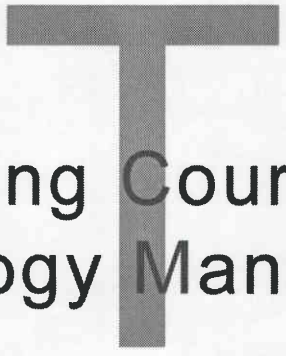
United Nations Industrial Development Organization
Vienna, Austria

International Centre for Science and High Technology
Trieste, Italy

Module 1

SIGNALS FOR CHANGE



Training Course on Technology Management

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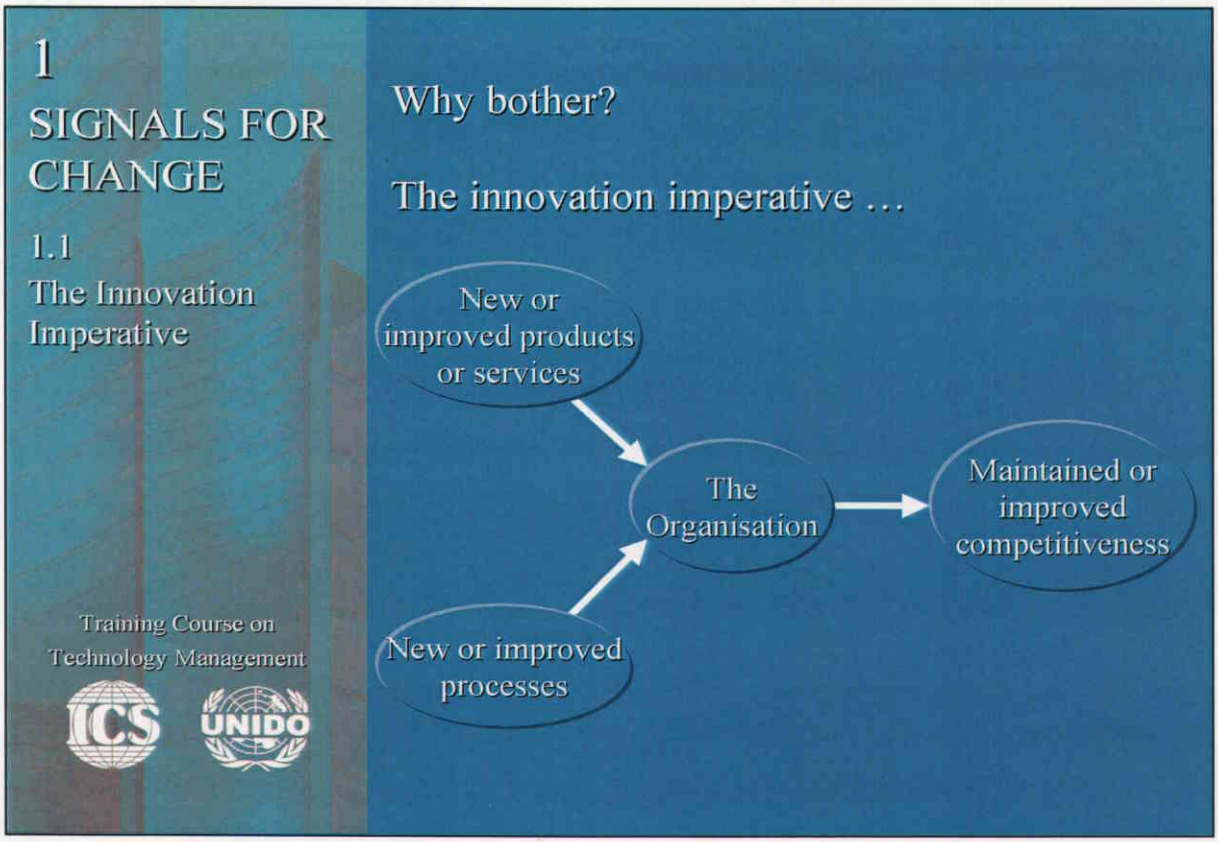


This module looks at the first stage of the technological change process and explores:

1. Challenges in the new environment – exploring current threats and opportunities arising from:

- increasing number and sources of competition
- increasing globalization of trade
- trade liberalization
- changing basis of competitiveness
- deployment of new technologies
- shifting regulatory frameworks
- a new technoeconomic paradigm

2. Emerging future threats and opportunities in the new environment:

- technological changes and impacts on entry barriers
- new markets and segmentation of existing markets

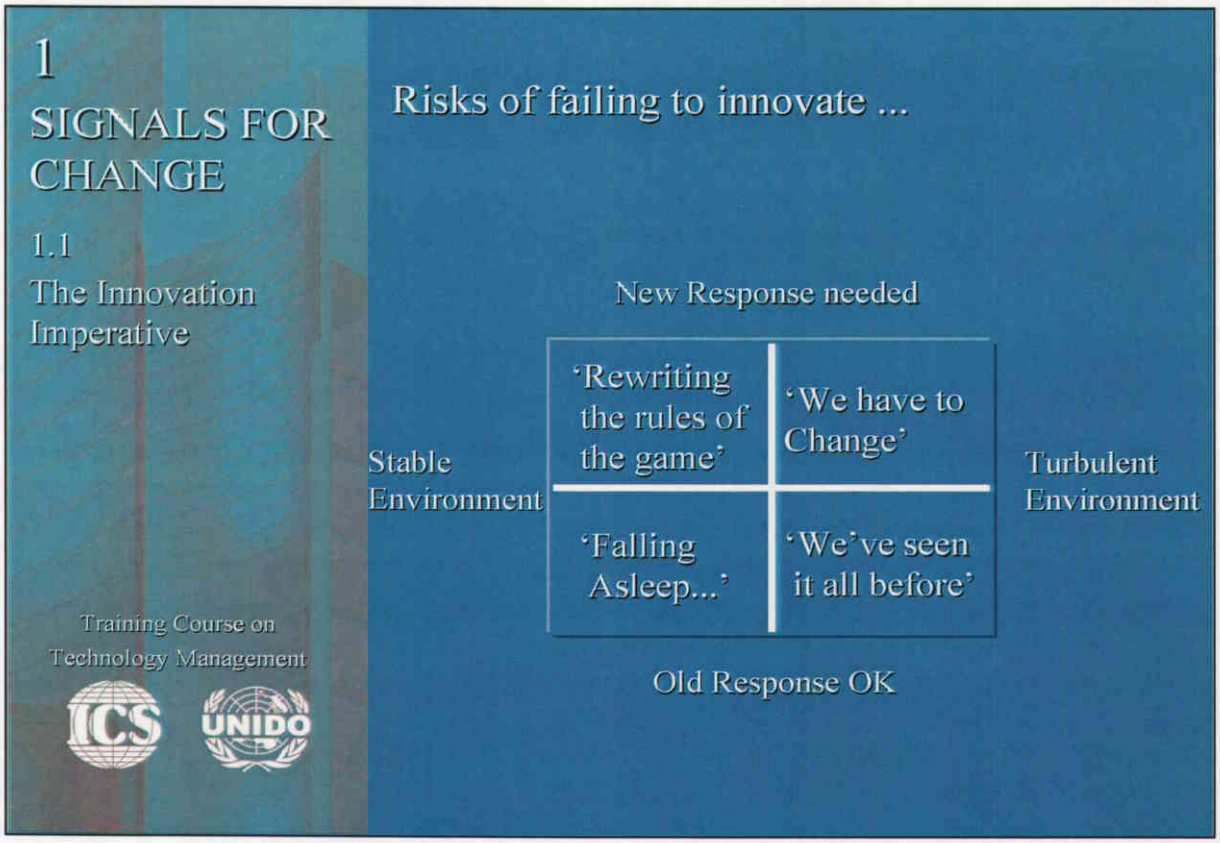
3. Learning about the environment – tools and techniques for scanning and signal processing

- market research and forecasting
- technological scanning and forecasting
- competitor analysis frameworks
- benchmarking

In order to survive in a hostile and competitive world organizations need to do two things: adapt and change the products and services which they offer, and adapt and change the ways in which they produce these. These two concepts are termed 'product innovation' and 'process innovation'.

There are many ways in which this ability can be improved. It could be, for example, faster, to higher quality, cheaper, with more choice for customers, etc.; in each case developing this ability will require change within the organization. This change could be in the equipment used to produce the product or service, or it could be in the way in which the process is organized and structured.

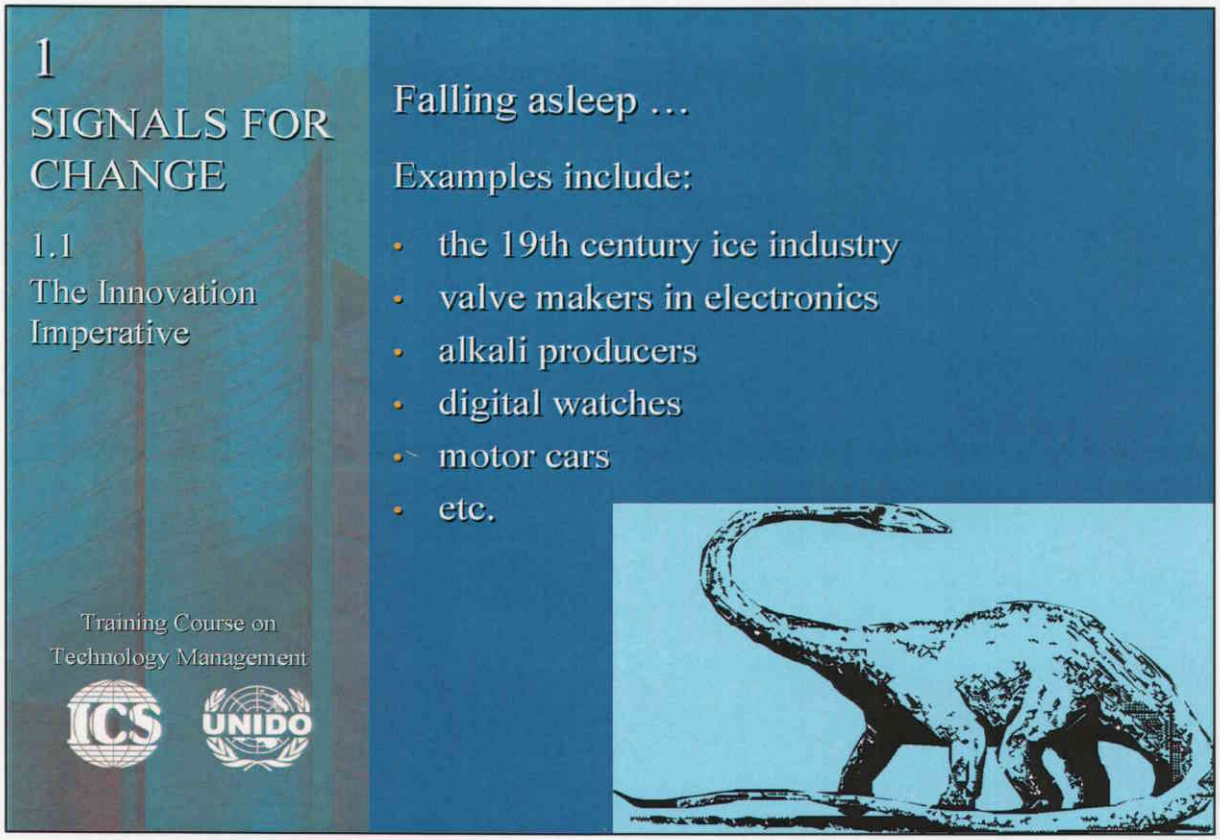
Changes do not always have to be great leaps forward or involve radical new ideas. Most of the time change is more gradual, moving incrementally forward with a sequence of small, cumulative improvements. For example, although the invention of the electric light bulb was a dramatic breakthrough, little improvements in the design of the bulb and in the process for manufacturing it led to a fall in price of over 80% between 1880 and 1896. In recent times, the dramatic growth and success of the Japanese car manufacturing industry is primarily the result of a forty-year program of systematic and continuous improvement of product and process design.



Innovation, technological change, is an essential requirement for any business to succeed. The pace and range of changes in the environment mean that there is no alternative; the choice is simply one of 'adapt or die'. At its heart, innovation is the way in which firms adapt and survive, some more effectively than others. Survival is not compulsory. It is a sobering thought to find that, of the Fortune Top 500 firms in 1975, over a third had disappeared by 1985. For smaller firms the odds are much worse; put simply, change is imperative.

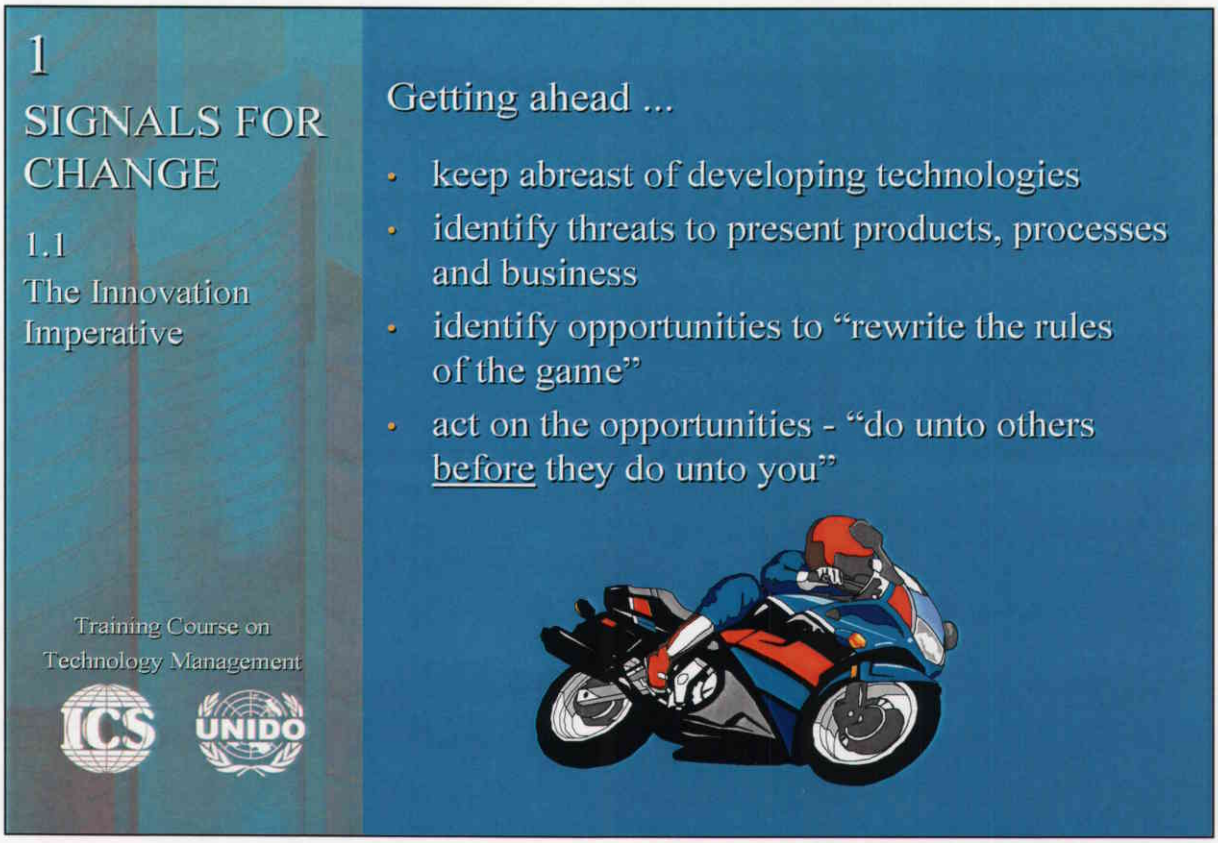
For some firms the challenge is obvious. Take, for example, the printing industry. Here the entire rules of the game are being rewritten by technological and market changes which have turned the industry upside down. Firms that do not recognize the need for change simply disappear, whilst those that recognize that 'we must change' can use this to build new and growing businesses.

Not all firms recognize the need to change; for some there appears to be security in size or in previous technological success. Take the case of IBM, a giant firm which can justly claim to have laid the foundations of the IT industry and one which came to dominate the architecture of hardware and software and the ways in which computers were marketed. But such core strength can sometimes become an obstacle to seeing the need for change as proved to be the case when, in the early 1990s the company moved slowly to counter the threat of networking technologies and nearly lost the business in the process. This is often a problem for large companies, GM and Kodak are two other examples. But it can be life-threatening for smaller, less well-resourced firms.

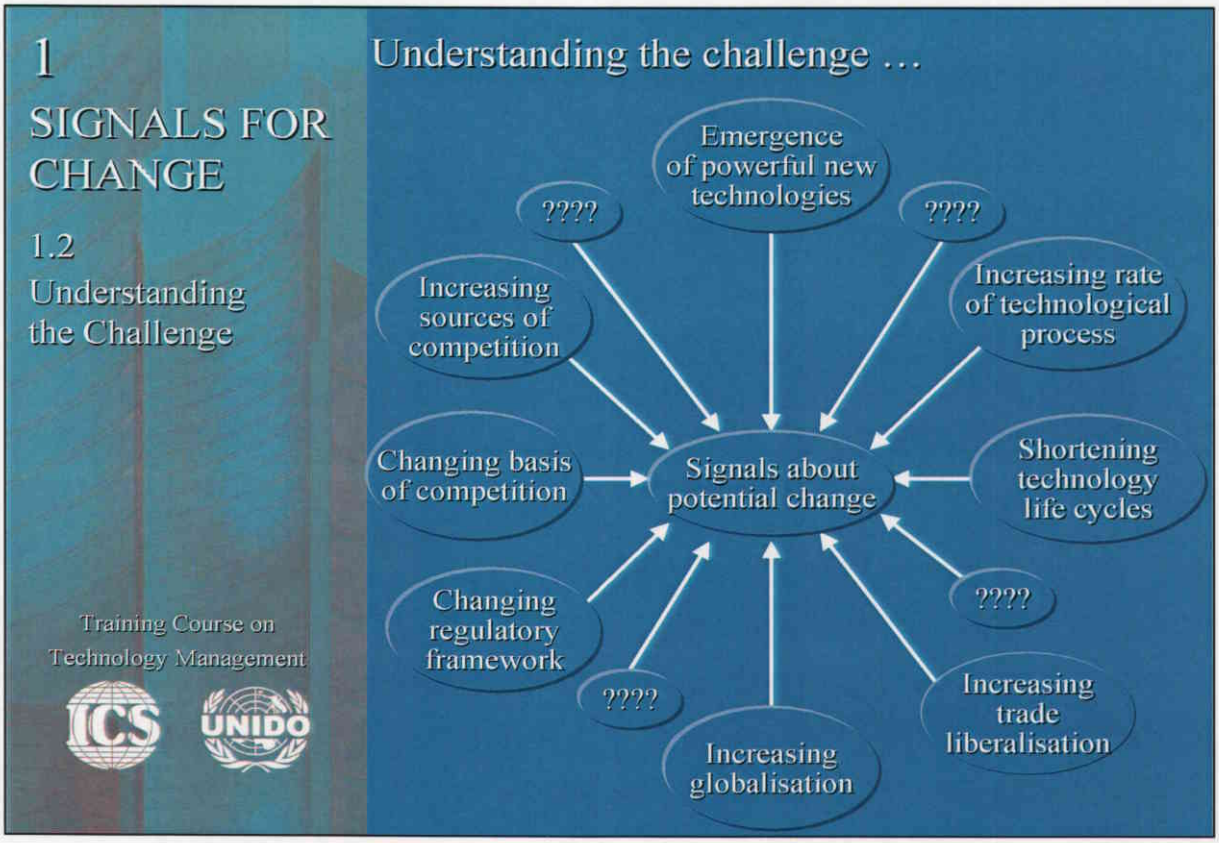


Sometimes the pace of change appears slow and the old responses seem to work well. It appears, to those within the industry, that they understand the rules of the game and that they have a good grasp of the relevant technological developments likely to change things. But what can sometimes happen here is that change comes along from outside the industry, and by the time the main players inside have reacted it is often too late. For example, in the late 19th century there was a thriving industry in New England based upon the harvesting and distribution of ice. In its heyday it was possible for ice harvesters to ship hundreds of tons of ice around the world on voyages that lasted as long as six months, and still have over half the cargo available for sale. By the late 1870s the 14 major firms in the Boston area of the USA were cutting around 700,000 tons per year and employing several thousand people. The industry made use of a variety of novel techniques for cutting, insulating and transporting ice around the world. But the industry was completely overthrown by the new developments which followed from Linde's invention of refrigeration and the growth of the modern cold storage industry. The problem, as Professor Utterback of MIT points out in his book studying a number of industries, is that the existing players often fail to respond fast enough to the new signals coming from outside their industry. Yet three-quarters of the industry-changing innovations that he examined originated from outside the industry itself! (Utterback 1994)

Entire industries can be (and have been) overthrown by new technology; for example, typewriters have given way to computers and word processors, electronic digital watches have replaced mechanical ones, motor cars have taken over the market occupied by horses and buggies. The list is endless. The trick is to recognize that technological change is happening and to take advantage of it rather than to be"blind-sided" by it.

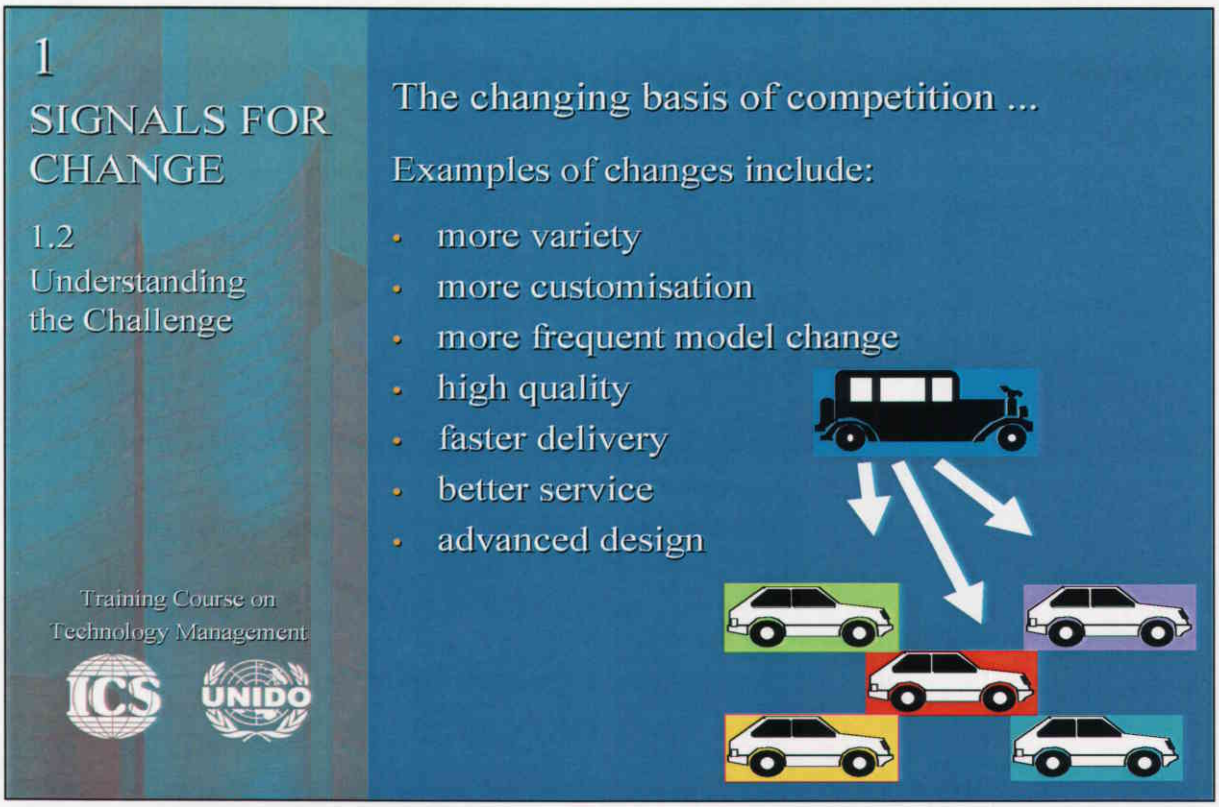


Of course for others these conditions provide an opportunity for moving ahead of the game and writing a new set of rules. The case of banking is an example; for many years the banking industry in the UK was a relatively stable environment. Small changes took place but each of the major players kept up and maintained their market shares. But in the 1980s, following developments which had radically shaken up the insurance industry, one or two banks began to rewrite the rules of the game by introducing telephone banking services backed up by sophisticated information technology systems. The results, as far as the customers were concerned were massive improvements in perceived levels of service; no longer did they have to wait until the banks were open but instead they had 24-hour access every day of the year. The range of services which could be offered was increased so that the telephone became a 'one stop shop' for a range of banking and other financial services. And, as far as the banks were concerned, the reduction in their cost base was enormous, switching from an expensive physical infrastructure with branches on the streets of most towns and many staff to run these to a streamlined and professional call center in one city handling all the business in the UK.



Change without some sense of direction is unlikely to succeed; if you start out not knowing where you are going, it is likely you will end up somewhere else! Technological change needs guiding and managing; there are no guarantees of success, but some useful lessons from experience can improve your chances. And the first step is to understand the nature of the threats and opportunities which operate in your environment – how to search for the signals, how to interpret the signals and how to select the options which are likely to have most effect on competitive survival.

Today's challenges take many forms, ranging from direct threats like increased competition or technological substitution, through to new opportunities opened up by emergent technologies or the development of new markets. In the following sessions we will look in more detail at some of the most significant of these trends.

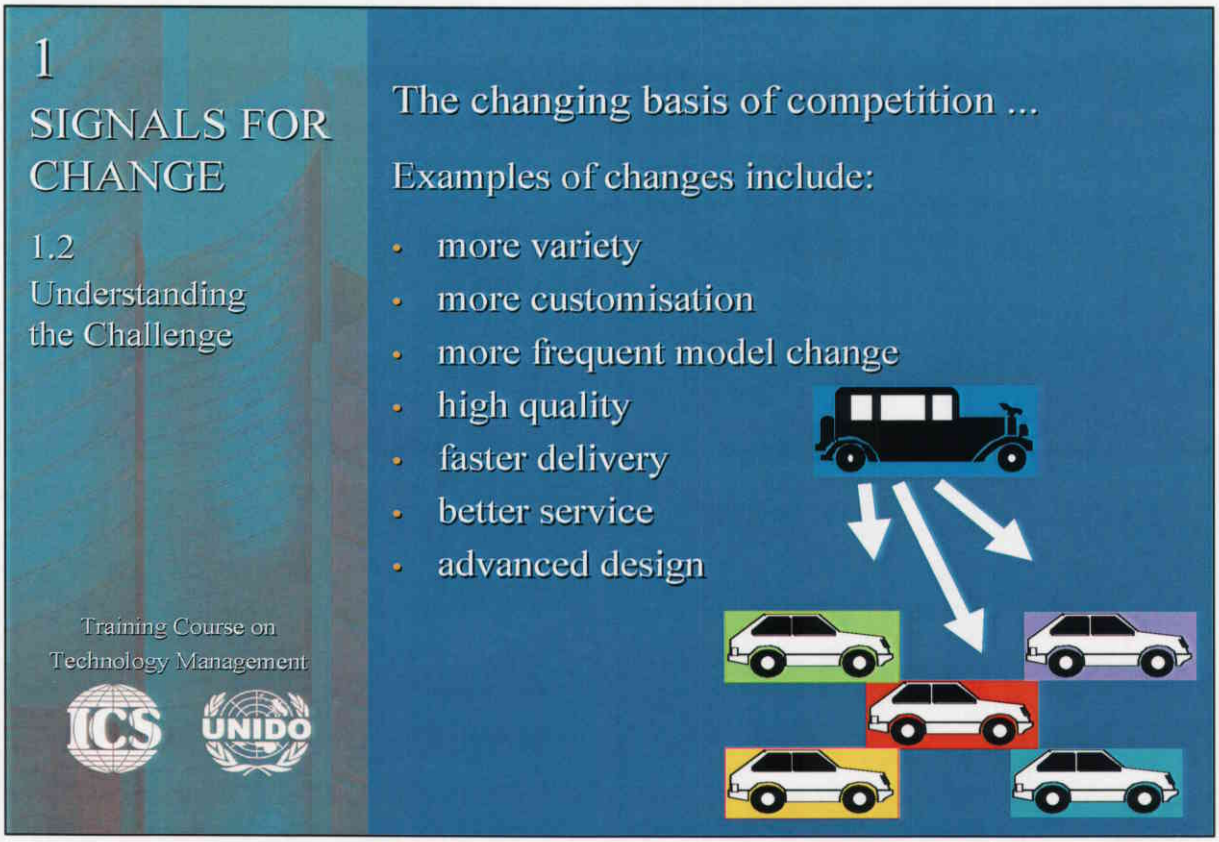


When Henry Ford built his Model T in the 1920s he created an approach to its manufacture which, for its time, was probably the most efficient in the world. Cars could be produced from raw iron ore in just over three days, quality was high and scrap levels low, inventory flowed through the plant with very little tied up in wasteful queues and the whole plant achieved extremely high levels of productivity. As the company learned and refined its methods so the improvements in productivity continued until by the early 1920s when production of the Model T was in full swing, the reduction in effort per car was of the order of 90% over the old style craft methods. Not only did this represent a huge advantage over competitors, it also enabled Ford to cut the price of the already highly-competitive Model T by an additional two-thirds. Not surprisingly, the Model T became the most successful car of its time, selling over 15 million and capturing over 60% of the US market before production was finally stopped in 1927.

Making things in this way was not problem-free; there was still the concern for better utilization of materials, labour, energy and other inputs to production. But it did offer a viable and effective model for serving hungry markets with high volume of demand. Over time it led to the concept of scale economies, the principle that with increasing size came increasing efficiency.

By contrast, today's environment is far less easy for manufacturers. Gone are the days of being able to sell all they could make, where output was the primary goal. Now a combination of massively-increased competition and more-discerning and powerful consumers have shifted the balance strongly to the demand side. For many years the industry has been moving away from the traditional high-volume/low-variety model which characterized Ford's early factories, to offering different models to serve particular market niches. Within each of these segments there is considerable variety – in basic design (2-door, 4-door, cabriolet, estate, sports version, etc.), and in engine size and performance. And within each model type there is variety in colour, styling, trim, fixtures and fittings, again, tailored to different market segments.

Further complications arise because the replacement lives of products are shortening so that the frequency with which new models are introduced increases. Each time the model changes it potentially requires a new production line with all the associated investment, not only in special purpose equipment but also in handling and transport equipment, storage facilities, plant layout and, most important, skills development via training. Whereas twenty years ago the life cycle of a car model was around 10 years, the time for new model development is being cut further and further back. In Western firms in the 1980s it was between five and seven years, whilst in Japan it was around four years. Now the average time for most manufacturers is around 24 months and Nissan is pushing for a 14-month cycle on their newest models. At one stage Japanese manufacturers were introducing model changes at a rate in excess of 100 per year!



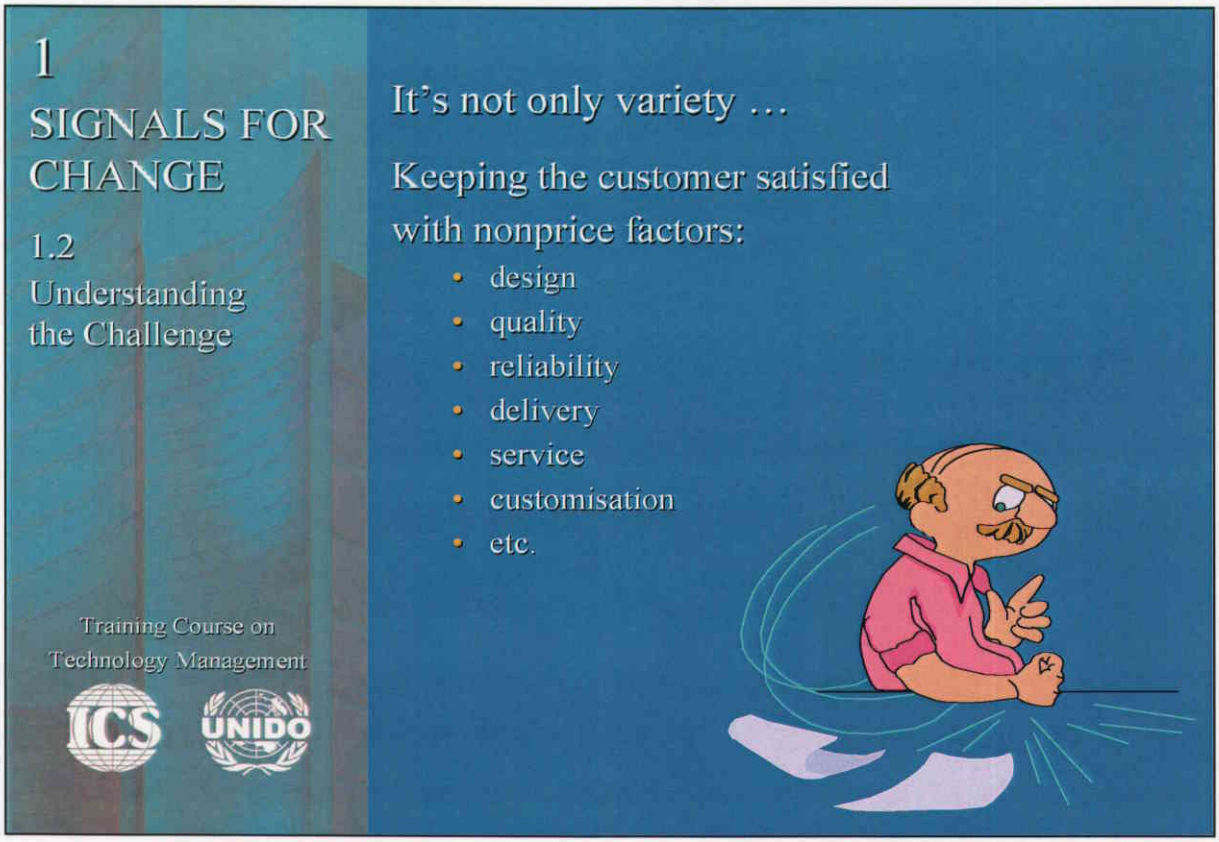
At the same time the break-even size for car manufacturing plants is falling, with some manufacturers now claiming to be able to operate economically producing less than 200,000 cars/year, as compared to the traditional picture which looked for volumes of 2 to 3 million cars/year.

The key message from this brief excursion into the car industry is that Ford's famous dictum: 'you can have any colour you like, as long as it's black!', has now been overtaken by an environment which demands constant change.

This same pattern of fragmentation of demand is being felt right across the industrial spectrum. A good example here is margarine – a simple product which grew out of wartime shortages of butter and which has since become a major commodity, typical of many in the food processing industry. In the margarine business, edible oils are hydrogenated and emulsified – relatively simple processes which used to be carried out in large-scale plants. But now the market demand has fragmented into various different sections for low-fat products, for low-cholesterol products, for different oil inputs such as sunflower seed, for the newer high-water products which are blended with buttermilk, and so on. A quick glance in the refrigerated cabinet of any supermarket will testify to that fact that even something as mundane as margarine now represents a high-variety consumer product. In the UK, Unilever's Van den Berghs division, responsible for margarine and related products currently make some 200 different varieties and they expect batch sizes to fall further and product variety to increase.

The National Bicycle Company of Japan now offers 18 basic models, a choice of 19 colours and 6 different calligraphies, giving a staggering potential choice of 11,231,862 variants! Seiko, the watch maker, now offers over 3,000 different designs of watch, whilst even capital goods makers like Westinghouse offer over 50,000 different turbine designs.

Another example comes from the paper industry, again, traditionally a commodity business based on scale economy. Here a variety of changes have increased pressure on this business, including energy and material cost rises and the growing concern with environmental issues. Competition forced a degree of product diversification on the industry in the early 1970s and this trend has accelerated in recent years with considerable variety now on offer, especially in areas like tissue and fine papers. Critical competitive advantages depend on nonprice factors such as quality, short delivery lead times, customized quantities and fulfillment of special needs.



For industries like consumer electronics the frequency of changeover is very high, running into several times per year. And whilst they often do not have the same levels of investment in special-purpose equipment, they still have significant problems in changing over assembly, test and other procedures. For example, the typical life cycle of a television set or video recorder is measured in months and a typical manufacturer would offer between 30 and 40 model varieties, with some offering as many as 70 different products, all targeted at different market segments. In Germany there are currently around 1,500 different models of TV set on the market from 70 manufacturers and at least 500 different video recorders.

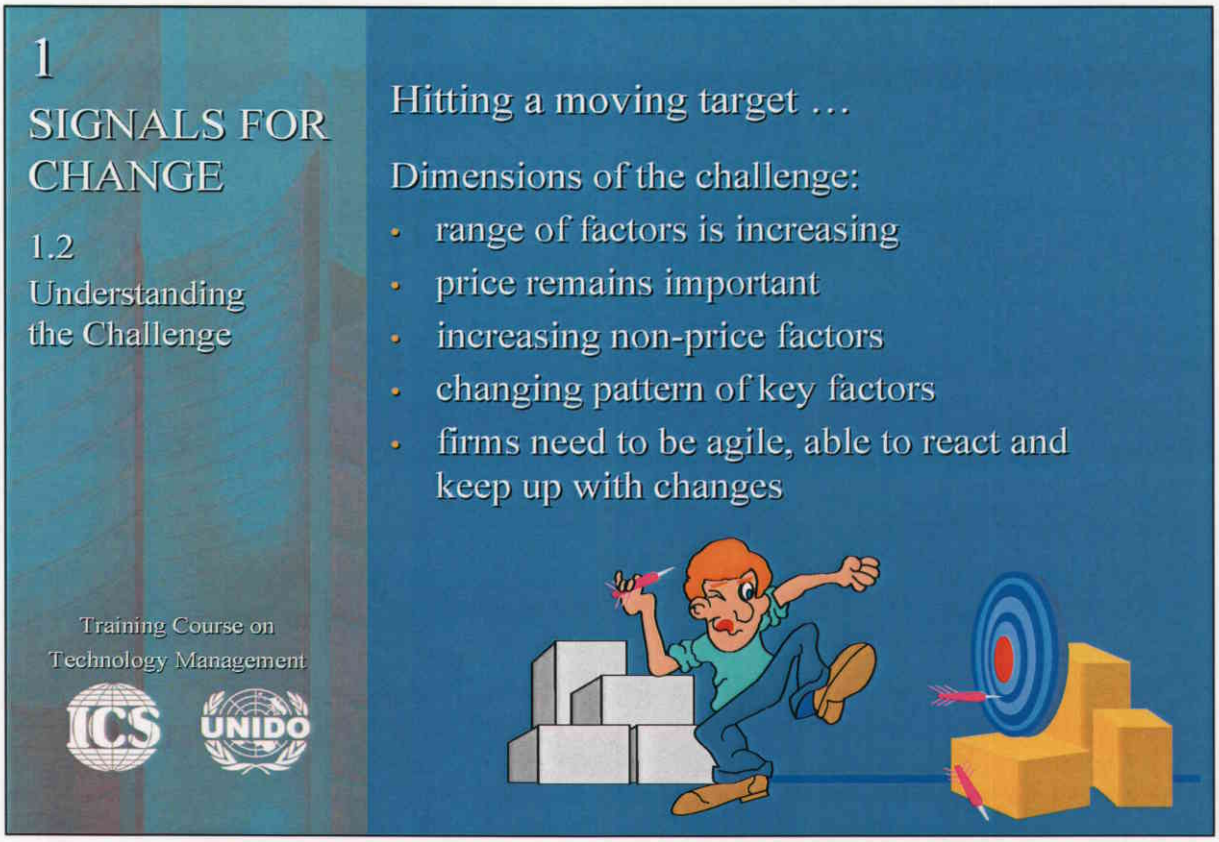
Another emerging trend is to move away from low-cost production to higher added value through nonprice factors like design and quality. A good example can be found in the field of textile production where Japanese industry suffered serious setbacks due to the high value of the yen, especially in relation to Taiwan and South Korea as lower cost producers. The strategy used to cope was to move away from price competition and into higher added value and product development, stressing better performance.

Another example of this can be found in the hosiery business. Traditionally the marketing of stockings, socks and tights has been on the basis of price. Indeed, during the 1970s such items became a supermarket product, sold on the basis of "pile 'em high and sell 'em cheap", often with the products offered in one size and one colour. But now the industry has been transformed into a successful fashion business. In the UK it is worth some £400m per year and is characterized by the emergence of specialist retailers like the Sock Shop which has over 100 outlets selling little besides hosiery. Import penetration is very low compared to other segments of the clothing industry, at around 20%, and the industry's recent growth has been in value rather than volume (five times that of volume), reflecting the changed emphasis on quality, design and product innovation.

It is important to recognize that it is not simply a matter of increasing variety. Change is being demanded along several other dimensions at the same time. The shift is away from price factors, and towards a range of nonprice factors which determine whether or not a customer will buy from a particular supplier. In some cases price is overruled, with customers being prepared to pay more for an item if the package of nonprice factors matches their needs. For example, in the Dominican Republic a cardboard carton producer was told that his clients in the cosmetics and pharmaceutical business would be prepared to pay a 60% premium – but only if he could supply in small lots, at very high quality and with very rapid response deliveries.

Even the products themselves are no longer something to be taken for granted. Whereas the life of a typical product might once have been measured in years or even decades, the life cycle of many products today is down to months. Some consumer products, like television sets or stereo systems, go through several changes every year. It has been estimated that up to 80% of the new products which we will be buying in ten year's time have yet to be invented! The effect of this is to challenge the idea that industries go through phases, moving from being new young and innovative sectors associated with new products to mature industries in which the product and the way in which it is made are well established. Pressure for shorter product life cycles means that industries now need to find ways of constant renewal.

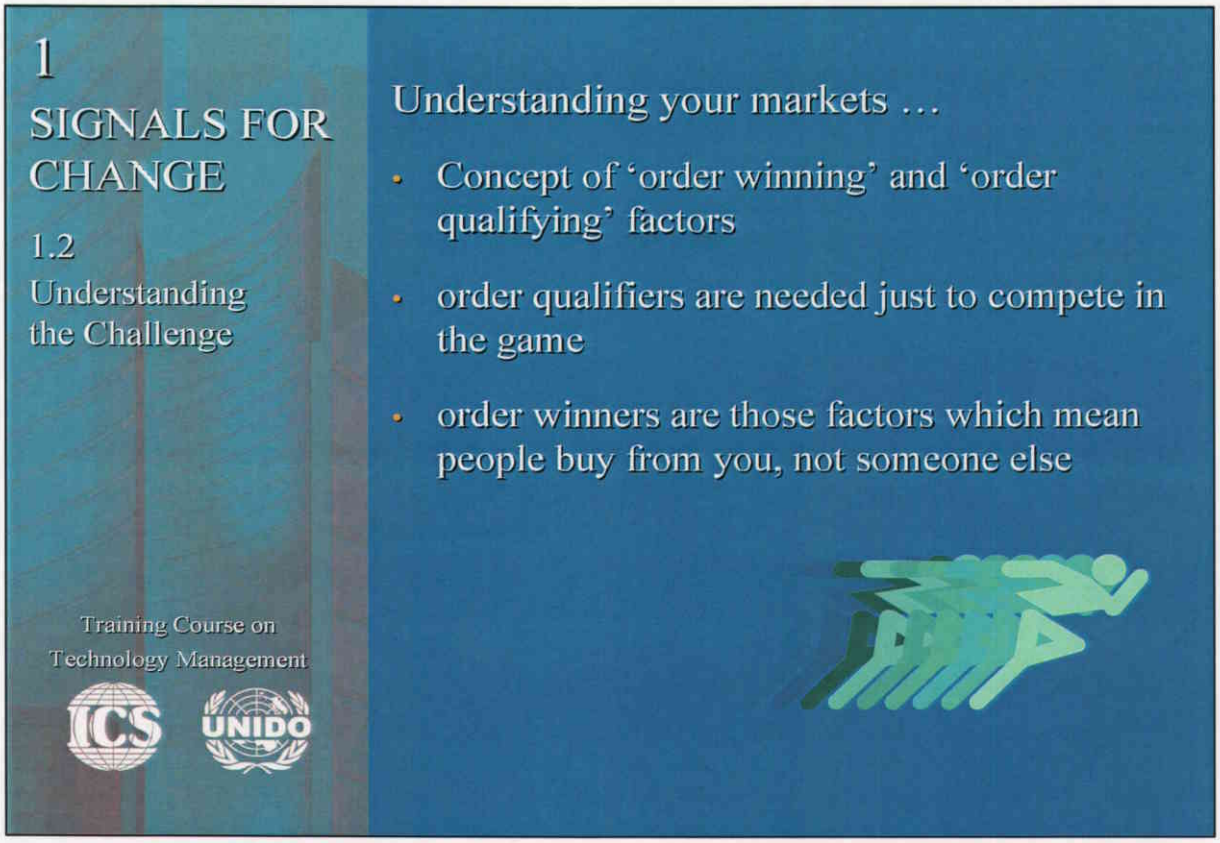
Although attention has shifted towards the role of nonprice factors in determining competitiveness, this should not blind us to the traditional concerns for productivity, the efficient use of inputs of capital, labour, raw materials, energy, etc. With rising costs of labour, energy and many raw materials, the question of efficient use of these inputs becomes critical. Such questions do not simply relate to using less but also to reducing waste in time, space, materials, energy, etc. In factories the concern is with reducing scrap levels and shortening lead times (and hence the time material in unfinished form is held) so that products can be sold faster bringing money back into the business. Similarly, while enormous strides have been made in energy saving since the 'energy crisis' of the 1970s, there are still problems for many manufacturers with energy-intensive processes, even at times of relatively low fuel costs. And whilst the overall proportion of labour involved in manufacturing has declined to 10 to 15% of the total work force in most developed countries, the actual costs of employing them have not changed so much. Certainly there is less direct labour (and in many industries this is below 5%), but this is often compensated by more indirect, support labour. Additionally, an increasing proportion of wage costs relate to a labour force which is more highly qualified and thus more expensive.



This is the nature of manufacturing environment in the 1990s, with massive competitive pressure forcing firms to be more flexible, agile, service-oriented, quality conscious and all underpinned by low price. The pattern in manufacturing is mirrored in services; if anything, the need for change is even more urgent, since productivity growth was sluggish in this sector for so long. The emerging model of 'mass customization' which emphasizes nonprice factors like speed, quality and customization is equally applicable to banking, hospital care, television programs, education and air travel as it is to manufacturing. Even in those sectors traditionally regarded as noncommercial – education, health care, social services, legal services, etc. – a similar picture can be found, with increasing emphasis on customer choice and on nonprice factors.

To make matters worse the problem is one of trying to hit a moving target. Factors that are important today may be less so tomorrow as new ones emerge. Concerns like quality, which used to be differentiators are now so widespread that if you cannot make the grade in the quality of what you offer, there is no point in being in the market.

The traditional trade-offs – between price and quality, or between price and choice – are being challenged and now customers are demanding competitive prices and a whole set of nonprice factors.



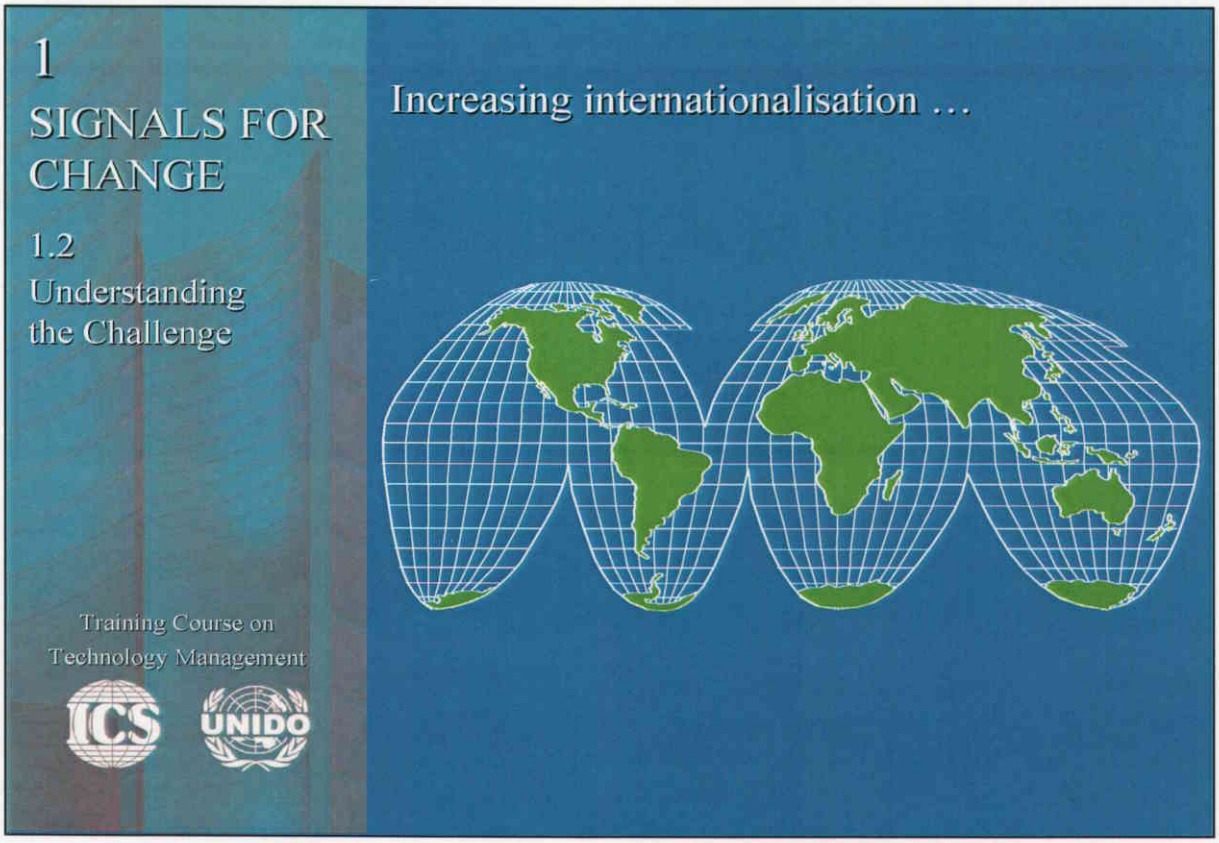
What this means in practice is that firms need to work hard to understand, as closely as they can, the particular set of needs being generated in the marketplace. One useful mechanism for dealing with this is to make the distinction between order-qualifying and order-winning factors. Order qualifying factors are those which are essential just to play in the game. For example, price is usually an order qualifier because if your prices are much different than others, customers will choose other suppliers. But now factors like quality and delivery reliability are becoming order qualifiers; quite simply, if firms cannot measure up they do not even get to open their stall in the marketplace. In some cases this becomes formalized; for example, supplying to many major manufacturers is now conditional on suppliers being quality assured to international standards (ISO 9000).

Order winners, by contrast, are those factors which you can offer which distinguish you and your products/services from the competition. Understanding what your order winners are, and how big the gap is between you and the competition, is a critical element in beginning the technological change process.

In addition to the changing basis on which competition is now taking place, we also need to be aware of the changing environment in which it takes place. There are many factors influencing this, including:

- increasing trends towards globalization
- increasing customer power
- changing regulatory patterns
- increasing trade liberalization

These factors are impacting your organization whether you realize it or not. The challenge begins at realizing these factors are real and they impact your business. It, however, does not stop there. Impact specifics must be understood and strategies for dealing with these factors need to be developed and implemented to ensure continued survival.



We have seen the massive increase in competition with many more providers of goods and services, both in the domestic market and overseas. But 'overseas' no longer means simply a handful of firms in the advanced industrialized nations serving largely dependent and captive colonial/imperial markets. Now we have many newly industrializing countries competing aggressively for a share not only of their local markets but also in the heartland of the old established manufacturing nations. Japan's export model provided an example successfully followed by other nations on the Pacific Rim to the extent that their growth rates are amongst the fastest in the world.

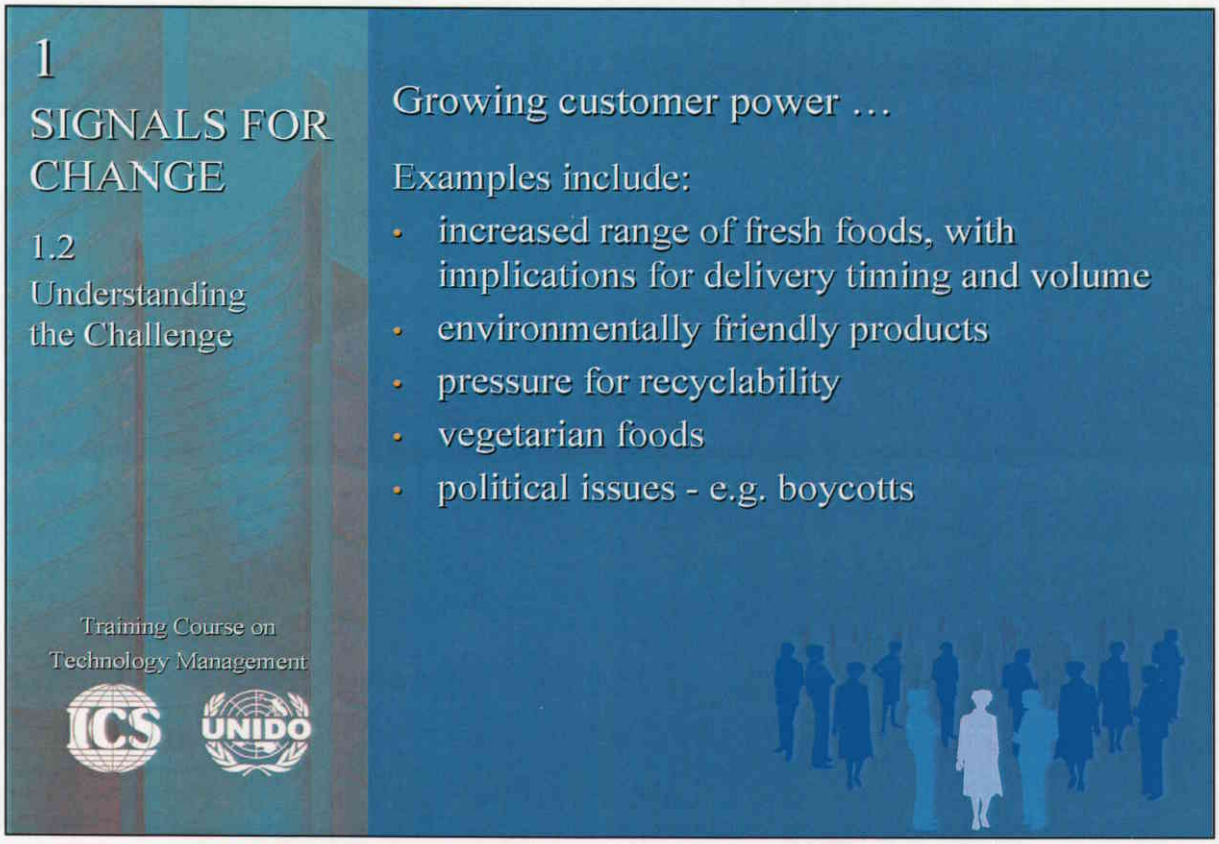
This international position is further complicated by the presence of the massive transnational corporations (TNCs), some of whom have a sales turnover exceeding the GNP of many substantially sized countries. Their elaborate networks of manufacturing, sales and distribution operations is spread throughout the world and their facility to move between these geographical locations to secure optimum trading conditions adds another key element to the complex environment of the 1990s.

Further change comes from the trend towards creating unified market trading blocs, such as NAFTA, the single European market and similar ventures in Latin America and South East Asia.

A consequence of the increasing internationalization of trade is the shifting pattern of location, with international firms moving production and distribution to take advantage of favourable local conditions or as a means to obtain access into new market blocs. The continuous movement within the electronics fabrication and assembly industries throughout South East Asia provides a good illustration of this process.

At the same time there is growing use of advanced communications technologies to enable global operation and execution of many core processes. For example, much software is now produced in India and a number of firms are using off-shore locations to carry out clerical data processing tasks such as ticketing and sales order processing.

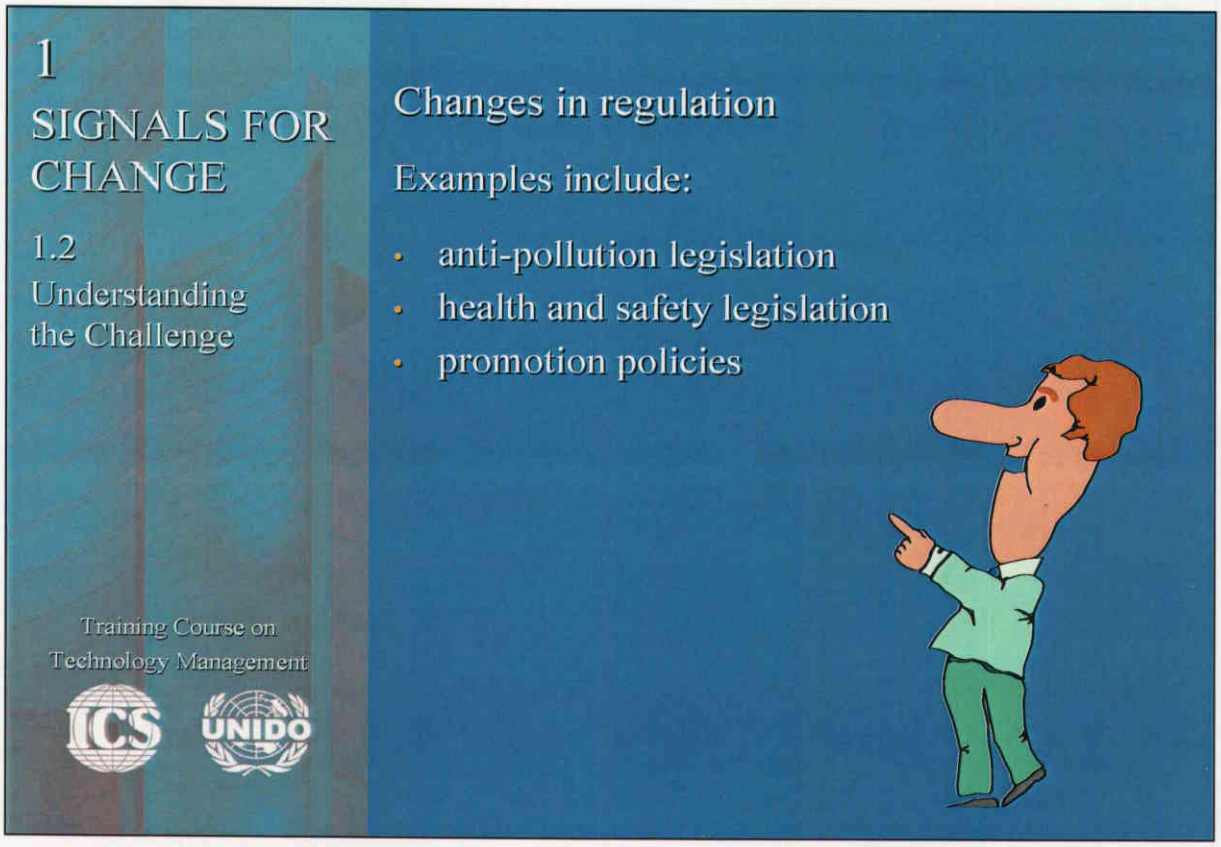
Globalization/internationalization has led to massively accelerated diffusion of new ideas and techniques. Whereas it took the mass production ideas of Henry Ford several decades to diffuse, newer ideas and technologies can be replicated and taken up very rapidly.



For the customer the range of choice of products and services is bewildering. However, it is becoming clear that competition for customers puts a degree of power in their hands. They can now begin to demand better levels of service, better quality products, better delivery and support, and greater specificity in what they buy. Such power is often increasingly concentrated in the hands of key groups, such as food retailers, who can exert enormous influence on manufacturers in terms of what they are asked to produce.

And when they produce it. Increasing interest has been shown in supply and distribution chain management with the emphasis on cutting out buffer stocks and inventory holding 'just in case' of problems; instead the move is now to producing and delivering 'just in time' for something to be used or sold.

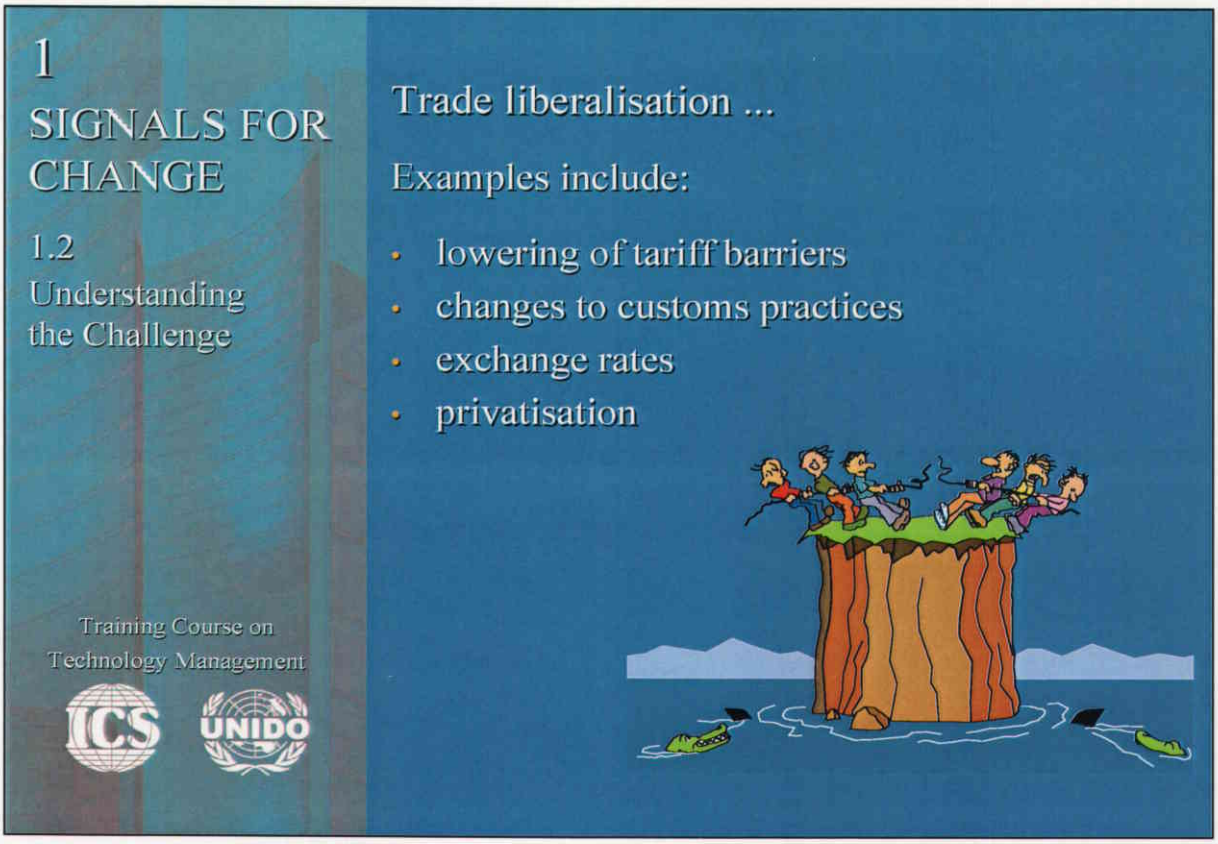
Related to this has been the growth in the influence of public opinion on what manufacturers produce. For example, the trend in many countries towards more environmentally-friendly products and services has been fuelled by strong demonstrations of public opinion. New products and processes, for example, disposable nappies made without the need for bleaching, or the use of recycled newsprint, emerge as a result of strong pressure groups. Estimates suggest that a significant proportion of consumers, especially women, would be prepared to pay more for products which have a positive environmental image.



Another source of influence is the regulatory environment which operates in and between countries. This can act to shape the rate and direction of change; for example, by imposing legislative controls on certain kinds of products or processes. The case of environmental pollution legislation in recent years has had a marked impact on what firms can do and the costs associated with their different approaches to production.

Health and safety regulation is another area in which there can be considerable shaping of the rate and direction of innovative activity.

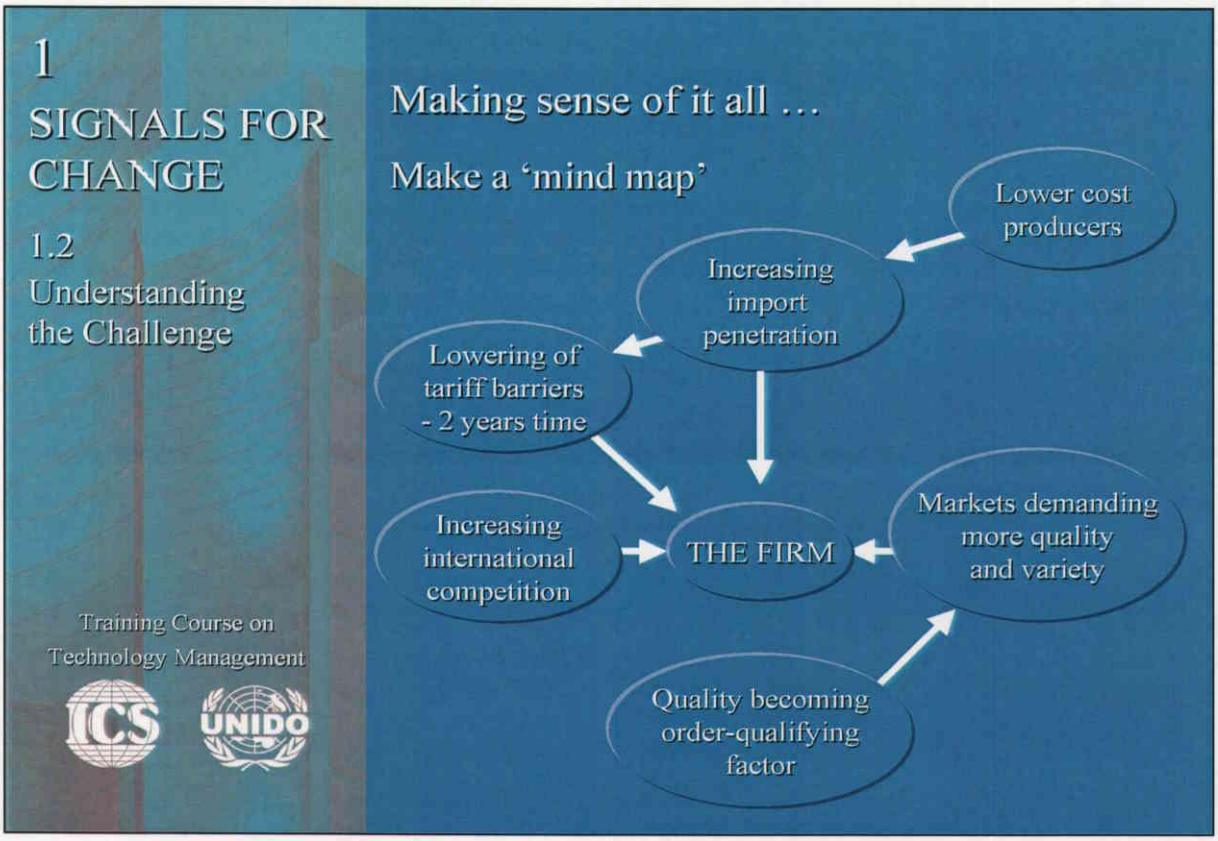
On the positive side, some countries actively promote particular directions through the use of various kinds of support initiatives, both financial and nonfinancial. These might include policies to promote energy-saving products, low- pollutant products or those which stress material conservation or recycling.



Another factor that has introduced considerable instability into the environment has been the growing trend towards trade liberalization. In a variety of countries external forces (especially the major financial institutions such as the IMF and World Bank) have been acting to lower tariff and other trade barriers and expose markets to open competition. This poses a considerable threat to many firms which have traditionally been insulated from the full extent and level of global competition. The challenge is, often in a short space of time, to recognize the new rules of the game and to develop capabilities to compete under these rules. Typically this will involve considerable technological change.

A further factor here is the increasing liberalization and privatization of public sector institutions, such as electricity supply and distribution, telecommunications and transport. These trends can have positive and negative aspects. For example, the privatization of telecommunications in Venezuela brought a major improvement not only in the levels of service for consumers, but also in the technological base amongst firms associated with that sector.

The opening of India's domestic airline industry to international players such as Lufthansa has brought the level of service provided by existing local carriers to an international level practically overnight. Threatened by the massive shift of business to the Indian-German joint venture, Modi-Luft, Air India successfully scrambled to improve their service. Trade liberalization left both companies in a stronger position and gave Indian travellers on-time service and more travelling comfort.

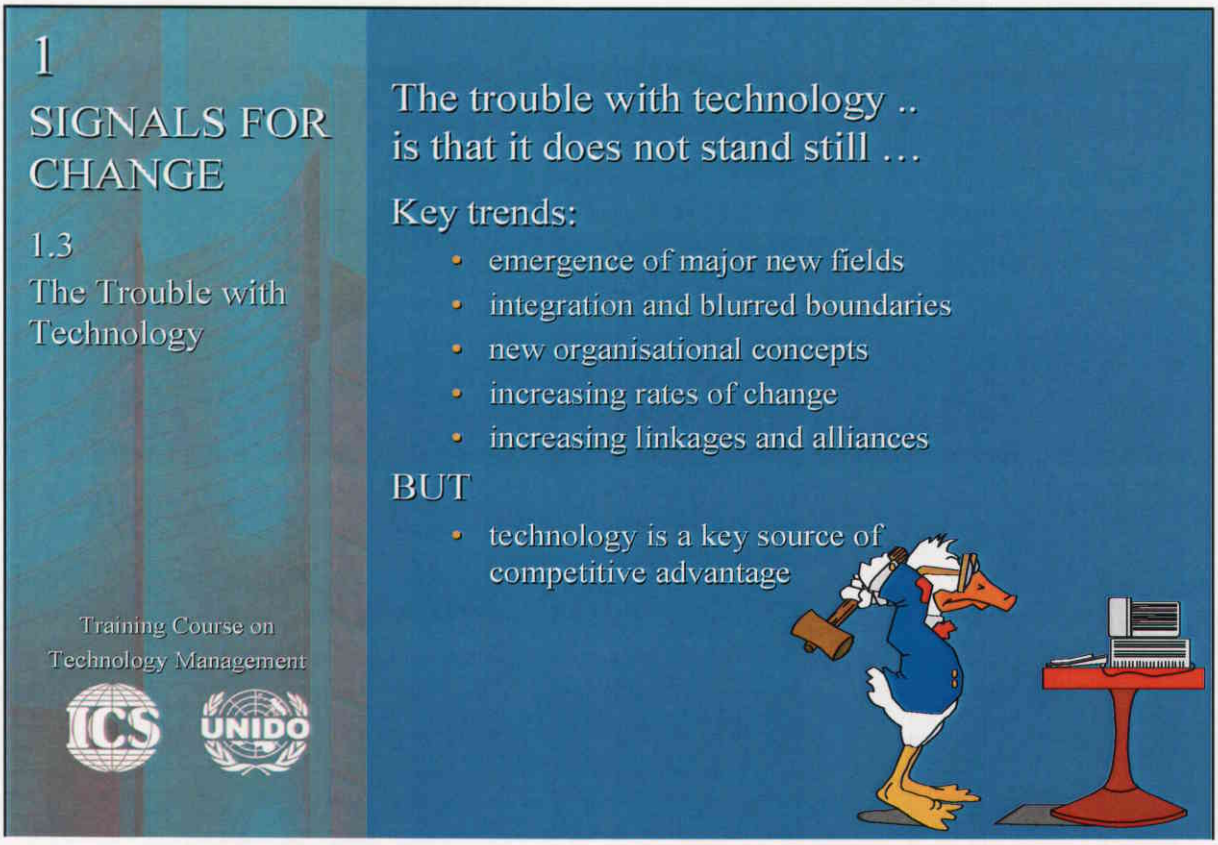


The effect of these factors is to increase uncertainty; with more players active as competitors, and operating on an increasingly-open global playing field, the key challenge is to build an understanding of this emerging environment.

A simple tool for helping with this structuring is what is sometimes called a 'mind map'. This is a structured way of listing all the major forces affecting the company, and can be produced alone or working with a group and discussing the issues. To create a mind map, first place the company in a box at the center of a page. Then list all the factors, like those above, which are having (or are likely to have) an effect (positive or negative) on the firm over the next few years.

For each new type of factor, start a new branch. For factors which are related to each other, cluster them around particular branches.

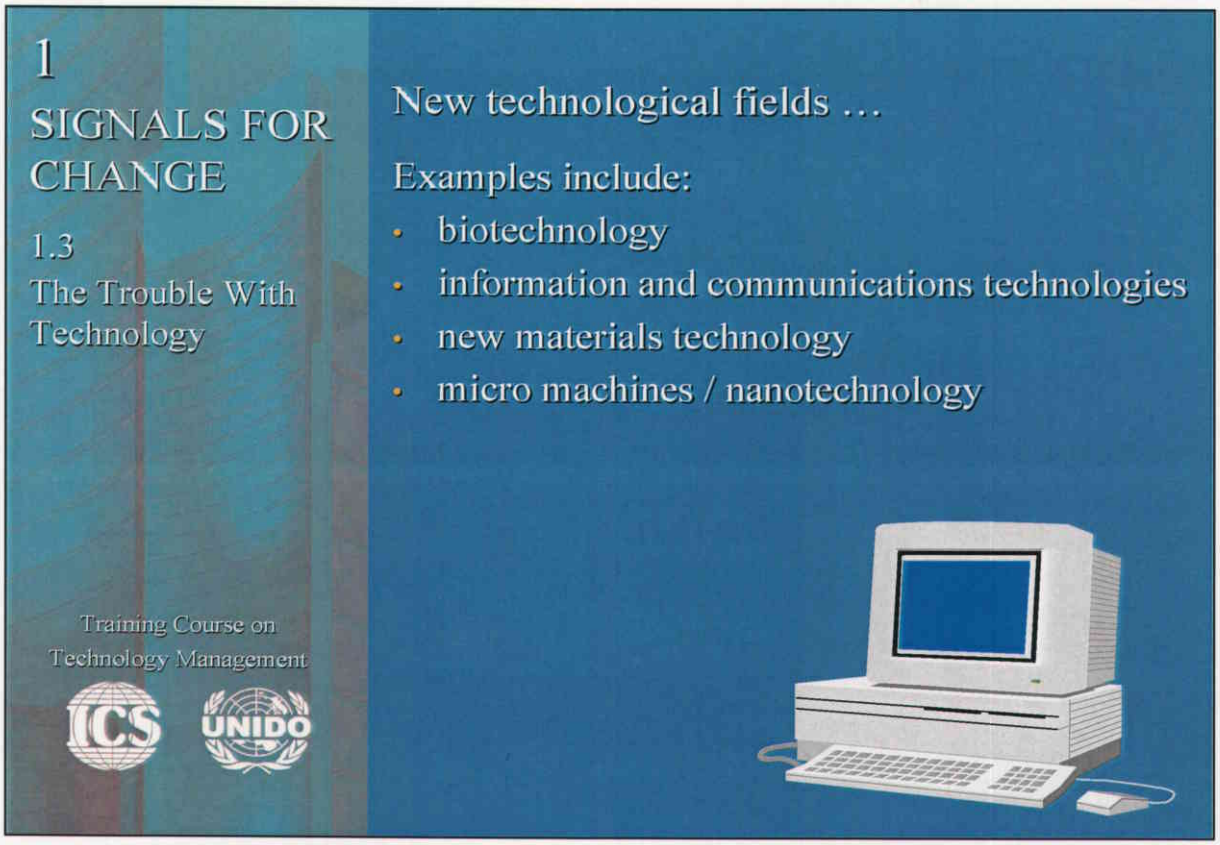
Finally you can colour-differentiate the factors which are likely to represent opportunities and those which are likely to represent threats. The result is a sketch map of the issues that are signals to which the firm must respond; the bigger or closer the cluster, the more significant they may be.



The trouble with technology ... is that it doesn't stand still. Apart from the major problems of changing competitive environment which we have just seen, we need to recognize that technology is a moving and accelerating frontier. As a consequence of the huge sums being invested in research and development worldwide, the pattern is essentially one of opportunities seeking application. Examples of whole new fields which are opening up include further applications of communications and information technology, the new world of genetic engineering which has led to cloning and other forms of DNA manipulation, the emergence of new materials and the new field of micromachine technology.

There is increasing dependence on technology as a source of competitive advantage through its impact on both price factors and nonprice factors (design, quality, customization, variety, product innovation frequency, service, etc.). As markets become more and more demanding, so technology is being used to meet the challenge, and to enable manufacturers to exploit strategic advantages through deployment of their technological capabilities. The trouble is that if you do not make use of a new technology, someone else might. So it is essential to find ways of monitoring what is gong on and picking up the key signals about technologies which may affect your business as early as possible.

Let's look at some of the key technological trends which are shaping the business environment.



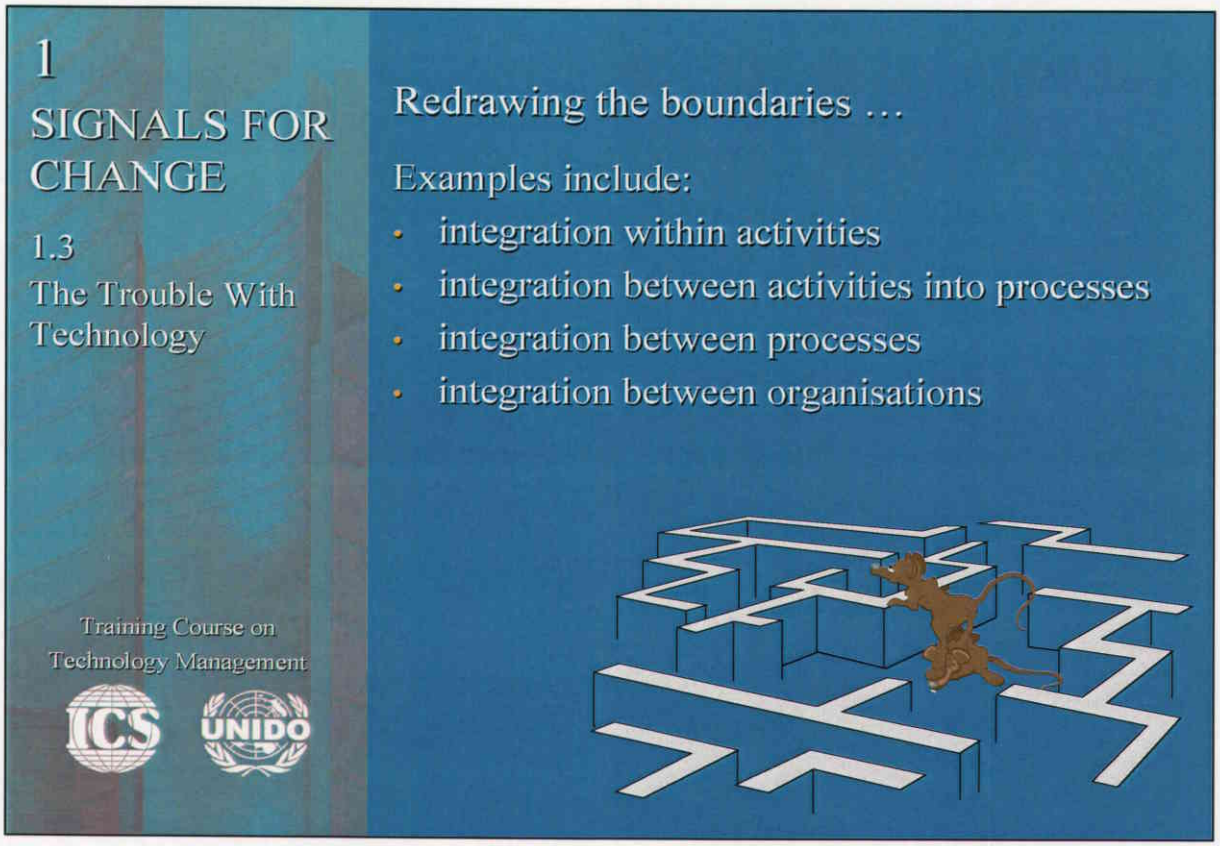
Whilst most technological change is confined to a single product or process, there are some which have a broader impact, for example, affecting a whole sector. And there are a few which have generic potential for application across the board – the example of steam power in the 18th century comes to mind. One of the key characteristics of the new industrial environment is that there are several of these generic technological fields emerging, with the potential for radical transformation of the things we produce and the ways in which we produce them. Examples include:

- the emergence of information technology (IT) with its potential to improve any activities which involve storing/retrieving, processing or communicating information. Since estimates suggest that up to 50% of manufacturing and 80% of some services like banking involve information activities, the potential application of IT in process renewal is enormous.

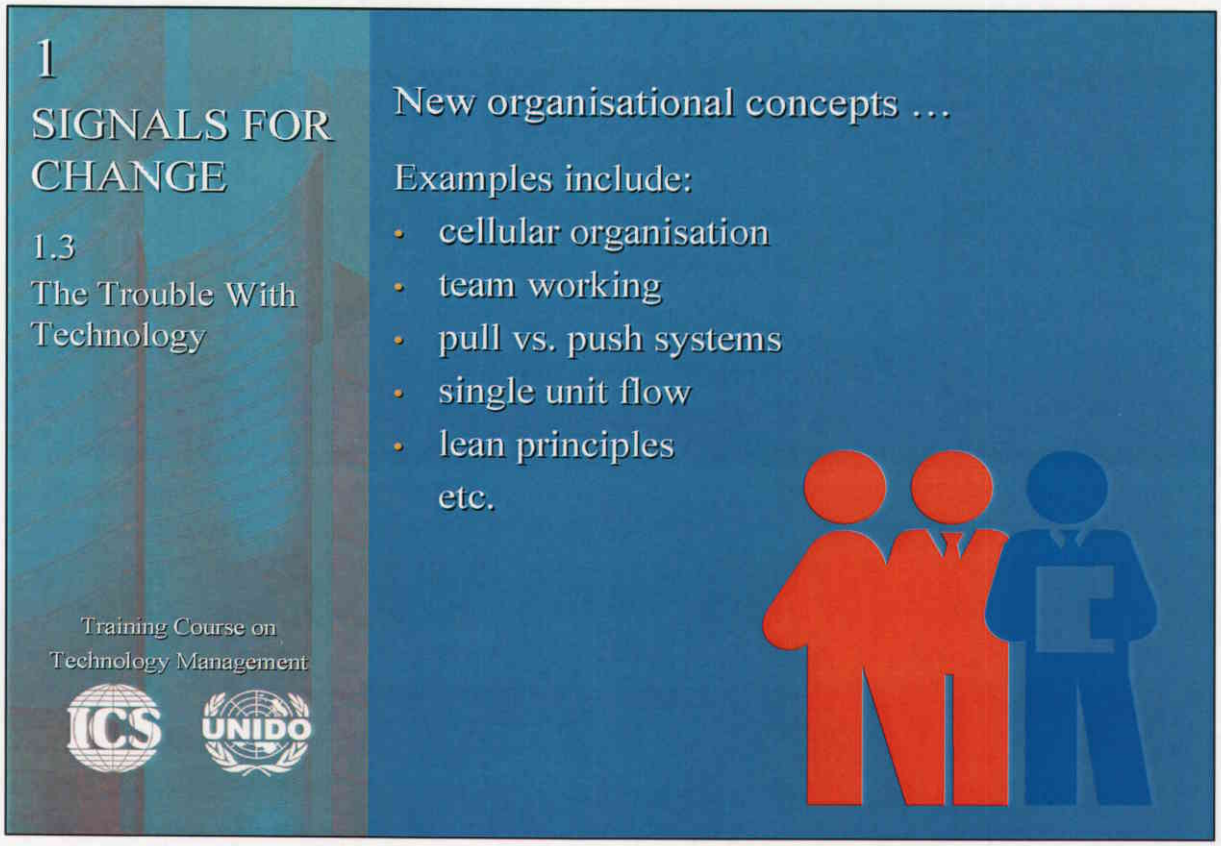
- developments in biotechnology and in the fundamental understanding of genetics and related fields have meant that radical new approaches and solutions are emerging in fields like pharmaceuticals, food and drink processing, agricultural industry and process engineering.

- the emergence of new materials and the improved understanding of the operations of existing materials make possible a huge range of new applications; for example, the increasing use of plastics and composites as structural materials. Often these developments go unnoticed but their collective impact is significant. For example, the surface coating industry is estimated to contribute around £3.5bn per year in economic performance but it is largely unrecognized because it represents a small contribution (paints, surface finishes, etc.). of a huge range of products.

- advanced communications networks now enable radically different modes of interaction, including virtual working and global location. The continuing rise of the Internet and the deployment of increased wireless and cellular phone and related technologies is likely to radically reshape both the distribution and scale of business activity.



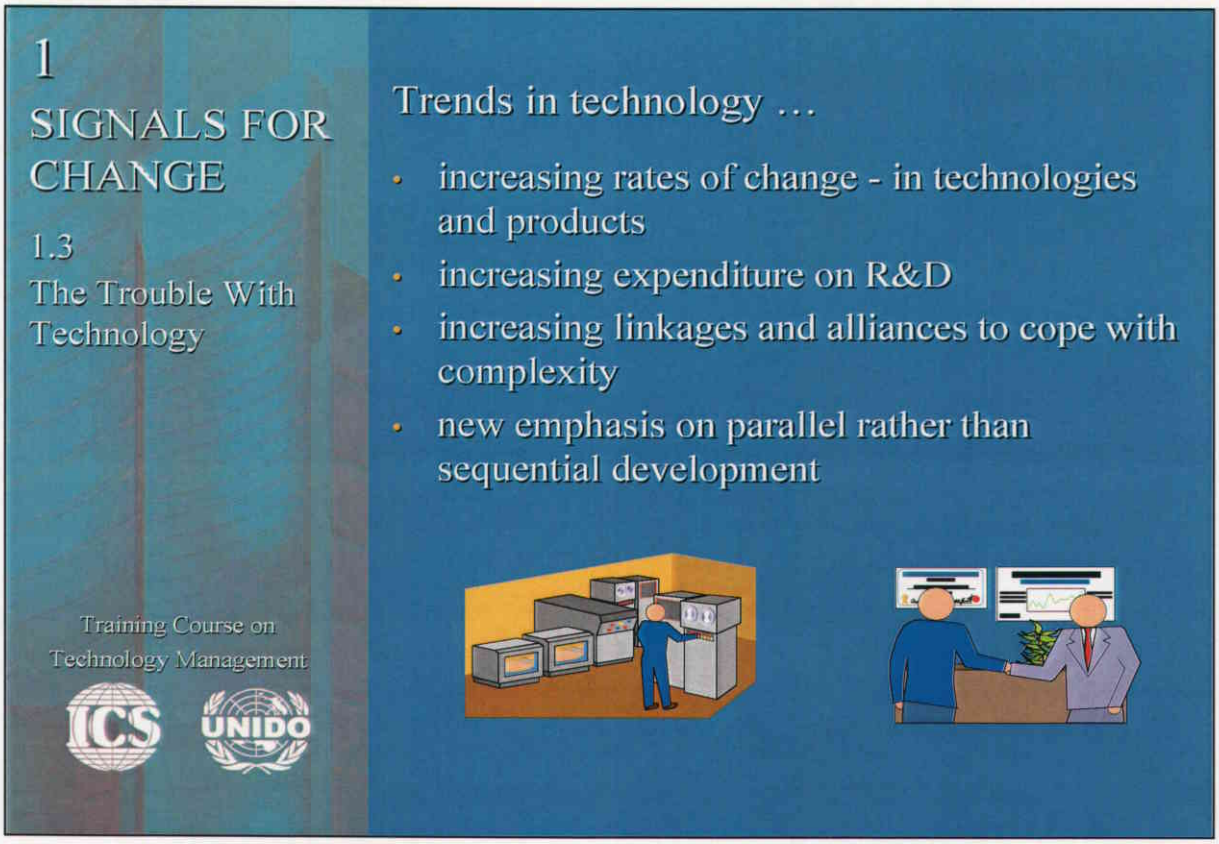
Although it has accelerated with the advent of IT, there has long been a trend towards integration of process components. So, for example, the different machines needed in a factory have gradually come together into single computer-controlled, multifunction systems. Similarly, many services have been transformed through the convergence of activities; for example, the current telephone banking and insurance services bring together processing of various transactions which previously would have occupied different departments and may have taken place in different physical locations. Such integration is also extending beyond the boundaries of the firm – for example, into interfirm collaboration.



The major change which Henry Ford made in his factories in developing mass production was not in the physical component; with the exception of the moving assembly line and some special purpose machinery, most of the plant used relatively standard machinery. The big shift was in the way in which work was organized and managed, with the extensive application of the principles of scientific management.

This illustrates the potential of organizational change as a component of technological change, and it is something which has assumed renewed significance in the late 1990s. As firms have moved beyond the mass production model so they have been discovering new approaches to the organization and management of their operations. Much of this change has been about redrawing the shape of organizational hierarchies, streamlining processes and devolving problem solving and decision making. It is exemplified in the concepts underpinning what were once called 'Japanese' management techniques: total quality management, just in time, and kaizen (continuous improvement), which have become enshrined in Western management under the label of 'lean thinking'.

The potential of this is clear when we consider that much of the 'revolution' in Japanese manufacturing, in sectors like cars and electronics, was not due to major new technological investments so much as to the adoption and refinement of such principles.

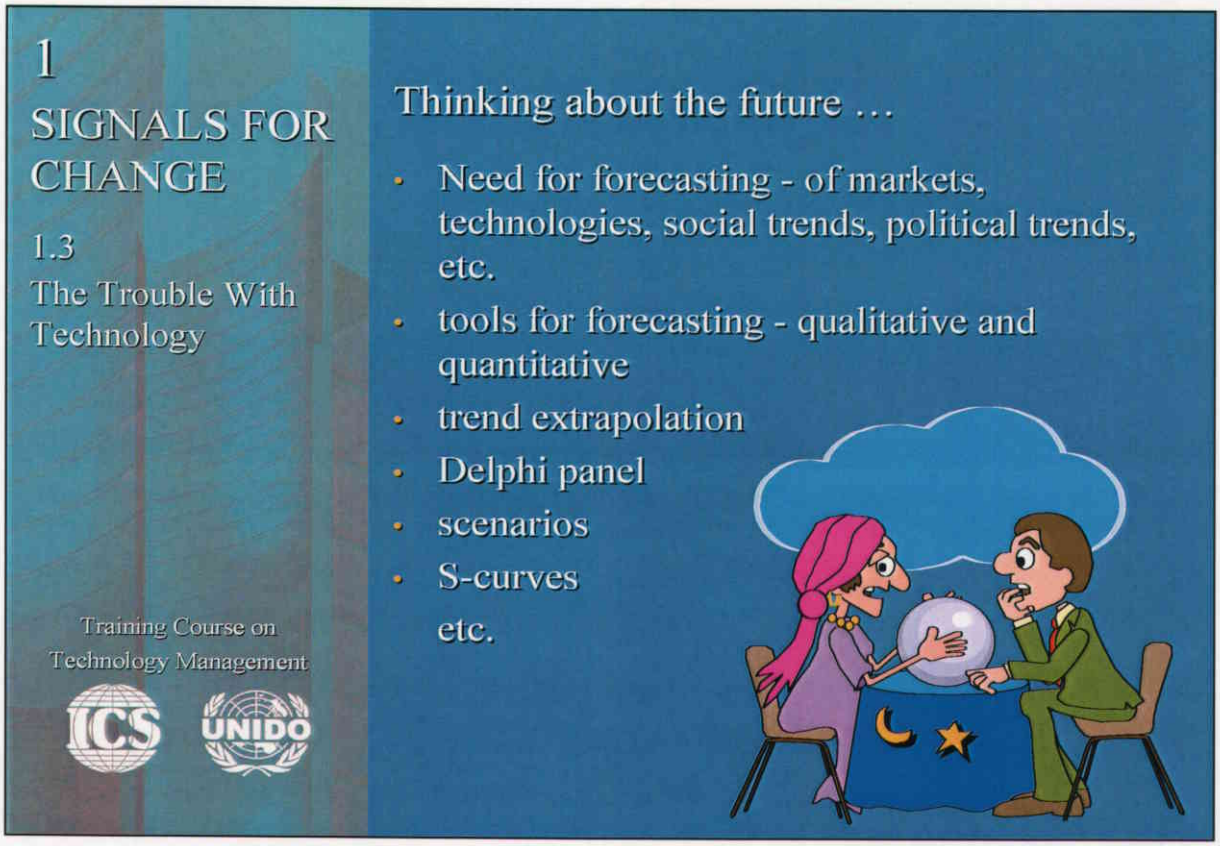


The rate of growth of new technological knowledge is increasing exponentially, so that the potential pool of new ideas from which to choose is massively larger than even a decade ago. Estimates for the USA suggest that there are now over 1 million scientists and engineers at work on projects with a total value of nearly $100bn per year. Investments in knowledge generation (through R&D) now exceed those in capital equipment in many firms. For example, figures for Japan and Sweden suggest that the money spent on R&D is two or three times that spent on fixed capital.

Another factor is that technological life cycles have become so brief that in some cases firms are prepared to make their own products obsolete in order to maintain a competitive advantage. Intense competition of this kind has seen the lead time from initial proposals through to high-volume production cut dramatically; for example, the average product life of a TV set in Europe is measured in months rather than years. In the car industry the design cycle for a new model car has been cut to less than two years, from an average of six years during the 1980s. Meeting this challenge requires radically new approaches to technological innovation, with increasing emphasis on parallel rather than sequential development.

One consequence of the near-exponential growth of technical knowledge, fuelled by ever-increasing R&D expenditure, is that not even the largest firm can hope to keep abreast of all developments, nor can it be expert in everything. The result is that there is a growing trend towards shared approaches to development of technology, through alliances and consortia, and a shift in emphasis towards ensuring effective transfer into firms of technologies developed outside.

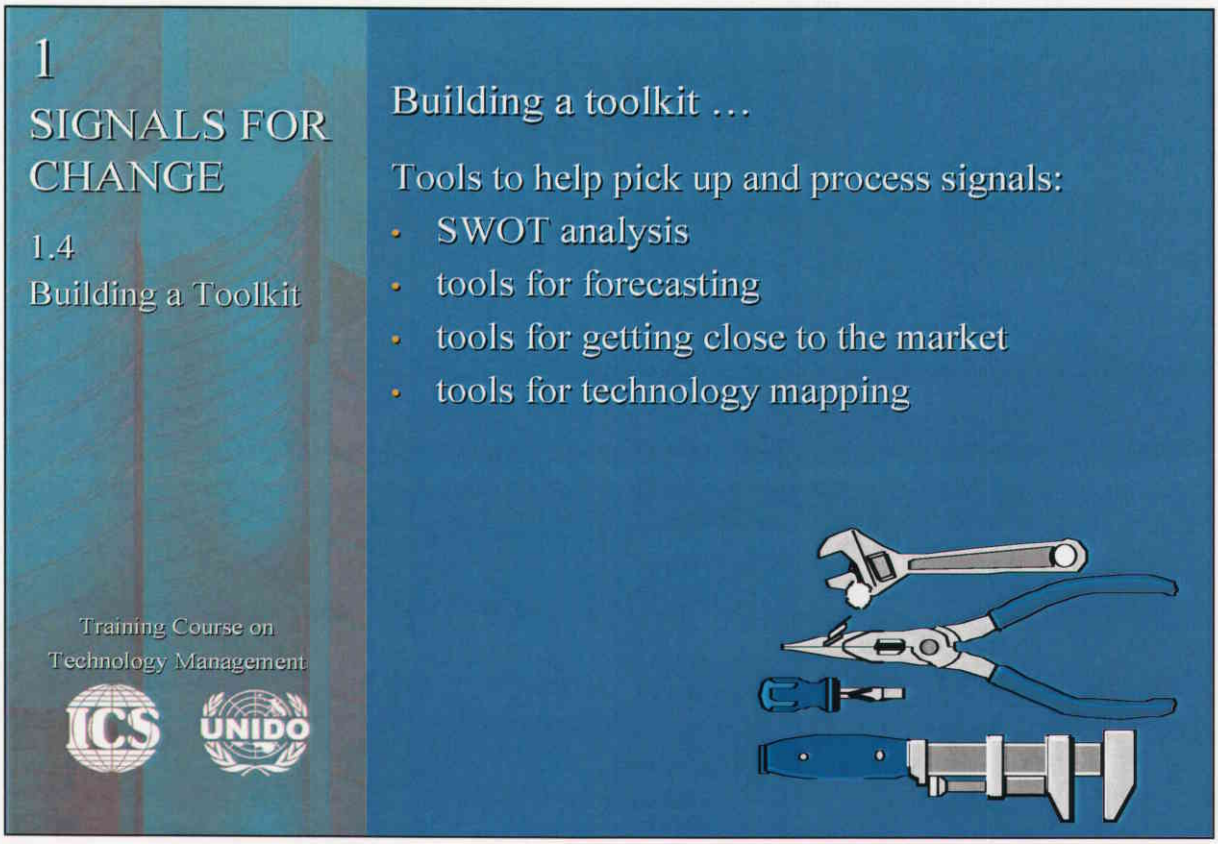
This raises a whole new set of management questions around the management of external relationships within development networks and with sources of technology transfer.



So far we have looked only at the present-day environment and seen the rich set of factors which have an influence and which we ignore at our peril. If we can map these they will help us recognize opportunities and minimize threats.

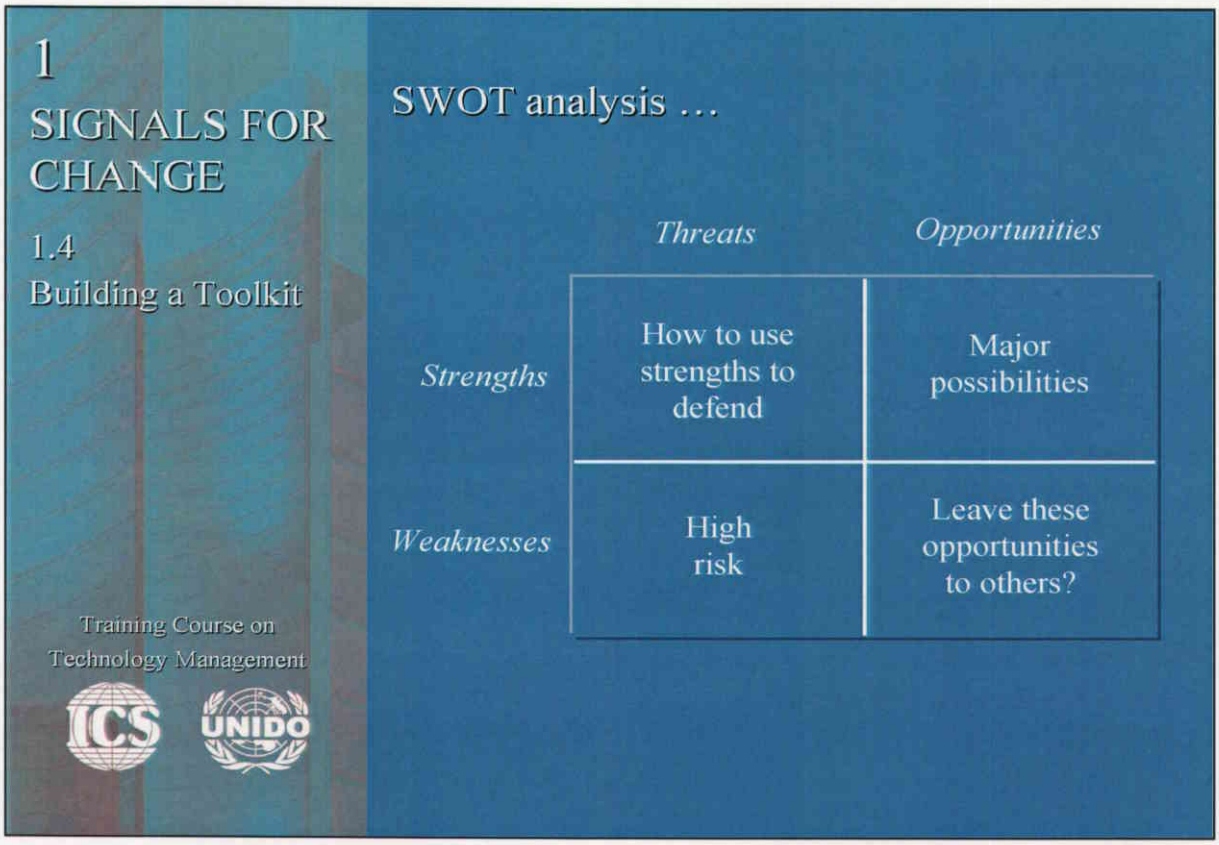
But we also need to recognize that the pace of change is increasing and we need to look to the future – try to get a sense of what is around the corner. To use a military analogy, the enemy planes are flying lower and faster so, not only do we need radar, we also need to increase our early warning systems even if they can only pick up relatively-weak signals.

This raises the question of forecasting, using formal tools and techniques to make some informed assessments of the future. There are many tools for doing this, ranging from simple extrapolation of existing trends through to sophisticated mathematical and computer-based simulations. That this is important is illustrated by the case of Shell, which used a technique known as scenario planning to explore potential futures for the oil industry. Although hypothetical, they looked at the possibilities of a world in which oil prices fell dramatically, and what they would do in this world. As a result, when oil prices did actually fall they were in a much stronger position than most of the other oil industry players.



Faced with these current and around-the-corner challenges we clearly need to get information early enough and in the right form to respond. This next section looks at a few of the many different tools and techniques which can be used to help this process.

There are many different tools and techniques to help map the environment; which one you choose will depend on what works for you. First we will look at an overview/mapping technique, the SWOT analysis, and then go on to consider briefly some specific tools and techniques which are widely used.



A simple structured tool for mapping the signals relevant to technological change is the SWOT analysis – SWOT stands for Strengths, Weaknesses, Threats and Opportunities.

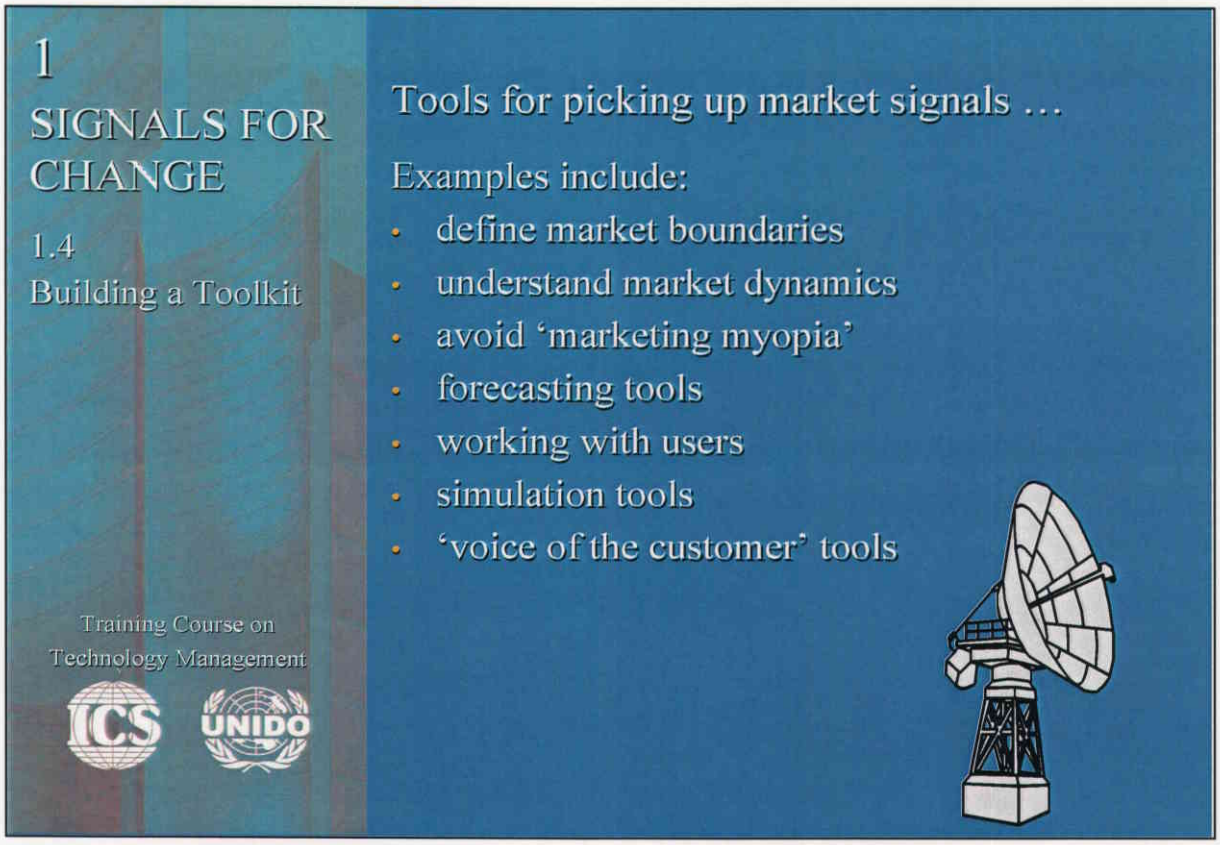
Step 1 is to ask the question 'What are the key threats and opportunities in our current environment?' These can be simply listed, or they can be clustered around themes; for example, a common set of clusters is represented by the acronym 'PEST' – Political, Economic, Social and Technological factors. For example, a small metalworking firm in Italy might cite the emerging European single currency, the problem of increasing competition from former Eastern European states, the difficulties of obtaining skilled labour, the emergence of substitute materials and the high cost of borrowing as important factors under the 'threats' heading. Equally they might list the new market opportunities in North Africa, the buoyant demand for bathroom fittings in China, the emergence of cheaper and higher quality surface finishing processes and low labour costs under the 'opportunities' heading.

Step 1 can be extended into the future by considering how these factors are likely to develop and change over the next 5 and 10 years There is no set way of capturing the key threats and opportunities but it is clearly valuable to build up the picture with different people to take advantage of different perspectives. Equally, the level of factual information may be limited at first, but the exercise can be repeated around a more focussed set of critical issues using more detailed, or even specially-commissioned, information.

Step 2 is to ask a different set of questions, concerned with the perceived strengths and weaknesses of the enterprise. These could be its technological capability, its work force, its location, its specialist or preferred access to markets, etc., and the contribution could be positive or negative.

Step 3 is to then look systematically at the four cells in the matrix formed by this information. In the areas of high opportunity in the external market and high perceived strengths there should be real possibilities for business growth and development. Equally in the cell concerned with major threats and where the firm is perceived to be weak, there is urgent concern for remedial action.

In each step the issue is less about getting a factually-accurate picture than about promoting discussion, debate and awareness raising about the key issues to be confronted. This helps simultaneously build a useful map of the external world and how it affects the firm, and also identifies where the high priority issues for change lie. This helps generate useful signals for the next stage in the technology management process. Beyond this overview map there is clearly a need to use different tools to obtain more specific information, to help look in more detail at key issues raised by the SWOT process.



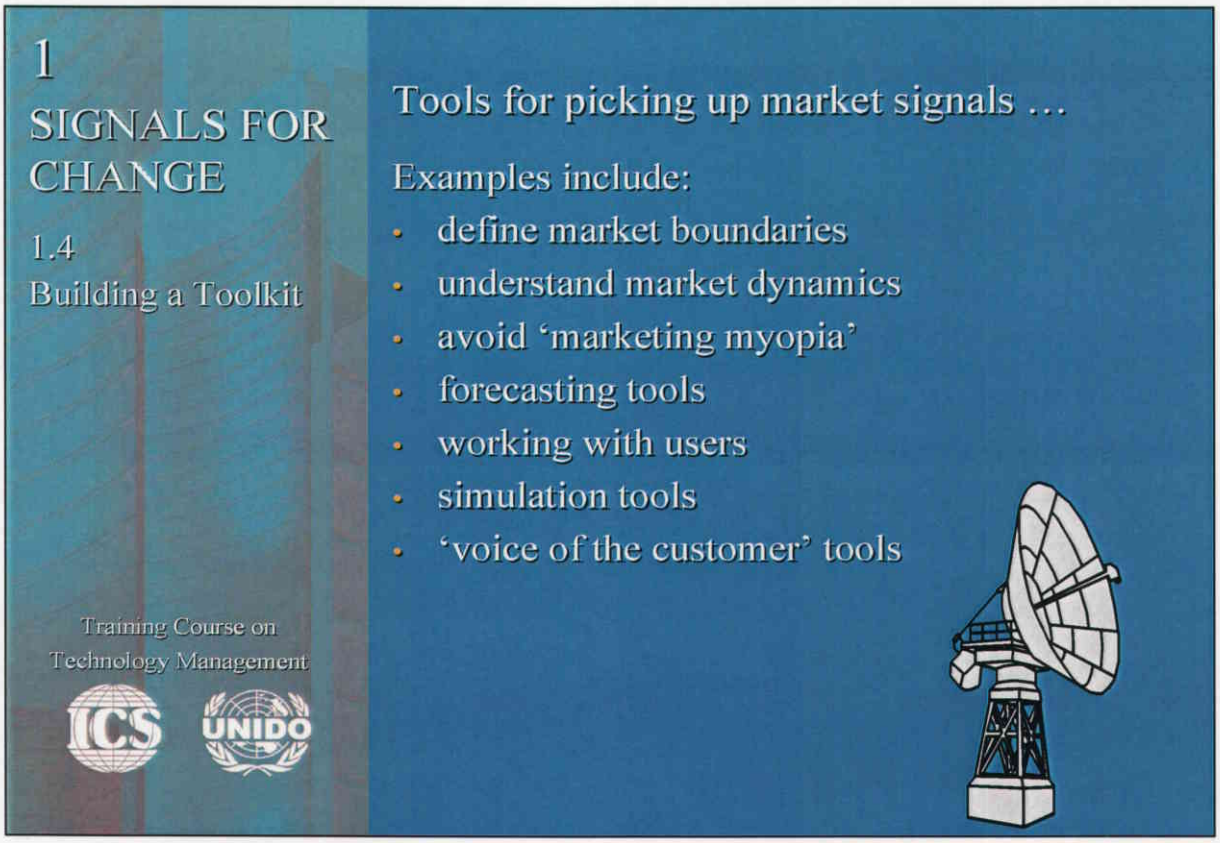
A first step is simply defining the boundaries of the marketplace. This is partly a consequence of having a clear business strategy – what business (and hence which markets) are we in? But it also relates to knowing where new opportunities in similar markets might lie.

Closely linked to the above is understanding where potential markets may arise as a consequence of various kinds of change. For example, the cellular phone business has moved from a specialist, high-price business market into the general marketplace as a result of both technological and cultural change. Similarly, low-cholesterol and other healthy foods are increasingly becoming relevant to a large segment of the population as a result of changing social attitudes and education. Building up such understanding of the changing marketplace requires various forms of communication and interaction, from monitoring through to customer panels and surveys.

Failure to appreciate the changing dynamics of the marketplace can lead to serious difficulties – a condition which Theodore Levitt characterized as 'marketing myopia' in a classic article. His argument was that companies often took too narrow a view of their marketing because they conceived it in terms of the products they offered, not in terms of the underlying pattern of user needs. The case of the US railroads which saw themselves as the ultimate in transportation and failed to respond to the challenge of the motor car is typical of this problem.

A wide range of techniques are available for trying to understand the likely dynamics of new markets, running from simple extrapolation of current trends through to complex techniques for handling discontinuous change, such as Delphi panels and scenario writing.

Market forecasting needs to move beyond sales-related information to include other features which will influence the potential market: for example, demographic, technological, political and environmental issues. For example, the present concern for environmentally-friendly 'green' products is likely to increase and will be shaped by a variety of these factors.



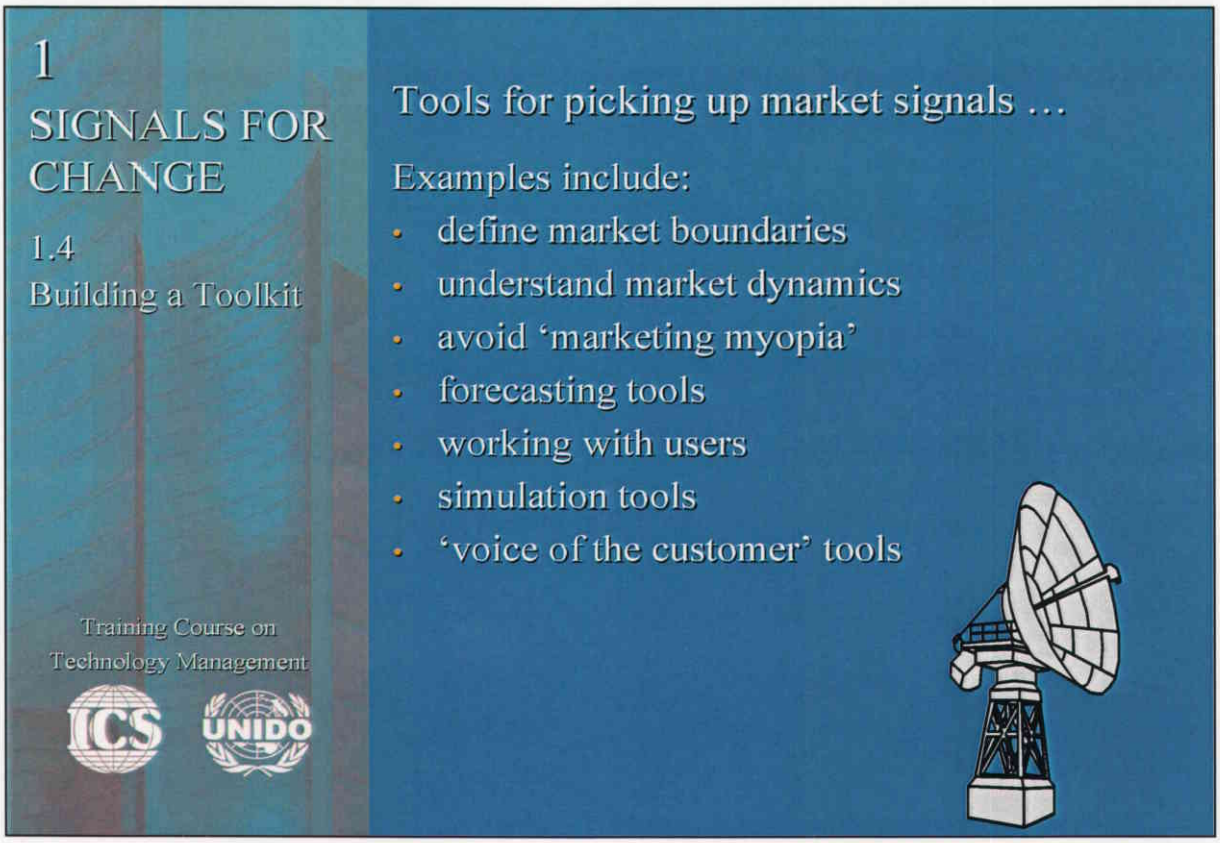
Understand market dynamics by:

- Working with users. An important routine is to involve customers in providing information about the kinds of products and services which they require. This can be done through regular surveys, through customer panels or through active involvement in product development.

- Using simulation tools, especially computer-aided design, to provide a powerful extra dimension to this process, offering users the chance to try out different product design options and work with designers. Work in the medical instruments industry suggests that in some cases customers may be the most important source of ideas for new products; this 'customer active paradigm' implies the development of formal mechanisms for working closely with customers to develop and modify product ideas.

- Continuing interaction. Successful product innovation depends on maintaining a strong user perspective over the development period, which argues for mechanisms which emphasize continuing interaction rather than a "one-of" information gathering exercise. Equally, working closely with customers over a sustained period of time helps put the product developer "in the user's shoes" and understand requirements at a more basic level.

- Communicating user perspectives into the development organization. An important set of routines is concerned with making sure that the user perspective is communicated to all those different functions and disciplines within the organization and not simply retained as marketing information. Amongst recipes for achieving this are to rotate staff so that they spend some time out working with and listening to customers. An example of this occurred in the development of the Lexus luxury car by Toyota. In trying to enter a new market, the US luxury sedan business, Toyota sent several development engineers to live the lifestyle of typical customers for that kind of car, so as to understand their requirements and preferences from an informed viewpoint.



An increasing number of tools and structured frameworks are now available for trying to identify, clarify, articulate and communicate 'the voice of the customer' throughout the development organization. Based on the principles of quality function deployment (QFD) these tools usually take as their starting point the customer needs as expressed in the customer's own words or images, and gradually and systematically decompose them into tasks for the various elements within the development organization.

The concept was originally developed by Mitsubishi in the Kobe shipyards back in 1972, and is widely used in Japan, though far less so in Western firms. The idea is to create a specific link between the attributes which customers want and the various parameters involved in design. From this specific contributing actions and responsibilities of various functions can be identified. The structure is organized into what is often termed 'the house of quality', which is built up in the following fashion:

1. establish critical customer attributes and measure or rank their importance – for example, they may be interested in things like 'looks', 'warm colours', 'weight', etc. These form the rows of the central matrix in the 'house'.

2. establish the critical design parameters which affect the product performance, and use these to form the columns in the matrix.

3. relate these to the customer attributes by filling in the cells of the matrix

4. compare customer perceptions of the company's product and its principal competitors

5. explore the interaction between different design parameters – what effect does change in one have on another? This information forms the roof of the house, with the two diagonals creating a matrix in which the interrelationships can be explored.

The power of QFD is less in the data representation than in its role as a common structure over which discussion and debate between different functions can take place. It provides a common language and a systematic mechanism for exploring and resolving many of the typical issues.

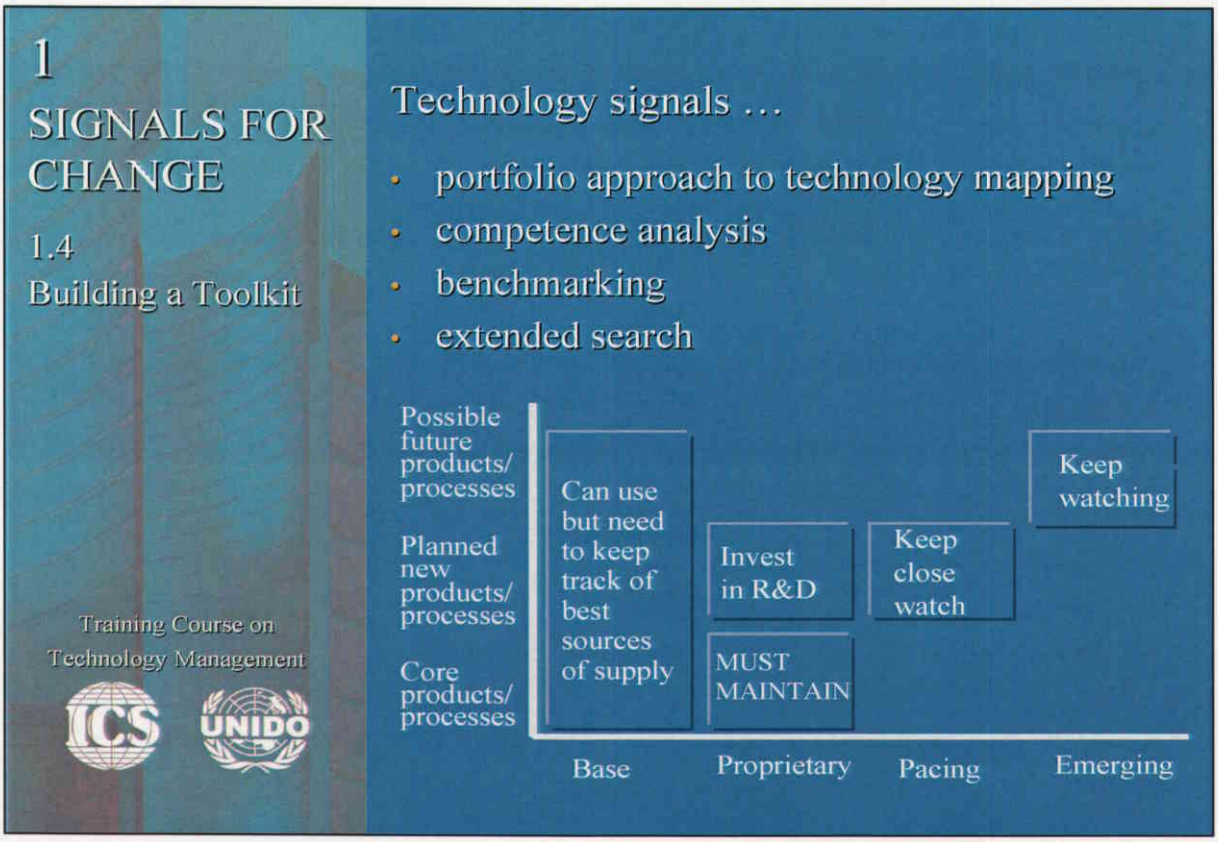
One useful tool for looking at potential new technologies is to map them on to a simple portfolio model. Typically we can classify new technologies into groups such as:

- basic or generic technologies – widely available, often not protected by patent and hard to defend as a source of strategic advantage

- proprietary technologies – those which the company owns and may have control over, via patents or other protection, or may have specialist knowledge or equipment which would make it hard for others to enter

- pacing technologies – the new set of technologies which are now making the running in defining the rules of the game in the marketplace, but may not yet be proprietary or generic. These might include things like the Internet and other communications tools today, and they need to be watched and looked at carefully since they could become sources of strategic advantage for someone.

- emerging technologies – those which are still a long way from commercial exploitation but which may represent a major force if they come to fruition. For example, current work on 'nanotechnology' – building machines and products on very small scale – might become a critical field in the next decade once the technological and market uncertainties become resolved. Technologies of this sort need watching and exploring as they become more significant. We can map these on to a simple portfolio and ask ourselves the extent to which they support or affect our current and likely future business.

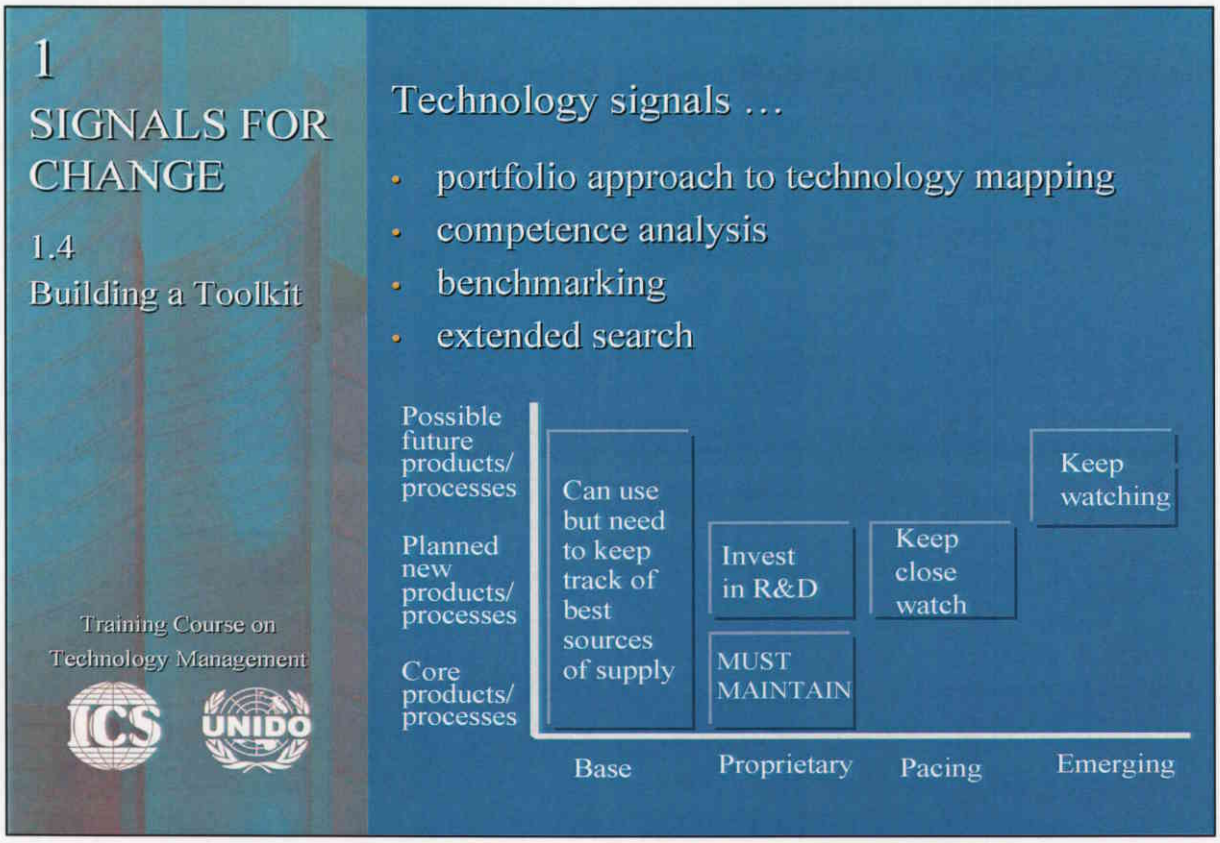


Various techniques exist for exploring technological futures, ranging from simple extrapolation of performance parameters and rates of development to complex, nonlinear techniques. Some, like Delphi panels and scenarios, are similar to market forecasting techniques, whilst others are more closely aligned to technological development models. For a good review of technological forecasting models and their applicability, see (Whiston, T, The uses and abuses of forecasting).

One of the most useful approaches is that of S-curve tracking. This is based on the theory that most technologies go through a life cycle, both in terms of their development and maturity and also in terms of the extent to which they are adopted. The potential of this method is that if you can identify when a particular technology is coming to the end of its life cycle, and a new S-curve is beginning to take off associated with its replacement, you are in a stronger position to exploit this. This theme is developed extensively and with good examples in Richard Foster's book 'Innovation - the attacker's advantage'.

Another mechanism for mapping what is going on technologically, and who is doing it, involves various forms of 'competence analysis' These are techniques, many of them based on searching patent literature and databases, which are designed to identify who is active in which areas.

Good discussion of these rather more advanced tools can be found in Keith Pavitts' work - for example, "Key characteristics of the large innovating firm", in the British Journal of Management (1991). Simpler versions of the approach can be done using a mapping approach, trying to classify which technologies a competitor is competent in using and where they are being, or might be, deployed.



One tool of particular relevance here is that of 'competitive benchmarking'. In this process, firms select examples of notional or actual 'best practice' and then compare their performance with this. Benchmarks can be constructed along several dimensions of performance – quality, productivity, flexibility, customer service, etc. – and comparisons can be made with similar firms (in terms of size, sector and product/markets) or with different ones but which are noted for world-class performance along a key dimension. The underlying principle is one of auditing the strengths and weaknesses of the firm and identifying the directions for future development of competitive advantage.

Benchmarks have been developed and used in a number of areas; of particular interest has been their impact in quality (see below). One of the most influential benchmarking studies has been that in the automobile industry, where comparisons amongst some 70 assembly plants worldwide led to major strategic rethinking in the industry. This work is now being extended into the components supply chain.

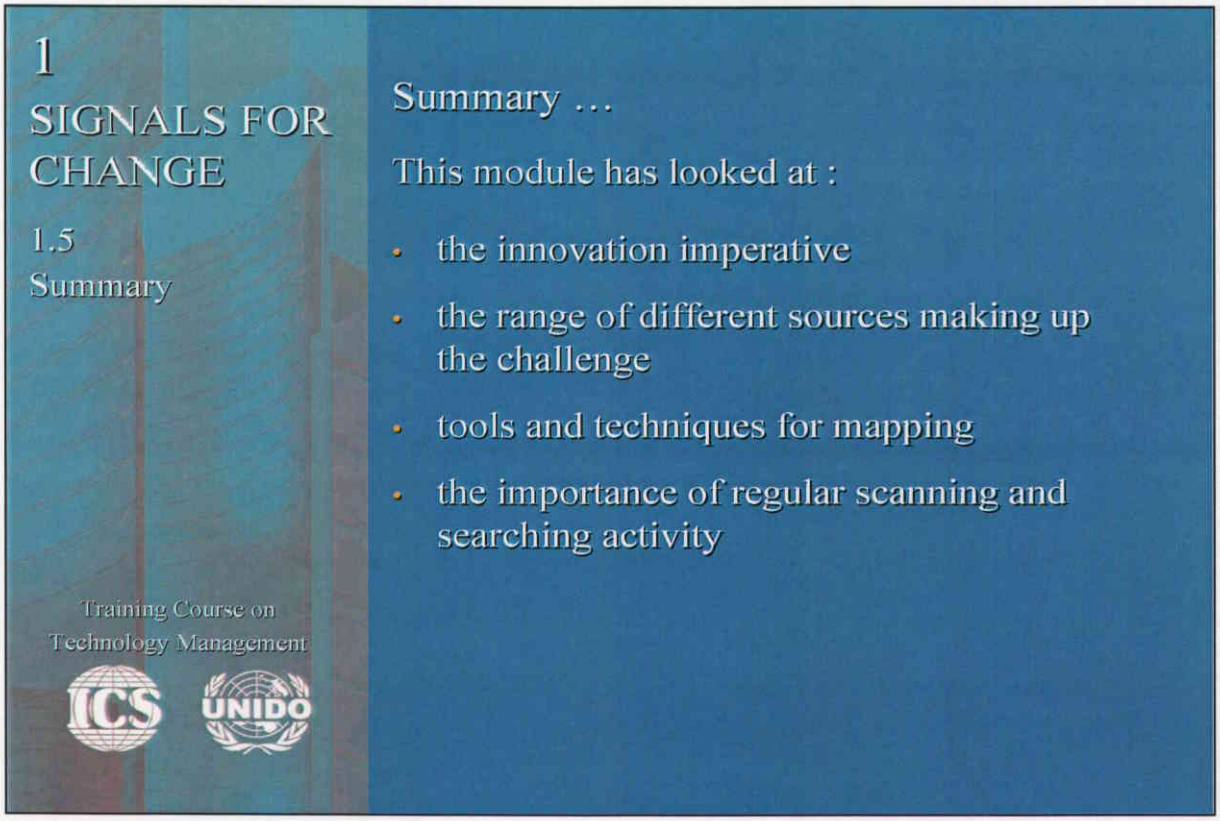
Benchmarking can be used in a variety of ways; typically there are four types of approach:

- activity level – where the comparison is made between how similar activities are carried out within the same organization; for example, who is the fastest at processing paperwork, who has the lowest stock levels, who is most flexible, and how?

- division level – where the comparison is made between different divisions in an organization doing the same basic processes

- interfirm – where the comparison is between different firms carrying out similar processes. The car industry example is an illustration of this.

- out-of-industry benchmarking – where a similar process is carried out in different sectors and where they may be opportunities for learning. For example, South-West Airlines became one of the most effective operators in the USA by reducing its turnaround times at airport terminals. It obtained many of the insights for this from studying the process of pit stops in motor racing. Similarly the Karolinska Hospital in Stockholm dramatically reduced patient waiting times by studying production flow techniques from manufacturing.



It is important to recognize that many new opportunities lie outside the normal sphere of activity of a particular firm. The cases of the ice industry and others which we looked at earlier is a reminder of what happens if we fail to scan beyond the boundaries of the 'normal' environment. A number of techniques exist for trying to stretch the scanning process, including benchmarking out of industry. Other examples include the idea of 'reverse engineering' – taking someone else's product to pieces in order to discover what new ideas are being built in, and attending demonstration visits covering new and different technologies.

Searching the environment for signals about threats and opportunities is not the end of the process but just the beginning. In order for it to make a difference, this activity needs to become part of the way of life in the firm. There is a need to develop what might be called a 'technological intelligence network' of sources and mechanisms through which the firm can keep on tracking its environment and picking up changes which might be of significance.

Research has consistently shown that those organizations which adopt an active as opposed to a parochial approach to seeking out such links are more successful innovators. Possible sources with which links can be made include suppliers, universities, research/technology institutions, other users and producers, trade associations, international bodies (e.g. for standards), etc. The principle behind this is to multiply the range of channels along which technological intelligence can flow; this principle also suggests that different kinds of inputs are important, for example, scanning journals, visiting exhibitions, attending conferences, etc. There is also research to suggest that encouraging the development of an 'invisible college' of contacts between technologists outside the firm is an important source of ideas.

This module has looked at the importance of scanning the environment for signals which can help shape and focus effective technological change. In particular, we have looked at:

- the innovation imperative
- the range of different sources making up the challenge
- tools and techniques for mapping
- the importance of regular scanning and searching activity

The next step is to decide which of these signals to respond to, and the form that response should take. This forms the theme of the next module.

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