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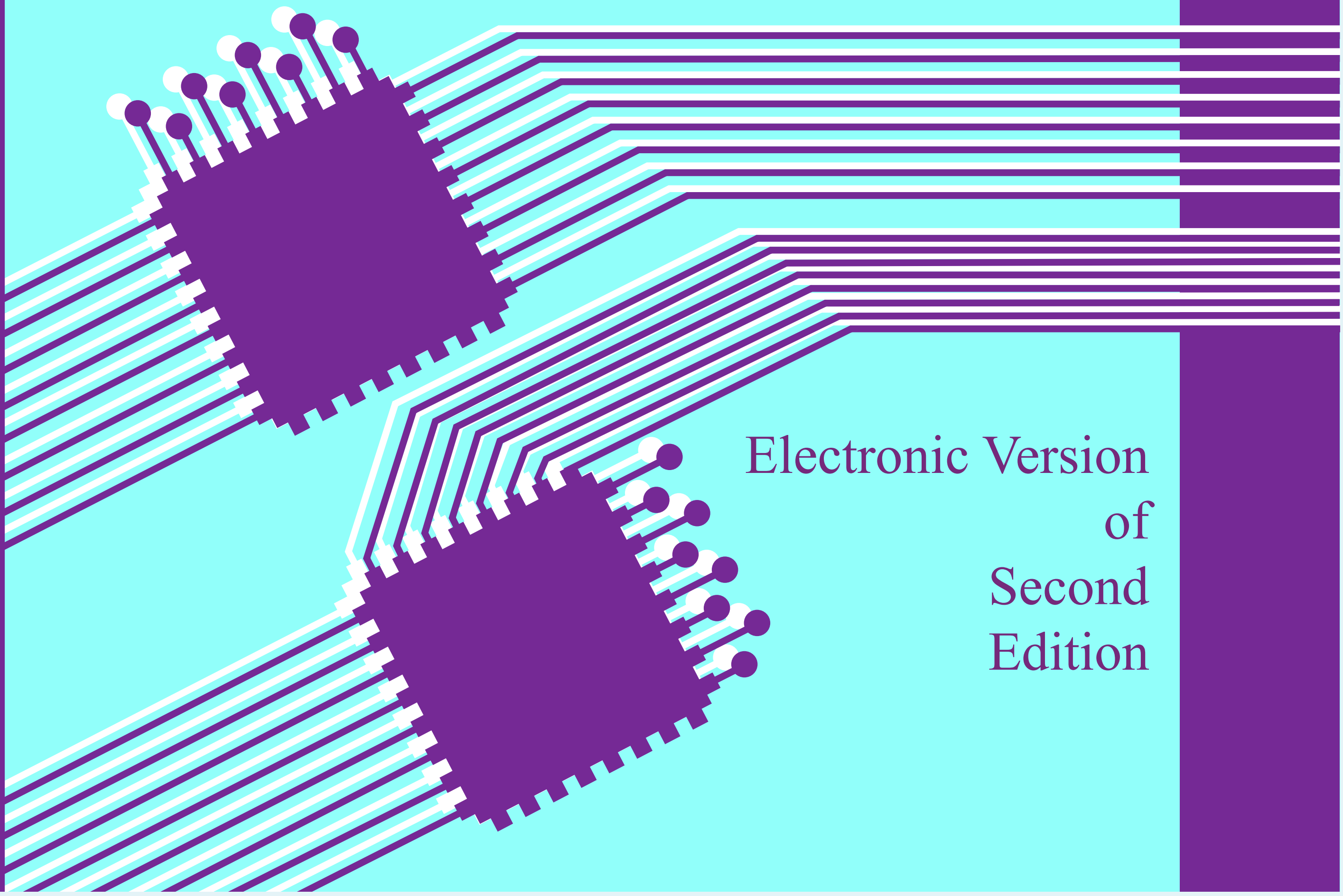
The Economics of Automatic Testing

Chapter 1
Introduction and overview

Brendan Davis



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1.3 The comparison of alternatives

If you are not convinced that performing an economic analysis is the best way to compare engineering alternatives, there is another reason to do it that is hard to refute. None of us are in business to make products or services. We are in business to make money for the shareholders and the employees. Successful businesses make more money than unsuccessful businesses. The products and services are a means to an end. We make money by doing what we do best. That is the essence of economics in its broader sense. We do what we do best, make some money and then buy what we need from someone who has specialised in that. For example, farmers sell their produce and buy PCs from electronics companies to enable them to run their businesses more efficiently. For these reasons it is logical that most important decisions should be based on an economic or financial analysis, but there is a more fundamental reason. Most of our engineering decisions involve comparing relatively similar alternatives such as one ASIC technology versus another or one in-circuit board tester versus another. Making the best decision is still a difficult task, but consider the following situation. The senior management who have to approve the spending of the money are usually comparing very different alternatives. They may have to decide between funding a new test system, a new CAD (computer aided design) system, a numerically controlled machine or some new vehicles. With such diverse alternatives to choose from, assuming they are not able to fund all of them, their relative financial performances will be the only sensible way to make a choice. This becomes obvious when you consider the main objectives of senior management. Their job is to maximise the return on the shareholders' investment in the company. Most companies are owned by one or more stockholders or shareholders. The majority of these stockholders do not work for the company. They invest their money in companies in the hope of a greater return than they can get by investing their money in a bank. A board of directors is appointed by the shareholders to look after their interests. In turn the directors employ a general manager, who also usually sits on the board, to run the company in such a way that the shareholders get a good return on their investments.

Many of these shareholders have no loyalty to the company at all. To them it is just an investment and if the company does not perform well they will sell their stock and put their money somewhere else. If a lot of shareholders try to sell their stock, then the price goes down and so does the value of the company. In order to keep a good market for its stock, the company therefore needs to perform well and 'performance' here means ***profitability*** and ***growth***.

The company also needs to obtain money from other sources, usually in the form of loans. In order to obtain such financing at a good rate of interest, the company must show a good 'track record' and show that its future prospects are good. To a large degree this is dependent on its management being seen as doing a good job and capable of continuing to do so by making correct decisions.

Any business enterprise exists to fulfil a specific mission and a social function. The mission is primarily one of economic performance and the social function is to contribute to the economy of the country and provide employment and a good standard of living for a number of people. If a business does not perform economically it will be unable to achieve this social function fully. The inevitable result will be redundancies, high unemployment and, possibly, the closure of factories. For this reason, business management must always put economic performance first in any decision it takes. Overall their decision making falls into three areas…

1. What business to be in
2. Marketing strategy—products, promotion, pricing, distribution, etc
3. The use of capital

The primary aim is long-term profitability and growth so that the company is attractive to shareholders and is able to obtain other sources of funds such as loans. If this is achieved, then other parts of its mission such as fulfilling social needs will fall naturally into place.

So far in this section there have been several mentions of profit and profitability. To many people 'profit' is a dirty word. It conjures up images of the fat mill owner making vast sums of money at the expense of his poorly paid workers. Perhaps if everyone were to switch to the American terminology of ***earnings***, there would be less stigma attached. For some reason, 'earnings' seems much more acceptable than 'profit'. Whatever we call it, however, does not change the fact that it is necessary for the continued well-being of a company and its employees.

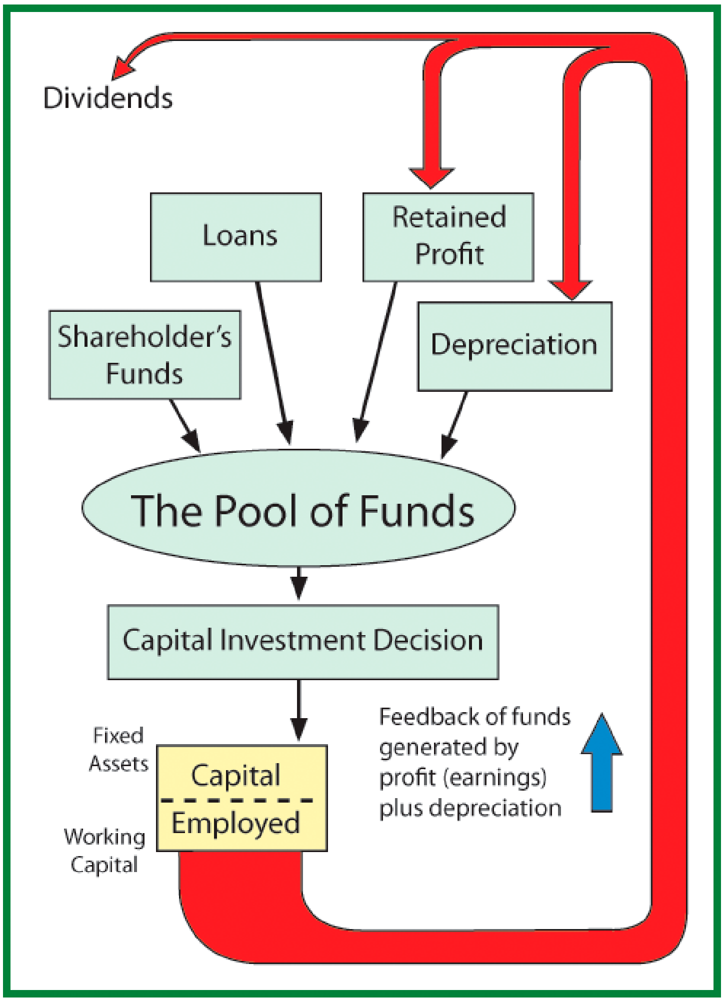

Figure 1.1 The flow of funds

The investment in ATE falls into the 'use of capital' area of management decision making. Figure 1.1 shows the flow of money within a company. The 'capital employed' is made up of 'fixed assets' such as buildings and equipment (including ATE) and 'working capital'. The decision to add to fixed assets needs a lot of thought, especially since management and directors are judged on the basis of return on capital employed (ROCE), so that for them the lower the assets are the better.

Making correct decisions on major capital investment is vital to maintaining profitability. Therefore, someone in the company should always be looking at major purchases from a purely financial point of view. If two totally different investment proposals are competing for some of the funds, a well-managed company will pick the one that gives the highest return on investment (ROI). The answer then to the question 'Why is a financial analysis necessary?' is that it is good (necessary) management practice to do so; the only way top management can decide between dissimilar investments is on the basis of financial performance.

Unfortunately, the economic performance of ATE is not always given the importance it deserves when equipment is evaluated. Research has shown that in many cases it is treated as an afterthought-a necessary evil to be performed because 'upper management likes that kind of thing'. The steps leading to a purchase often look like those in Figure1.2. Based upon technical performance, the support capabilities of the suppliers and the overall credibility of the suppliers, a decision is taken in favour of one piece of equipment. Having made this decision the evaluation team will then perform some economic analysis to see if this system will ***'pay its way'.*** Quite often at this stage it is compared with the alternative of 'not using this ATE' and so just about any system will show a good economic performance. Since the whole point of purchasing the system is to achieve a better economic performance it would be more appropriate to include economics as one of the primary parameters at the stage when the short list of possibilities is being evaluated, as in Figure 1.3.

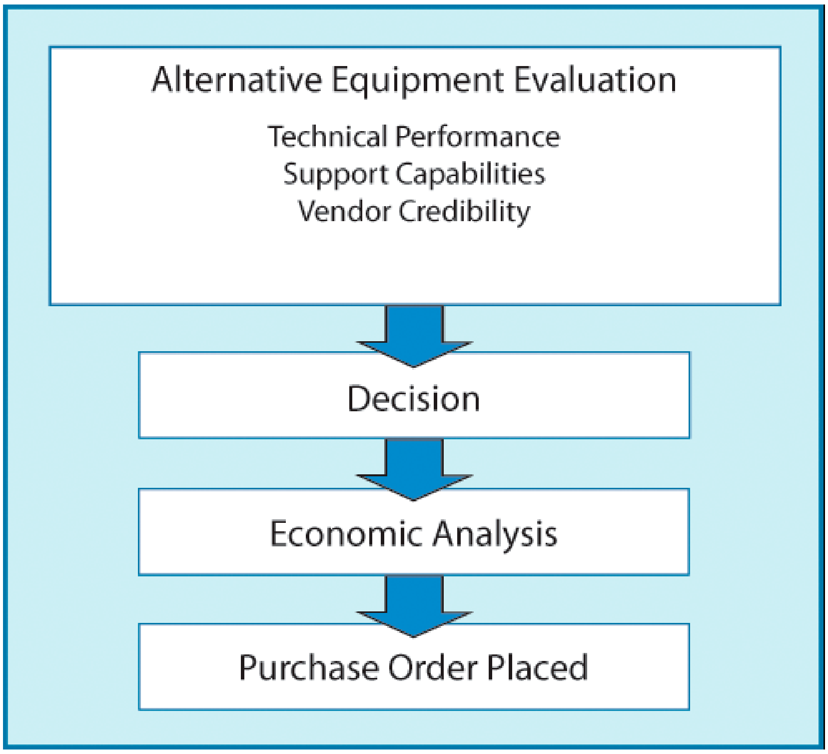

Figure 1.2 The wrong approach to the use of economic analysis

Other problems that research has shown to exist are that the economic analysis and financial appraisal are sometimes performed by a financial person who has little knowledge of the applications; that the most common method used is simple payback analysis, which is very poor for comparing alternatives; and that the person responsible for the running of the equipment was often unaware of the criteria used for measuring the financial performance of the equipment.

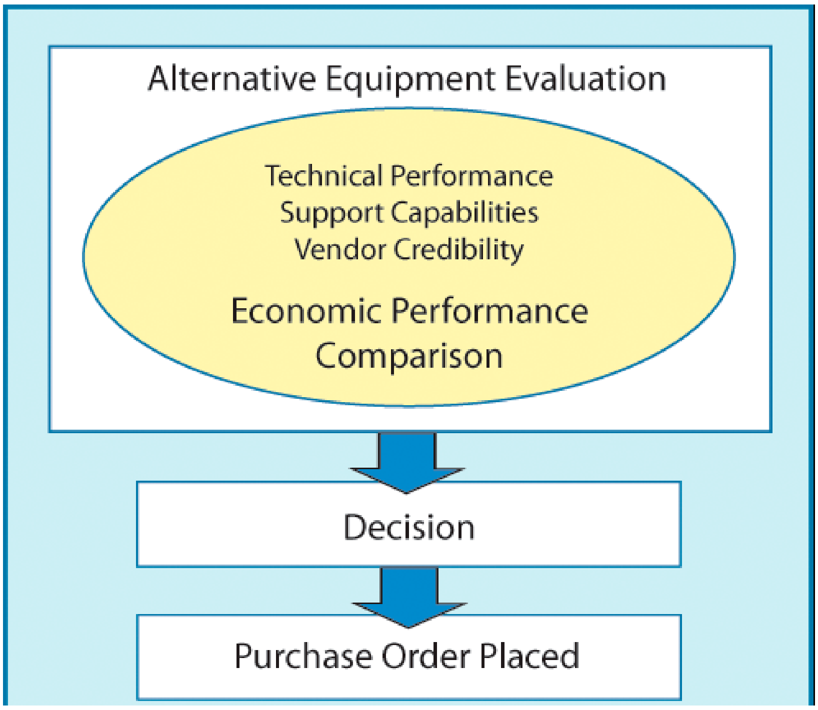

Figure 1.3 The correct use of economic analysis

The usual result of poor or inadequate economic and financial appraisal is that management will reject the proposal with a request for more information. This results in a delay in getting the purchase approved, which could have a major impact on a new product introduction or the efficiency of present operations.

1.4 Other factors

The way in which an ATE system will perform economically is obviously a function of how it is designed. The philosophy of the design, the importance given by the manufacturer to different aspects of what it should be and the way the various capabilities are handled from a hardware and software point of view will all have a bearing on the efficiency and, therefore, economic performance of the equipment. Naturally, the equipment must meet the minimum technical requirements of the job it is to perform in order for it to have any form of economic performance at all. Equally, if the equipment is capable of doing things we do not need to do—and these features cost money—then a portion of our cash will have been invested in a useless asset. A common mistake made when purchasing ATE is to buy more technical capability than is really required. The two main reasons for this are…

1. As an 'insurance' for the future. "We may need that feature at some time".

2. The—"since we are asking management for a pile of money anyway, we may as well go the whole hog" syndrome.

In any event it will be necessary to evaluate the technical capabilities of available equipment. However, this should be done with economics in mind so that we only buy what we need now and for the foreseeable future, and that specified accuracies, etc, are not out of court relative to the real requirement.

Another important consideration will be the evaluation of the vendor (supplier). This again should be done with economics in mind. It is, however, rather difficult to assign a value to having a system out of operation, or not getting some other form of support when it is needed. It is a fact of life that very few, if any, companies purchasing a large software-based tester can be totally independent of the vendor. Such systems need regular updating to keep track with advances in technology, and the user will be dependent on the vendor for that support.

Buying a large ATE system can be analogous to getting married. You develop a partnership and if you do not get the support and cooperation you need you end up living in a state of simply tolerating the partner or getting involved in an expensive divorce. The evaluation of the vendor in terms of credibility—'Will the vendor be around tomorrow?'—and the support that can be provided are, therefore, as important as the other selection parameters. The system with the best technical performance and the best economic performance will be of little use if the vendor goes out of business or is unable to support the products, since without this support the expected economic performance will not be achieved.

Throughout the book, the more detailed analysis of cost savings and economics generated by ATE apply to the testing of electronic components and assembled printed circuit boards (PCBs). It is hoped that the principles discussed will also be applicable to other forms of automatic testing. The techniques covered in the financial analysis section will, of course, apply to any capital investment decision.

1.5 Test strategy defined

It is unfortunate but the term 'test strategy' can mean different things to different people. There are to my knowledge three major uses of the term. The first of these relates to the nature and the order of the tests performed at a specific test stage. For example, the test program generated for an in-circuit test system (usually automatically) typically has the following sequence:

1. Shorts test.
2. Passive component tests.
3. Apply power.
4. Test linear devices.
5. Test non-bussed digital devices.
6. Test the busses.
7. Test the bussed digital devices.
8. Special tests.

This is a fairly logical sequence and many programmers will refer to it as the ***test strategy***, but I prefer to call this the ***test plan*** or simply the ***test program***. The second use of the term relates simply to the testing technology that is used. You can therefore have an in-circuit, a functional or a boundary scan test strategy. This use of the term is characterised by the name 'strategy independent tester' or 'multi-strategy tester' applied to some of the more sophisticated board testers that can perform a very wide range of tests. These are really different testing techniques, methods or tactics rather than strategies.

The third use of the term, and the one used throughout this book, relates to the overall philosophy of test and the routing of the units under test. This routing is important because you can have two very different strategies based upon the same set of test stages, as is indicated in Figure 1.4.

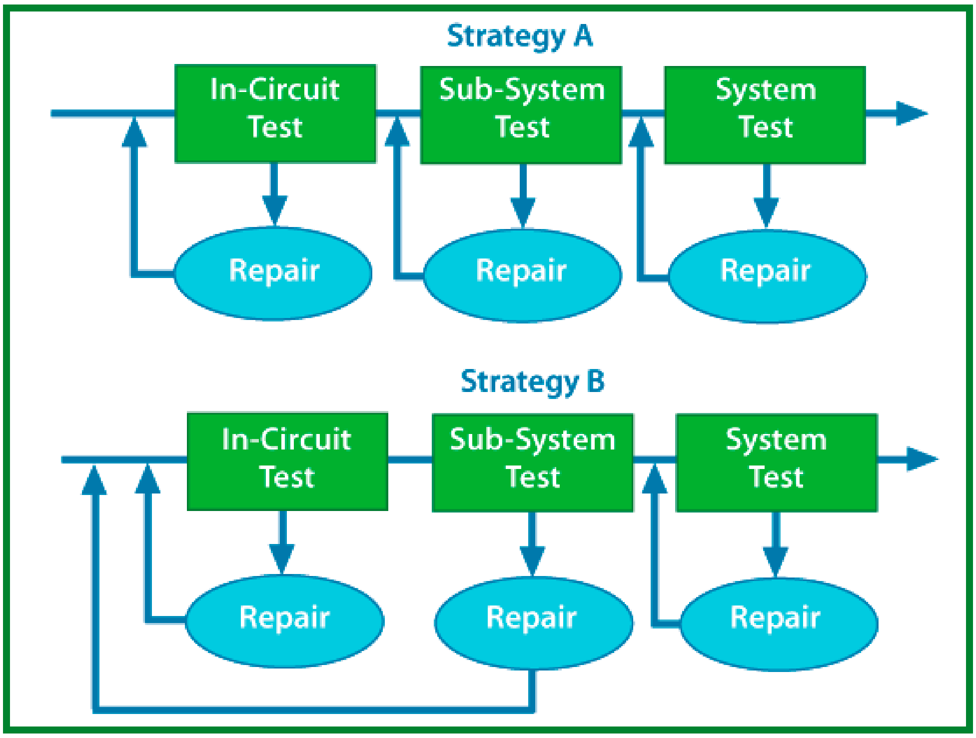

Figure 1.4 Two strategies with the same set of test stages

The only difference here is the route that the boards take. However, these diagrams do not show the complete test strategy. They simply show what happens after the boards are assembled and soldered. There will be other elements of the test strategy prior to this stage. The amount and the nature of any design for test (DFT) or built-in self-test (BIST) in the product design is a part of the test strategy, as is the decision to perform or not perform any incoming inspection on selected devices. This will be the definition used throughout the book. Of the three common uses of the term 'test strategy' this is the only one that can really be called a 'strategy' since a strategy is the overall plan that is put in place to reach a specific objective. Everything else is the tactics, plans or methods that are employed to implement the strategy.

1.6 Optimization versus sub-optimization

An emphasis throughout this book will be the need to determine optimum solutions to engineering problems. Whether these are design related, manufacturing related, test related, quality related or whatever, the analysis should consider all the issues. Too many of the problems in the industry are caused by sub-optimal decisions. In most cases such decisions are taken because of a narrow viewpoint in terms of the scope or the time hori-

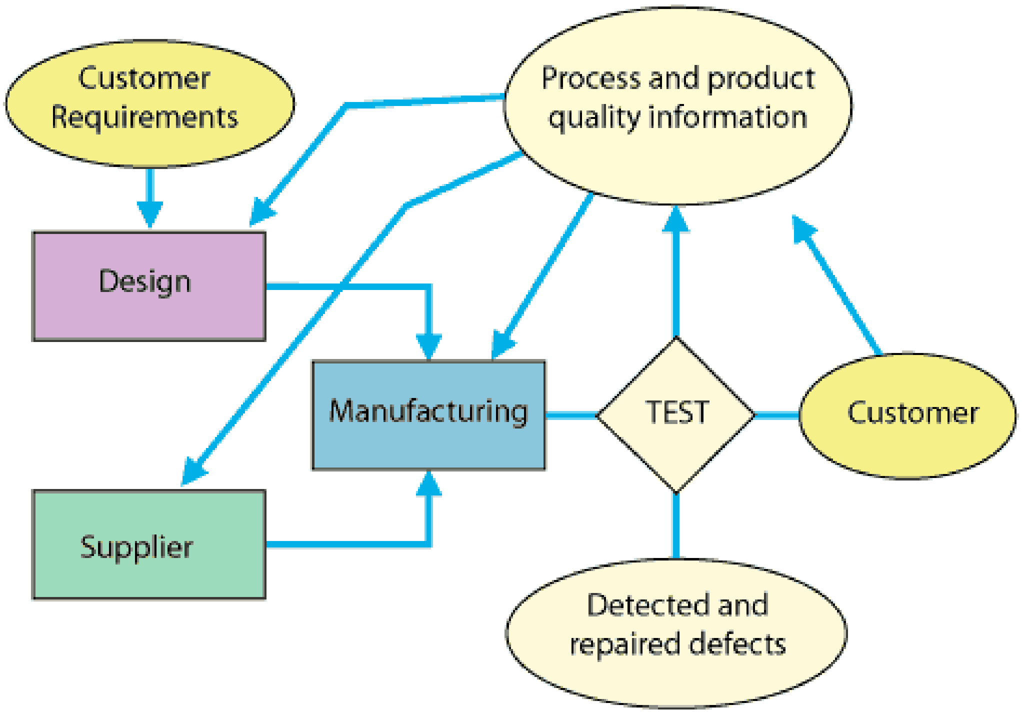

Figure 1.12 A simplified 'defect occurence' model showing three primary sources of defects

and essentially says that there are three basic sources of defects. Defects can be generated by your design process, by your supplier's processes and by your manufacturing process. In other words, your test process (test strategy) will need to deal with design induced defects, supplier induced defects and manufacturing induced defects. The more detailed fault spectrum needed for analysis work is effectively an expansion of this simple three-part fault spectrum.

The overall yield coming out of the production process will be the result of the sum of the defects in these three categories. The job of the production test strategy will be to prevent as many of these defects as possible from escaping to the field by detecting the defects and providing the diagnostic information to enable an effective repair. At the same time the various test stages should collect defect data and repair data for your quality improvement process.

1.12 Forecasting, estimating and guesswork

The economic analysis of test strategies will typically fall into two areas:

1. The analysis of present methods to see if any changes would be worth while.
2. The analysis required to determine the best alternative for some future period or some future product.

The first of these situations is usually relatively straightforward because there will be a lot of real valid data available. This is not the case for the second situation, which is also likely to be the more common of the two. Most of the time this type of analysis will require a forecast of the likely situation in the future, possibly up to five years ahead. This will be particularly true when calculating a return on investment for the purchase of some new equipment, since this is most commonly done over a three to five year period. Virtually all analyses involving design or design to test issues will be for some future time and so require a lot of prediction. Even if the project is similar to something that has already been done the inevitable change in component, manufacturing or test technology that will be implemented in the new design will mean that some of the key parameters will change.

As a minimum it will be necessary to predict the number of new designs, their complexity, the production volumes, the process yield and the fault spectrum-quite a tall order. However, it has to be done if you are to have any chance of making the right decisions. If you think about it, almost all business decisions involve a lot of forecasting, estimating, guesstimating or just plain guesswork. The successful managers and the successful companies are the ones that guess correctly more often than they guess wrongly. Forecasting is usually more scientific than pure guesswork and we have to use whatever techniques we can to get close to the right numbers. It is also necessary to look at a range of outcomes and to determine which of the variables have the biggest impact on the results. In this way we can devote more time to determining what these high sensitivity variables might be. It can be tempting to leave something out of the equation because we are not sure of its value, but there are two simple rules that need to be uppermost in the mind of any analyst:

1. If you wait to get all of the data for an accurate result, it is probably too late.
2. If you leave a parameter out of the equation you are effectively making an assumption about its value and its importance.

The first of these rules is particularly valid in the electronics industry where the only thing that is constant is change.

1.13 Business perspectives

Selecting the optimum test strategy by performing a thorough economic analysis is only a part of a much bigger scheme of things. Decisions about the inclusion of 'design for test' features in a new design, the production test strategy, the test tactics that will be employed, the field-service strategy, and so on, cannot be taken in isolation. These decisions have to be made with due consideration and understanding of the wider business issues. What is driving the market for our products? What are the customers' expectations? How long will the product last? These and other issues have to be understood by everyone in the organisation who can make or influence a decision that will affect the performance of the product in the market-place. Understanding the primary market forces that drive the electronics industry is fairly easy because they have not really changed for some years. They have not changed but they have intensified and they continue to intensify. It is very simple (see Figure 1.13)…

All you have to do, product after product, is to lower the costs, increase the quality, include the latest technology and get it to market on time.

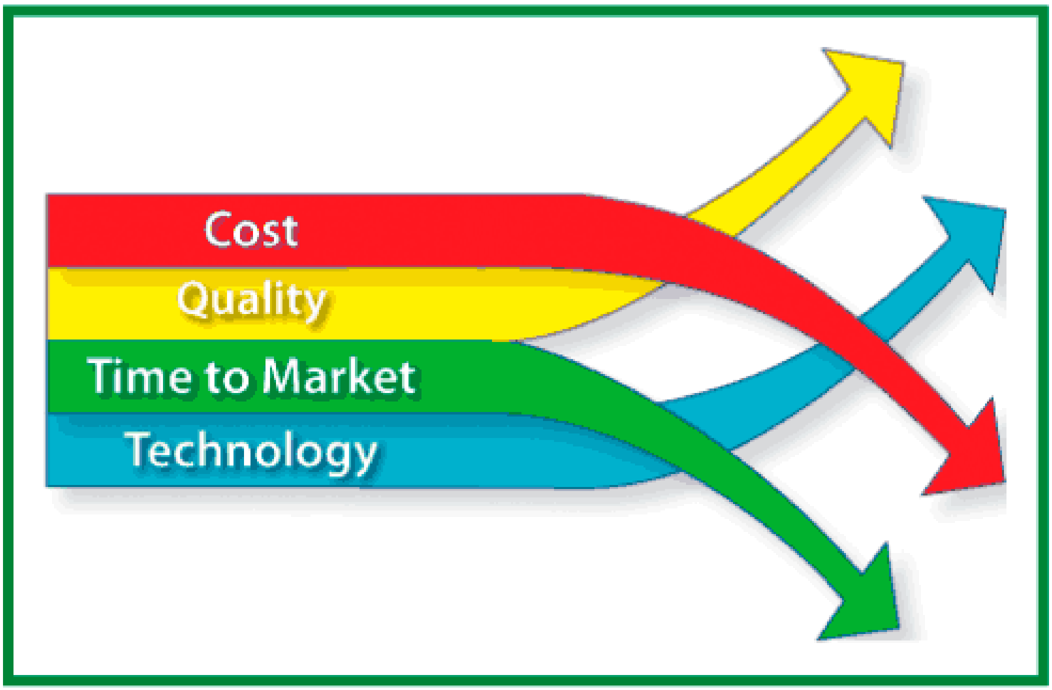

Figure 1.13 The challenge of the four market forces—reduce costs, increase quality, reduce time to market and implement new technologies

If these are the driving forces then they are also the goals that you have to meet, and this is where the problems start. It is generally felt that these goals are in conflict with each other:

1. Lowering costs may cause a lowering of quality.
2. Reducing time to market may lower quality.
3. Introducing a new technology may lengthen the time to market and also increase costs.
4. Pressure to improve quality may slow down time to market and increase production costs.

This can be thought of as the conventional wisdom that is based upon years and years of experience. However, conventional wisdom has been challenged many times in recent years and proved to be wrong. New ways of looking at problems and new ways of solving them have emerged in many areas. The quality revolution discussed in the next chapter is perhaps one of the better examples. The conventional wisdom used to be that productivity was all important, but that had a negative effect on quality.

The new wisdom says that if you improve quality in the right manner then productivity will increase automatically. The conventional wisdom used to say that you should have many suppliers for a given part so that you do not run out of stock and you can play one off against the other to get the best prices. The new wisdom says that you should have only one supplier of a given part and that you should develop a closer relationship with them to get the best quality. I believe we have a similar situation when it comes to meeting the four market driven goals simultaneously:

1. Cost and quality are not in conflict. The lowest overall life cycle cost for a product will generally be achieved when the quality is at or near the maximum. If we could achieve zero defects by doing everything right the first time—every time, then we would have minimum costs.

2. Reducing time to market, done the correct way, should have a positive impact on quality. Increasing the degree of integration between design and test while taking advantage of the widely available design for test techniques will result in shorter design cycles, more rapid test program generation and higher fault coverage test programs. Concurrent engineering saves time and improves quality.

3. Incorporating a new technology into a product should improve the performance and lower the cost. It need not increase the time to market if the design and test integration is done well with the right tools in place.

4. Your quality improvement drives should result in lowered costs and improved time to market. Doing things right first time costs less and takes less time. Since the constantly increasing complexity of electronic products means that we cannot yet eliminate testing then we also have to do the right testing—and do it right—first time and every time.

There is therefore no need for there to be any conflict between the four major market forces (see Figure 1.14), but to reach this situation will require careful planning and implementation of all the pieces that are needed to operate an electronics operation in today's

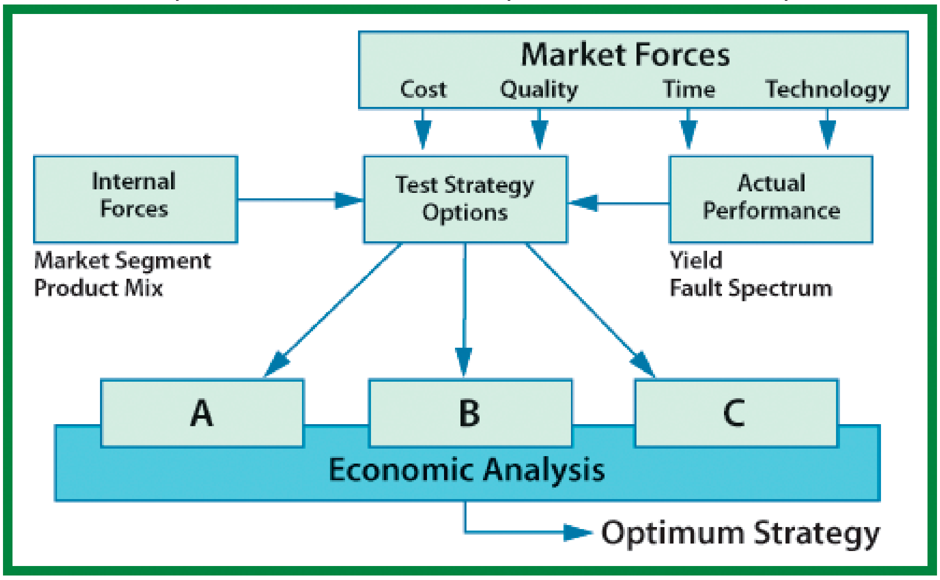

Figure 1.14 The four primary market forces influence the choice of test strategy because they are the objectives that we must reach in order to survive

highly competitive market.

A change of emphasis

The four forces of cost, quality, time and technology have been the main driving forces for the past twenty to thirty years, but not always with the same degree of importance. In