost analysis within the program's management;
- be deterred from its mission because of lack of integration between Earned Value Management and Cost Estimating and Analysis;
- be deterred from its mission because knowledge of cost and productivity metrics is not being shared among program teams and with other programs;
- be deterred from its mission because of surprise cost overruns and schedule delays.

Figure 1.1 Program Affordability Management (PAM)

Program Affordability is achieved through three elements of Cost Engineering:

1. *TrueMethods* – which are best practices in Advanced Planning, Bid and Proposal Development, Supplier Assessment and Selection, and Project Cost Control. These are the processes which are applications of a cost model taught by experts and applied by the relevant staff.

2. *TruePlanning* – which is a comprehensive cost analysis and knowledge management tool. It is a cost model framework which can be applied in numerous applications with the right training and experience.

3. *Parametric consultants* – who are experts in building budgets, evaluating performance, identifying risks, analysing tradeoffs and continuously monitoring program value. They are able to customize standard processes and training, to suit the environment, with models that relate directly to the organization. Alternatively, they can mentor the relevant staff in the same tasks.

Purpose of this Book

The purpose of this book is to describe how to achieve applications of cost and schedule models within an organization. The applications described in the following chapters have evolved over many years, until they have become elements of the philosophy of Program Affordability Management (PAM).

Figure 1.2 shows the structure of the documentation which parametric cost model vendors provide. The Graphical User Interface (GUI) Guide details the software and its use in terms of file storage, retrieval and screen manipulation. The model references are used to describe the characteristics of those models: their inputs, outputs and functional relationships – what makes them tick.

This book is an overarching guide to the application of the individual cost models. Independently of the parametric model being used, its intention is to provide solutions to the cost estimating problems posed in businesses today; enabling a return on the investment for a parametric model.

Each of the following chapters tackles a different application of the parametric methodology of cost and schedule estimating. As such, it is independent of the specific cost model used.

Frequently the terms Cost Estimator, Cost Analyst, Parametrician, Cost Engineer, Cost Forecaster and others are used interchangeably. In some organizations these terms have very specific and defined meanings. In this book

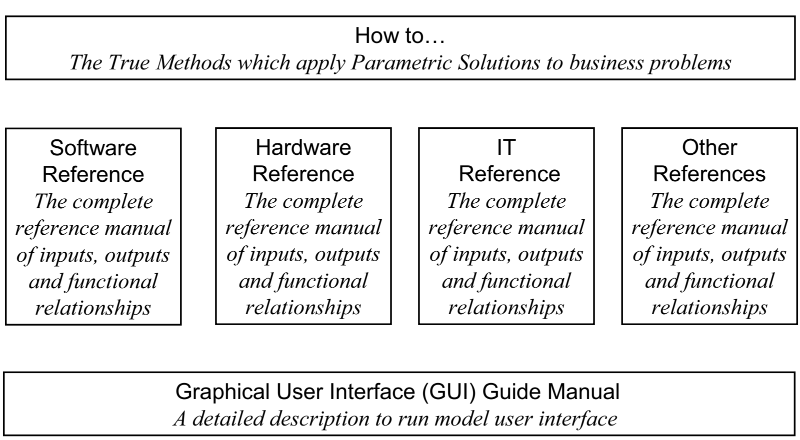

Figure 1.2 Example of documentation structure

the term Cost Engineer will be consistently used to describe a trained person able to operate, interpret and calculate a parametrically generated estimate. This is not intended to exclude staff who do not have the title Cost Engineer, but is simply designed to make the book more consistent.

2

How to … Appreciate Parametrics

Why do so many large organizations around the world use parametrics? The reason is to provide speed in estimating the cost and schedule duration when little information exists (see Figure 2.1) regarding a project, proposed program, competitors product or suppliers equipment. During the early stages it is possible to influence the design decisions that are being made and thus reduce the cost of the technology being designed. Parametrics does not necessarily provide more accuracy; although it can contribute when combined with other methods, as we will see in later chapters.

Parametrics is a similar method of estimating to those used by any Cost Engineer who has constructed a spreadsheet model. When constructing a cost model the first step is to gather an international database of historical past projects. From this database, the Cost Drivers – those design and performance characteristics that influence the out-turn project costs, schedule and performance – can be observed. This enables the establishing of equations or algorithms which relate the Cost Drivers to the outputs. These are usually referred to as Cost Estimating Relationships or CERs.

The part of the process which distinguishes the commercial parametric model from the building of spreadsheet models is the final part – continuous calibration. This ensures that the commercial cost model is maintained. While spreadsheet models tend to be created for a project and then not re-used, commercial models are continuously used and need to be maintained. In parametrics, the algorithms or Cost Estimating Relationships are recycled, thus ensuring a return on investment for the time spent researching.

Figure 2.2 is an example of a simple parametric cost model. In the example, it was established that on average the door took 30 minutes to prepare and for this configuration it took 60 minutes to paint. The project characteristics are provided to go with this data: the area, number of layers of paint and the number of sides painted. As is clear to see, a simple equation can be produced to relate the independent variables (characteristics) to the dependent variable (time taken). The parametric model can be re-used for different scenarios and different projects.

This is a core equation. Keep in mind the fact that we do not take all the parameters which could impact the cost – such as the brush size, work regulation, skill of the painter and so on – into account. Commercial parametric cost models take many person years of cost research. They involve many cost estimating relationships and numerous Cost Drivers. Parametric cost models are conceived in the same manner as the simple door painting model, that is, built around a core equation. In the case of the PRICE Systems hardware model, the core equation is the weight and technology index.

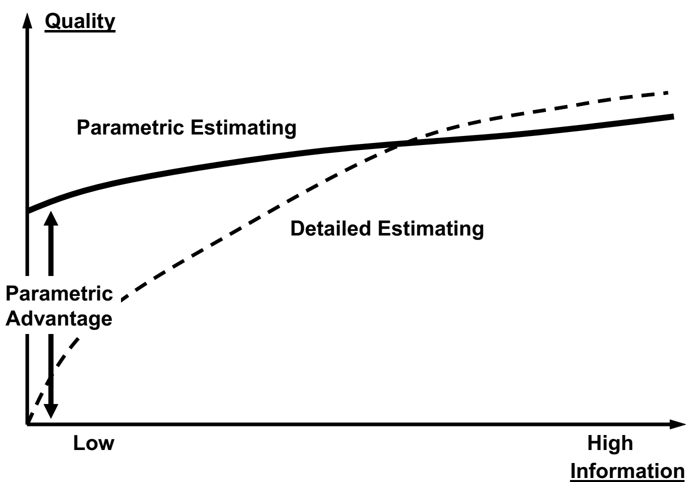

Figure 2.1 The advantage of parametrics

Characteristics	Observations
Door area	2 square metres
Layers of paint	2
Sides painted	2

Characteristics	Metric
Preparation time	30 minutes
Painting time	60 minutes

Equation:

Time (minutes) = 30 + 7.5 × (Area × Number of Layers × Number of Sides)

Figure 2.2 Parametric model example

Parametric vendors will employ a Chief Scientist and a cost research team. This team will be well versed in statistics, mathematics and cost research. They generate the parametric cost models which are communicated to the software programmers in the form of a White Paper. These White Papers are the documents which link the cost research to the software models. They enable commercial organizations, who supply cost models, to employ the best cost analyst for cost research and expert programmers for the software models, without the two roles complicating the two separate disciplines.

It is often said that if cost research could be provided in tablet form life would be simpler, however, for the time being software is the easiest way to communicate cost research.

Use of Parametrics throughout the Organization

Commercial parametric models have many applications (see Figure 2.3). At the top of the organization, they are able to solve problems for the decision-makers and senior management. At this level, senior managers can more quickly consider costs which influence the decision. Hence, bid or no-bid decisions can be made with a view to the cost. Furthermore, market strategy and business plans can be assessed alongside benchmarked productivity, competitor analysis and productivity tracking.

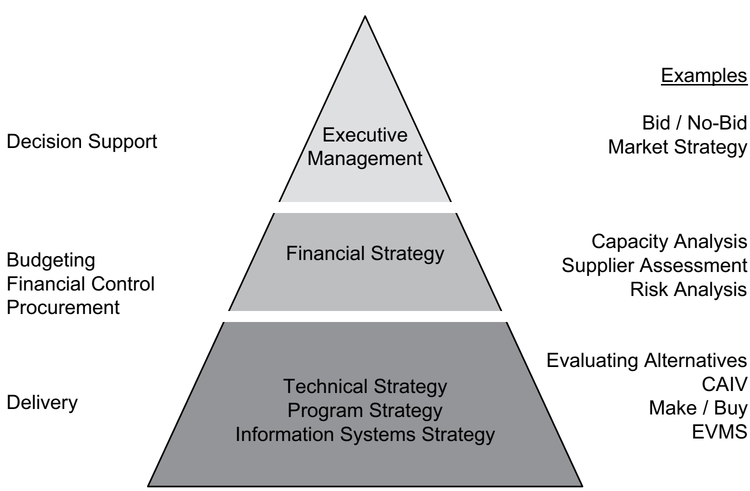

Figure 2.3 Enterprise applications

At the executive level, financial decisions can be accelerated with parametric estimates. Capacity planning will ensure best use of the available resources, supplier assessment employed to select the preferred supplier, and risk analysis used to consider the uncertainty in budgets and financial reporting.

At the operational level, parametrics can be deployed to deliver technology programs on the basis of the effective consideration of alternative options and the tracking of the program throughout its life with Cost as An Independent Variable (CAIV) and Earned Value Management (EVM) (through the integration of parametric estimating).

Ease of Use

Commercial parametric models, such as computerized models, offer many benefits over manual systems: reduced risk of accounting mistakes, faster operation, added capability, and greater facility for sensitivity analysis. The essentials of operating commercial cost models are easy to learn and provide a fast and effective method of cost estimating. The key ingredients of this methodology are:

- interactive operation with easily identifiable inputs which prompt answers through a dialogue with the user, for example, 'Percentage of new design?';
- outputs that are defined to the level of the tasks conducted when this estimate in finished;
- a parametric approach derived from experience and supported by empirical evidence;
- the efficient description of the problem that uses a small set of easily understood input factors;
- internal self-checking to test the consistency of input data sets;
- flexibility so that the model may be adapted to local definitions and accounting procedures;
- performance calibration that relates current estimates to actual achievements on prior projects.

The Windows-based user interface provides control of the model, its outputs and the storage of input data. The simple interface allows the user to develop and re-use large numbers of historical files. It enables the parametric model to be used following a course of intense instruction, and provides an audit trail for any study. An illustration of the look and feel of a parametric cost model is provided in Figure 2.4 with an example of a GPS Receiver system estimate.

In December 1995 the Commander of the Defence Contract Management Agency (DCMA) and the Director of the Defence Contract Audit Agency (DCAA) in the United States sponsored the Parametric Estimating Reinvention Laboratory under the Parametric Cost Estimating Initiative (PCEI). The purpose of the Reinvention Laboratory was to test the use of parametric estimating techniques on proposals and to recommend processes to enable others to implement these techniques.

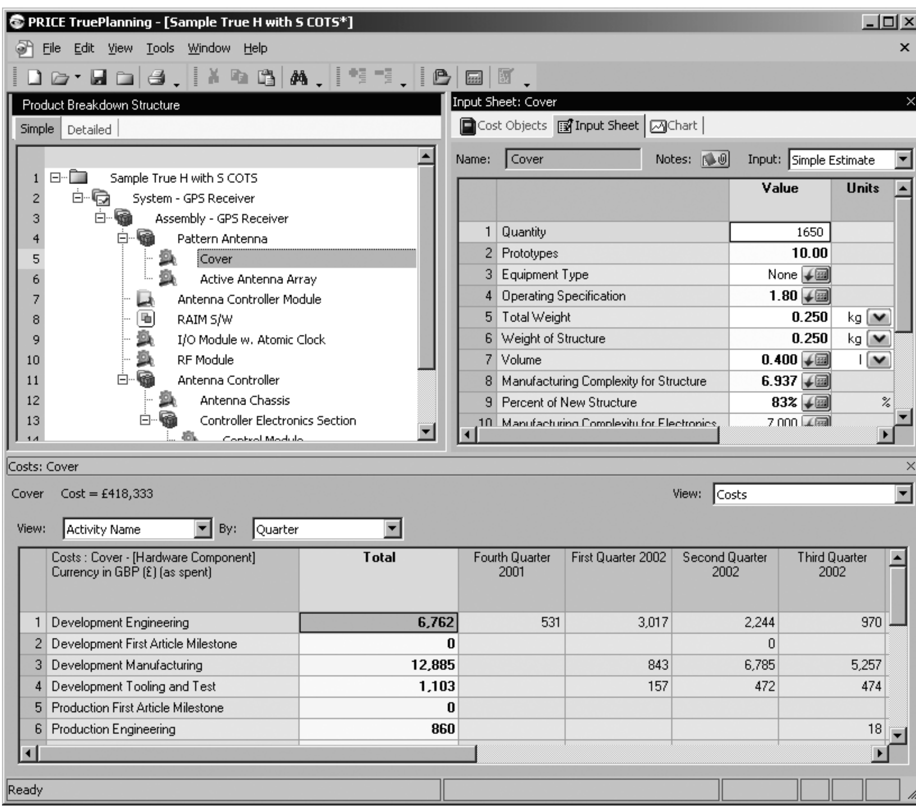

Figure 2.4 Example parametric cost model – Product Breakdown Structure (PBS), Cost Drivers and outputs

Thirteen Parametric Estimating Reinvention Laboratory teams tested and implemented parametric techniques. The estimates covered the range of use from specific elements of cost to major-assembly costs. The teams generally found that using parametric techniques facilitated rapid development of more reliable estimates while establishing a sound basis for estimating and negotiation. In addition, the teams reported proposal preparation, evaluation and negotiation cost savings of up to 80 per cent, and a cycle time reduced by up to 80 per cent.[1]

A parametric model permits rapid and early probability cost evaluations based on project scope, program composition, and demonstrated organizational performance. Operational and testing requirements are incorporated, together with technology growth and inflation.

In addition to cost, parametric models derive typical schedules for the work to be accomplished. Schedule constraints that have been imposed are examined within the parametric model, and costs are adjusted to account for apparent acceleration or slippage of the program.

Modelling can also provide rapid analysis of alternative policies and strategies. Parametric models allow the user to access historically based data records, including the results of previous applications of the model, so that the impacts of policy revisions and other changes can be compared.

Moreover commercial parametric cost models offer a quick response time for Cost Engineers; this enables senior managers and decision-makers to ask more demanding questions. Typical applications of commercial cost models and the questions to which they offer answers include:

- How much does the hardware or software development cost?
- How much time is required for hardware or software development?
- What is the effect of an accelerated schedule?
- Is the prescribed schedule unreasonable?

1 Chapter 1 – *Introduction, International Society of Parametric Analysts (ISPA) Parametric Handbook*, Issue 2.

- What are the trade-offs between schedule and cost?
- What size hardware or software development project can be undertaken with a fixed budget?
- What are the cost impacts from varying efficiency, experience, or design skill?
- How will costs vary among different organizations?
- What are the effects of the operating environment and hardware reliability requirements?
- What savings can be obtained by using customer-furnished or existing hardware or software?
- How much does it cost to modify existing hardware or software?
- How much will technology growth affect hardware or software development?
- What effect do modern hardware and software development practices have on cost and schedule?
- How does previous experience relate to new projects?

The Complexity Concept

A commercial parametric estimating tool will have the ability to adapt itself to many different environments, both business and industry. Parametric models also have the ability to represent the magnitude of a problem as a simple core equation, adjusted using secondary equations. In some parametric models these inputs are hidden from the user, in others the numeric inputs are explicit.

Cost models also need a basic hypothesis for this core theory. The simplest theory for a hardware parametric model, for example, is the higher the weight, the higher the cost, for the same technology and productivity. Engineering instinct indicates that this holds true for all situations, providing the technology and productivity are the same. If either of these parameters changes, then all bets are off. These technology and productivity elements are encapsulated in a single input parameter for hardware called Manufacturing Complexity. But in the case of software cost models several separate parameters are often involved. This core theory forms the central equation of many cost models.

In simple terms the central equation finds that the more of a single type of technology acquired, the more it will cost (see Figure 2.5). In the instance of hardware, this magnitude of technology is commonly assessed in terms of weight. Hence, the larger the item (for example, an aircraft wing) becomes, the greater the expense required to manufacture it in terms of the material content and labour. If the wing needs to be lighter, this can be achieved by changing the technology, but this may not necessarily result in lower cost as the new Manufacturing Complexity of the lighter technology is likely to be higher – resulting in a high normalized cost.

If it is accepted that cost is a function of the weight and the complexity, it is possible to obtain a normalized basic cost. To estimate all scenarios, several additional parameters need to be added, through the adjustment equations, involving elements such as quality, quantity, skill of the team, and so on to achieve a realistic estimate. Using the simple door-painting example, adjustment equations are the equivalent of the brush size, labour experience and so on.

The effect of producing a normalized cost density from the historical projects is to generate a trend line or average Manufacturing Complexity on condition that the technology involved is the same.

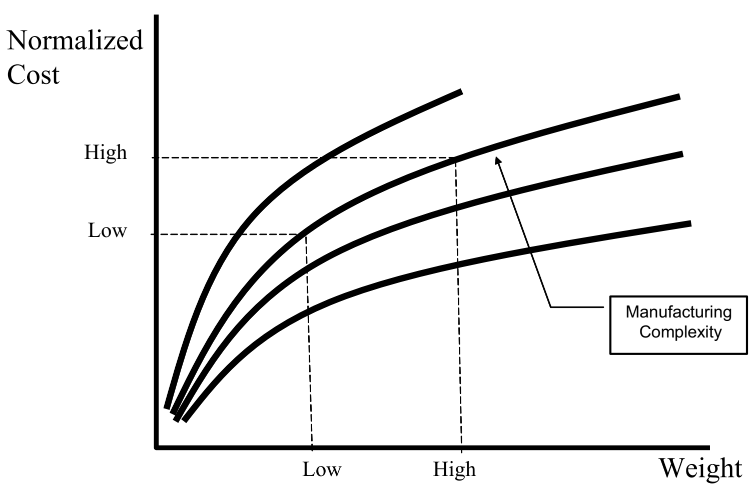

Figure 2.5 Normalized cost as a function of weight and complexity

MANUFACTURING COMPLEXITY

The complexity factor is the normalized representation of the cost density; though it is not measured in dollars ($) per pound (lb) or Euros (€) per kilogram (kg), these units provide an easy visualization of the parameter. In fact it is a unit-less, empirical factor comprising the technology implicit in a product and the productivity of its manufacturer (see Glossary).

By way of illustration, consider something heavy and inexpensive, such as a railway rail, for which the Manufacturing Complexity factor is low. Compare this to something that is light and yet expensive such as a hybrid module for a satellite, where the Manufacturing Complexity factor is high.

Following the calibration process, historical project information regarding equipments, sub-systems or systems will have been stripped of their unique project features. A process of normalization will have eliminated the effects of differences in quantity, economics, production rate, technology maturity and so forth. Mathematically the residual at the end of this process is a representation of the technology, from which the item was produced, and the productivity difference between one producer of the technology and another.

In the example in Figure 2.6, the 1960s Harrier has been in existence for a considerable time and needs to be replaced by a new generation of Joint Strike Fighters (JSF) with Vertical Short Take Off and Landing (V/STOL) capability. The next generation of aircraft will have greater capability provided by newer technology, placing it further along the technology axis.

The F16 has been produced in many variants since the late 1970s, hence it is placed between the Harrier and the JSF in terms of technology. But it has been manufactured both by the original systems designer and other manufacturers. Hence the technology will be constant, but the productivity of the company producing it will result in a different Manufacturing Complexity. The company with the lower Manufacturing Complexity will produce the F16 for the lowest cost due to their higher productivity.

HOW ARE COMPLEXITY FACTORS OBTAINED?

There are several methods for obtaining complexity factors, the simplest of which involve embedded tables in the models. These calibration tables contain typical values for a product or technology: they contain reference (industry

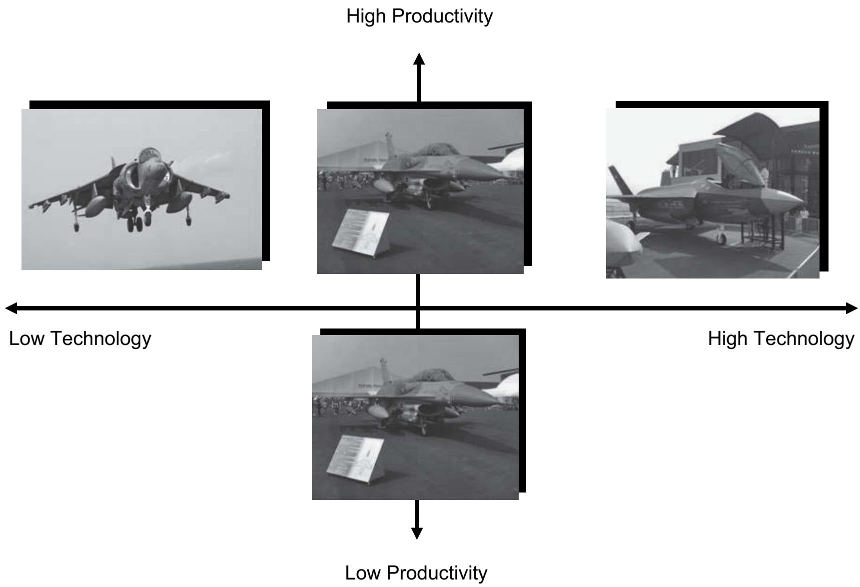

Figure 2.6 Manufacturing Complexity attributes
Source: http://www.navy.mil/search/photolist.asp

average) complexity factors based on data collected over a long period. These factors can be used to generate a 'should cost' when internal data is missing.

It is also possible to derive parameter inputs via calculations, for example, Manufacturing Complexity generators derived from an assessment of the technical characteristics of the equipment. For mechanical Manufacturing Complexities these characteristics include:

- material;
- process;
- precision or tolerance;
- number of parts or layers of composite;
- hogout (the manufacturing process of rapid material removal when machining from solid);
- roughness.