OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

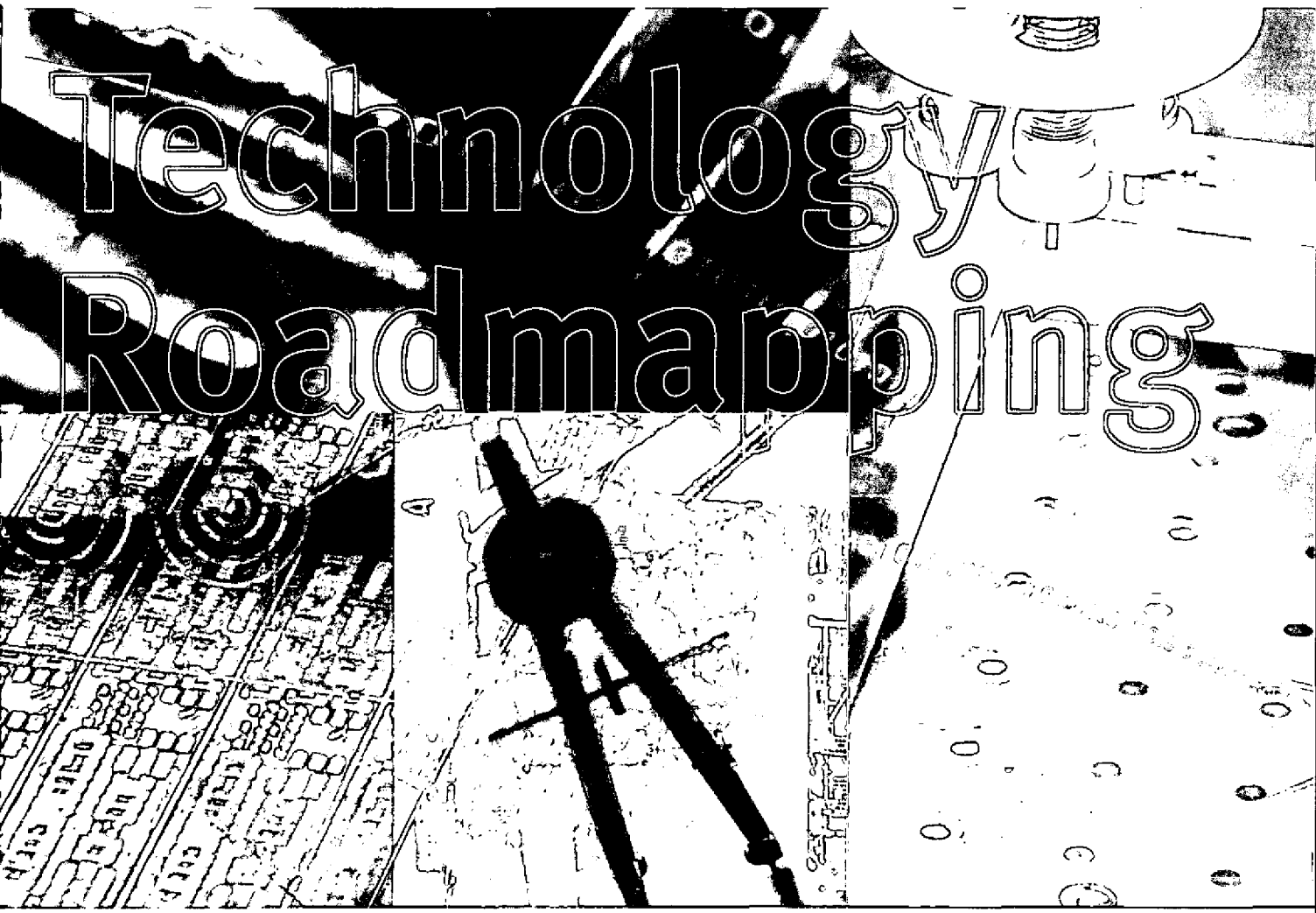
FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



Technology Roadmapping

for Developing Countries

Concept Paper

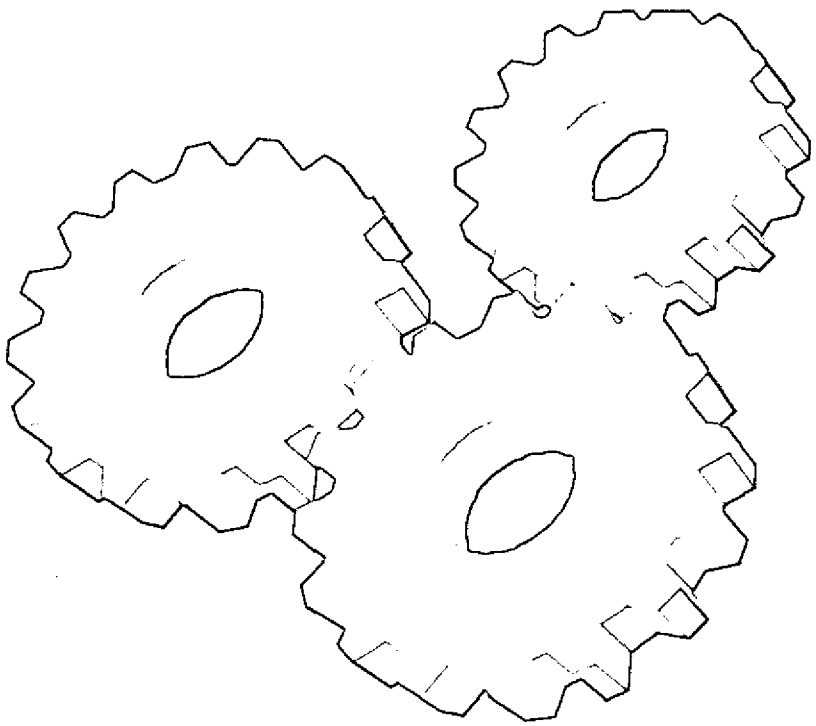
UNIDO
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Roadmapping in Developing Countries

United Nations Industrial Development Organization

Concept Paper

Author: Professor Anthony Clayton, University of the West Indies



EXECUTIVE SUMMARY

Individuals, firms and governments have a common interest in trying to get a more accurate sense of the future, either to improve their chances of making a successful investment, or to reduce the risk of making a loss. The main difference between rich countries and poor countries, in this regard, is that the cost of a policy failure in a rich country is usually in terms of the opportunity cost; the loss of the wealth that might have otherwise been generated. The cost of a policy failure in a poor country, however, is usually measured in terms of additional years of poverty and human misery. Thus the poor and developing countries have a greater need to prepare for the future, but most of them have just a small fraction of the capacity (in terms of the skills, knowledge base, access to information networks and so on) that rich countries have available to deploy on such exercises.

It is very important, therefore, to identify relatively straightforward, cost-effective procedures that organizations in relatively poor and developing countries can use to identify likely future changes, map out their options and make good strategic decisions. There are now a number of cost-effective, strategic future-oriented planning tools designed to assist organizations in developing countries to implement these processes. One of the most effective of these new planning tools is the **technology roadmap**, which is the subject of this report.

This report has three sections, as follows:

- The first section provides a general introduction to dynamic planning methods, with a particular focus on technology roadmapping.
- The second section reviews some of the issues involved in making and using technology roadmaps in developing countries.
- The third section reviews some recent case studies and examples from developing countries.

CONTENTS

Further reading

This document forms part of a series of papers published by UNIDO. Related documents include:

- UNIDO Technology Foresight Manual Volume 1: Organization and Methods
- UNIDO Technology Foresight Manual Volume 2: Technology Foresight in Action

Acknowledgements

I would like to acknowledge the advice and support of the project team at the United Nations Industrial Development Organization. The project idea was launched by Ms. Dan Liang, Director Invesment Promotion and Technology Branch, the project officer was Emilio Vento, and the collobarating team members were Toshiyuki Miyake, Pauline Alnaher, Claudia Kaufmann and Julien Daligault .

I would also like to acknowledge the vital intellectual contribution of Dr Walter Wehrmeyer and Dr Jonathan Chenoweth of the University of Surrey, and Professor Robin Williams of the University of Edinburgh. Some of the material cited here is drawn from earlier joint publications.

Any errors and omissions are the sole responsibility of the author.

Part 1

Introduction

1.1 Planning for the future

Most decisions are taken on the basis of a set of implicit assumptions about the future. Anyone depositing funds with a bank assumes that they will be able to withdraw their capital again when it is required. An investor funds a new business venture because they anticipate profits. Farmers set some seed aside in order to plant again next season. People of working age save money in order to have an income when they are too old to work. Assumptions such as these are both rational and functional; few decisions can be made without assuming that there will be a significant degree of stability and continuity. It is also true, however, that sometimes these assumptions prove to be incorrect; banks collapse, business ventures fail, droughts destroy crops, and people die before they retire.

One approach to this problem is to assess the balance between risk and reward, or cost and benefit, involved in each of these decisions. For example, leaving money on deposit with a respectable bank is usually low risk, but may only make modest returns; investing money in a speculative business venture is usually high risk, but the rewards may be commensurately large. The cost (in terms of foregone consumption) incurred when money is put into a pension plan is outweighed by the benefit of having an income in old age. Many of these outcomes depend, in turn, on the assumption that institutions will behave in a predictable manner; for example, that respectable banks will continue to invest prudently, mainly in solid assets and well-managed companies, and will not suddenly risk all their capital in highly leveraged, exposed positions in futures markets. This is also a reasonable assumption, but it too has failed on occasion.

Most future outcomes depend, in part, on the decisions made by other people, so the assessment of risk and reward often involves trying to predict these decisions. For example, a farmer might decide to give over more land to a particular crop, on the basis of good prices in the market, only to find at the next harvest-time that many farmers have made the same decision; the market is now over-supplied, prices have fallen, and the crop must therefore be sold at a loss. So the farmer must try to assess the probability that other farmers will make the same decision. The other farmers, of course, are all making similar calculations, and investing accordingly, each hoping that they have invested against the trend.

Governments and firms have similar problems in this regard. They have to allocate limited resources, so they develop a set of priorities. These will, in general, allocate relatively generous or more consistent support to those measures that they believe will do most to improve their prospects or profits[1]. These beliefs depend, in turn, on certain assumptions about the future. Governments build new transport infrastructure, for example, because they believe that this will encourage business development and growth, and that the increased tax revenue will repay the investment. Firms build new manufacturing plant because they believe that the market for their products will continue to grow, and they want to be able to supply that market.

These assumptions can also prove to be

[1] This will change in a crisis, of course, as they then usually focus on survival.

incorrect. Some important factor might have been inadvertently overlooked, or there might be an unexpected development that changes the course of events. A government might have to decide, for example, whether to recruit more police, build new hospitals, or supply schools with computers. They might decide to prioritize their spending on the basis of the economic prosperity and development of the nation, conclude that the best investment is in education and supply the schools with computers, only to find that the more technologically-literate graduates are rapidly migrating to wealthier countries where they can earn higher salaries. A firm might decide to invest in upgrading its production facility in order to meet the increasingly exacting standards required by its main export market, only to find that a larger, better-resourced rival has just developed a more advanced product that immediately captures their market share.

Some of these outcomes are determined by events within the same sector, and these are usually seen as being the responsibility of the individual or entity involved. A firm that makes electronic switches, for example, has to keep abreast of developments with electronic switch technology if it is to stay in business. Some outcomes, however, are determined by extraneous events or wider processes of change, and these may be harder to anticipate. A small farmer in a developing country cannot be expected to keep abreast of complex trade negotiations, for example, even though the trade agreement that results may determine whether he can sell his crop next year.

Individuals, firms and governments therefore have a common interest in trying to get a more accurate sense of the future, either to improve their chances of making a successful investment, or to reduce the risk of making a loss. The problem, of course, is that the future for any given sector, nation or individual will be determined by an exceptionally complex combination of interacting variables, including demographic change, economic development, increasing competition, market liberalization, environmental impacts, political dynamics, scientific advance and technological innovation. This complexity makes it impossible to predict outcomes with any certainty. Thus the first requirement in planning for the future is to recognize that you cannot **plan** for the future; at least not in the sense which the design for an aircraft exactly specifies every single wire, bolt and rivet in that aircraft.

The dilemma, however, is that decisions still have to be made, capital invested, infrastructure built, children educated and adults trained. How should the capital be invested? What infrastructure should be built, where and on what scale? What skills should be taught? The lags inherent in all such decisions - it may take years for the investment to pay off, to build the infrastructure or to change the curriculum and hire new teachers - means that we are all, inescapably, in the business of trying to guess the shape of the future. Will the new factory make a profit? That depends on whether there will still be a demand for the product in five years time. Will the bridge be adequate for the traffic load? That depends on how many people will be using it in ten years from now. Are we teaching children skills that will be of diminishing impor-

tance - or the ones that they will need in their future careers? That depends on how the economy will restructure over the next twenty years.

Given that we cannot see into the future, the only solution is to try to improve the way in which we **think about** and **prepare** for the future (Postrel, 1998)[i]. Some of these improvements are relatively straightforward. If an organization consults more widely, it is more likely to be informed of potentially significant developments. If people are encouraged to state their opinions, weak assumptions are more likely to be challenged. If a firm undertakes periodic reviews of its market and competitive environment, it is more likely to detect the early signs of an emerging challenge. If a government develops robust building and planning controls, factoring in adaptive strategies for climate change, it is less likely that infrastructure will be sited in vulnerable areas. As these examples suggest, many of the changes are not technically difficult; they mostly involve a combination of better management and greater flexibility with some practical measures to improve information flow, reduce exposure to risk and increase resilience. As these examples also suggest, however, preparing for the future often involves developing new sources of information and advice, establishing where and when there is a need for change, building a consensus and mobilizing people and institutions around the new strategy. This means that strategies for change usually have to address issues such as institutional culture and local politics.

The main difference between rich countries and poor countries, in this regard, is that the cost of a policy failure in a rich country is usually in terms of the opportunity cost; the loss of the wealth that might have otherwise been generated. The cost of a policy failure in a poor country, however, is usually measured in terms of additional years of poverty and human misery. Thus the poor and developing countries have a greater need to prepare for the future, but most of them have just a small fraction of the capacity (in terms of the skills, knowledge base, access to information networks and so on) that rich countries have available to deploy on such exercises (Juma and Yee-Chong, 2005)[ii].

It is very important, therefore, to identify relatively straightforward, cost-effective procedures that organizations in relatively poor and developing countries can use to identify likely future changes, map out their options and make good strategic decisions. There are now a number of cost-effective, strategic future-oriented planning tools designed to assist organizations in developing countries to implement these processes. One of the most effective of these new planning tools is the **technology roadmap**, which is the subject of this report.

1.2 Introduction to technology roadmaps

A technology roadmap is a strategic planning tool, used by organizations to help them prepare for change, profit from opportunities and achieve their goals. It involves identifying market trends and needs for new products, then choosing the optimal technology needed to produce those products at the right price. The main benefit of technology roadmapping is that it inte-

grates market demand, customer needs, product development, technology management and corporate financial management into a single coherent plan, which helps to identify any weaknesses in technical capacity or gaps in the supply chain that will have to be addressed and clarifies the priorities for investment, research and development.

Technology roadmapping is one of a set of future-oriented strategic planning tools. There are a number of related tools, including technology planning, Delphi studies, foresighting and backcasting exercises, each of which has a different role, purpose, timescale and audience. These tools also vary in terms of their logistics, the financial cost and the kind of organizational commitment required.

It is easier to understand the purpose of a technology roadmap if it is compared to some of the other future-oriented strategic planning tools in the same toolbox. Table 1.1 shows some of the important variables and differences, including the time horizon, the typical user, and the organizational demands involved.

As Table 1.1 suggests, technology roadmapping exercises can be run by individual firms, replying mostly on internal resources. They are usually focused on the short to medium term, and are designed to give very practical guidance for immediate, high-priority business decisions. They are therefore becoming increasingly popular at the level of the individual firm or enterprises.

Time horizons

The time horizon is a particularly important variable. The choice of time horizon

Table 1.1: Foresight Tools

Foresight tool	Roadmapping	Delphi	Foresight/backcasting
Purpose	Identify key trends in market, clarify organizational goals, make technological and managerial choices to achieve preferred future	Review significant trends in relevant areas, identify most likely outcome, plus any associated threats and opportunities	Identify key drivers of change plus their interactions, identify 'known unknowns', assess impact of 'wild card' events, identify possible broad outcomes, backcast to present day, build robust strategy for managing change
Typical user	Individual firms	Industry associations	Large multinational corporations, governments
Typical time horizon (years)	1-10	5-20	10-50+
People involved	Experts plus decision-makers	Experts (different disciplines)	Experts plus stakeholders
Typical numbers	10-20	30 – 100+	20 - 50
Type of process	Assume 1 day introduction, 1 day run-time, continuous monitoring and implementation	Coordinated, iterative discussion, minimum 3 rounds, assume 3 months preparation, 3 months run-time	Facilitated discussion, present 'what-if' challenges and counterfactuals, assume 3 months preparation, 2 days run-time. Large national exercise 1 year preparation, 2 years run-time.
Role of foresight expert	Introduce concept	Coordinate, derive scenarios	Facilitate, challenge, manage process
Key challenges	Getting the experts and decision-makers to engage, overcoming organizational inertia	Identifying and recruiting the right panels, managing the process	Identifying and recruiting the key stakeholders, facilitating the process, maintaining momentum

will be determined by factors such as:

- **Organizational priorities**. A firm that has to make important investment decisions in the next quarter cannot wait for the results of a two-year national foresight exercise.

- **The sector.** Firms working in sectors with long lead times, such as the oil and gas industry, have to make projections of market demand, technological improvement and political change over decades ahead. These firms are more likely to engage in a foresight exercise. Firms working in sectors with short lead times, such as consumer electronics, are more likely to use a technology roadmap. This issue is addressed in more detail in the section on sectoral dynamics (see below).

Linking management to strategy

So technology roadmapping can be located on a continuum which runs from the normal process of day-to-day business planning and decision-making to the very long-range scenario-building exercises involved in the kind of foresight exercises run by governments and large multinational corporations. Technology roadmaps have a particularly important role, therefore, in bridging between the long-term vision and the day-to-day management decisions involved in running a business, as can be seen in the following examples:

Technology planning is conventional forward business planning, based on an analysis of current needs and a projection of demand.

Example: Competing soda bottlers in Jamaica noted that bottling in glass incurred several cost penalties (in additional weight, higher transport costs and the cost of returning and re-using the bottles), while new entrants to the market used disposable PET bottles. As a result of increasing competition, differential cost structure and growth in export and domestic markets, more firms switched to PET bottles.

Technology foresight is a long-range scenario-planning exercise, typically looking 15 - 50 years ahead.

Example: Several large multinational tobacco companies, including BAT, have noted the increasingly strong social and legislative pressures against smoking in the North American and European markets; strategies include developing new tobacco products, focusing on emerging markets and diversifying out of tobacco.

Example: Royal Dutch Shell, a large multinational petrochemical corporation, developed energy scenarios to 2050. This showed a transition beyond oil, initially to liquefied natural gas (LNG) then to hydrogen as fuel. The corporation's strategy involved investing in LNG train technology and also in hydrogen technology; the latter included a cooperative project with the Government of Iceland which saw hydrogen technology as a route to exporting its geothermal power.

Technology roadmaps, which have been widely used since the 1990's, form a bridge between conventional business planning and foresight-based scenario planning. There are three core ele-

ments in a technology roadmap, as follows:

- Market demand, which will determine which strategies and technologies will succeed and which will fail.
- The organization, which needs to antici pate and meet market demand in order to achieve its goals and ambitions.
- The technologies that the organization will use to produce the products and services that the market demands. This includes current technologies, technolo- gies that will soon become available, and technologies that the organization may develop specifically in order to meet market demand and realize its ambitions.

Example: Airbus and Boeing, two large manufacturers of civil aircraft adopted different strategies, based on competing assessments of the future market. Airbus thought that the hub-and-spoke model would continue to dominate the long-haul segment of the market, concluded that the main limiting factor would be hub capacity, and developed a new, very large civil aircraft - the A380 - to increase passenger through-put with the same number of landing slots. Boeing thought that point-to-point travel would replace the hub-and-spoke model, and developed the 7E7 Dreamliner, a smaller aircraft, to fill the projected market niche. As of the date of this report, more advance orders have been received for the A380, indicating that the market is more inclined to believe that the hub-and-spoke model will continue to dominate.

All three core elements of the roadmap are dynamic.

- Market demand changes over time as a result of demographic change, rising per capita levels of income and technological change.
- Organizations operate in a constantly evolving competitive environment, as new competitors emerge, new products are launched, unsuccessful businesses fail and their market share is seized by others.
- The pace of innovation, technological development and change continues to accelerate across a broad front, as a result of dramatic progress in fundamental science, engineering applications and new product development. This is particularly rapid in 'hot' areas such as bioscience, informatics and nanotechnology, where both the fundamental science and the engineering applications are evolving simultaneously, changing basic concepts and perceptions as to what is possible[iii].

The Columbia disaster could spur faster development of a radically different approach to reaching outer space: the space elevator. The space-elevator concept has advanced dramatically in recent years along with leaps forward in the design of carbon nanotubes. Using the lightweight, strong carbon material, it's feasible to talk of building a meter-wide 'ribbon' that would start on a mobile ocean platform at the equator, west of Ecuador, and extend 62,000 miles up into space. An elevator

could be attached to this ribbon to ferry materials such as satellites and replacement parts for space stations - or even people- up into space. The project could become a reality as soon as 15 years from now.

The key to the concept's feasibility lies in the material that will be used to construct the ribbon between the Earth and outer space. Nanotubes are essentially sheets of graphite -- a lattice of carbon -- seamlessly rolled into long tubes that are mere nanometers in diameter. These are 100 times as strong as steel, but much lighter.

"Technically it's feasible," said Robert Cassanova, director of the NASA Institute for Advanced Concepts. "There's nothing wrong with the physics." David Raitt, senior technology transfer officer for the European Space Agency, believes the question is not whether to build a space elevator, but only how long it will take. Bradley Edwards, chief technology officer of Seattle-based HighLift Systems, said that a space elevator could transport materials into the cosmos for about $100 a kilogram. He estimated that sending materials on a shuttle costs $10,000 to $40,000 per kilogram. That could make it affordable, for example, to build huge solar-energy gatherers and send them into space on the elevator. "African countries could send up a solar satellite, and use that energy to build wells, and pump water and develop their economies," Edwards said. Bill Rever, senior manager of business development for BP Solar, has been in contact with Edwards and said the space-elevator concept is "very promising."

Abridged from S Kettman. To the Moon in a Space Elevator? Wired News February 4th 2003[iv]

The co-evolution of markets, organizations, products and technologies creates a complex and dynamic environment, which is why technology roadmapping is always a collaborative exercise. It requires cross-departmental cooperation and inputs from a small group of key experts and decision-makers, who share their knowledge of the market, the competitive environment, the changing technological options, and the structure and culture of the organization in order to develop a robust business strategy. This then determines investment priorities, guides research and development, and forms the basis for corporate planning, including recruitment and training programmes.

Of course, an organization is more likely to be successful if it has a clear, shared vision, ambitious but realizable goals, strong technical and managerial capacity, and a shrewd understanding of both the market and its competitive environment. A technology roadmapping exercise is not a substitute for these qualities, its role is to augment these qualities by helping a firm to clarify its goals, focus its knowledge of the market and then make informed, strategic choices as to which technologies will help it to meet the needs of both the market and the organization itself in the most efficient, effective and profitable manner.

The technology roadmap that results from the roadmapping exercise is a document that sets out the market parameters, the firm's goals and performance objectives, and the alternative technological routes (or 'pathways')

that will allow the firm to achieve its goals by meeting market demand.

Technology roadmaps have, to date, mostly been used by large corporations working in areas of rapid market change and technological advance, such as information and communication technologies. Firms such as Motorola, Philips and Lucent, for example, use technology roadmaps to help them think systematically about product development trajectories and changing consumer preferences (Williard and McClees (1987) have documented the process used by Motorola)[v]. This helps them to focus their corporate strategy and develop the kind of products that they think that the market will demand. It also helps them to close down lines of research or sell off product lines that don't fit into the corporate strategy, and reallocate those resources into the development of the core products that are vital to the company's future.

Technology roadmaps have also been used by industry associations, where a number of companies working in the same sector come together to run a joint roadmapping exercise. The UK's Institute of Grocery Distribution, for example, managed a foresight and roadmapping exercise in 2002-3 to 'identify food production issues that may affect the food chain and help to facilitate a more considered introduction of new technologies in the future' on behalf of its members, which included the UK's major retailers as well as food and agricultural research institutes.[vi]

Finally, technology roadmaps have been assembled in operations coordinated by government agencies. Industry Canada, for example, which is the government department concerned with industrial development, trade and investment, has supported technology roadmapping exercises for important sectors of Canadian industry.

There is, therefore, reasonably extensive experience in the development and use of technology roadmaps, and many accessible sources of information about different models and experiences. Sandia, for example, explain the principles[vii], Kostoff and Schaller (2001) review and classify roadmapping strategies[viii], Porter (2000) examines the business applications[ix], Groenveld (1997) explains how roadmapping integrates business and technology management[x], the Management of Accelerated Technology Innovation group has identified current best practice in the field[xi], and Kappel (2001) has identified the factors needed for success[xii].

Sectoral dynamics

The planning horizon and the associated investment and capital renewal cycle vary markedly between different sectors of industry. Clayton, Spinardi and Williams (1999) point out, for example, that a specialist electronic engineering firm, operating in a dynamic product market, might change its capital equipment base over some four years[xiii]. A distillery, in contrast, might use the same copper pot wash still for twenty-five years. This difference relates partly to the nature of the product market, in particular the maturity and stability of the product, the dynamics of competition, and to the capital cost of the

equipment. In capital-intensive operations, particularly where much of the capital is locked up in large and relatively inflexible plant, the huge cost of plant replacement means that the pace of change is more likely to be determined by the length of the capital renewal cycle.

Most primary resource-extraction industries, such as mining, heavy industries such as iron and steel production, and the large-scale production end of the chemical sector, such as oil refineries, petrochemicals and the volume end of the fine chemicals sector have large plant and high fixed capital costs, which means that there is an inherent delay entailed in significant plant upgrades or in the construction of new plant. This in turn means that firms in these sectors have to operate with significant time-lags before any change in management strategy can be fully reflected in factors such as plant location or design, although there are still important differences between firms and sectors in batch size, technological inseparabilities and the level of fixed capital and the intensity of competition.

The key differences within this grouping are less related to sectoral boundaries (there is little difference, in practice, between petrochemicals and fine chemicals) than to the scale of production. The important distinction lies between smaller scale batch and larger-scale continuous process production. The latter is characterized by substantial levels of fixed capital investment design. The configuration of plant is also relatively fixed, and expensive to change except during periodic plant replacements (technological inseparability). Batch production, in contrast, may involve more flexible combinations of devices (which are often generic). This allows greater flexibility in changing processes.

All of these factors are reflected in differences in the speed at which technological change can be implemented, since it is often cheaper to implement changes, such as increasing efficiency or improving environmental performance, when capital equipment is being renewed, rather than trying to retrofit existing fixed plant.
These factors relate in turn to the planning horizon adopted by firms. The enormous investment in fixed plant required in the refinery sector, for example, obliges firms to plan over 10 years ahead or more. The more sophisticated of those firms with long-term planning horizons now routinely incorporate political and environmental factors (in the form of anticipated regulatory change) as well as market demand, the competitive environment and technological change in their long-term planning, particularly in regard to factors in their product markets and future compliance requirements which may affect their ability to operate. In contrast, many small firms, especially those working in mature markets with relatively stable products, operate with a planning horizon measured in months.

As this suggests, size is also an important differentiating factor; but this too varies by sector. Smaller, younger firms in areas such as mobile communications and software development can be more agile and flexible than larger firms, and do not have the same commitment to maintaining legacy technologies. Some of them are therefore more willing to invest in the develop-

ment of innovative solutions than their larger rivals. As a general rule, however, smaller firms tend to be less sophisticated and have little spare management capacity, which means that they are more likely to be reactive to external changes such as regulatory pressures and market forces. With shorter-term planning horizons, they tend to focus on immediately available solutions.

The competitiveness and dynamism of the market are also important factors in this regard. Firms operating in dynamic and rapidly-evolving markets have to devote considerable resources to market intelligence, to monitoring technological developments and to modeling future conditions. Firms that engage in long-term planning of their technologies and markets (especially in sectors like refining, where even maintenance has to fit within infrequent planned shut-downs) are obliged to carry out sophisticated economic and operational assessments of procedures, and processes are routinely subject to detailed advance planning and assessment. As a result, emerging priorities (such as resource efficiency or environmental concerns) can be built in to future solutions. However, long-term planning does not invariably mean that firms will adopt more radical solutions. In the refinery sector, for example, if a firm decides that improvements are needed in environmental standards before the next plant upgrading the result could be the implementation of known end-of-pipe solutions. However, this does depend partly on the expertise within the firm and the extent of its access to external knowledge networks.

The role of governance

This also highlights the role of government and regulatory authorities in influencing corporate decisions. Clayton, Spinardi and Williams (1999) found, for example, that business and industry could be encouraged to undertake longer-term research and commit to development of more efficient, competitive and cleaner processes and products if increasingly stringent regulations were signaled in advance and gradually applied over a long time frame (such as five to ten years). This approach had two clear benefits. One was that it made the future more predictable, and reduced the risk of over-investing in unnecessary technological changes. The other was that it allowed research and development programmes to be incorporated into normal commercial planning, which is particularly important in industries in which process changes require substantial and therefore infrequent replacements of fixed capital equipment. Some flexibility in the timeframe for implementing regulations can also help to reduce the risks for firms embarking on a search for as yet unproven opportunities for process improvement. This flexibility gives time and space for a more open-ended search for innovative process upgrades and product improvements, offsetting the tendency of many managers to reduce risk and avoid uncertainty by opting for tried and tested solutions. Subsidies and other measures to offset or share the costs of research and development have also proved helpful in some countries.

Commodity sectors

Firms involved in the production and export of agricultural or mineral com-

modities have to manage an additional, imposed cycle of demand, investment and prices. In the late 1990's, for example, many commodity prices were depressed by increases in supply. These increases in supply resulted from increases in capacity that were planned when commodity prices picked up in the early 1990's, but took some years to fully come on stream. This highlights an important feature of commodity markets; the inherent lags involved in increasing the production of most commodities typically impose a large, cyclical fluctuation on prices. It takes at least one growing cycle to increase crop production, and years to open a new mine, build a new ore processing plant or find, survey and develop a new oil field. High commodity prices encourage investment, but there are usually significant delays before these investments can generate results. Eventually, the investments will result in increased production, which will then bring prices back down. If demand has slowed or fallen in the meantime, of course, the market may then be oversupplied, which will depress prices further. A sustained period of low prices will deter investment, force inefficient producers out of the market, and lead to the closure or mothballing of some plant, thus reducing supply. This will tend to push up prices (especially if demand also picks up again), thus starting a new cycle. As a result, production levels for many commodities will track market prices, with a lag that - as Tustin (1952) and Bellany (1997) have pointed out effectively guarantees relatively large oscillations [xiv-xv].

There are therefore two relatively predictable underlying variables driving the market price of many commodities; the long-term trend decline associated with the introduction of new technology and structural change in the industry, and the commodity price cycle. There are also, however, more short-term and less predictable extraneous factors, some of which can superimpose sharp fluctuations on market prices. The explosion in the Gramercy alumina processing plant in the US on July 5th 1999, for example, temporarily removed capacity from the market and sharply reduced exports of bauxite from Jamaica over the following year. Similarly, an outbreak of civil unrest might force multinational corporations to shut down their production in the country concerned, or a producer cartel such as OPEC might decide to force up prices by reducing production. Natural events also shape markets; an unusually cold winter, for example, will increase demand for fuels. Alternatively, new environmental constraints might be imposed. Growing concerns about global warming, for example, might lead to government action to reduce carbon emissions, which would then impact on the price of hydrocarbon commodities.

Thus (pseudo) random shocks can be superimposed on the trend rate, which makes the task of managing the economies of countries that are overly dependent on commodity exports particularly difficult (Clayton, 2005)[xvi]. In the most extreme cases, where a country's foreign revenue derives largely from the sale of one commodity (Guinea, for example, derives some 85% of foreign revenue from exports of raw bauxite, while countries such as Libya and Iraq are largely dependent on exports of oil) the economy tends to works on a 'stop-go' basis, with general

business activity slowing markedly when the market price of the key commodity falls and foreign revenues decline.

The aluminium industry provides a recent example of several of the above effects. The former CEO of Alcan recently reviewed some of the factors shaping the world market:

"Despite all the ups and downs in the world economy, Western World aluminum consumption has continued to rise, increasing by about 25% - from about 20 million tonnes to 25.5 million tones between 1990 and 1997. That works out to a compound annual growth rate of 3.5% for aluminum consumption, versus growth of only 2.5% for world GDP over the same seven-year period. Looking ahead, current forecasts call for overall Western World consumption to rise from the current level of 25.5 million tonnes to 32 million tonnes by the year 2004. That would translate into compound annual growth of 3.3% for aluminum - exceeding the annual growth rate of 3% forecast for world GDP between now and 2004. So over the next seven years, we expect our industry to outstrip the global economy in terms of growth - just as it did over the past seven years. (But) those reasonably positive statistics.....don't tell the whole story of aluminum in the 1990s. Beginning in 1991, with Perestroika and the subsequent collapse of the old-style Soviet economy, massive shipments of Russian metal began pouring into the international aluminum market. Aluminum was the single Western industry most hard hit by the Soviet upheaval. Exports from Russia and other members of the Commonwealth of Independent States (CIS) zoomed from practically zero to a level of about 2.5 million tonnes - more than 10% of the market. Not surprisingly.....the sudden influx disrupted markets, resulting in a steep decline in prices as inventories increased. Specifically, from 1990 to 1993 average aluminum prices fell over 35% in real terms. Can you imagine if that sort of jolt occurred in your line of business - and at a time when much of the Western World was in recession?" [xvii]

Long pipelines

Finally, some sectors have to operate with extremely long product development times, with no guarantee of success, which also obliges them to plan relatively far into the future. The pharmaceutical industry is a good example. As Clayton, Young and Vermeylen (2005) point out, the financial commitments and associated risks are high, mainly because it is intrinsically expensive to maintain a long-term research programme, or to research across a broad front[2] [xviii]. A pharmaceutical company will typically start assessing approximately 10,000 molecules for every one that finally gets brought to market as a product, and success is not always guaranteed even at that stage. Parlange (1999) has pointed out that - as a result of the need to assess many possibilities for each viable product - a new drug takes, on average, 12 years and costs some $300 to $400 million to develop[xix], while the Tufts Centre for the Study of Drug Development estimate that it takes 10-15 years and on average $897m to bring a new drug to

[2] The revenue allocation structure of the pharmaceutical industry is quite unlike other sectors of industry. The 10 largest US-based companies, for example, spend about 20 per cent of their revenues on research and development, which is exceptionally high (although it is less than the 40 per cent that the same companies spend on administration and marketing). Tax rates are unusually low, however, sometimes not much above 15 per cent, resulting in profit margins being unusually high, in some cases approaching 30 per cent.

market[xx]. Other estimates indicate that the total cost from initial testing to first sales can now be as much as US$1.2bn (Murray-West, 2004)[xxi]. These assessments are supported by the IMS Health 2002 Annual Review of New Active Substances, which found that development times (measured from priority product patent application to first world launch) ranged from a little under 6 years to over 23 years, depending largely on the type of product[xxii]. The coxibs took on average 6 years to develop, the biotechnology NASs took 8 years, while the antibiotics generally took between 10 and 15 years.

Firms working in these sectors can assume that some parameters will remain relatively stable (humans will always be subject to illness and disease), but demographic trends, regulatory change, market liberalization, emerging competition and advancing technology means that markets are, in practice, relatively dynamic, so that these parameters have to be modeled years ahead in order to assess market conditions, product viability and potential profitability before committing very large sums of money to particular research programmes. Another characteristic of such sectors is the importance of 'early failure'; there is a non-linear increase in the investment required at each stage of the development of a new drug, so it is very important to eliminate unpromising lines of research and new product development (in this case, to screen out any harmful, useless or unpromising compounds) as early as possible [3]. This means that an increase in accuracy at an early stage represents a greater hidden cost saving than could be achieved at later stages.

Limits to roadmaps

It is important to remember that technology roadmaps and other foresight tools (and all other strategic planning methodologies) have limitations. These tools can help to make people think more systematically and strategically about the future, about the choices that must be made today and about the nature and extent of their knowledge of the current environment and important trends. This can help them to make better-informed decisions, so these are important advantages. There is no guarantee, however, that the future will actually turn out as planned.

As Dyson (1992) put it; "Whenever things seem to be moving smoothly along a predictable path, some unexpected twist changes the rules of the game and makes the old predictions irrelevant.... A nineteenth-century development program aimed at the mechanical reproduction of music might have produced a superbly engineered music box or Pianola, but it would never have imagined a transistor radio..."
Similarly, Drucker (1996) points out that "It's not given to mortals to see the future. All one can do is analyze the present, especially those parts that do not fit what everybody knows and takes for granted[4]. Then one can apply to this analysis the lessons of history and come out with a few possible

[3] About 40 per cent of drugs developed by the pharmaceutical industry are screened out in this way, but usually after significant expenditure has been incurred. The ineffectiveness of many compounds is not detected until mid-stage clinical trials, by which time there are large sunk costs. The importance of 'early failure' can been seen in the development by Novartis (launched in May 2005) of a fast trials process specifically designed to screen out compounds before clinical trials in order to reduce the expenditure of time and money on drugs that are later found not to work

[4] See also under **faint signals.**

scenarios...Even then there are always surprises." [xxiii]

This highlights a very important caveat; there is always a possibility of unexpected events and developments. It is very important, therefore, to continue to monitor the external environment. If it appears that events are not unfolding as planned, then the roadmap must be reassessed. It is important to have a good plan, so that the organization's efforts have focus and purpose, but it is also important to recognize when unanticipated problems or opportunities make it necessary to amend the plan. *If there is a significant divergence* between reality and the plan, it is the plan that must change.

1.3 Components of technology roadmaps

A technology roadmap will include a number of key factors, as follows[xxiv]:

Current technologies and applications: what are the key technologies that define our business?

Example: For an engineering company this might be the metal machining, pressing and plating equipment required to produce components. For an on-line retailer, this might be the servers, software and distribution networks needed to match sales with supplies.

Technological applications, advances and innovations: *how do we use these* technologies? Could we use them more efficiently? Are there other technologies that could give the same results at lower cost? Have there been any important innovations recently? Is it likely that there will be important innovations in future?

In this context, it is extremely important to note Christensen's (1997) finding that given a choice between an expensive solution that has many underutilized features and a cheap solution that gives 'good enough' performance, most *consumers opt for a technology that* gives them most of what they want at an affordable price[xxv]. This factor means that firms can fail by investing too much in researching and developing the perfect product, only to find that a rival seizes their market share by supplying a cheaper, 'good enough' *version.*

Example: British Telecom, Cable and Wireless and other telecommunications companies with significant sunk investment in landlines assessed the maximum performance obtainable from their existing copper-wire network using Asymmetric Digital Subscriber Line (ADSL) technology as compared to the cost and performance advantages of replacing the old system with fibre-optic technology. By adding line-splitters and more powerful processors at each end, it proved to be possible to make the old landline network operate at broadband speed, thereby making it possible to start migrating the existing customers over to broadband services without prohibitive delays and capital outlays[xxvi].

Goals and targets: what are our goals for the business? What technologies do we need to help us achieve these goals? Will our current technologies suffice, or do we need new technologies? What are the financial implications?

Potential discontinuities, shocks and risks: what are the important current

trends in our sector? Where will we be in five years (for example) if these trends continue? What is the possibility that our sector might change significantly in that time? Could a powerful new competitor or an important new customer emerge? Where will our major markets be? Is it possible that some new innovation could make our current technology obsolete? How quickly could we adopt this new technology? Is the trend towards market liberalization set to continue, or might there be a resurgence of nationalism and protectionism? Is there a risk of political change or civil unrest in our markets? Are our internal transport links, our international supply chains or distribution networks exposed to terrorism or to terrorism-related disruption? When are these risks most likely to arise?

Competitiveness: what is our current competitive advantage? Is it our technology, our product, our technical skills, our management or our marketing? When it comes to technological change; are we first-movers, or are we late-adopters? Do we have a technological lead? Do we have potentially valuable intellectual properties? Can we protect these with patents? Do we have access to the technologies we need? Will we be able to develop, buy or license the intellectual property rights (IPRs) or patents required? Are we good at dealing with challenges?

Investment, finance and planning: what are our capital reserves? What investment capital or other financial resources are available? What are the priorities for maintaining, upgrading or replacing our core technologies? What resources will be required to update/replace our plant and technologies, and to upgrade our skills? When will these resources be required?

1.4 Core concepts and terminology of technology roadmaps

There are some important concepts involved in technology roadmapping, with a related terminology that has evolved as the approach has been extended into new areas[xxvii]. Some of the most important ideas and definitions are as follows:

Alternative technological solutions

How many technologies exist (or are known to be in development) that could help the organization meet its primary goals? Gap analysis (see below) is a related concept. Analysis might reveal a gap, i.e. that the organization needs to develop or buy-in a new technology in order to meet its goals.

Boundary conditions/scope

What is the scope of the roadmapping project? How wide-ranging should it be? What are the boundary conditions (the rules that determine what is within the scope of the project, and what is not)?

Champion/sponsor

Who will drive the project, who will coordinate it and who will be in charge of implementation?

Corporate technology roadmap

This is a roadmap developed by an individual organization, either internally or, more usually, with some assistance or facilitation from outside. Some organizations prepare their own corporate

roadmap in response to an industry roadmap or national foresight exercise; others are entirely independent.

Cost reduction

A forward cost model is often included as part of a technology roadmap, since cost reduction over time is almost always a key product driver. This usually involves analyzing the overall industry trajectory to determine the average speed of cost reduction, then using that as a basis for setting a target. If the goal is to compete on the basis of price, then the future cost target for the product will have to be lower than the industry average.

The industry trajectory itself results from a number of factors, including the level of research and development, the percentage of successful projects and the volume of production. Moore's Law is a well-known example; it indicates that the cost of a given unit of processing power approximately halves every 18 months. This sets a clear target that firms can chose to track or lead. If they chose to lead, they will then focus their research and development efforts on the technologies that are most likely to help them achieve their target.

Critical/emerging technology

This is a new technology, still in development but which appears likely to have a major impact on the market. It is therefore necessary to prepare for change, even though the full range of uses and benefits of the new technology cannot be yet determined in any detail. At this stage, the preparation is typically strategic, rather than technical, involving questions such as 'is this development a threat or an opportunity?' and 'do we have the skills needed to adapt to the new market conditions?'

Example: the move by manufacturers such as Airbus and Boeing to replace aluminium with carbon fibre and other advanced composites in aircraft construction has implications for corporations such as Alcoa and Alcan that currently supply the aircraft manufacturers with high-grade aluminium.

Boeing, the US aerospace and defence group, is accelerating the move away from aluminium to advanced composites. Its new 7E7 would be the first commercial jet to have a majority of the primary structure, including the wings and fuselage, made of composites. Boeing have chosen a graphite combined with toughened epoxy resin as the main composite, and composites combining titanium and graphite for the wings.
The technology shift could prove a *significant blow to the world aluminium industry*. Aerospace remains a relatively small user (by volume) but it is a high-specification, high-margin part of the market.

Abridged from K Done. Boeing set for design revamp Financial Times Friday June 13 2003[xxviii]

Critical Path Analysis

Critical Path Analysis (CPA) and the related Program Evaluation and Review Technique (PERT) were developed in the 1950s to manage military projects, but are now more generally used to manage any particularly large, complex project[xxix]. Another related tool, the Gantt chart, was developed three

decades earlier[5]. These tools involve listing all the sub-tasks in a project, then organizing them into two groups:

- Sequential: the first group consists of hose tasks that have to be completed in sequence, because each stage depends on the one before. When building a factoy, for example, the foundation must be finished before the load-bearing walls go up, and the walls must be ready before the roof can be fitted.
- Parallel: the second group consists of those tasks that do not depend on the completion of other tasks. These can therefore be completed in parallel, i.e. at the same time as other tasks. In the same factory building project, for example, the contractor might decide that the tarmac for the car park can be laid at any time; thisdoes not depend on progress with the foundations, walls or floors of the main building.

The tasks are then represented in a diagram which shows the flow of events. The critical path is the line through the series of sequential events. This shows the minimum amount of time needed to complete the project as a whole. This also shows where the project might be vulnerable, because any failure on the critical path will always have implications for either the timetable (the completion will be delayed) or the budget (we will have to hire more people to get this phase finished on schedule). The key points along the critical path usually serve as the **development targets** and sometimes the **decision points** for the project (see below).

This process shows where additional resources would have the most effect. Additional expenditure on a critical path event can shorten the amount of time required, and thereby help to get a late project back on schedule. Hiring more bricklayers, for example, can help to get the walls finished earlier, thus making it possible to get the roof fitted. Additional expenditure on a parallel task, however, such as bringing in another roller to level the car park, will not help to shorten the timetable. This analysis also reveals how resources can be reallocated from parallel tasks to sequential tasks in order to speed up a project. If, for example, the people working on the car park are redeployed to assist the bricklayers, this will help to accelerate progress down the critical path. This sort of tactic is sometimes referred to as a **crash action programme**, which means redeploying resources (or allocating additional resources) to shorten the critical path. In Japan's post-war reconstruction, for example, resources were deployed strategically to shorten the time it would take Japan to industrialize, focusing on important sectors (such as steel, automobiles and electronics) in turn.

PERT is a form of Critical Path Analysis which also corrects for the fact that most people underestimate how long each task will take, while some people will overestimate the time required in order to inflate their bonuses. PERT is calculated by estimating the shortest possible time each task will take, the longest likely time each task could take, and the most likely amount of time that

each task will actually take. In effect, PERT uses a band of values, with a top and bottom end and a 'most likely' value, as opposed to a single value. This band is then resolved into a single value, usually in the following formula: shortest time + 4* the most likely time + the longest time/6. So if, for example, the shortest time was 2 days, the longest time 8 days, and the most likely time 4 days, that would give: 2 + (4*4) + 8 = 26/6 = 4.3 days. This final value is then used instead of the shortest time value of 2 days or the longest value of 8 days, thus correcting for over-optimism or under-bidding.

The Gantt chart is a horizontal bar chart that shows the sequential and parallel events listed over time. This is a useful visual tool for illustrating the critical path events.

These related tools therefore help to:

- Identify the important sub-tasks.
- Identify the dependencies between sub- tasks.
- Organize the dependent sub-tasks into the appropriate sequence.
- Identify potential vulnerabilities.
- Identify the minimum time required to complete a project.
- Identify where resources can be optimally allocated in order to accelerate progress.

Critical product attribute/critical system attribute

This refers to a core feature or function of a product or technological system; an essential and indispensable attribute that defines the value and purpose of the product, or the desired function of the system. Mobility has become a critical product attribute of many electronic devices, for example, as consumers now want their communication, data storage processing and access needs to be available from any location.

Decision points

These are critical '**milestones**' in a project; the point at which one important phase ends and another begins. Once the product has been developed and tested, for example, its performance can be assessed and a decision made as to whether it can be moved into production. A decision point therefore has two key characteristics. The first is that a phase has ended, and that important information has therefore become available. The second is that the following phase will require a significant additional commitment, which makes it essential to decide whether to take the project on to that next stage, or to terminate it in order not to expend any further resources.

The purpose of a decision point is not to demonstrate renewed commitment to a potential product. The most important function of a decision point is to eliminate as many failures as possible.

Most complex projects, such as the development of a new pharmaceutical, have multiple decision points. As noted earlier, there is a non-linear increase in

the investment required at each stage of the development of a new drug, so it is very important to eliminate unpromising lines of research and new product development. For example, Vagelos (1991) found that in 1991 in the United States, for every 10,000 compounds (most based on synthesis) undergoing preliminary in vitro biological evaluation, 20 would go on to be tested in animal models, of which 10 would be approved for clinical evaluation, of which one would be submitted to the FDA for approval. At each decision point, therefore, most potential new drugs were eliminated, leaving only the most promising to go forward into the next stage of development.

Decision support

There are various methodologies, software packages and so on that can be used as decision-support tools. These are essentially procedures for analyzing data, eliciting the factors that are important to the organization, and presenting them in a way that helps the decision-makers to make better and more focused decisions. This is particularly useful in situations where there is so much data that it is difficult to distinguish between relevant factors and background noise. Retailers and banks, for example, use data mining software to analyze their information about their customers, and pick out important correlations (such as whether someone who buys one type of product is also likely to buy a second product) that can then allow targeted marketing and product placement.

Example: the software company Quadstone developed data mining software that was used to analyze consumer purchase patterns. This revealed a number of previously unknown patterns, such as the correlation between sales of diapers and beer on Friday evenings. On investigation, it was discovered that fathers of young children were buying diapers on the way home from work on Friday, and taking the opportunity to get a 6-pack of beer for the weekend. The retailer then installed a beer display near the check-out tills every Friday afternoon, and increased sales of beer as a result.

Development targets

These are the goals set for the development of a new product or technology. If, for example, a gap analysis reveals that a new product will be needed if the organization is to still be competitive next year, then that imposed deadline has to assessed in terms of the organization's capacity to develop that new product, and then broken down into a detailed timetable for the actual process of development. If the product has to be ready in 12 months, for example, then the components must be ready within 11 months, and the subcomponents ready within 10 months, and so on.

Development targets often serve a dual purpose as project milestones or decision points. If the development target for a particular subcomponent is not ready in month 10, for example, the entire project may be at risk of failure. **Critical path analysis** is sometimes used to identify the sequence of developments and milestones that is at the core of the project, and will determine its ultimate success or failure.

Large-scale or particularly complex projects frequently have to integrate

multiple, parallel lines of development, each with their own development targets, which makes the core task of **project integration** extremely important (see also **product platform roadmaps**). This is particularly important in situations where it is not possible to shut down the core operation, so that upgrades have to fit into an existing work schedule. Hospitals, airports and defence installations, for example, must continue to function even as major changes are made. This imposes a complex combination of logistical, spatial, budgetary and timetabling constraints, which requires a high level of control over the precise sequencing of every task and completion of project sub-components.

The importance of project integration can be seen in the following contemporary example, which also illustrates the need to introduce innovative project management methods across disciplines and sub-project boundaries in order to control exceptionally complex projects.

TO THE west of London, crammed between Europe's busiest stretch of motorway and its busiest international airport, is a vast building site. In the midst of a landscape of mud and men rises a vast glass-fronted box that will soon be Britain's largest free-standing building; Heathrow airport's fifth terminal. Some 67m passengers used Heathrow last year; Terminal 5 will have room for 30m more. The project, which covers 260 hectares, will include not just a terminal that will be the equivalent of Europe's fourth-largest airport in its own right, but also two satellite buildings, 60 aircraft stands, a new air traffic control tower, a 4,000 space multi-storey car park, the creation of a new spur road from the M25, a 600-bed hotel, the diversion of two rivers and over 13km of bored tunnel, including extensions to the Heathrow Express and Piccadilly Line services. This encompasses a vast and hugely complex programme of works, with 16 major construction projects and over 147 sub-projects, requiring a multitude of construction-related skills including civil engineering, fabrication and building, highway engineering, mechanical and electrical engineering, tunnelling, railway engineering, specialist systems technology and project logistics management.

Big construction projects are always tricky: just look at the mess in Athens, site of Europe's other giant construction project. Airports bring special problems: tricky building techniques, and the need to mesh with other transport links and to install sophisticated electronics to handle passengers and baggage. In Paris, Charles de Gaulle airport's new terminal went hideously wrong. The risks attached to this vast project are so great that the British Airports Authority (BAA) has been forced to tackle it in novel ways. If this giant endeavour is not completed on time and on budget, it could take the whole company down.

Tony Douglas, the man in charge, is adamant that Terminal 5 will open as planned at 0400 on the 30th March 2008. Why the confidence? New technology is one reason. Every wire, pillar and pipe is digitally modeled, which helps to prevent the costly mistakes that can arise if members of the design team are working under different assumptions about where bits of the

buildings go. The entire project is contained in a single computer simulation, and individual parts of the terminal - such as the labyrinthine baggage-handling system-can be given a digital dry run. That's useful for preventing problems later on, since virtual mistakes are much easier to fix than real ones. Technology has helped in other areas too. Just-in-time scheduling, borrowed from the manufacturing industry, means that very little needs to be stored on site.

As much as possible of the construction--including 60% of all the mechanical and electrical systems--is taking place off-site. This reflects the site's physical constraints: it has only one entry point, through which a 40-foot (12-metre) load must move every 30 seconds for a period of four years. "If you get the choreography wrong, it makes London's motorways on a Friday night look tame," says Tony Douglas. And the site has capacity for no more than two days of inventory. The solution, he says, has been some "car-industry logistics"--a large investment in computing and training that no individual supplier would have made. The consequence has been fewer people on the site. And factories are safer places to assemble than building sites. T5's project director, Andrew Wolstenholme, boasts that the site has not had a single fatality so far.

Set to be a template for major construction projects of the future, T5 is pushing the boundaries of traditional construction, harnessing innovation and best practice from other industries and translating it into mainstream construction management.

Abridged from:

- *The challenge of running massive construction projects The Economist Jul 22nd 2004* [xxx]
- *Blue skies thinking The Economist August 20th 2005* [xxxi]
- *British Airports Authority* [xxxii]: http://www.baa.com/portal/site/default/menuitem.9117dc974bda4acc0fb42410c02865a0/

Disruptive Technology

Christensen (1999) distinguishes between incremental improvements and innovations that remain within the current core solution parameters, and disruptive innovations that essentially substitute for existing solutions.

A disruptive innovation refers to a new technology that has three important characteristics. First, it is significantly (sometimes radically) different from the technology currently used to perform a particular function. Second, it is markedly better in one or more ways than the current technology (such as being faster, cheaper, more reliable and so on). Third, it not only changes how a problem is solved, it also changes the market, usually by dramatically altering customer's expectations, requirements, patterns of usage and sense of what is possible, desirable and normal with regard to that type of product.

As the term 'disruptive' implies; this relates both to innovative capacity and to the market position of the firm involved. Firms with monopolies or dominant market positions tend to have the greatest commitment of people, capital and plant tied up in existing solutions, so prefer to innovate within existing parameters. From that perspective, disruptive innovations are indeed disruptive; they are threatening because they may force companies to write down existing investments. New

entrants, however, may adopt disruptive solutions for exactly the same reason, simultaneously giving the new entrant a competitive advantage and forcing the incumbent dominant firm to write off their investment in the obsolete technology.

Example: the introduction of the telegraph represented a disruptive innovation. In the first half of the 19th century, it took three weeks to get a letter from New York to California by overland mail, because the service relied on stagecoaches which also carried people and other freight. The introduction of the Pony Express, a dedicated mail service with lighter, faster horses, reduced delivery time to around ten days. This was very significantly better, but still represented an incremental improvement within existing parameters. In effect, it represented the most advanced technical solution available to the problem, given that the problem was to extract the greatest possible efficiency from a system that relied on horses.

The first trans-continental telegraph line was completed on October 24, 1861. On that day, the first telegram was sent from California to the east. The early telegraph required a line of operators, each one receiving and then transmitting the message to the next station, so communication was not instantaneous, but coast to coast transmission speeds were still measured in hours rather than days.

The Pony Express went out of business on the same day, its market destroyed by a radical innovation. The telegraph had rendered it obsolete.

As this suggests, the most important characteristic of a disruptive technology is that it does not just represent a better solution to the same problem, it changes the problem. The disruptive technology introduces new capabilities, which then transform customers' expectations and requirements. Some of the technologies taken for granted today, such as the telephone, automobile and Internet, were all disruptive technologies when first introduced.

Christensen (1999) points out that some disruptive technologies do not satisfy all customer requirements when first available, which means that the firms that currently dominate the marketplace may not immediately recognize the threat, but have such a rapid trajectory of improvement that they soon overcome their limitations, overtake and then replace the existing technology.

Example: Many software developers believe that open-source software, such as Linux, has several important advantages over proprietorial software, such as Windows. It is free, and its development in an open environment helps to ensure that it is both more stable and less vulnerable to virus attack. Windows continues to dominate the desktop environment, however, partly because inertia and legacy issues; many existing users are reluctant to port their entire portfolio of files into a Linux o/s. Microsoft are aware, however, of the threat posed by Linux, and have had to offer significant discounts to persuade major users to remain with Windows.

Emerging technology

This is a promising new technology, still in development, which is thought to have significant potential. Of course, as

Clayton, Spinardi and Williams (1999) and Green et al (1994) have pointed out, most ideas never get off the drawing-board, many early experiments and trials simply eliminate failures, and the majority of new products fail in the marketplace, so the majority of technology development projects do not result in a viable new product [xxxiii]. Of the few that do succeed, only a very small fraction have significant market impact, and, of those, only a minute fraction have the kind of transformative impact associated with disruptive technologies.

Three conditions must be met, therefore, before an idea can be classed as an emerging technology. First, that it looks as though the process of development will continue to be successful, and that any problems that arise or limitations that emerge while the technology is in development can be overcome. Second, that there really is a potential demand for the new technology, which usually means that it has to offer one or more significant advantages over the status quo (by being faster, cheaper, lighter, stronger, more stylish or whatever combination of attributes is important in the particular market). Third, that the technology has the potential for extensive or even transformative impact on the market. A technology will not be classed as an emerging technology, for example, if it will add just another reasonably successful product to the large number of reasonably successful products already in the marketplace. It will only be classed as an emerging technology if it promises to change the pattern of consumer demand and expectations. It is very difficult, of course, to assess any of these three factors with much certainty, so investments in emerging technologies tend to be both more speculative and more long-term than usual. The risks are intrinsically higher, but so are the potential rewards. Investments in emerging technologies tend to be made, therefore, where a fourth condition is also met; that the technology offers significant first-mover advantages in its marketplace. In some cases this means that it is, potentially, a disruptive technology; it has the potential to displace the existing dominant technology and to become the new dominant technology, so the potential benefits outweigh the relatively high risks of investment.

One of the most important reasons for the **horizon scan**, which is usually done at an early stage in a technology roadmapping or foresight exercise, is to list any possible emerging technologies plus their potential impact on the relevant markets for related products. Sometimes horizon scans are done for that purpose alone, and used as the basis for a **product technology roadmap** or an **emerging technology roadmap** (see below).

Emerging technology roadmap

This is a roadmap of emerging technologies, mapping (as far as possible) the anticipated development trajectory, important milestones, estimated time line and expected performance for technologies that are known to exist, at least in embryo, but are still in early development. An emerging technology roadmap will, of course, pertain specifically to the market that is of interest to the company developing the map, and will normally include an assessment of who owns which technology, which company is likely to gain market share,

which technology might become obsolete, the identity of both current and potential competitors, the rate of progress being made by rivals, and which company is leading in the race to develop the technology that will come to dominate the market in future.

Faint signals

There are two ways in which a firm can be seriously disadvantaged by a significant change in its core markets or technologies. The first is to misread the trend, and move too soon, so that products are launched into unreceptive markets and the investment has to be written down. The second is to move too late, so that other firms develop dominant positions in the emerging market and define the standards, making it more difficult for late entrants to win market share.

The timing of strategic moves and investments is therefore critical. This involves two key components. First, a firm must be able to detect **faint signals** in the market; the early signs of trends that have not yet become dominant. Second, the firm must have the flexibility and capacity to respond appropriately.

The first component is the most difficult. Most markets are awash in information, facts and rumours, a combination that keeps prices in constant motion. The high noise to signal ratio makes it hard to discern the early trace of a genuinely important trend. Convincing evidence, however, is usually historical; it is not until the trend is firmly established that its shape and direction becomes clear. By that time, of course, opportunities for first-mover advantage may have been lost.

Anthony (2005) suggests that there are three factors that help to identify an important trend at an early stage. These are:

- A growth gap
- Signs of overshooting
- Disruption in the core or adjacent markets

Growth gap: This is a form of **gap analysis**. It involves looking at the new products and services in a firm's pipeline, projecting the likely revenues and profit margins five or ten years into the future, then comparing those outputs with the firm's strategic targets (which reflect what the firm thinks it will have to achieve in order to remain competitive). If there is not enough material in the pipeline to generate the growth required, the firm will be obliged to change its products, its technology, its management or all three.

This kind of analysis is also reflected in the price/earnings (P/E) ratio, which is the market value of a share dividing by the earnings per share. A company that has issued 1 million shares, for example, and earns $5 million in the relevant period (usually the last financial year) has earnings per share of $5. If the stock is trading at $50 per share, the P/E ratio is 10. If the stock is trading at $500 per share, the P/E ratio is 100. As this indicates, a high P/E means that the company is expected to earn much more in future than it does today, a low P/E means that the firm is expected to continue to perform at about its current level in a mature, low-growth market, while a negative P/E usually means that the firm is making losses and might not survive. So the P/E represents the market's assessment of the firm's potential.

Overshooting: This involves identifying signs that a firm has lost touch with its market, and is launching products that are over-specified or in some other way no longer what the market requires. As Christensen (1997) discovered, given a choice between an expensive solution that has many underutilized features and a cheap solution that gives 'good enough' performance, most consumers opt for a technology that gives them most of what they want at an affordable price.

One of the best-known examples is the Ford Edsel car, which was launched in 1957. The firm thought that the trend towards larger, more ornate and fully-featured cars would continue, and developed a model to lead that trend. The Edsel contained a number of stylistic and technological innovations, but none of these impressed the consumers, and quality control was poor. The critical factor, however, was timing; the car was launched just before a national recession, when consumer demand switched to simpler, cheaper cars. Few Edsels were sold, and the entire division was shut down less than three years later.

Anthony (2005) points out that overshooting is often a cause of industry change, since companies can innovate much faster than people can adopt and benefit from those innovations [xxxiv]. The mistake, therefore, is to over-invest in products and services that are over-elaborate, over-specified, can deliver more performance than is actually required and cost too much for the problems that customers are actually trying to solve. Anthony suggests that early signs of overshooting include:

- Lack of enthusiasm in the market about a major new feature or improvement.
- Consumer demand for price reductions, rather than more features.
- Declining prices and margins, so that the firm can no longer get premium prices for its products.
- The firm ceding increasingly unprofitable markets to lower-cost competitors with cheaper, simpler solutions.

These signals indicate that the firm's innovations are no longer valued.

Disruption: The ceding of market share to lower-cost competitors is a particularly significant harbinger of change. As Christensen points out, the threat from a disruptive technology or business strategy is not usually apparent at first. The disruptive attacker often provides relatively simple, convenient, low-cost alternatives, focused initially on the budget end of the market. The real significance of the attack becomes apparent when the disruptive attacker improves their product, expands, and starts to move into the premium end of the market.

There are many examples of this process. Budget airlines, for example, are now displacing the full-service carriers in all but the long-haul business market, while Toyota, a Japanese car corporation initially focused on small, cheap models now offers luxury brands, and is displacing the US car corporations in their own home markets. In

most cases, the disruptive attacker grows from a low starting position, so previously dominant companies retain market share and respectable growth rates for some time after the initial emergence of the disruptive attacker. This can create a false sense of security, and lead companies to underestimate the threat.

OVER the past four years, America's airlines have lost $32 billion, hit by the effects of terrorist attacks, the collapse of the dotcom bubble, the war in Iraq, the SARS epidemic in Asia and fiercer competition from new low-cost carriers. This devastated landscape is now being visited by a sixth horseman of the apocalypse: oil prices. On Wednesday September 14th Delta Air Lines and Northwest Airlines, America's third and fourth-largest airlines, filed for bankruptcy. With United and US Airways already operating under Chapter 11 bankruptcy regulations, at least half of America's airline industry has now been declared bankrupt. These firms will keep flying on empty, thanks to court protection from their creditors. But a once-proud industry is officially on its knees.

Facing fierce competition from relative newcomers like Southwest and JetBlue, which are still profitable, the older, 'legacy' airlines, with their much bigger fixed-costs, are unable simply to pass the higher oil prices on to their customers.

Abridged from The Economist. America's airlines, flying on empty. Sept 16th 2005 [xxxv]

Anthony suggests that the most vulnerable firms are those operating in markets where there are factors that limit consumption. For example, early models of computing relied on central processors. This created a bottleneck, which led to a demand for decentralized processing power, which led to the development of the PC, which then took over most of the market. Another common limiting factor is price. Airfares, for example, used to be set at premium prices, a model that has been largely supplanted by the rise of the low-cost carriers. Thus one of the common characteristics of a disruptive technology is that it overcomes one or more of the factors that limit consumption, enabling the new technology to drive the next phase of market development and expansion. This, in turn, is what enables and spurs the improvement of the disruptive technology, eventually to the point where it captures the core and dominant share of the market.

Ryanair is claiming to have stolen the title of 'the world's favourite airline' from British Airways after it carried more passengers than BA for the first time. The no-frills carrier said it took more than 3.26 million passengers last month - up by 27 per cent on August last year and 156,000 more than the 3.1 million carried by BA. This knocked the UK firm off the top spot as Europe's most popular carrier for the first time, although BA dismissed the figures, saying: 'It doesn't matter.'

Abridged from G Bowes. Ryanair 'now the world's favourite airline' The Observer Sept 11th 2005 [xxxvi]

Reacting to faint signals

Anthony suggests that there are three strategies for responding to faint, early signals of impending structural change.

Acquire, merge and consolidate: This involves taking over former rivals in

order to remain the dominant player in the market. The problem with this approach, of course, is that the majority of mergers fail. Some acquisitions actually destroy shareholder value; the combined worth of the new corporation is less than the sum of the two predecessors. This is more likely to happen if it becomes apparent that the underlying strategy was to try and create one good organization out of two failing companies.

Reinvent the company, create new platforms: Another strategy is to reinvent the company, as far as is necessary, and develop new families of products. IBM, for example, became uncompetitive as a PC manufacturer, but evolved into a computer consultancy and services company. The companies that succeed with this strategy are usually those that see the need for change while they still have the time and resources required to develop the new products and services required.

Acquire emerging challengers: The third strategy involves elements of both of the previous two strategies. It involves acquiring the new firms and emerging technologies, so that the competition between the old approach and the new model becomes internalized within the firm. One US bank, for example, decided that internet banking posed a serious threat to its traditional branch-based model, so moved to acquire a small, internet-based rival. The strategy was to let the two divisions compete against each other, so that the bank would emerge structured around the successful model. Similarly, the petrochemical corporations BP and Shell have invested in hydrogen fuel cell technology. If their new hydrogen divisions remain small, they will continue to be useful adjuncts to the core business. If, however, the new hydrogen divisions start to supplant their traditional petrochemical divisions, these companies will gradually re-shape around their new core technologies.

The companies that succeed with this strategy are usually those that make their strategic acquisition before the market recognizes the disruptive potential of the emerging growth company, and then avoid the temptation to integrate the new divisions too tightly. The attempt to make new divisions fit into the old corporate planning framework and meet, for example, the return on investment (RoI) criteria applied to the rest of the organization can destroy the corporate culture and disperse the skill base in the new acquisition; the very qualities that made it valuable.

Gap analysis

This involves analyzing a company, or a group of companies linked together down a supply chain, to identify any systemic deficiencies in technical capability, skill or management capacity that are significantly reducing efficiency or could prevent the adoption of a new technology or the development of a new product.

Example: an attempt to develop an export market in flavourings, essences and other refined plant extracts from Jamaica involved acquiring a new centrifuge extractor in order to deliver the level of purity required, recruiting and training technicians to run the extractor, improving logistical capacity in order to ensure that raw material was delivered to

the processing plant while still fresh, and adopting TQM management systems in order to ensure that any problems with batch contamination could be detected, then prevented. It was realized, however, that this effort could be undermined by (a) inadequate supplies and (b) delays and inadequate security at the wharf. The first problem entailed persuading enough farmers to try producing the new crops. The second problem involved the risk of missed shipping deadlines and of batches being broken open and used to smuggle illegal narcotics. Thus the key gap was not in the company, but at two other stages in the supply chain, one upstream and the other downstream.

Gap analysis is also used to identify the gap between the technologies used today, and the technical capacity that will be needed in the future. A car manufacturer, for example, might conclude that the market will eventually demand zero-emission vehicles, while their current capabilities are centred around conventional internal-combustion engines, and thereby identify the gap between their current skills, technologies and marketing strategies and those skills, technologies and strategies that will be required in future.

Example: the Republic of South Africa's national foresight exercise assessed all major sectors of the economy. The analysis of the important mining sector assessed the potential impact of a radical new technology, biological mining. This involved the use of genetically modified bacteria to sequester metal from underground deposits by using shaped charges to fracture the rock, then pumping the GMOs, in a solution under pressure, above the ore-bearing seam and extracting them from underneath, then pumping the charged solution back to the surface to recover the metal. It was decided that this was a potential disruptive technology that might displace existing mining technologies and skills, which meant that the mining industry had to invest in and remain abreast of all developments with this new concept.

Example: Iran has developed biotechnological processes to enrich uranium, thereby closing a gap in its ability to produce nuclear fuels [xxxvii]

> Iran continues to press ahead with its controversial efforts to master technologies that could one day give it the domestic ability to produce nuclear fuel. The latest sign comes with an announcement this week that Tehran has successfully used biotechnology to convert uranium ore mined in Iran's central desert region into a concentrated form of uranium. The concentrated uranium - known as yellowcake - is used in an early stage of the complex process of producing nuclear fuel. State television provided few details of the biotechnology technique, other than to say it is more efficient and less expensive than Iran's previous method of using acid. Biotechnology techniques involve the use of microscopic organisms to convert material through organic processes from one form to another.

Abridged from C Recknagel. Tehran claims breakthrough. Middle East September 2nd 2005 [xxxviii].

Horizon scan

A horizon scan involves taking stock of developments, such as emerging technologies, across both the market in which the company is involved and potentially relevant fields. A company

involved in mining and refining metal, for example, might assess advances in mining and smelting technology, but their markets could also be affected by advances being made in other areas of materials science. Their projections of future demand and supply, therefore, might take account both of the long-term trends within their market and of possible displacement or substitution effects from other materials.

The example reviewed earlier as to the move by both Airbus and Boeing to replace aluminium with carbon fibre and other advanced composites in aircraft construction also illustrates the need to assess related developments in other fields; these substitution effects have implications for the market for high-grade aluminium, and therefore for aluminium mining and smelting companies such as Alcoa and Alcan.

Industry roadmap

This is a roadmap that looks at the prospects and challenges for an entire sector of industry. These are usually developed either by very large multinational corporations, by a consortium of firms, an industry body that represents the firms in a particular sector, or a government agency concerned to promote the interests of an economically-important sector. An industry roadmap assesses the probability of possible events and developments, such as emerging technologies or increasing competition from emerging economies, which could potentially affect an entire sector of industry.

Example: Albright gives the International Technology Roadmap for Semiconductors as an example of an industry roadmap; it sets ambitious goals for the industry and its suppliers, defining the framework within which all participants will contribute and compete [xxxix].

Probability - impact matrix

In practice, the conclusions and implications from a strategic planning exercise usually have to be absorbed into a business or government agenda that is already crowded. It is important to have greater clarity about where the market opportunities will be or what the administrative problems might be in five years time, but that does not remove the need to make the large number of day-to-day decisions involved in managing a business or government department. So it is important to have a clear set of priorities for action.

A probability - impact matrix is a way of organizing these priorities. It is similar to the triage used by military doctors when dealing with overwhelming numbers of incoming casualties[6].

	Low Impact	**High impact**
Low probability	Ignore	Monitor, review - Risk of critical failure
High probability	Low priority	Top priority

- Events that are thought relatively unlikely to occur, and would not have very serious consequences if they did, can be safely ignored

[6] Triage is a rough classification of the casualties into three groups; those unlikely to survive, who can be left to die, those with relatively minor wounds, who can be left until later, and those whose lives can be saved with a medical intervention, who are the first priority for treatment.

- Events that are thought likely to happen, but are not expected to have very serious consequences, can be given a low priority
- Events that are thought likely to happen, and likely to have important consequences, are clearly the top priority. These are the events that might, for example, pose a serious threat to the firm or to the state.
- The most difficult category, with regard to the formulation of an appropriate response, is the high impact, low probability events. These are events that are not currently thought likely to occur, but would have very serious consequences if they did. This makes it important to monitor these situations carefully, and remain alert to possible signs of change (such as **faint signals**).

It is obviously sensible to allocate most of the scarce management time and investment capital to high impact, high probability events, but it is also important to make provision for monitoring high impact, low probability events. For example, the US Federal Emergency Management Agency knew that New Orleans was potentially vulnerable to a severe hurricane, and had identified this as one of the three worst disasters that could befall the United States. This was, however, seen by the administration as a relatively low probability event.

On the 28th - 29th August 2005, Hurricane Katrina resulted in a 28-foot storm surge as well as torrential rain, the latter raised the height of Lake Pontchartrain by 7.6 feet, and the combination overwhelmed the levees that protected the city of New Orleans. About 80% of the city, which is on average about 6 feet below sea level, was then flooded, resulting in many fatalities and extensive, costly damage.

The 'ultra-catastrophe' of Hurricane Katrina, as Homeland Security Secretary Michael Chertoff put it - the devastation of an entire city, its communications, power, transportation and other infrastructure; the dislocation of hundreds of thousands of people - is beyond anything the nation has ever dealt with. Still, coming four years and tens of billions of dollars in preparedness spending after the Sept. 11 attacks, it suggests that the country's readiness to cope with a major disaster remains woefully lacking.

The governmental failure exposed by Katrina is multilayered and long-standing. It begins with the shortsighted decision not to confront the inescapable geographic reality of a city built largely below sea level. Every disaster brings in its wake the inevitable exhuming of obscure reports warning of shortcomings and the inevitable second-guessing about money that could have been spent to prevent it. But in the case of Katrina, the precarious situation of New Orleans was well-known -- the Federal Emergency Management Agency in 2001 put a hurricane in New Orleans among the top three most catastrophic events the country could face. New Orleans faced a clear and present danger from the combination of sinking land, rising sea levels, and the rapid shrinking of wetlands and barrier islands, which served as a buffer to hurricanes by sapping their energy and absorbing sea surges. Despite President Bush's assertion that

no one could have anticipated that the levees would fail, officials were well aware that the levees could be counted on to withstand only a Category 3 hurricane, not a Category 4 storm such as Katrina. Similarly, a mandatory evacuation order was in no way a sufficient response to Katrina's impending arrival; it was clear that a significant number of New Orleans residents would remain - many because they had no alternative. Where were the buses or other vehicles to help them leave? Where was the plan to avoid the bedlam that developed in the Superdome and the convention center? How could it have taken four days for National Guard troops to arrive to restore order in the anarchic city?

The vulnerability of New Orleans to a major hurricane was well-known; the path and force of Katrina were charted for days in advance. If the response to an anticipated risk is so poor, what, then, would happen in the face of a surprise event such as a bioterrorism incident or nuclear attack? Katrina is, in that sense, an ill omen in addition to a disaster in its own right, one whose lessons must be faced once the immediate catastrophe has been addressed.

Abridged from Unprepared. The Washington Post. Monday, September 5th, 2005 [xl]

Product needs

Product needs emerge from the interplay of market pull (what consumers want now) and technology push (what technological advances make possible). Product needs fall into two categories. The first is a list of consumer demands and preferences. These are usually based on consumer surveys or **user requirements capture** exercises (see below). The second is a list of new products and services that can, in principle, be generated from either existing or emerging technologies, and for which there is likely to be a significant demand.

As this suggests, product needs are not solely defined in terms of the needs that customers express today. They can extend beyond present circumstances to include probable future needs, and even to needs that have not yet been conceived.

Example: a mid-range projection of product needs related to transport might consider the impact of the ultra-efficient car[7] *on consumer expectations, while a long-range projection might consider the impact of personal air travel* [8].

Product platform roadmaps

Most products lines, in a modern industrial economy, are based on an underlying platform; a core set of functions with a common architecture and technological underpinning. The car industry, for example, uses common platforms, standardized body parts and engines, which in turn include core technological functions such as the internal combustion engine, transmission and so on. These functions represent technological solutions to particular needs, such as 'what is the most efficient way to deliver power to the wheels?'

[7] The 'hypercar' combines all currently available technological advances in a vehicle. These available technologies, which include carbon fibre bodies, electric drives mounted on each axle and regenerative braking, result in a car that can travel some 3,000 miles on a single tank of gasoline.

[8] Prototype 'flying car' mini-aircraft have been designed, but no-one has yet devised the urban air traffic control systems that would be needed to prevent collisions in dense commuter traffic.

Markets, however, are complex and differentiated. There is a large aggregate demand for motor vehicles, for example, but this includes corporate fleet managers who want reliable, low-maintenance cars, wealthy customers who want luxurious cars, regular commuters who want fuel-efficient cars, parents who want safe, capacious cars to get their children to school, adolescents who want fast, stylish cars and so on. There may also be regulatory or cultural differences between different regions. For example, one group of customers may live in a country with particularly strict emission standards, or some customers may live in countries that drive on the left-hand side of the road, while another group live in countries that drive on the right-hand side.

It would be very inefficient and costly to design and build a different model from first principles for each of these important market segments. The solution is to use the same underlying platform for a 'family' of products. A range of cars, for example, might use one or two standard engines and one chassis throughout the range, but use different bodies to tailor the final product to different market segments.

This strategy is becoming increasingly important as markets liberalize. Corporations increasingly operate in global markets, and so have to become better at reconciling the unique requirements of particular market segments with the dramatic efficiency gains of using standard platforms and as many standardized components as possible. Roadmaps are therefore used to manage the complex process of coordinating specific, tailored features and the technologies needed to produce those features while simultaneously retaining the advantages of designing and producing platform-based products.

Most innovation is incremental. There is constant pressure, in a competitive market, to anticipate the needs and wants of the customers, and to increase efficiency and reduce the costs of production in order to increase profit margins. These pressures result in constant experimentation with different models and styles, and frequent improvement and restructuring in order to remain competitive. Most innovation is therefore directed towards these ends, while the basic platform and underlying concepts remain relatively stable. In the aircraft industry, for example, a model platform may be in use for twenty years or more, although many improvements and modifications will be introduced in that time.

From time to time, however, there are more radical changes, when the platform itself evolves. For example, a move to replace the internal combustion engine with a hydrogen fuel-cell system, with four motors mounted individually on each axle, or a move to replace the human driver with a GIS-based voice-controlled navigation system would represent transformative changes in the drive chain and car usage patterns respectively. Radical changes usually involve significantly greater risk and cost, as most of the existing manufacturing capacity and core competences may also have to be changed. This is the point, therefore, where established firms are at greater risk of failure, while new businesses may be able to gain a competitive advantage.

As a general rule, however, platforms remain stable, and multiple market segments are addressed with different models and versions. Market needs evolve over time, but many of these changes are relatively modest, and can be met by issuing a new release, based on the same platform but re-tailored to meet the new market requirements.

As this suggests, a product technology roadmap and a product platform technology roadmap have different purposes. A product technology roadmapping exercise may be done on the basis of the assumption that the basic platform will remain stable throughout the planning period. A product platform technology roadmap, however, is a more fundamental exercise, and involves specifying a new platform that will then provide a basis for a whole family of new products, models and variants.

Albright notes that a product platform technology roadmap will normally include four components:

- A market and competitive strategy
- A product roadmap
- A technology roadmap
- An action plan

All four components are strongly interlinked by the prioritized customer needs, the specification of the product, the choice of technology and the characteristics of the platform.

The **market and competitive strategy** section describes the market and its pattern of segmentation, identifies the key customers, market drivers and any regional variations, and describes the competitive landscape. The rival firms are listed, along with their competing products, strengths and weaknesses, market shares and forecasts, core competencies, competitive strategies and strategic alliances. This helps the organization to identify its market niche, its critically-important customers and its product marketing strategy, which forms the core of its competitive strategy for the product line and the associated business plan. It may decide, for example, to aim at the mass market and compete on the basis of price, by offering the lowest cost product in the market. Alternatively, it may decide to target high net worth consumers and trendsetters, and to compete by offering a full-specification model, with many advanced features and bundled services. This process is a crucial part of the roadmapping exercise, partly because it defines the market, the product and the strategy, but also because it helps the organization achieve clarity and make explicit choices between alternative possibilities. The market and competitive analysis process results in a prioritized list of customers, customer drivers (what the customers want and value) and a strategy for competitive positioning in the market, which defines the product.

The next stage is to develop the **product roadmap**. This maps the customer drivers (what the customers want) with product drivers (the qualities that must be built into the product), then maps the product drivers into the design and architecture of the product. This may include identifying possible synergies and conflicts between different product drivers. For example, customers may want cars that are more fuel-efficient, which means making cars lighter, but they also want cars that are safer, which

means reinforcing the passenger compartment and adding other safety features that make cars heavier. The need to solve both problems simultaneously will help to define the technology required. It might involve, for example, substituting carbon fibre for steel in most places, but incorporating a stronger steel cage around the passenger compartment, thereby delivering a car that is both lighter and safer.

Albright gives the example of a mobile phone to illustrate how key customer drivers, such as price, style and talk time, are linked to product drivers, which creates a prioritized list of key product characteristics. For example, the customer need for low price drives lower product cost, the need for style drives small size, low weight and attractive appearance, and the need for longer talk time drives longer battery life. These too may require trade-offs. Longer talk time may require a bigger battery, for example, given the limits of currently available battery technology, which has to be traded-off against the preference for smaller, lighter handsets.

This two-stage mapping process makes it clear why particular attributes have to be embodied in the design of the product. It also assigns priorities, so that any conflicts between attributes can be solved with appropriate trade-offs or technological changes. This then feeds back into the selection of the competitive strategy. In the mobile phone example, the firm might decide that the ideal market niche is with customers that most value style, as they are most likely to change handsets repeatedly, so they prioritize smaller size, lower weight and sleek appearance. Their competitive strategy, therefore, is to develop market-leading products that are significantly smaller and lighter than rival products, to maintain parity with competing products with regard to price, but to lag their competitors in terms of talk time (because of the battery/weight trade-off).

The product roadmap then specifies the parameters for the **technology roadmap**. Most products are launched into markets that already have a dominant architecture or platform. If it appears unlikely that this can be challenged, the development efforts have to be focused on optimizing the desired characteristics within the confines of the existing platform. In the mobile phone example, the firm might examine all the components to determine which ones add most to the weight and size of the handset, then to consider how to make them smaller and lighter. This might involve, for example, reducing the number of separate components and consolidating functions into fewer integrated circuits, with the long-term goal of making all functions software-defined and able to run on a single integrated processor.

There are also times when the dominant architecture or platform itself changes, possibly as a result of a disruptive technology that radically increases efficiency, reduces cost or enables the incorporation of a completely new set of features. This actually happens quite regularly in 'hot' areas of technological development, such as information and communication technologies. One current trend, for example, is towards convergence, where separate functions that were formerly delivered by distinct appliances such as cameras, photo albums, personal digital assistants (PDAs), televisions, videos, entertain-

ment centres, calculators, memo recorders, faxes, mobile phones and personal computers (PCs) can now be incorporated into a single, hand-held appliance. However, as firms that were previously competing in separate markets now find themselves competing in the same market, but with different platforms, it is not yet clear which architecture will prevail. PDAs now routinely incorporate cell phone functions, while cell phones routinely incorporate many PDA functions, so one of these platforms may eventually dominate.

Example: Google, the search engine company, has added many new functions to make itself the core of a complete information management service. This strategy may lead Google to move directly into banking services, and compete with existing corporations such as Citibank, or to move into telecommunications, and compete with companies such as Vodaphone. This illustrates the point above; that technological advance can revolutionize one market by bringing it into the domain of another, so that firms that formerly competed in completely different markets, with corporate structures and products that reflected the demands of their separate markets, can suddenly find their territories invaded, their products no longer adequate and their corporate systems in need of radical re-engineering.

This can happen as a result of technological convergence; a platform or solution developed for one application generalizes to other markets. It can also happen when someone realizes that two conceptually-different problems actually have deep structural similarities, so that a solution developed for one can be readily adapted to solve the other. This process is accelerated by economic drivers; many companies now use new technologies to extract additional revenue streams from their existing infrastructure (in the UK, for example, supermarkets now offer tourism and banking services and electricity companies have become internet service providers), and many corporations now use data mining software to extract previously-inaccessible commercially valuable information from their own customer databases about correlated consumption patterns, and develop additional products and services as a result, which also leads them to compete in new areas.

Convergence is not the only driver, however, other important drivers are towards inter-operability, simplification and personalization of the user interface. There may be trade-offs here too; adding many more functions into a single handset, for example, may eventually make the device so complicated that users will start looking for simpler, cheaper alternatives.

In such cases, firms will study technology trends and undertake marketing studies in order to be able to form an opinion as to which architecture and combination of features will win, so that they can plan their investments and projects accordingly.

The end result is the **action plan**, which identifies the highest priority projects to achieve the objectives, determines the schedule and sequencing of tasks, sets out the milestones and decision-points, and allocates the budgets and personnel. A comprehensive roadmap will also build in risk assessment, so that the firm will continue to monitor the external environment for early warning

of the development of a disruptive technology, the emergence of a new competitor, or any other significant change that might jeopardize the plan.

The most complex platform roadmaps are called **offer platforms**. Albright notes that these are commonly used in the telecommunications, aircraft, defense, and services industries, where very large and complex projects have to be delivered by very large firms, linked in turn to an extended web of specialist sub-contractors and component suppliers. The task of integrating these projects has itself become a specialized skill.

Example: the UK Government recently commissioned two new aircraft carriers. Of the currently estimated cost of some £13 billion, only £3 billion is required for the actual ships. The remaining £10 billion is for the advanced electronics, aircraft and weapons systems, for which each ship will serve as a platform. All of these exceptionally complex systems and sub-systems have to be completely interoperable and mesh perfectly, in an environment where a significant failure can be fatal. The specification, manufacture, timely delivery and assembly of tens of millions of the components and sub-components required is such a complex undertaking that very few firms had the capacity and the experience required to be able to bid for the role of project integrator.

So the offer platform is a roadmap of roadmaps. It is the master plan that coordinates and links together all the roadmaps used by the contractors, the sub-contractors and so on, integrates the systems and the sub-systems that they supply, and keeps the products and the schedules aligned and on time.

All these roadmaps are still held together, however, by the same set of core themes; the customer drivers. The need to deliver a high-specification, robust and effective weapons system is, in this case, the factor that ultimately drives the entire enterprise.

Product technology roadmap

This is a variant of a basic technology roadmap. A product technology roadmap lists current, mid-range and long-range product needs. These are usually given in both general terms (such as personal mobility) and specific targets (such as a 'flying car' mini-aircraft). This is similar to an emerging technology roadmap, except that a product technology roadmap lists needs, and can therefore be relatively abstract, whereas an emerging technology roadmap maps the probable development trajectory of a given technology without necessarily going into detail as to the kinds of products that might be made possible at different points in the future. Product technology roadmaps and emerging technology roadmaps can therefore be compared to identify possible gaps between what people will want, and what particular technologies can deliver (see also under gap analysis).

Project integration

As noted above, large-scale or particularly complex projects frequently have to integrate multiple parallel and sequential lines of development, each with their own development targets, which makes the core task of **project integration** extremely important. This usually requires the management of the information, technologies, expenditure

and people involved in the project, coordinating all these elements in a single strategic plan, and meeting multiple objectives (such as completing the project to specification, on time and within budget).

Quality function deployment

Technology roadmapping requires the simultaneous consideration of markets, market niches, products and technologies, all of which are dynamic. These factors also interact, as a new technology can itself change consumer expectations. It is important to have tools, therefore, such as quality function deployment (QFD), which are used to reduce this complexity. QFD is used to determine the parameters of the customer's needs, the engineering characteristics of the product, the technology required to manufacture the product, and the amount of time that has to be invested in the start-up phase. QFD is also used to define the **nodes** and **links** in a schematic technology roadmap (see below).

Scenario planning

Scenario planning is the core of foresighting. The main drivers of change are identified and projected forward into the future, and the possible outcomes resolved into a small set (typically four) of the most plausible and internally-consistent outcomes. The outcomes and their consequences are then elaborated. This is sometimes done as a prelude to **backcasting**, which involves tracing back from a given future scenario to present day, sketching in the sequence of decisions and events that will lead to that outcome rather than another. In effect, backcasting resembles critical path analysis, but it is done from the future backwards rather than from the present forwards.

Example: the UK Government, which has completed three national foresight cycles, asked a panel of experts to review the possible outcomes of research into genetic engineering. The panel identified two key variables, the speed of scientific and technological advance, and the social acceptability of particular applications. The cross-matching of these two variables gave four possible outcomes, which can be broadly characterized in the table below:

		Social acceptability	
		High	Low
Rate of scientific advance	High	High, High. A wealthy and highly technologically advanced society, able to use and control biotechnology in the production of meat, food and industrial crops and genotype-specific pharmaceuticals.	High, Low. A wealthy but unequal society with deep, unresolved social tensions between a technical elite and the rest.
	Low	Low, High. A society in which technical capacity lags social needs, likely to be overtaken by more technologically-advanced societies.	Low, Low. A society turning away from technological advance and a sense of progress, likely to be socially conservative and regressive.

This approach also is used to think through the consequences of current decisions and possible future outcomes, to make the future less uncertain, to clarify the implications of particular technological developments and to address concerns about future societal or product needs.

Technology drivers

These are factors that influence technological development trajectories. This includes the factors involved in a choice between competing technologies, i.e. the factors that lead people to develop one technological solution rather than another. This includes human needs and wants, usually expressed as market demand, the extent to which the technology in question can meet those needs and wants, the full range of the technology's capabilities (i.e. what else can it do?), its absolute and relative cost, the potential development time to market, and any risk factors. The risk factors will normally include any health, safety or environmental concerns, the amount of waste generated, any side-effects, regulatory controls, social acceptability and political risks.

Technology insertion point

This is a predefined point in a project schedule (usually a **milestone**) where a given technology or technological solution is considered for possible inclusion in the project. A project to develop a new fuel-efficient car, for example, may reach a point where the project managers will review the best available technology for manufacturing engine components from ceramics or other advanced materials in order to determine the precise balance of cost and benefit that that solution would bring to the overall project.

In general, insertion points are carefully planned and scheduled in order to ensure that the project managers can take full advantage of any new technological development without disrupting the smooth flow of the main project. In practice, this is usually done by using sub-teams to investigate particular technological developments and new solutions, while more senior management retain control of overall **project integration.**

Technology roadmap

The technology roadmap itself is a document. It is the single most important output (but not the only output) of the technology roadmapping process, which is a systematic attempt to identify both a future market need and the technology needed to satisfy that need. This document lists the future product needs (the attributes that have been assessed as vital to a proposed future product), the associated performance targets (both for the product and for the associated manufacturing process), any technological alternatives, and the business development plan and associated milestones for achieving those targets.

A technology roadmap will usually include at least four major sections, covering the following topics:

- The definition and scope of the project, including any boundary conditions.
- The assessed product need, its attributes, the technology required, the technological development trajectory and the associated research agenda.

- The technological alternatives, possible challenges, unknowns and risk factors.
- An action plan, complete with the conclusions of the gap analysis (and any remedial measures required), the priorities for investment, milestones and technology insertion points.

A small company will usually select just one technological path to pursue, but a large company may invest in more than one line of research and development, using alternative technological alternatives, if the potential reward is sufficiently great. There are also cases where development strategies are coordinated by government agencies, usually when the development of a particular technological solution is seen as a national priority, when a number of firms will pursue parallel lines of research and development and the government agency will act as the project integrator [9].

As this suggests, a technology roadmap can be used to:

- Build a consensus within a firm as to its future market opportunities, its key products, its core technologies and its investment priorities.
- Help to anticipate important changes in markets and technologies.
- Provide a coherent basis for planning and coordinating strategic changes within a firm, or even across an entire sector of industry.

Technology roadmaps usually include diagrams to show the spatial and temporal dimensions. The example in Figure 1 (right), a generic technology roadmap, which gives the spatial dimension on the Y-axis, shows the links between particular market demands, the products needed to satisfy those demands, the technology needed to produce those products, and the research projects needed to develop each technology. The X-axis shows the time needed to complete particular research projects and develop new technologies, manufacture new products and meet evolving market demands. The graphic helps to illustrate the discrete projects, technologies and so on, by showing them as **nodes**, but it also illustrates the ways in which they are connected by **links**. The links can be used to show both the direction and the magnitude of particular connections. So, for example, the first research project (RD1) will be used to develop a technology (T1) which will enable the manufacture of an intermediate product (P1) and a market-ready product (P2), and which will also enable the development of a second technology (T2) and so on.

User requirements capture

This is an iterative process, typically used to ensure that a particular technological solution is genuinely tailored to user needs and will therefore be immediately absorbed. It is iterative because it is also an educational process; the users themselves may not have a clear idea of their needs at the outset, and they may also have unrealistic expectations of the new technology. The process is mostly commonly used in the development of new software.

[9] For example, the Ministry of International Trade and Industry played a key coordinating role in the post-war development of Japan, and the US Navy played a similarly important role in coordinating and driving the development of strategic GPS technology (Economist Technology Quarterly, 2002).

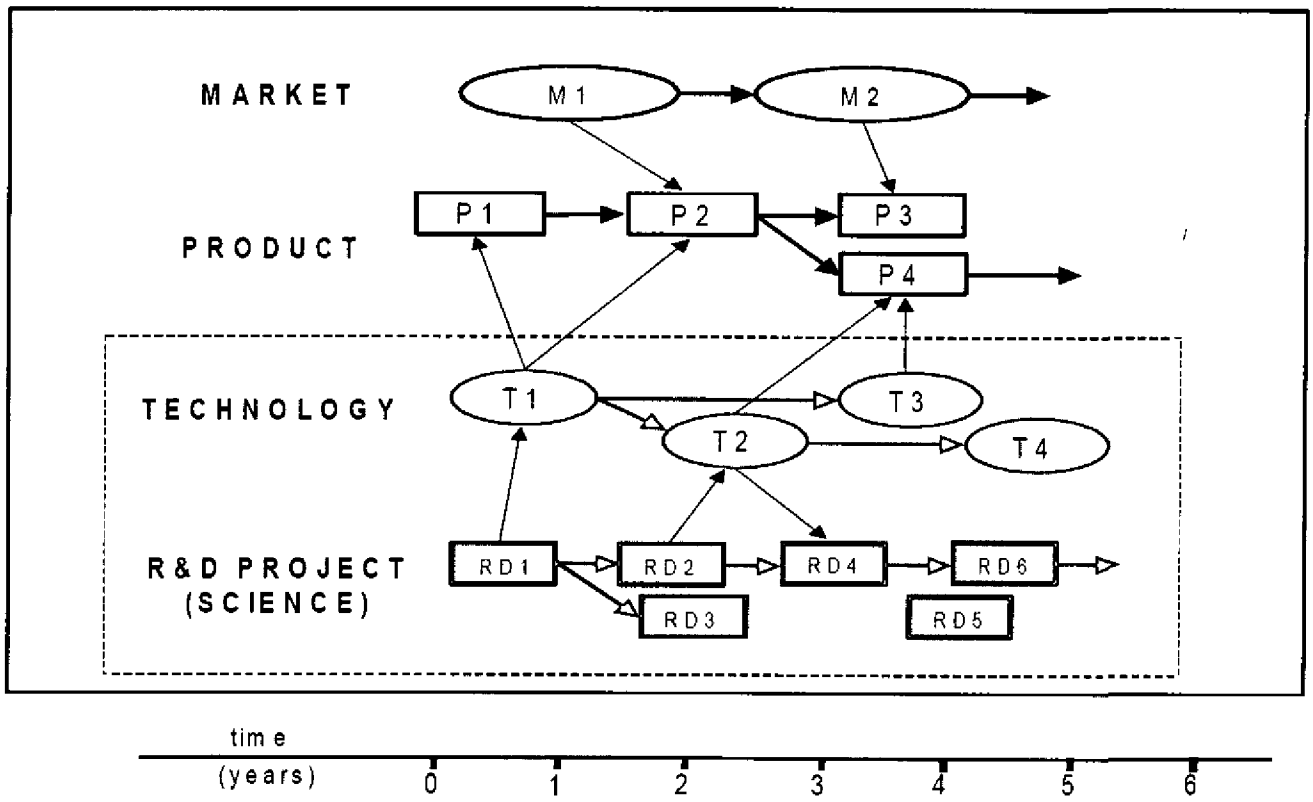


Figure 1: Generic technology roadmap, showing nodes and links. Adapted from Industry Canada, original source Kostoff and Schaller (2001).

A typical cycle will start with a technical and social survey to assess the situation with regard to any problems and perceived needs. This will be followed by a first approximation of the solution to those problems. This will be explained to the users, and their reactions will be used to shape the second approximation. The second approximation may be a working prototype that will be trialed, so that any shortcomings and weaknesses can be identified. This will then be used as the basis for the first full version.

Example: a large European Commission-funded project involving a number of European universities was designed to identify the information needs of rural land-users. The task was to design a high-integrated system that would access highly diverse data from many different sources controlled by different authorities (such as land ownership, soil type, vegetation cover, land usage pattern, conservation status, water tables, high tide marks and so on), and make all this information available in a GIS-based system that had to be accessible to people with no prior experience of computers. This involved a multi-stage process of user requirements capture in order to ensure that the system that resulted gave people the information that they needed in a format that was intuitively obvious, user-friendly and very accessible.

Verification / validation

This is usually done at several stages in a user requirements capture process, but it is more commonly done when a new technology has got to prototype stage. The technology is tested in order

to ensure that the components work, and meet their specified performance metrics, that the system performs as designed, and that the overall result is on track to meet all customer expectations with regard to performance requirements; efficacy, cost and so on.

Part 2

Roadmapping in developing countries

2.1 Mapping the future agenda: innovation, technology and development

We live in an era of unprecedented technological change and development. Some estimates indicate that innovation per se now accounts for more than half of economic growth in the advanced industrial/post-industrial economies[xli] with much of the remainder derived from incremental technological and managerial improvements that raise per capita productivity and thereby increase both output and real incomes. There are a number of rapidly maturing technologies in the pipeline, and new composite materials, biotechnologies, informatics, microfabrication techniques and nanotechnologies will soon allow a wide range of radically new solutions and opportunities.

The rate of technological development has been accelerating since the first industrial revolution, as many new technologies themselves stimulate or enable further scientific and technological advances. This ensures that the process broadens and gathers momentum, with increasingly rapid progress being made on an expanding front. More recently, the rate of dissemination and uptake has also started accelerating, as the technical developments that increase manufacturing productivity now transfer very rapidly across borders. There is considerable variation by sector; but many improvements in design, manufacturing or management can now be copied in a matter of months. Partly as a result, the process of global economic development and growth has widened dramatically in recent decades, bringing both additional competition and a range of new business opportunities into the market. Countries as diverse as Ireland and Vietnam have engineered a successful transition from low-growth to high-growth trajectories. Countries such as Brazil, South Korea and Malaysia are now highly competitive in areas that range from aviation to electronics; China is emerging as the new global hub of manufacturing, while India has built a world-class industry in information and communication technologies and services. China's development has been particularly rapid; over the last two decades, China has moved from being a poor developing country to become the world's fourth-largest industrial manufacturer and the largest exporter to the US[10] [xlii] ; some projections indicate that China could become the world's second largest economy by 2020[xliii].

This widening process of development has generated a range of global economic gains. The significantly lower costs of production in countries like China[11], which still has a reserve pool of 400 million underemployed workers, have exported deflation to other economies; falling prices have increased both profits and real incomes, thus generating additional funds for both investment and consumption. This is powering a sustained increase in world per capita productivity and aggregate output. Average per capita productivity was just $1,925 (in 1995 dollars) in 1950, giving a GWP of $4.9 trillion[xliv]. By 1995 technological advances had raised average per capita productivity to $4,733, giving a GWP of

[10] In 2002, for example, China made 50% of the world's cameras, 30% of all air conditioning units, 25% of all washing machines and 20% of all refrigerators.

[11] For example, the cost of electronics manufacturing in China is now about 8% of the cost in the UK.

$26.9 trillion[12] [xlv], and current World Bank projections indicate that GWP will be approaching $140 trillion by 2050[xlvi]. The output from today's developing and transitional economies will, by then, have risen from less than 1/3rd of total world output to just under half, which means that by 2050 the developing and transitional economies will be generating about twice as much wealth as the entire planet does today. Rates of re-investment in education, science and technology are rising commensurately in countries like China and India, which will spur the next phase of development and growth.

The pace of change is likely to be further accelerated by the process of globalization; the progressive removal of barriers to international trade, as the general effect of market liberalization is to encourage trade and investment, promote greater specialization and efficiency, increase competition, reduce costs, accelerate the dissemination of ideas and technologies and thereby spur innovation. This combination stimulates development and growth, partly by increasing the size and efficiency of markets, partly by encouraging the development of new products and services, and partly by forcing the pace of restructuring and the redeployment of labour and materials into more productive uses.

The accelerating pace of both technological development and market liberalization indicate that we are moving into an era of particularly rapid change, where corporations and countries alike have to learn to operate in an increasingly fluid, dynamic and borderless world economy, and where a stream of new technologies will constantly transform the array of business constraints and opportunities. The resolution of remaining trade barriers under WTO rules will allow multinational corporations to accelerate the rate at which they are expanding their share of world trade, which will result in a further extension of international supply chains and globally-dispersed corporate systems of research, development, manufacture and marketing, with each activity increasingly concentrated on the basis of regional comparative advantage or proximity to key markets. Many industrial and service activities will relocate, and both economic growth rates and the pattern of resource demand and environmental impact will change accordingly.

The implications for development

Sustained economic growth creates jobs, and the combination of increasing wealth and expanding employment solves many social problems. The relationship between these two factors is not necessarily linear, however, as strong growth frequently coincides with economic restructuring and a transition to more capital-intensive, less labour-intensive industries. This means that pockets of high unemployment can persist even in strongly-growing economies, when entire communities (defined by economic status, geographical area or sometimes ethnic background) can become 'encapsulated', trapped by a lack of marketable qualifications and skills, and isolated from the economic development and growth around them. This can result in significant social problems.

Thus the process of restructuring can itself present some serious practical

[12] World output grew by some $7 trillion between 1986 and 1996, which means that the growth in that decade was substantially more than the total growth over the rest of human history.

and political difficulties, particularly for weaker nations with a narrow economic base and little capacity to fund the welfare and retraining programmes that would ease the process of transition. It is important to note, therefore, that we are still at an early stage in the process of international market liberalization. At present, only 20% of world output is contestable, which means open to both international acquisition and global competition in the supply of goods or services. If the transitional logistical and political difficulties can be resolved, however, that segment appears set for rapid growth. Micklethwait (1999), analyzing reports by McKinsey, recently predicted that by 2030 some 80% of world output would be contestable [xlvii].

The solution to the social problems associated with economic restructuring is not to resist market liberalization, because that is likely to reduce the rate of economic growth. If the rate of growth falls below the rate of population increase, high levels of unemployment and underemployment can become chronic, which is likely to result in far more serious social problems; falling government revenues make it more difficult to support social programmes, and the educational underperformance, de-skilling and social disaffection commonly associated with persistent unemployment can make the task of rekindling economic development and growth increasingly difficult[13].

This does, however, highlight the importance of managing the process of liberalization carefully. It is advisable, for example, to sequence particular stages, to liberalize markets for goods before liberalizing financial services[14], to ensure that the requisite institutional mechanisms for oversight and regulation are in place before liberalizing each sector, to build in reasonable transitional periods, and to ensure that technical advice and support is available, where necessary, to the private sector to assist them to adjust to an era of open markets, without preferences or subsidies.

The south-south divide

These profound changes in the production and distribution of global wealth, and in the associated pattern of demands and impacts, have very different social, economic and environmental implications for different countries. Some of these effects are clearly benign. The remarkable acceleration of the rate of technological advance and global economic growth has transformed the development prospects of many countries, which has in turn transformed human potential and the quality of life. World averages for health, nutritional and educational status have

[13] This downward spiral is sometimes compounded with denial; governments may have invested too much political capital in a policy to acknowledge failure, or the policy process may be dominated by vested interests, or the nature, extent and causes of the problem may be misrepresented or widely misunderstood. This can be seen, for example, in the apparent paradox that legislation to protect jobs can increase unemployment (if it is difficult and costly to make workers redundant, employers are more reluctant to hire). Thus policies can achieve the opposite of what was actually intended, but still be supported by the government, who may have invested a large amount of political capital, and by the beneficiaries of the policy (in this example, those in employment, who - understandably - want to retain their job security). This highlights the critical importance of the quality of governance.

[14] Liberalization of financial services is extremely important, as it allows the transfer of expertise, brings in new investment capital and allows risk to be better managed. A mishandled liberalization however, can seriously destabilize a national economy.

improved markedly, infant mortality and poverty indices have fallen significantly, and life expectancy has increased from 47 years in 1950 to 66.4 years today, a 41% gain over the period. The 2001 Human Development Report noted the astonishing progress made in recent years [xlviii]. In 1975 the majority of countries were defined as 'low and medium' human development, but by 2001 the majority of countries were defined as 'medium and high' development. The UN Human Development Report 2003 [xlix] notes, for example, that the number of people living on less than a dollar a day fell during the 1990's from 30% of the world's population to 23%, and that most of this remarkable improvement was a result of progress in just two countries, China and India. As these are the two most populous countries, improvements here have a marked influence on global totals and averages.

There is a second group, however, comprising about fifty countries, that in spite of decades of development assistance appear to be locked into low or even negative development pathways. Most of these countries are in Africa; thirty of the 34 countries classified by the UNDP 2003 report as "low human development" are in sub-Saharan Africa. Typically, these countries have had erratic development, with periods of low or negative growth that have diluted or erased the impact of periods of positive growth. Some countries have fallen back in both relative and absolute terms. In 1960 per capita incomes in Africa were three times higher than in East Asia, now they are less than half as high; reflecting a six-fold shift in the relative prosperity of the two regions. Countries like Thailand and Malaysia have industrialized, diversified and grown, while about ten countries in Africa now have lower standards of living than they did in 1960.

As Clayton and Wehrmeyer (2003) point out, this widening 'south-south' divide indicates that some developing countries are capitalizing on opportunities and adapting successfully to the new global environment, while others are not[l]. The urgent question now is to understand what makes that difference; why some countries are succeeding, while others appear to be locked into patterns of underdevelopment.

Under-development

Under-development is an exceptionally difficult problem. A number of internal and external factors are involved; the former includes poor governance, weak institutions, corruption, ethnic tensions and gender discrimination, the latter includes tariff and non-tariff barriers, low commodity prices and poorly-structured aid programmes. Another common characteristic of the under-developing countries is their narrow economic base; many rely disproportionately on remittances, aid and exports of a few commodities and other primary goods for foreign exchange. Most commodity prices have risen since 2002, as growing demand from China has created supply bottlenecks, but the under-developing countries generally lack the technical and logistical capacity required to expand production at the pace required and can therefore lose market share to major exporters even as prices are rising. New and emerging technologies, such as ICTs and biotechnologies, are creating new economic opportunities, but these too tend to be seized by those countries with the tech-

nical capacity and skill base required to develop and exploit new applications. Market liberalization is gradually removing the protection afforded to uncompetitive local manufacturers, and rising quality control standards in the major markets can present very effective non-tariff barriers to increased exports. Thus even traditional markets are being transformed by a combination of technological and economic developments, in a manner that could further widen the south-south divide.

The most important factor implicated in the growing divide between the developing and the under-developing countries, however, lies in the nature of development itself.

Development is a highly complex process. It reflects, in essence, a series of economic changes and transformations, each with a technological underpinning. The primary driver of change is innovation, which creates new services, products and markets, and thereby generates additional wealth. This, in conjunction with the associated redistribution of power and resources, fosters social and political change, which in turn shapes the next phase of technological innovation and economic development. As Schumpeter (1950[li]) noted, this process entails a powerful intertwined cycle of constant creation and destruction, as new ideas and technologies create new opportunities, demands and markets, but simultaneously render old technologies obsolete and the associated skills redundant. Thus the economic status quo and the associated political arrangements are constantly disrupted by innovations that fundamentally restructure the competitive environment.

This process develops its own momentum, as each radical development, incremental improvement and new deployment of technology both enables and spurs further phases of economic and technological change, in a positive reciprocating dynamic. Where there is no technological capacity, however, there is no technological dynamism. The process of economic and social development will remain weak, and largely dependent on the vicissitudes of external factors such as commodity prices, because the prime driver of change is absent. Thus the disparity between nations in terms of their innovative and technological dynamism is perhaps the most fundamental factor underlying the disparities in development pathways[15 lii].

The true significance of this fundamental divide can be seen in the markedly different responses to the same factors in the changing external environment. The same process of trade liberalization that has underpinned much of the current era of economic development and growth and opened new development opportunities for the newly industrializing countries has also exposed structur-

[15] Technological capacity and dynamism are still highly concentrated. Sachs (2000) has pointed out that 98.5% of patentable innovations are generated by about 15% of the population of the planet, almost all based in OECD nations. A second tranche, comprising roughly half of the world's population, is able to adopt these technologies to varying degrees in improving production, communications, logistics and consumption. The third tranche, about one-third of the total world population, is effectively disconnected from this process, with very low rates of technological innovation and uptake. The extent of the disparity is profound; Sachs notes that the US issued 51,000 patents to foreign inventors in 1997, almost all to citizens of other OECD nations. A group of 48 largely technologically-disconnected countries, with a total population of 750 million, took out just 47 of these 51,000 US patents, 0.009% of the total.

al economic weaknesses in some of the under-developing countries, and thereby undermined their development prospects. Some of the newly industrializing countries have moved rapidly from exporting commodities into manufactures, and more recently into services, whereas the under-developing countries have tended to remain primarily dependent on commodity exports, and have therefore become trapped by falling commodity prices that have eroded their sources of the foreign exchange needed to support development and diversification.

This suggests that the process of market liberalization is not formulaic, but interacts with internal factors (such as, for example, political systems, cultural behaviours and beliefs, market structures and other economic and institutional arrangements that can either facilitate or obstruct change), and that this complex interplay then determines whether the process operates to a country's advantage or accelerates its decline. At a minimum, it is clearly important for countries to have the human capacity and other resources required to accommodate change and manage the process of transition to a more open, competitive trading environment.

2.2 Human capital

As the previous section suggests, the real impediments to progress can be the economic, cultural and political factors that determine how, when and which technologies are adopted and supported. These can create path-dependency effects; particular technological development trajectories can become locked-in by the real or perceived cost of developing alternatives, the reluctance to write-off sunk expenditure, or a lack of the relevant skills. More generally, solutions cannot usually be imposed, essentially because a solution that is not widely understood, or which cannot be easily assimilated or at least accommodated by local cultural and political systems, will not generally be widely supported, and thus will tend to fail once external funding and/or pressure is withdrawn. Some aid projects have attempted to supply technological solutions, for example, which worked well in the cultural context in which they were developed and understood, but then failed in a context where the maintenance skills, infrastructure and commitment to that particular solution were lacking. As Williams and Markusson (2002) have pointed out, the dynamics of innovation and change cannot be understood without a broad concept of knowledge, including competence and capabilities, practices and routines, meanings, beliefs and perceptions [liii] . People can be supplied with new information, but new information does not automatically translate into an increase in knowledge and understanding; it is probably more accurate to think of information as a resource that can be utilized with the help of adequate knowledge. There are human factors involved in technology choices, which can sometimes be more influential than the relevant technical or engineering considerations.

The south-south disparity is likely to become increasingly marked as innovation emerges as one of the most fundamental determinants of competitiveness. It is essential, in dynamic and rapidly evolving fields of economic activity, to be fully abreast of both the relevant

research and the various factors shaping the emerging market, and to have the capacity to respond in a pro-active manner to anticipated consumer demands, basing investment and product development on forward market projections. To develop a position of competitive advantage, in this complex and fluid terrain, requires a broad and diverse set of skills. Innovative ability, flexibility and agility are critically important, as is the ability to anticipate a change in the structure of the market. This in turn requires building the innovative and technological dynamism, decision-making capacity, the knowledge networks and business clusters needed to develop and disseminate information and capitalize on the rapidly transforming array of problems and opportunities in the global environment.

It is essential, therefore, to build the necessary skill-base, the technical and managerial capacity required to compete in open markets. As the disparities between states widen, however, it becomes increasingly difficult for poor countries to retain or attract the necessary skilled personnel; many are likely to migrate in search of better jobs in the wealthy, expanding economies.

2.3 Politics and governance: the role of the state in the economy

As noted earlier, one of the most important issues in development studies today is to determine why some countries are able to develop and maintain high-growth trajectories, while others fail on one or both counts. This is even true, in some cases, of neighbouring states. This suggests that internal factors (such as politics, the quality of governance, the integrity of institutions and cultural attitudes to education, work, saving and investment) can be more important determinants of development than external factors (such as world market prices for commodities, goods and services).

At present, the situation of many of the under-developing countries is not promising, as many of them are now contending with an exceptionally difficult set of complex, interacting problems. They have to determine their areas of comparative advantage and restructure their economies accordingly, improve general productivity in order to increase the output of wealth, increase business efficiency in order to make domestic firms competitive, stimulate new business development and create job opportunities in order to meet the needs and aspirations of growing populations, and increase the efficiency of energy and resource-use in order to reduce the rate of environmental depletion - and all against a background of declining aid, growing public health problems and a degrading environmental resource base.

In such difficult circumstances, many people are understandably reluctant to contemplate yet further change. At times of great uncertainty, in particular, there is a common human tendency to hold fast to residual beliefs, and a reluctance to relinquish familiar theories and institutional arrangements. Unfortunately, it has also become clear that some traditional models of development have failed, while others are still current but have become increasingly contentious.

For example:

- The oil crisis and recession of the 1970s precipitated the collapse of developmentalism - the idea that every nation could catch up economically if the state took appropriate action - as many of the countries pursuing these policies saw their investments fail, debts and financial dependency increase, credibility erode and average living standards decline. This combination frequently led to internal disorder, which further discouraged foreign investment.

- State-led development per se is no longer very credible, basically because civil servants and politicians have typically been less skilled at understanding markets and managing developments than industrialists[16] , while politically-directed investment has frequently been influenced by political rather than business criteria[17], and this combination has resulted in a history of poor performance, clientelism and corruption[18].

- The 'Fordist' belief during the 1970's and 1980's that heavy industry was the key to economic development, in conjunction with a common donor preference for large projects, resulted in the provision of large-scale plant and infrastructure; but this frequently failed to demonstrate the projected economic multiplier effect. In some cases, undermined by inadequate market and technical analysis, the failure of these projects left little apart from a significantly increased debt burden.

- The even more pervasive and long-term belief that capital would unlock development by

[16] When governments try to 'pick winners' and support particular firms or projects they are, in effect, trying to second-guess the market. This approach depends on the assumption that a small number of politicians and officials have superior knowledge or in some way understand the market better than industrialists, investors and traders. This is not usually true, which is why this approach does not have a good track record.

[17] There may be political pressure, for example, to locate plant within constituencies with high unemployment, or those represented by powerful politicians. The plant may therefore not be built on the most efficient scale, or awkwardly located, which can result in lost economies of scale and increased transport costs. There may be similar pressure to resist shedding labour, as workers are also voters. This can result in resistance to modernisation and mechanisation, unnecessary wage costs and falling per capita productivity. Finally, firms with political access and privileges frequently exploit their position to secure state contracts and subsidies, while using their political contacts to close off their markets to rivals. These factors, in conjunction, can steadily erode efficiency, profitability and competitiveness. The high costs and poor service that result are usually then passed on to consumers, adding to their costs, reducing levels of disposable income and thereby reducing the rate of new business development.

[18] There is an important distinction between state-led and state-coordinated; some state-coordinated initiatives have been very successful. As noted earlier, the Ministry of International Trade and Industry played a key coordinating role in the post-war development of Japan, and the US Navy played a similarly important role in coordinating and driving the development of strategic GPS technology (Economist Technology Quarterly, 2002). There is, similarly, an important distinction between the failed model of state-led development and the widely accepted core role of the state in actively providing the conditions needed for business to flourish, which Keynesians would extend to include activist measures such as counter-cyclical economic stimulation to shorten the depth and duration of a recession.

raising disposable incomes and encouraging investment led to an emphasis over some four decades on bilateral and multilateral government budgetary assistance to remedy shortages of development capital. The argument for this approach has been weakened by the growth of foreign direct investment (FDI), as global flows of private investment capital now dwarf flows of aid and development assistance. More fundamentally, the World Bank's finding that countries with bad policies and poor governance can absorb large amounts of donor capital over decades to no effect has undermined the earlier emphasis on the role of capital per se in enabling development (World Bank, 1998 [liv]).

- Recent research indicates that technical capacity is a critically important factor in development (Sachs, 2000 [lv]), and that managerial capacity is the key to successful transfer of both technology and technical capacity (Xiaobai Shen [lvi]) [19]. These findings, in conjunction with the two points above, suggest that the role of FDI in transferring managerial and technical capacity may have greater long-term developmental significance than the provision of capital or physical plant per se. This in turn suggests that good ideas, worthwhile projects and good management can attract capital, but that the converse is not necessarily true.

- The effectiveness of traditional aid delivery mechanisms has also been questioned. As Easterley (2002) points out:

> *"(Foreign aid) allows rich country politicians to feel that they are doing all in their power to help the world's poor, supports rich nations' foreign policy goals, preserves a panoply of large national and international institutions, and provides resources to poor country politicians with which to buy political support. In short, foreign aid works for everyone except for those whom it was intended to help, with results*

[19] The management capacity transferred via foreign investment, acquisitions and joint ventures tends to be practical and focused on the specific issues and problems associated with the business and the sector. This can then transfer fairly readily to supply or other satellite activities, and thus underpin the gradual development of a strong cluster, especially as a number of large corporations increasingly see the benefits of providing training and thereby supporting the development of a larger pool of more skilled suppliers (as this tends to improve the reliability and ensure the consistent quality of their supplies). This market-pulled development may therefore provide a more durable and useful means of skill and technology transfer than the abstract 'capacity-building' projects currently fashionable with most of the major donors. Donor-driven approaches to 'capacity-building' usually result in funding for new degree courses, support programmes in government ministries or new posts in NGOs. The problem with the first is that - in the absence of a strong market-pull factor - the students may graduate into unemployment, the problem with the second is that government policy can become donor-driven, constantly redrafted to reflect current donor priorities, while the problem with the third is that NGOs can become increasingly top-heavy, dependent on continued donor funding, and more remote and less effective as a result. Thus the more applied management skills transferred via FDI may have more chance of transferring successfully, of being of more practical value in a development context, and of underpinning a wider and more durable process of economic expansion.

such as the aid agencies' calculation that it takes $3,521 in aid to raise a poor person's income by $3.65 a year" [lvii].

- The failings of the traditional aid formula have led various governments and NGOs to re-focus on the role of trade as an engine of development. However, a complete replacement with a 'trade not aid' formula would risk bypassing the countries that are still too constrained by logistical, governance or other deficits to be able to trade normally or effectively.

- On a similar point; the recent re-emphasis of the role of trade has highlighted the importance of competitiveness, but this has in turn led to some misunderstanding as to the role of the state in this regard, as states do not compete (individual firms compete, but nations trade on the basis of comparative advantage). This common misunderstanding has led some to believe that trade negotiations must be win-lose games[20] ; a particularly unfortunate outcome that has resulted in several mishandled negotiations.

- There have also been several shifts in donor focus even under the general heading of trade-enabled development, so that development assistance has switched from helping countries to remove the physical and institutional constraints on trade (e.g. by building access roads) to analyzing the characteristics of export markets (e.g. by market-scoping studies) to market access issues (e.g. by negotiating for the removal of tariff and non-tariff barriers to particular markets). Of course, all of these issues are important, but shifts like this in donor focus can cause the policies of the recipient government to become 'donor-driven' and thereby gradually erode the sense of local ownership and control.

- Preferential trade arrangements have a particularly poor record. For example, the preferential arrangements that the EU accords the ACP nations were intended to help the ACP countries to increase their share of the European market, diversify their economies and establish a positive dynamic for growth. However, an EU review in 1997 of the preferential arrangements noted that the ACP share of the EU market had declined from 6.7% in 1976 to just 3% in 1998, that just 10 products still accounted for 60% of total ACP exports to the EU, and that per capita GDP in sub-Saharan countries covered by the trade terms grew by just 0.4% per annum over the period 1960 - 1992, compared with 2.3% for the developing countries as a whole [lviii]. Thus the preferential trade terms had failed to achieve any of their primary objectives. However, an even

[20] This is, of course, incorrect, as the primary reason for trade is that both parties benefit; each party exchanges something of lesser value (to them) for something of greater value (to them). This means, in turn, that trade negotiations should be aimed not at win-lose outcomes, but at agreeing the regulatory and legal context (definitions, standards, mechanisms of contract enforcement and so on) needed to provide a durable platform for win-win exchanges.

more serious indictment was the possibility that the preferential trade terms had had the unintended effect of encouraging countries to persist in economic activities in areas in which they had no real competitive advantage, discouraged diversification and allowed overmanning, thereby postponing the inevitable accommodation to market reality to the point where the adjustment would inevitably be more painful.

- Finally, the IMF's 'Washington Consensus' model, which emphasizes a small set of simple and apparently universal principles of good macroeconomic management, has been widely critiqued because of its perceived inflexibility and failure to acknowledge the significance of variants in governance, institutional arrangements and sociocultural values. It became apparent during the 1980's and 1990's, for example, that similar programmes of economic reform in different countries facing apparently similar problems could result in significantly different outcomes, highlighting the important role that internal factors can play in shaping national outcomes.

This patchy, costly history of theories and attempts at development, and the apparent intransigence of the barriers to development in the 'non-developing' countries have left a legacy of donor fatigue and cynicism, both amongst donors and recipients. As Easterley (ibid) also points out:

"If all foreign aid given since 1950 had been invested in US Treasury Bills, the cumulative assets of poor countries by 2001 would have amounted to $2.3 trillion. The World Bank's administrative expenses went from $81 million in 1959-60 to $1.5 billion in 1993-94 (in constant 1993 dollars), while its staff went from 657 to 7,106 (Kapur et al. 1997). Meanwhile, the typical poor country has stagnated over the last two decades, and in many aid-intensive African countries for even longer. There have been individual success stories and progress on other indicators like infant mortality and school enrollment. But the goal of increased living standards and reduced poverty in the typical poor country was not attained. The decline in the 1990s reflects some aid weariness amidst the feeling that foreign aid created something much less than $2.3 trillion in productive assets".

This history also partly explains why the Johannesburg WSSD 2002 summit made most progress on basic health and infrastructure issues, such as water supply and sewerage, and on 'commons' issues, such as fisheries management. These are clearly essential goals in themselves, but the relatively limited set of agreements also represents a partial retreat from earlier, more ambitious development aims.

However, the extent of the theoretical and ideological change over the last four decades, and the growing contrast between development failures and successes does at least support the general conclusion that an approach that works well for one country will not necessarily work equally well for all. Development cannot be reduced to a simple formula; if it could, all countries would be prosperous. As indicated earlier, however,

countries have diverse histories, climates, natural endowments, demographics, institutions, cultures, problems, opportunities and constraints, and these factors clearly have an important role in shaping events and influencing outcomes.

The need for better governance and stronger institutions

Easterly and Levine (2003) pose a critically important question: what matters most for development -- geography, institutions or economic policy? [lix] In practice, as noted in the DIFD 'The Roots of Development' report[lx], successful development can depend on all of the above. The factors also tend to cluster, in that rich economies usually combine competent policy (on the whole), sound and stable institutions and favourable geography, whereas many of the world's poorest countries score badly on all three counts.

It is also true that the importance of the factors probably varies at different points of development. At an early stage of development, factors such as fertile soils, gentle terrain, river and sea transport options, temperate climates and relative freedom from virulent pests and diseases are obviously vitally important factors.

As economies develop, however, they assume an 'inverted pyramid' shape. Tertiary service sectors increasingly dominate secondary processing and manufacturing sectors, which in turn increasingly dominate primary mining and agricultural sectors. In the advanced industrial (or post-industrial) economies, services generate the greater part of GDP; typically 70 - 80%. As this happens, the physical factors of production become less important, and policies and institutions become the determinants of development and success.

Easterly and Ross conclude that, at this stage of global development, geography and even policy matter far less than institutions. They found that countries with good institutions can survive even bad policies [21], whereas countries with bad institutions generally do badly regardless. There are examples in sub-Saharan Africa, for example, that suggest that even a reform-minded, honest President can be easily thwarted by corruption in Parliament and incompetence in the bureaucracy, illustrating the point that good policies are unlikely to be implemented successfully (or at all) by bad institutions. There are also examples of the deliberate destruction of established institutions and constitutional safeguards in order to remove constraints on the government and entrench a political hegemony, which usually results in a shriveling economy and social disintegration.

Institutional reform can be very difficult, but at least institutions are not (usually) as resistant to reform as geography. The critically important task, for many developing countries, is to discover how to build good, impartial, robust institutions. This, in turn, requires clarity about the role of the state in economic development.

The role for the state

The failure of most attempts at large-scale, comprehensive state-directed

[21] Strong institutions can resist overtly political interference and uphold constitutional rules, at least for a while, and can thereby reduce or delay the impact of bad policy.

national economic planning has highlighted the vital role of market **incentives,** which motivate people to produce and distribute goods and services, and market **information**, which connects demand to supply. It is generally agreed, however, that markets too can fail in certain specific areas, and that the state therefore still has to play a small number of key roles if the market is to operate reasonably smoothly and efficiently.

One role is to provide public goods; services necessary for the common weal that cannot be efficiently supplied by the market (usually because it is necessary to make these services universally available, which means that in practice they have to be funded from general taxation rather than user-fees). The first and most important role for the state in this regard is in protecting the lives and property of its citizens, both from external aggression and, to a reasonable measure, from the state itself; people are understandably reluctant to make long-term investments under predatory regimes where the profits are liable to be seized by others. This function therefore requires force majeur, the state must be able to control, defend, police, protect and enforce. It also requires an impartial rule of law, by which the state itself is bound, which thus requires a largely independent judiciary. A related role is in ensuring that certain merit goods (such as health, education and in some cases welfare) are available to all members of society, in particular the more vulnerable members. This is an important public good; an uneducated, diseased population is far less productive, and infectious diseases spread, so any significant failure in this regard can impact negatively on the health, welfare and prosperity of society as a whole. Another important policing role for the state is in monitoring and regulating markets, ensuring fair competition, enforcing contract compliance, preventing abuses and permitting legal redress, limiting monopolies, maintaining impartial systems of definitions, weights, measures and standards, and obliging firms to internalize costs (such as pollution) that they might otherwise impose on others.

Another key role for the state is to ensure another important public good; sound money. Money is used as a store of wealth, as well as a medium of exchange. Inflation erodes the value of that store of wealth, leaving less available for investment or consumption. By analogy, it is as if part of the seed-corn in the granary was eaten by mice, leaving less for planting next season. In general, money only retains its value when the government manages the public accounts competently, does not default and is also prevented from printing more money to cover its debts, which in turn requires that the central bank has de jure or at least de facto independence. Most central banks today target inflation, which means that they act (usually by raising the base rate of interest when necessary) to keep the rate of inflation below a certain threshold. Deflation can also be a serious problem, however, as many people will defer purchases when prices are falling if they expect prices to be still lower in future. Declining revenues oblige retailers to reduce their purchases, which results in declining revenues for manufacturers, which results in job-losses, and the ensuing climate of uncertainty makes many people try and reduce their

expenditure, thus triggering a further round of economic contraction. Many central banks have therefore adopted symmetrical targets, and now aim to maintain a low, positive rate of inflation. Mild inflation is generally constructive, if people expect the value of their savings to erode slowly, they will seek some form of investment that will give them a return above the rate of inflation, thus encouraging them to make their capital available (directly or indirectly) to the entrepreneurs who need to borrow capital to start up or expand their businesses.

Finally, states also manage markets, with varying degrees of success, by determining the rules for trade and investment, encouraging or preventing cross-border sales or investments, raising taxes on certain forms of activity and creating demand by public procurement.

The paradox

The important paradox here is that governments in relatively poor developing countries with critical skill shortages, and where the private sector consists largely of very small companies, may have to play a more active role in assisting the private sector than is desirable. It is unlikely that the poorest countries could support or benefit from a technology roadmapping or foresight exercise, for example, without the full involvement of the government.

The solution to this paradox requires that the state itself has an exit strategy, so that it can progressively reduce its role as and when it becomes possible, allowing the private sector to expand its role and eventually take on the task of initiating, managing and driving these exercises.

2.4 Infrastructure and the supply chain

The previous section reviewed some of the gaps in the **institutional** architecture. It is clearly important, for example, to have a functioning judiciary to ensure basic functions such as contract compliance.

Another key problem in many of the poorer developing countries is that there are usually significant gaps in the **physical** infrastructure, typically at several points in the supply chain. Many of the things that can be safely taken for granted in mature economies, such as reliable supplies of water and power, fast communications links, good roads, efficient ports and airports, sanitation services and so on cannot always be assumed in some of the poorer developing countries.

These can be very effective bottlenecks, making it difficult for any business to compete effectively in an export market. To understand the extent of this problem, it is necessary to review the issues involved in the management of a supply chain.

The supply chain

The supply chain maps the flows of material from the source to the final consumer. At any one time, material is being produced, processed to add value, stored or being transported to the next stage of the chain. Each stage adds both cost and value.

A simple supply chain might look like

this: the fertilizer and seed merchant imports agrochemicals and sells them to the farmer, the farmer sells the crop to a wholesaler/distributor, who sells on to a food processor, who cooks, cans and packages the food and sells on to a retailer, who sells to the final consumer.

As this suggests, different people and discrete organizations are usually involved at each stage of the supply chain. In a market economy, the chain is ultimately driven by the consumer. The demand generated by consumer decisions works back through the economic system against the direction of the flow of materials until it reaches the primary producers.

So the physical material generally flows one way, i.e. downstream. Information, however, flows both up and down the chain. Information flows upstream in the form of market forecasts, projected demand, futures markets, advance orders, sales data and so on, and information flows downstream in the form of invoices, shipping notes and bills of lading.

The final consumer is not usually concerned with what happens higher up the chain. They are, however, sensitive to the issues that impact directly on them, such as the availability, quality, reliability, cost, and perceived value for money of the final product. This means that the retailer has to be sensitive to these issues, which means that they have to ensure that their supplies meet the required standards, and so on. Thus the discipline imposed by the market is another form of information that flows upstream until it impacts on the primary producers.

The fact that the final consumer is mainly concerned only with the final product at the end of the supply chain has a number of important consequences, some of which are not immediately obvious. For example, a farmer might invest heavily in improving quality and output, but sells to a processor who does not have the same concern for quality, or the same drive to increase sales. This means that the best efforts of the farmer are in vain, because the final consumer does not see any difference in the quality or availability of the finished product. Similarly, a supply chain that involves fresh produce, where it is vital to get the produce to market while it is in peak condition, is extremely sensitive to logistical and shipping problems. Farmers, distributors and processors might all invest in improved productivity, but their efforts can be undermined by shipping delays which result in spoiled, blemished or over-ripe produce getting to market. As this suggests, the supply chain is as only as good as its weakest link.

It is even possible for efforts to improve performance at one point in the chain to disrupt an operation further downstream, so that there is a net loss in the efficiency of the supply chain as a whole. For example, improved productivity and a faster work-rate in the packaging plant may result in the shipment getting to the wharf too early, so that it spoils before it can be loaded.

Managing the supply chain

There are particularly important supply chain management problems with regard to the need to mediate between supply and demand in a situation with relatively lengthy delays. Market

demand can change extremely rapidly, but it takes a long time to develop an oil field, open a mine, or sow and reap a crop, and to refine, manufacture, and ship the final product. This means that it is necessary to make key investment decisions on the basis of projections of future demand. When oil companies are deciding how much to invest in new refineries, for example, they have to do so on the basis of estimates of market demand over future decades. Similarly, farmers want to know as much as possible about the likely demand for a given crop, and the price that they can therefore expect to get, before they decide what to sow. If they decide not to sow a particular crop, output will fall and the price will rise, giving a good market for those farmers who went against the trend. But if they do sow, output will rise and the price will fall, which may put some farmers out of business.

One way to smooth out the effect of these time lags is to restrict production or build up inventory when markets are over-supplied and prices are low, then to increase production or release material when markets are under-supplied and prices are rising, thus damping out price extremes. This is similar to the role that Saudi Arabia plays in regulating the world oil price. More generally, manufacturing needs to have economies of scale, whereas customer service may require meeting many small orders, which requires holding buffer stocks at some point in the system so that demand can be aggregated into manufacturing-scale quantities.

Inventory is expensive, however, partly because there may be a real cost associated with storage, but mainly because it represents an investment of cash that has not yet generated a return. So it is important to keep the amount of cash tied up in inventory to a minimum, while still holding sufficient buffer stocks to meet likely demand.

In effect, therefore, inventory is a solution (not necessarily the best solution) to the underlying problem, which is that of information. A number of the organizations in a supply chain have to hold stocks because they don't know how much they will be able to sell, and at what price. This means that inventory can build up at more than one point in the chain, which adds to the overall cost and reduces the efficiency of the whole chain.

There are various possible solutions to this problem. For example, some governments have tried to make agricultural markets more predictable and stable by holding buffer stocks and setting intervention price rates to give farmers guaranteed sales and minimum prices. This approach tends to encourage overproduction, however, at the tax-payer's expense, so it is not now regarded as a good solution. Futures markets, which allow price-hedging, are more flexible. Producers can use them as a form of insurance against low prices, but the risk is carried by those willing to take the risk, as opposed to the long-suffering tax-payer. Farmers may also secure individual contracts-to-supply from processors, which allows the farmer to get a guaranteed sale, albeit possibly at a slightly lower price. In effect, the farmer can trade off the risk of an unsold crop against the risk that they might not get the best prices.

An alternative solution is to improve overall coordination and management

of the supply chain, which means focusing on the flows of information. As noted earlier, however, different people and discrete organizations are usually involved at each stage of the supply chain, so good supply chain management involves strengthening relationships between the companies in the chain, improving flows of information and signaling any significant changes in advance. Accurate and timely information can improve mediocre supply chain performance, but disconnected improvements at individual stages (even to world-class standards) cannot usually overcome the problems caused by poor information flows.

2.5 Methodology for technology roadmapping in developing countries

Identifying the drivers of change

The first stage in a horizon scan is to identify the major drivers of change, and the associated implications for export markets and business opportunities. This process is illustrated in the following examples, which are drawn from a recent **horizon scan** exercise of global macroeconomic changes (Clayton, 2005)[lxi].

Market and industrial restructuring

The resolution of remaining trade barriers under WTO rules will allow multinational corporations to accelerate the rate at which they are expanding their share of world trade, which will result in a further extension of international supply chains and globally-dispersed corporate systems of research, development, manufacture and marketing, with each activity increasingly concentrated on the basis of regional comparative advantage or proximity to key markets. Many industrial and service activities will relocate, and both economic growth rates and the pattern of resource demand and environmental impact will change accordingly.

Market implications: The internationalization of supply chains will open many new opportunities for participating in global markets. This highlights the importance of developing strategic partnerships with multinational corporations, and on the ability to supply partners with reliable, high-quality goods and services.

The changing pattern of resource demand and environmental impact

The pattern of energy demand will change as part of this process of global economic restructuring. In 2002 the OECD states accounted for 52% of world primary energy demand and the transitional and developing economies for 48%. By 2030, however, the OECD share is projected to shrink to 43%, while the transitional and developing economies will account for 57% [lxi], reflecting both the increased dominance of services in the post-industrial economies and the rapid relocation of manufacturing activities into the transitional economies[22] [lxiii].

[22] It also reflects, of course, the re-emergence of nations such as China. China used to be a highly innovative society, and led the development of metallurgy, chemistry, spinning and weaving, mining, navigation, ship building, paper, porcelain, clocks, gunpowder, iron casting, systematic medicine and many other technologies centuries before they were known in Europe. In 1000 China may have generated 25% of Gross World Product (GWP), and may have contributed as high as 33% during Europe's 'dark age'. In the 15th century, however, the Ming dynasty made harmony, stability, obedience and order the central principles of the state, which largely prevented innovation and ...

Some of the environmental problems (such as industrial waste disposal) in the developed economies will reduce as manufacturing activities are increasingly relocated into nations like China, others (such as packaging waste, and the congestion and emissions problems related to transport) are likely to increase with further rises in levels of disposable income. In parallel, the problems with air, water and ground contamination in the emerging centres of world manufacturing are likely to increase.

It is clear, however, that China cannot continue to follow a resource-intensive path to industrial development without major global environmental consequences; if paper use/person in China were to reach the US level, China would consume more than total world production. It is also clear that this is not a transient problem; India's economy is currently growing more slowly than that of China, but by 2050 India will be the larger of the two nations (1.6 to 1.4 billion), so pressure on resources will continue to rise. This is untenable; the productivity of 15 out of 24 key global environmental 'services' (water, capture fisheries etc.) are already declining as environmental resources are progressively depleted (UN Millennium Ecosystem Assessment 2005).

The next phase of development is therefore likely to be driven by a combination of economic and environmental pressures to simultaneously reduce costs, increase resource-use efficiency and control environmental impacts, and the relatively new concepts of cleaner production and industrial symbiosis are increasingly seen as offering a solution to both problems (Clayton, 1999). These are strategies that focus on raising energy and resource-use efficiency in business and industry, typically by minimizing or eliminating wastes at source (by process or product redesign) or by using wastes as inputs into other processes and thereby converting them into auxiliary products. This approach offers significant potential gains; a series of studies by von Weizsäcker et al (1997) has suggested it should be economically feasible and technically possible to increasing average energy and resource-use productivity by a factor of four, which holds out the promise of an effective doubling of total global wealth while simultaneously halving total resource use [lxiv].

Developments such as these represent steps towards what Stahel (1993) has termed the **dematerialized economy**, an economy in which the process of economic development is progressively decoupled from environmental demand, with a transitional period in which resource-use efficiency rises faster than growth in GDP, thus achieving economic growth on a basis of declining resource consumption [lxv].

Example: this effect has already started to become visible in various sectors, including the markets for metals such as steel and aluminium. The mini-mills that recycle scrap steel have taken significant market share from the integrated producers that rely on iron ore. The economic advantages are even more apparent with aluminium, as the energy costs of recycled aluminium are about 15% of the energy cost of obtaining aluminium from

... change. This was compounded by the later transition into communism. By 1950, China generated just 5% of GWP. The impediments to innovation, development and growth were finally relaxed when the government indicated that they would allow entrepreneurs to flourish. By 2005, China generated 15% of GWP. Current projections indicate that by 2041 China will generate 20% of GWP, and may have recovered its former position as the largest national economy in the world.

bauxite, reflecting the additional energy required to mine, process and transport bauxite and alumina, so there are strong incentives for increasing these recovery rates further towards the technical-economic limit. Once industrial and domestic recovery loops for metals and other resources are fully established in the major markets it will be possible to further increase in demand could then be met via increased recovery rather than increased bauxite production.

Example: water consumption in the US closely tracked growth in GDP from 1900 - 1980. Since 1980, however, GDP has doubled, while water consumption has actually fallen by about 20%, indicating the extent to which technological improvement and efficiency gains can decouple the level of resource consumption from the rate of economic development and growth.

Example: Sheik Yamani, the former Saudi oil minister, indicated in a recent interview that the rate of economic growth had already started to decouple from the consumption of oil, for example, and that the importance of oil in the world economy had already diminished as a result of this development:

"In the past...for every one percentage point rise in the rate of growth, there would be another one-point rise in the oil consumption. Then that factor (the energy co-efficient) came to 0.5 to 1. But in Europe in the year 1999/2000 you have a rate of growth averaging around 2.5 per cent and the rate of energy growth is below zero. In the US they had a rate of growth of 4.9 per cent with consumption up only about 50,000 bpd [lxvi]*."*

Market implications: There will be important new market opportunities for businesses that understand this trend, and have developed the technologies and skills to operate waste reduction programmes within manufacturing processes and closed-loop production systems within the supply chain.

Demographic trends

Current UN projections indicate that global population will rise from 6.1 billion to about 9.3 billion by 2050, predominantly because of two factors; the continuing rise in world average life expectancy and the relatively high fertility levels in developing countries[23] [lxvii] . The populations of the world's 48 least developed countries are expected to rise from a total of 658 million to 1.8 billion, while the population of the less developed regions is projected to rise from 4.9 billion to at least 8.2 billion[24] . As a result, by 2050 about 90% of the world's population will live in one of today's developing countries, indicating that a significant part of the world's population will be increasingly concentrated in those countries least able to support it.

Some developed countries will also grow; the population of the US is projected to increase by 44% to 420 million by 2050. Much of Europe, however, will face an existential crisis, as fertility has now fallen far below the replacement level of 2.1 children/woman. Projections based on current demographic trends indicate that Slovakia could lose 8% of its population by 2050, Poland 15%, the Czech Republic 17%, Italy 22%, Romania

[23] In poor regions, average life expectancy will increase from 63 to 75 by 2050, in developed regions from 75 to 82.

[24] This assumes that fertility will continue to decline; otherwise the population of the less developed regions will increase to 11.9 billion over the period.

27%, Moldova 28%, Russia 30%, Ukraine 35%, Bulgaria 36%, Latvia 44% and Estonia 52%, while the population of Europe as a whole could fall by 60 million; the most extensive population decline since the 'Black Death' epidemic in the fourteenth century. The populations of France and Germany will decline slightly, with low birth rates offset by immigration, the UK's fertility rate is equally low, at 1.6, but the UK's higher rates of immigration mean that it is the only major European state expected to experience population growth, from 59 to 65 million by 2050. The growth will be very uneven, however, with parts of the UK depopulating; the population of Scotland is projected to decline from 5.05 million to 4.84 million by 2027, partly due to migration loss [lxviii].

This represents a profound shift in world demography. In 1950, Europe accounted for almost a quarter of the world's population, while Africa represented less than one-tenth. By 2050, the population of Africa will have risen from 800 million to about 2 billion, which means that the population of Africa will then be three times greater than that of Europe[25].

Market implications: These trends have several significant implications. The first is to highlight the importance of emerging markets for future growth prospects. A presence in China and India is obviously very important, but it is also increasingly important to develop strategies for marketing products in regions where per capita incomes are likely to remain low, but where the projected increase in population will create significant market opportunities. This requires a strategy for marketing to the 'bottom of the pyramid'.

Example: Unilever have significantly increased sales in India by making many household items such as shampoo available in smaller packs; this has reduced the unit cost to the point where items become affordable in low-income areas.

Example: Several mobile phone companies have achieved exceptionally high sales growth rates in Africa. In a number of countries, the service offered by the monopoly fixed-line provider was so poor that there was little real competition with the mobile networks. The mobile networks unlocked this potential by marketing simplified, cheaper handsets, and encouraging the development of mobile phone-based call rental businesses.

A second important implication of demographic change is the support that increasingly ageing populations will require. A smaller population is not necessarily problematic, but the age structure of the population during the transitional period presents a significant challenge, with a shrinking workforce supporting a growing number of elderly dependents. In 1998 about one-fifth of Europeans were aged 60 or over, by 2050 this will be over one-third, while the number of children will have fallen to just 14% of the population. As a result, there will be two elderly people for every child in Europe.

Europe's current position is strong; the addition of the ten accession states have consolidated Europe's position as

[25] This is net of the 300 million deaths expected to occur as the result of HIV/Aids in the period, total population is still rising even in the most HIV-affected countries. The population of the nine most HIV- affected countries in Africa is projected to increase from 115 million to 196 million by 2050. In Botswana, HIV prevalence is 36% but the population is projected to increase by 37%, in Zimbabwe the infection rate is above 25% but the population will still increase by 86% and in Swaziland the infection rate is thought to be well above 25% but the population is expected to increase by 148%.

the world's largest exporter and largest internal market, and European-based transnational companies are the dominant players in many key sectors of business and trade, including commercial banking, insurance, chemicals, engineering, construction, food and aerospace. Partly as a result, Europe hosts the largest cluster of the world's biggest corporations; sixty-one of the 140 largest corporations in the world are based in Europe [26]. Further harmonization of business and environmental regulatory regimes, merged trade policies and integrated transport networks, communications and power grids will help to maintain this position for some time. However, the mid-term prospect for most of Europe is one of elderly populations and shrinking workforces, increasingly dependent on migrant labour, so Europe's future depends to a significant extent on its ability to manage the social engineering and technological changes required to transcend demographic decline.

Market implications: This opens up a vast new array of business opportunities, tracking the technological development trajectory. It is clear, for example, that biosensors, web-based clinics and telemedicine will be required in order to support a rich but elderly population in a cost-effective manner, and telecommuting is likely to become the norm as a large part of the working population becomes increasingly frail. Companies that develop both the technologies and the web-based services required by the affluent elderly will therefore be well-positioned to supply these markets.

This is an area with long-term growth prospects. Japan's demographic transition will be even more marked than that of Europe, while China's will be exceptionally abrupt as a result of the 'one-child' policy.

Urbanization

Current trends suggest that by 2050 about two-thirds of the world's population will live in cities. There are currently 15 mega-cities (cities with over ten million inhabitants) in developing countries. By 2050 there will be 54 mega-cities in countries currently classed as developing, with the drift to the cities being simultaneously pushed by the decline of rural employment and pulled by the development of the urban economies. At present, almost one-sixth of the world's population lives in informal settlements (favelas, or shanty towns), most of them in developing countries. Many of these favelas are on hillsides, flood plains, in rubbish dumps or downstream of industrial polluters, under threat of eviction, natural disasters and disease. This is about to become the predominant pattern of human settlement; most of the projected increased population will be born in or migrate into favelas, so that by 2050 there will be about 3.5 billion people-nearly 40% of total world population-living in favelas.

Market implications: Cost-efficient 'urban technologies' will be required to solve the inexorably increasing pressure of rising population and demand. These include the design, installation and management of transit routes and technologies, the supply of water, electricity and sanitation, and the collection, processing and recovery of urban wastes. Firms that understand both the technologies and the political and cul-

[26] Fifty are based in the US, most of the remainder are based in Japan.

tural factors involved in city management will be well positioned to service a major global market.

The projected growth of the favelas will also require strategies for marketing to the 'bottom of the pyramid', both to deliver goods and services to vast informal settlements and to provide a means whereby
favela-dwellers can improve their security, economic prospects and environment so that they do not become (or remain) a social burden; a source of crime and disease, and thereby reduce growth and development prospects.

Technological transformation

Many markets will be increasingly transformed by a dynamic interaction of a number of factors, including mechanization, incremental technical improvements, improved scientific understanding, new technologies and structural technological change. With regard to agricultural and mineral commodity markets, for example, these changes will be reflected in the discovery and exploitation of new sources, increased volumes of production and consequently greater economies and efficiencies of scale, improved logistics and better supply chain management, increased competition, and, in some cases, substitution (Clayton, 2005).

Technological development has transformed the oil industry, for example, making it possible to extract previously (economically) unrecoverable deposits. If it proves possible to economically recover hydrocarbons from unconventional sources, such as tar sands, there would be a dramatic expansion in global oil reserves and a parallel downward pressure on the price[27]. New technologies also have implications for patterns of demand. For example, the transition to fibre-optics, opto-electronics and mobile rather than landline-based communications will increasingly dilute the demand for copper. A number of related developments are in the pipeline. Takehashi (2001), for example, notes that reconfigurable semiconductors will allow the development of 'universal devices', which will reduce the demand for a range of plastics and metals [lxix]. Similarly, recent developments with carbon nanotubes and graphite-reinforced polymers hold out the promise of a new generation of strong, light materials, which may eventually displace aluminium and other metals in aerospace engineering, car body parts and other engineering and construction applications. Hydrogen-powered fuel cells may displace petroleum-powered internal combustion engines in motor vehicles, thus reducing demand for oil, while the transition to mass use of hydrogen-powered fuel cells may in turn enable much greater use of alternative base energy sources, such as geothermal power from countries such as Iceland, thereby displacing other power station fuels such as coal. As the last example illustrates, many of these technological developments stimulate or enable further technological developments, which further accelerates the pace of change.

Another key technology is transgenic genetic engineering, which permits the translocation of properties from one species to another. If, for example, a gene from the legumes that confers the ability to fix atmospheric nitrogen can

[27] Canada's tar sands, which are mostly in the province of Alberta, are estimated to contain about as much oil as Saudi Arabia's reserves, but will remain largely unexploited until technological developments make it possible to recover the hydrocarbons economically.

be transplanted successfully into non-legume crops, there would be a displacement of demand for nitrogenous fertilizer. Similarly, if a gene that conferred the ability to survive in a more arid or a more saline environment could be transplanted into a food or industrial crop, there would be a dramatic increase in the area of cultivable land.

Molecular engineering, or nanotechnology, also has profound implications for the future direction of industrial development. Drexler (1996) has suggested that nanotechnology will allow the construction of replicating molecular assemblers and disassemblers, which will in turn allow the construction of many innovative materials with radically new combinations of properties, thus resolving many current physical constraints[28] lxx.

Market implications: The developments reviewed in this section suggest that we are at an early stage in a decisive transition from an era of materials-based to knowledge-based economies. All of the examples above can be classed as emerging technologies, in that they all exist, but are still at a relatively early stage of development. The full impact of many of these technological development trajectories still lies some years - or decades - ahead. The general trend, however, is clear. It is likely that, in future, increasing value will be attached to the knowledge component of a good or service rather than the physical component. In electronics, for example, the physical content of metals and polymers is being continuously reduced, and could in principle fall by perhaps another two orders of magnitude even on the basis of existing technology. What matters, of course, is the knowledge embodied in the assembly.

Similar principles apply in biotechnology. Microfabrication and nanotechnologies will permit more radical examples, especially with regard to appliances that customers want to be smaller and lighter, and where there is therefore a market penalty attached to mass. This development will coincide with the development of reconfigurable semiconductors, and the move to reduce the number of separate components and consolidating functions into fewer integrated circuits, with the long-term goal of making all functions software-defined and able to run on a single integrated processor. These two trends, in conjunction, are likely to lead to radically new forms of convergence, where processing capacity, appliances and services can be incorporated into common domestic items. It has been suggested, for example, that computers might be wearable in future, with all necessary access to communications, information and computational processing being incorporated into items of clothing such as shirts.

It is difficult to predict the implications of such potentially radical developments, even when most of these new properties can already be seen in embryo. It is even more difficult to predict the synergistic implications, when one emerging technology (such as nanotechnology) enables a dramatic advance in the development of another emerging technology (such as reconfigurable semiconductors). This is an example of a general phenomenon; it is increasingly common for advances in one area to enable progress in another. For example, recent advances in parallel computing have made it possible to

[28] One current research programme, for example, is directed at the development of military battle-dress that is as soft and flexible as cloth, but impervious to bullets or shrapnel.

model exceptionally complex events, such as protein-folding and climate change, which were previously inaccessible.

Partly as a result, many of the key scientific and technological advances today are made at the interface between disciplines, rather than at the core of a subject. For example, the recent development of a prototype bionic eye at Johns Hopkins University drew on optics, electronics, biochemistry and neuroanatomy. It is now generally agreed, therefore, that research is most productive when the research arrangements and criteria are not solely determined by disciplinary divisions or sectoral walls that then obstruct the most productive synergistic effects and the dissemination of innovative ideas and solutions.

The implications, therefore, are for business **strategy** and **structure**, rather than for any given emerging market opportunity. In a increasingly complex, dynamic and technologically-driven market place, it will be important to combine market awareness with an ability to anticipate the impact of technological change and the flexibility to adjust the product line and the business strategy accordingly. This is illustrated in the example of the cement company in Trinidad described in the next section.

Scoping emerging markets

A large-scale horizon scan, as illustrated above, can indicate in broad terms where new market opportunities are likely to arise in future, and the nature of those markets.

The next stage in developing a business strategy is to identify the preferred market, then to undertake a more detailed scoping study of that market. This will involve a much more close-grained analysis of the opportunities, trends, key technologies, products and the competitive environment.

Matching drivers and markets with the ability to supply

This involves a detailed assessment of the drivers in the market place, the translation of those drivers into specific product requirements, and then a matching of those product requirements with the current (or feasibly achievable) capacity to supply. This will entail an analysis of the skills and technologies required at each stage of the supply chain, an identification of any gaps and the measures necessary to close those gaps.

Identifying the technologies needed to supply these markets efficiently

This involves a detailed assessment of available (or feasibly achievable) technologies required to supply the chosen market, an assessment of the competitive, financial and technical profile of each technology, and the identification of the optimal technological solution.

The case study of the embryonic nutraceuticals and functional foods industry in Jamaica (see next section) illustrates the various stages in this process.

Part 3

Case studies & examples in developing countries

The case studies and examples reviewed in this section are as follows:

1. Nutraceuticals and functional foods: exports from Jamaica
2. Cement industry in Trinidad
3. Integrated solid waste management in Hyderabad, India
4. Food processing in India (cereals)
5. Food processing in India (milk)
6. Food processing in India (fruit and vegetables)
7. Energy training in Trinidad
8. Shandy exports from the Caribbean
9. Engineering training in Trinidad

Case study (1) is an abridged extract of a market scoping study for the National Commission on Science and Technology (NCST) of Jamaica (Clayton and Staple-Ebanks, 2002) [lxxi] . The last three examples (7 - 9) were generated in a technology roadmapping training course held under the auspices of the National Institute of Higher Education, Research, Science and Technology (NIHERST) of Trinidad and Tobago.

1) Nutraceuticals and functional foods market-scoping study for Jamaica

Horizon scan: scoping emerging markets

Leighton (2000) lists the drivers of change in the food and pharmaceutical industries [lxxii]:

- Demography. Increasing life expectancy and a fall in family size are causing a rise in the average age of the population in Europe, North America and Japan. Partly as a result, there are strong, established trends in the three largest markets towards fitness, self-care, better nutrition and a more preventative approach to managing the age-related degenerative diseases.

- Rising health-care costs. There is increasing economic pressure for a more prevention-based healthcare model. The US healthcare system cost taxpayers over $1 trillion in 1996. In 1998, retail pharmacy prescription drug sales alone totaled $102 billion, an 85% increase in only five years.

- Lifestyles. The promotion of healthier lifestyles can improve and extend lives while reducing healthcare costs; the most effective steps in this regard are relatively simple measures such as stopping smoking, more exercise and better diet.

- Consumer preferences. Markets for foods and even some pharmaceuticals are increasingly driven by consumer lifestyle needs. Healthy foods and dietary supplements have to be in convenient, ready-prepared formats so that they can be easily adopted in fast-paced, demanding lifestyles.

- Market demand. In 1996 US consumers spent $15 billion on general practitioners, but spent $80 billion on alternative medicines, including dietary supplements. In general, products that give consumers more control and allow them to self-prescribe are more likely to be successful[lxxi].

These drivers are forcing the pace of development of a new, global market for **nutraceuticals and functional foods**, where the distinction between foods and pharmaceuticals is becoming blurred. Consumers with high-pressure lifestyles, concerned about their health, are now looking to enhanced food products to deliver preventative health care, improved health status and increased life expectancy.

Market assessment

There is a rapidly growing market for nutraceuticals and functional foods, defined as those purchased primarily because they deliver an additional health or nutritional benefit. Using a strict definition of functional foods (limited to food and drinks that tend to make specific health claims of some kind on the packaging or in advertising), the functional food and drinks market in the five major European markets, the US, Japan and Australia had a combined value of US$9.925bn in 2003, with the largest single market - valued at US$4.5bn - in Japan. If a broader definition is used (this includes a wide range of products that do not necessarily make specific health claims, but that are still (or perceived to be) functional, the market rises to nearly US$24.2bn, with Japan accounting for over half of the total (LFRI 2004)[lxxiv]. The rate of US market growth is over 12 % [lxxv], and broadly similar rates of growth obtain in some of the other major market [lxxvi]. This compares favorably with the relatively sluggish 3% growth for traditional foods.

This high-value market offers a development opportunity for a country like Jamaica, as it has the potential to demand-pull a range of new business opportunities in agriculture, agro-processing and manufacturing for farmers, manufacturers and processors, and brokers and exporters.

Diversification out of traditional agricultural areas into production for high value products such as nutraceuticals and functional foods would allow existing uneconomic crops to be replaced by crops with higher economic returns, and create employment opportunities in a form of agricultural activity for which there is a real and expanding market as opposed to the protected and subsidized market for certain traditional agricultural exports. Instead of exporting bananas for ripening, for example, it would be possible to process the bananas in Jamaica, extract various value streams (such as phospholipids for the pharmaceutical industry, flavourings and essences for the food and cosmetics industries and so on), and sell these extracts into high-value, lucrative niche markets. The value of the exports would be significantly higher while the weight would be significantly lower, thus improving value to weight ratios, largely eliminating the transport cost penalty of island production and greatly increasing profit margins.

The potential customers in, for example, the nutraceuticals and functional foods industry, typically require oleoresins or other processed fractions, standardized and refined to a very high level of purity before export. This means that both primary (production) and secondary (extraction) stages would be based in Jamaica, thus capturing more of the value-added. In the long term, it also may be possible to capture another value-added stage by expanding into

the finished products market.

Preliminary estimates suggest that the potential share of world market for standardized extracts from sub-tropical plants in the Caribbean region could be in the range of 1 - 5% of the global ingredients market, while the potential share of the world market for finished nutraceutical and functional foods products could be perhaps 0.5%.

Competitive environment

The nations of the Caribbean have certain natural advantages - a long growing season, high rainfall and consequent rapid rates of plant growth offer favourable conditions for certain tropical plants with high levels of desirable actives - but these conditions would not, by themselves, be sufficient to guarantee a competitive position. India, Africa and China are already suppliers to the nutraceuticals and functional foods industry, for example, and will in some cases be able to compete in the same product lines.

There are a number of species that are endemic to Jamaica, some of which may prove to contain valuable actives. Other species are not endemic, but may still contain unusually high levels of valuable actives. The local variety of ginger, for example, is noted for its pungency, which indicates a high flavonoid content. Either situation could give Jamaica a valuable lead-time advantage, but this would probably prove to be temporary as other countries could replant with cultivars of the plants and varieties concerned.

The higher costs of production in Jamaica, however, would not necessarily be a serious impediment, as the ingredient cost in a finished nutraceuticals product can be less than 1% of the final consumer price. Thus India can produce ginger, for example, at about 1/7th of the Jamaican cost, but this advantage becomes less important (in comparison to other factors) when it has relatively little impact on the final price.

Matching drivers and markets with the ability to supply

Strategy for competitive advantage

The market is sophisticated, complex and fast-moving, and it is essential to ensure that any strategy for entering the market is based on a good understanding of all the important parameters, including consumer preference, marketing, technical, biomedical and regulatory issues. The primary determinants of competitive advantage, in this case, are likely to be quality control and product consistency, reliability with regard to both quality control and delivery schedules, anticipatory market awareness and technical capability, and effective marketing, branding and positioning.

Quality. With food ingredients, in particular, both the reality and the image of product purity are vital. Thus quality control and product consistency are of paramount importance.

Reliability. Reliability with regard to both quality control and delivery schedules is critically important. Manufacturers running batch processes and using just-in-time supply chain management need the ingredients to be there precisely on time, in exactly the quantity and quality specified. Failure in this regard is likely to have a

very high cost in terms of lost contracts, contacts and credibility.

Anticipatory market intelligence. It will be essential, in a dynamic and rapidly evolving field, to be fully abreast of both the biomedical research and the various factors shaping the emerging market, so that the nascent industry can respond in a pro-active manner to anticipated consumer demands. Farmers, for example, must be advised to plant on the basis of forward market projections, a radically different discipline from the traditional 'on a cart to market' model.

Marketing. Actives from Jamaica will, in most cases, be chemically identical to various actives produced elsewhere. In a consumer-driven market, however, this factor is usually less important than image (consider, for example, the 10-fold price difference between leading brands of training shoes and otherwise identical clones). This highlights the crucial importance of branding, and of building on the Jamaican image to establish a strong consumer demand for the Jamaican product lines.

More generally, the process of product identification, development and marketing is fundamentally important, as it is with most consumer products. Markets must be identified and assessed, prototypes developed, consumer reaction gauged, prototypes sifted and modified, and so on, in an iterative process that eventually leads to the launch of a new (or modified) product. Thus the key factor in securing and maintaining a competitive position in these new markets is to develop strong relationships with customers, brokers, and biomedical research institutes. Product development and marketing is a two-way, interactive process. The precise formulation of each product must be determined in close collaboration with both the technical and marketing divisions of the client firms. On the production side, it is essential to develop a market entry strategy, target a market share, secure a client base and distribution channels, determine the optimal product mix, and agree polices on branding, pricing and volume.

Various features of particular key market groups - such as the baby boomers in the US - indicate possible market entry strategies. This group, as a whole, tends to be influential, affluent and increasingly computer and internet-literate. This indicates that intelligent, targeted internet marketing might be a useful way of penetrating this market segment.

SWOT analysis: supply chain assessment for ginger flavonoids

There was a general perception at the outset that the only constraint was insufficient supply. The analysis revealed, however, that there were bottlenecks and problems right through the supply chain, all of which had to be resolved before the industry could supply export markets on a reliable and price-competitive basis. In particular:

- The crop has been badly affected by fungal infections in the past; farmers have to be taught how to sterilize planting material with hot water before planting. A better long-term solution is to increase the supply of tissue-cultured planting material.

- Many of the farms are small; it will be necessary to encourage cooperatives or aggregation of the output of multiple units.

- Market information is inadequate. There will also be problems, especially at the outset, meeting requirements for quantities and quality control.

The supply chain issues are represented schematically in diagram 3.1.

3.1 Supply chain for the Jamaican ginger industry

1) Materials	2) Farms	3) Processors	4:1) Market requirements	4:2) Market demand
Land ✓ Irrigation systems ✓ Clean planting material ✗ Tissue-cultured plants ✗	Skills ✓ Comfort level as to market volumes and prices ✗ Low yields ✗	Drying, grinding ✓ Extract oleoresin ✓ Extract flavonoids ✗	Reliability ✗ Quality ✓ Consistency ✗ Cost ✗ Volume ✗	*Domestic*: Consumers, processors. *Export*: Food, flavourings, nutraceutical, pharmaceutical processors & retailers.
1) Problems:	**2) Problems:**	**3) Problems:**	**4:1) Problems:**	**4:2) Problems:**
Lack of clean planting material. No commercial-scale tissue culture. **Solutions**: Training in hot water & other fungal/pest management techniques. Construct commercial-scale tissue culture facility. **Goals**: Adequate supplies of clean planting material. Better hybrids.	Farmers worried about market volumes and prices. Low yields. **Solutions**: Reliable information about market demand. Training, better practice, more fertilizer. Larger acreages of better land in ginger production. **Goals**: Farmers willing to plant. Increased yields.	Extraction facility needed to access higher-value markets. **Solutions**: Construct extraction facility. **Goals**: Ability to supply higher-value markets.	Low volumes. Inconsistent supply. High cost. **Solutions**: Encourage better practice to increase volume and quality of output plus reduce cost. **Goals**: Reliable, cost-efficient volume supplies, consistent quality.	*Domestic*: Price. *Export*: Reliability, consistency, quality, price. **Solutions**: Encourage better practice to increase volume and quality of output plus reduce cost. Use domestic market as test-bed. **Goals**: Reliable, cost-efficient volume supplies, consistent quality, penetration of export markets.

Identifying the technologies needed to supply these markets efficiently

One of the key technologies involved is the essential oil extraction/distillation process.

1. Steam Distillation

Steam distillation is the most common method of extracting essential oils. Many traditional distillers still prefer this method for most oils, and say that none of the newer methods produce better quality oils. Fresh or dried botanical material is placed in the plant chamber of the still, and pressurized steam is generated in a separate chamber and circulated through the plant material. The heat of the steam forces the tiny intercellular pockets that hold the essential oils to open and release them. The temperature of the steammust be high enough to open the pouches, yet not so high that it destroys the plants or fractures or burns the essential oils. As they are released, the tiny droplets of essential oil evaporate and travel with the steam through a tube into the condensation chamber. As the steam cools, it condenses into water. The essential oil forms a film on the surface of the water. To separate the essential oil from the water, the film is then decanted or skimmed off the top. The remaining water, a byproduct of distillation, is called floral water, distillate, or hydrosol. It retains many of the therapeutic properties of the plant, making it valuable in skin care for facial mists and toners. In certain situations, floral water may be preferable to pure essential oil, such as when treating a sensitive individual or a child, or when a more diluted treatment is required.

2. Cold Pressing/Centrifugation

Enfleurage

Some flowers, such as jasmine or tuberose, have such low contents of essential oil or are so delicate that heating them would destroy the blossoms before releasing the essential oils. In such cases, an expensive and lengthy process called enfleurage is sometimes used to remove the essential oils. Flower petals are placed on trays of odorless vegetable or animal fat, which will gradually absorb the flowers' essential oils. When the fat has absorbed as much of the essential oil as can be readily recovered (this can take hours or days, depending on the type of flower), the depleted petals are removed and replaced with fresh ones. This procedure continues until the fat becomes saturated with the essential oil. Alcohol is then added to separate the essential oil from the fat base. Afterwards, the alcohol is evaporated off, leaving the essential oil.

Centrifugation

Another method of extracting essential oils is cold-pressed expression, or scarification. It is used to obtain oils from citrus fruits such as bergamot, grapefruit, lemon, lime, mandarin, orange and tangerine. In this process, fruit rolls over a trough with sharp projections that penetrate the peel. This pierces the tiny pouches containing the essential oil. Then the whole fruit is pressed to squeeze the juice from the pulp and release the essential oil from the pouches. The essential oil rises to the surface of the juice and is separated from the juice by centrifugation.

Spinning-cone centrifuge

This is a more advanced centrifuge

process that can do a more efficient cold extraction, so that the all the essential oils can be recovered without being heated and denatured.

3. Solvent Extraction

Another method of extraction used on delicate plants is solvent extraction, which yields a higher amount of essential oil at a lower cost. In this process, a chemical solvent such as hexane is used to saturate the plant material and extract the aromatic compounds. This renders a substance called a concrete. The concrete can then be dissolved in alcohol to remove the solvent. When the alcohol evaporates, an absolute remains.

Disadvantages of Solvent Extraction

Although more cost-efficient than enfleurage, solvent extraction has disadvantages. Residues of the solvent may remain in the absolute and can cause side effects. While absolutes or concretes may be suitable for fragrances or perfumes, they are not especially desirable for skin care applications.

Some trees, such as benzoin, frankincense, and myrrh, exude aromatic 'tears' or sap that is too thick to use easily in aromatherapy. In these cases, a resin or essential oil can be extracted from the tears with alcohol or a solvent such as hexane. This renders a resin or an essential oil that is easier to use. However, only those oils or resin extracted with alcohol should be used for aromatherapy purposes, as a precaution against contamination with solvent residues.

4. Turbo-distillation, Hydro-diffusion, and Carbon Dioxide Extraction

Several modern methods of extraction are becoming popular alternatives to traditional steam distillation. Turbo-distillation is suitable for hard-to-extract or coarse plant material, such as bark, roots, and seeds. In this process, the plants soak in water and steam is circulated through this plant and water mixture. Throughout the entire process, the same water is continually recycled through the plant material. This method allows faster extraction of essential oils from hard-to-extract plant materials. In the hydro-diffusion process, steam at atmospheric pressure is dispersed through the plant material from the top of the plant chamber. In this way the steam can saturate the plants more evenly and in less time than with steam distillation. This method is also less harsh than steam distillation and the resulting essential oils smell much more like the original plant.

5. Supercritical carbon dioxide extraction

Supercritical carbon dioxide extraction uses carbon dioxide under extremely high pressure to extract essential oils. Plants are placed in a stainless steel tank. Carbon dioxide is then injected into the tank under pressure. At a sufficiently high pressure, the carbon dioxide turns into a liquid and acts as a solvent to extract the essential oils from the plants. The pressure is then decreased, allowing the carbon dioxide to return to a gaseous state, leaving no residues behind.

Carbon dioxide extraction produces particularly high quality, pure and potent essential oils. This is probably because this extraction method uses

lower temperatures than steam distillation, making it less likely to damage the oils. As a result, many carbon dioxide extractions have fresher, cleaner, crisper aromas than steam-distilled essential oils, and smell more like the living plants. The process is more efficient, giving higher yields and can be used to deal with materials (such as gums and resins) that would otherwise be difficult to handle. Thus many essential oils that cannot be extracted by steam distillation are obtainable with carbon dioxide extraction.

6. Pulsed mixed extraction

This relatively new technology is a variant on the supercritical extraction method, but has several additional advantages. It typically uses an organic solvent, in a gas / liquid mix, and combines super-critical extraction with cold fluid extraction. This low temperature extraction produces the cleanest of all extracts, with no loss or degradation of the thermo-volatiles and -labiles that constitute the top olfactory notes so important to perfumiers and gastronomes.

One important advantage is that the low pressures involved (typically 1 to 5 bar) permit the extraction plant to be made much more cheaply than that required for CO2 extraction, which must withstand far higher pressures. A secondary advantage is that the low polarity of the solvents used gives higher efficiency extraction than is possible with liquid CO2. Extraction can be 99.9% efficient when the process is properly managed. The final removal of solvent (using controlled warming and / or partial vacuum) is so efficient that no traces of solvent can be measured in the extracts, and the closed-loop recovery of the solvent means that the cost of the solvent becomes negligible.

The two short-listed technologies were the spinning cone centrifuge and pulsed mixed extraction. The chosen technology was the spinning cone centrifuge.

2) Remaining competitive in the cement market (Caribbean)

A Trinidad-based cement company was reviewing its business strategy. Their immediate concerns were focused on cheaper imports of cement from other countries, tariff levels, and the possibility of being taken over by a significantly larger Mexican-based cement company (which was known to be trying to expand across the region, and which had recently purchased a strategic stake in its smaller rival). A wider horizon scan, however, revealed two other issues that also had significant implications for the company. These related to innovation in the manufacturing process and in the product. The **process** innovation involved using low-cost waste materials to fuel cement kilns, thus reducing production costs.

Blue Circle Industries is to link with Michelin in an initiative to use tyres as fuel for cement kilns in a deal worth £24 million. BCI will use half of the 39.5 million tyres scrapped in the UK as fuel for its kilns. The tyres will replace some of the coal and petroleum coke now used as fuel. The company burns 800,000 tons of coal a year in the UK and it hopes to cut consumption by a quarter by using tyres. The move to

tyres will also result in a drastic cut in the level of harmful oxide emissions from Blue Circle's kilns. Rob Davies, the operations director, said: "This venture will provide BCI with a saving of £6 million within the next five years and is a further step towards the delivery of our performance targets".
Blue Circle is the UK's largest cement company, with 50 per cent of the UK market and the fifth largest in the world. The company has embarked upon a strategy of cutting costs and boosting returns to shareholders after it successfully fended off a hostile takeover bid by French rival Lafarge earlier this year.

Abridged from A Murray-Watson. The Scotsman. Tuesday 5th December 2000 [lxxvii]

The product innovation involved making fibre-reinforced cement, a new concept with a number of important engineering advantages.

It is no surprise to find an aerospace company at the cutting edge of technological innovation. But even a company producing building materials can use breakthrough research to reinvigorate its business. The Paris-based Lafarge group, the world leader in construction materials, spends a paltry 1% of sales on corporate research and development. But with sales of 14.6 billion in 2002, that still means Lafarge has close on 150m a year to spend on learning "how to crush stones and put them back together," says Denis Maitre, senior VP of the company's central R&D labs.

Lafarge's most recent innovation is Ductal, a fibre-reinforced concrete with six to eight times the compressive strength of ordinary concrete, ten to 100 times the durability, and much greater ductility. The concrete is so strong that a 25-metre bridge beam that is one metre thick can be deflected 30cm without breaking. Ductal has already been used to build a 120-metre footbridge with a deck that is only 3cm thick. Lafarge's next challenge is to get the fragmented and conservative construction industry to use Ductal. But the most important lesson is that even the construction industry need not regard its technology as being set in concrete.

The example also illustrates that success does not come quickly. Ductal took over 10 years to develop and it could be another 10 before it is adopted by industry in a commercially significant way. It is necessary to devise production methods, rewrite design and safety codes, encourage multiple sources of supply, and develop repair and maintenance procedures, so new materials (such as eng ineering plastics, super-strength ceramics or carbon fibre) can take 30 years to go from invention to commercial use.

Abridged from The Economist. Reinventing Europe. Sep 4th 2003 [lxxviii]

3) Road mapping for integrated solid waste management in Hyderabad, India

Introduction

The Administrative Staff College of India carried out a roadmapping exercise to develop an integrated solid waste management strategy for the city of Hyderabad. The aim was to increase the efficiency and effectiveness of municipal solid waste management in the city. The summary below was adapted from a more detailed description written by Thilotham R Kolanu .
Hyderabad is the fifth largest city in

India, and the capital of the state of Andhra Pradesh. The city and the neighbouring city of Secunderbad form part of the Municipal Corporation of Hyderabad (MCH). The population of the city has been growing by around 25% per decade for the last three decades, and is now about 3.6 million (2001 census). Nearly 20% of the inhabitants live in 793 slums spread over the city. Current projections indicate that the population will be over 6 million by 2020.

The city's solid waste management

The city currently generates 2,200 tonnes of solid waste per day, of which about 500 tonnes comes from markets and commercial areas. Municipal solid waste in Hyderabad is managed by MCH. The process, as in most other cities in India, has been mainly focused on collection rather than processing and disposal, and involves a combination of street bins and house collection. The waste is not segregated when collected. The waste is transported in closed trucks, which is required by regulation, brought to three transfer stations and goes from there to a secluded dumping site, Jawaharnagar. This dumpsite does not meet the required sanitary standards for a secured landfill site, and is therefore in breach of regulation. With regard to treatment, one private entity processes about 400 tonnes of waste per day, but MCH has not yet implemented any of the treatment alternatives proposed under MSW (M&H) Rules, 2000, even though the stipulated time to meet this requirement has elapsed. The revenue expenditure required to manage the city's solid waste is about 717.5 million rupees for financial year 2004-2005, which is about 14% of total municipal revenue expenditure.

Roadmapping for integrated municipal solid waste management

Most aspects of solid waste management in Hyderabad were not satisfactory. There were organizational, financial and managerial problems, amongst others. With support from the World Bank and MCH a roadmapping exercise was carried out with active involvement of select stakeholders such as MCH officials, private sector players, non governmental organizations, research institutes and other academic agencies. This roadmapping exercise focused on the following critical aspects of solid waste management:

- Segregated door-to-door collection
- Closure of the abandoned dumpsite at Autonagar
- Exploring alternative treatment options
- Disposal of solid waste in scientifically designed landfill site and
- Institutional and implementation arrangements

The exercise involved:

- Analyzing MCH's policies and proposed plans.
- Preparing different scenarios of a mix of public-private partnership strategies.

The main conclusions were:

- The city should improve the collection service, with increased storage at source for easier door-to-door collection in all

parts of the city. This would cost 28 million rupees. Experience elsewhere indicated a need for continuous city-wide awareness programs to support waste segregation at source.

- The city needed a strategy for closing the abandoned dumpsite at Autonagar and returning it to an acceptable state. A part of the site might then be used for transfer or treatment operations. This involved assessing engineering options, cost estimates and scheme optimization, estimates of potential revenue (land, CERs, use of void space), environmental and social aspects and contracting arrangements. The cost of the closure and remediation of the Autonagar dumpsite was estimated to be 180 million rupees.

- With regard to waste treatment, the most realistic option was the construction of a Waste to Energy (WTE) plant by the private sector, with compost plants in units of about 200 tonnes/day of compost, representing 600 tonnes/day of mixed waste, with about 300 tonnes/day rejects and the remainder lost mainly by reduction in water content. This solution could be scaled up, with additional schemes added in increments of these units.

- With regard to satisfactory landfill, the best option was to convert part of the existing dumpsite at Jawaharnagar into a landfill site to serve for the next three years. This would allow time for MCH to explore the option of a common regional approach, looking at nearby towns and villages for both additional sources of waste and for suitable landfill sites. This would require both logistical changes and balancing financial arrangements between the various settlements involved.

- With regard to the institutional arrangements and implementation strategies needed for a more integrated approach to solid waste management, it was concluded that MCH should undertake an organizational restructuring and bring all aspects of solid waste management under the control of one entity with expertise in management, costing, operations, waste management and environmental controls.

These recommendations from the roadmapping exercise are now being used for the planning and implementation of an integrated municipal solid waste management strategy for Hyderabad.

4, 5 and 6) Food processing in India

Introduction

The roadmap for the food processing industry in India was prepared by a team of 20 people drawn from government, industry, industry associations and academic institutions, chaired by Dr Abdul Kalam. This project was a part of

the Government of India's 2020 Vision Project, so all the sectoral studies were done in a common format. The purpose of the roadmapping exercise was to distil the perspectives of the major players and clarify the long-term vision and options. The group held a series of meetings, conducted interviews and then drafted the detailed vision and the roadmap, which summarized the conclusions of a detailed report on the future of food processing. The roadmap was both extrapolative and normative, combining ideas as to what might be the possible future and views as to the preferred future (taking into account the public interest, resources, export markets and lifestyles). The roadmap emerged as an integrated perspective, summarized in diagrams 3.2, 3.3 and 3.4 below. This description was provided by Dr. Bowonder, formerly of the Administrative Staff College of India, now with TATA.

Diagram 3.2

AGRO-FOOD CEREALS

1995

2020

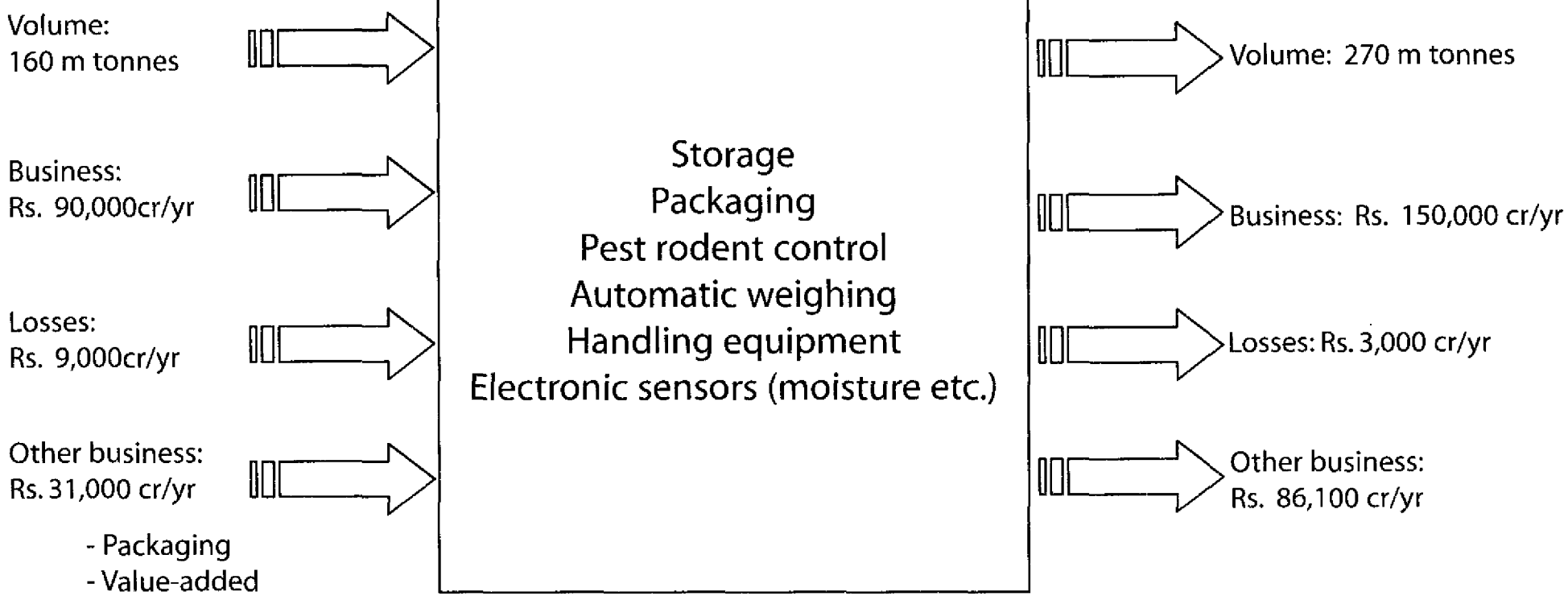


Diagram 3.3

AGRO-FOOD
MILK

1995

2020

CORE TECHNOLOGIES

Cold chain
Cyro fluid
Aseptic packing
Container
Fodders
Electronic testing machines
Training for cleanliness
To avoid wastage

Volume:
61 m tonnes

Business:
Rs. 61,000cr/yr

Losses:
Rs. 3,050 cr/yr

Other business:
Rs. 31,000 cr/yr

- Packaging
- Value Addition
- Chilling

Volume: 300 m tonnes

Business: Rs. 30,000 cr/yr

Losses: Rs. 3,000 cr/yr

Other business:
Rs. 310,000 cr/yr

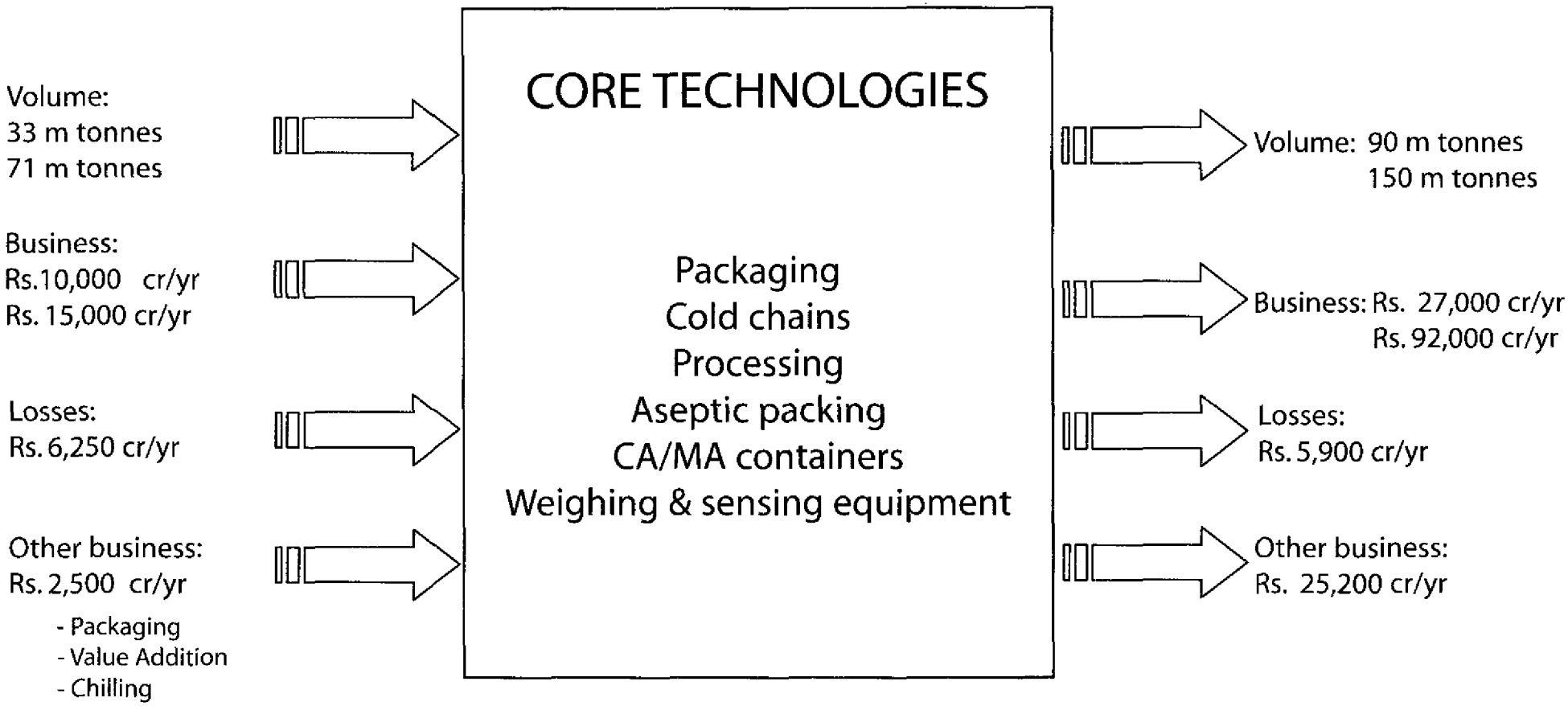
- Packaging
- New Products
- Chilling

Diagram 3.4

AGRO-FOOD
FRUIT AND VEGETABLES

1995

2020



7) Global Energy Trainers (Trinidad and Tobago)

Idea and market

- Vision: to be a state-of-the-art global provider of professional development and training for the energy sector.
- Goal: to enable our trainees to function more effectively both today and in the future.
- Our emphasis will be on an innovative curriculum and flexible, customized delivery.

Scope of the market
Customers

- Local, regional and international students, workers and companies involved in energy.
- Low, medium and high end energy services

Competitors

- International training organizations - their competitive strategies are focused on a host of training options (consulting, project management, on-line training, CD's, on-site training etc.)

Scope and content

- Varied course content

Examples are:
- Production Operations
- Process Operations
- Emergency Response Training and Assessment
- Maintenance
- Technician Training Programmes

How is the market changing?

Our current patterns are leading us down a path of resource depletion and environmental destruction. The degradation and exhaustion of resources will force us to relinquish current practices and seek new solutions that are globally sustainable. Creating a new consciousness allows us to care deeply for ourselves through our respect for the earth and our global community. (Source: Excerpt from Powering Our Future: An Energy Sourcebook for Sustainable Living.)

Non-Renewable → ***Renewable***

- *Coal* → *Biomass Energy*
- *Natural Gas* → *Geothermal Energy*
- *Nuclear Energy* → *Hydrogen and Fuel Cells*
- *Petrolum* → *Hydro Power*
- → *Nuclear Fusion*
- → *Oceanic Energy*
- → *Solar Energy*
- → *Wind Energy*

↓

Solutions: Creating a new energy consciousness where consciousness and action convene

Who would be the customers in the future and what would they want ?

We envision three major segments of the future market.

- Individuals, governments and companies wishing to operate at the cutting edge of oil and gas extraction and production.
- Individuals, governments and companies interested in renewable energy.
- Emerging new customers in Africa, Asia, Caribbean and Latin America.

Our competitive strategy

- Flexible, multiple mode of delivery.
- High adaptablity to changing trends.
- Affordability.
- Partnering with leading international training providers, globally recognised certification.
- Partnering with local and regional universities and TLIs *(UTT, UWI etc)*

What do we have to offer our international partners?

- Extension of reach to new markets/clients - cosmopolitan, culturally flexible and adaptable facilitators/trainers, less costly than first world facilitators/trainers.
- Our long tradition and international reputation of the expertise/skill set of our industry personnel.

  Acquired expertise and international branding of competence in a new niche skill area needed by clients world-wide e.g. bio-remediation and enhanced recovery techniques. This will be supported by government and private sector partnering in *related R&D.*

- Relative to competitors in other developing countries, T&T has a strong enabling environment for business operation of this nature:
  - ✓ Supportive TE framework with national accreditation mechanism that is harmonised with regional and international quality assurance frameworks
  - ✓ Enabling ICT framework
  - ✓ *Reformed taxation regime*

Required Technology Skills Sets for Operating this Service

Existing Capability	*Gap Analysis*	Needed Capabilities
Skill sets o World pool of trained energy economists, managers and engineers o World pool of experienced industry personnel (avg. 20 years plus industry experience) o World pool of construction and maintenance personnel for rigs, pipelines etc. o Available supply of cheaper trained personnel from Eastern Europe (Ukraine, Poland etc) and Latin America (Venezuela, Peru, Ecuador etc) **Technology** Modern classroom and web-based learning facilities at UWI, UTT technology		**Skill sets** o Acquire expert facilitators in renewable sources of energy o Need world-wide partner firms/ institutions/ TLIs in emerging areas of engineering, management, operations, evaluation, monitoring etc. o Acquire partners in key niche markets (e.g. Africa & India for non-oil, Asia for oil and gas etc.) o Acquire point of contact staff with foreign language skills **Technology** o Firm to acquire modern classroom and web-based learning facilities o Build WAN/LAN etc. o Acquire subscriptions to electronic learning resources, libraries etc. ***Memberships*** Join all relevant bodies (training, professional etc...)

Year	2005	2010	2015	2020
Customers	o Students/companies seeking an affordable, high quality alternative to North American and UK Institutes o Firms and companies focussing on capacity building of employees	Students from all over the world seeking affordable training		
Market demand	5,000	8,000	10,000	13,000
Competitors	International firms offering similar services	South American institutes	Another Caribbean institute	Local rival
Their competitive strategy	Leveraging their reputation and existing links	Similar to us, they would provide flexible modes of delivery	Even more similar to us these could compete on price, location	They could attempt to compete directly with us, perhaps attempting to poach our staff and partners
Our competitive strategy	o Flexible, multiple modes of delivery. o Affordability o Focus on the mass market o The best facilitators from around the world o Customized programs	o Continuing adaptability to changing technologies o Globally recognised certification		An established reputation
Technology	Internet based learning and CDs, video conferencing, electronic etc.	o 3D learning resources o Simulation centres	Remote on-the-job training and tutoring (cells; satellites; global tracking)	Interactive, virtual teachers.Visual display glasses
Skills	Professionals with at least 10 years experience in the specified field (targeting training in non-renewable products	Wide network of professionals (targeting training in non-renewable and renewable products)	Specialized personnel (ICT support; trainers; negotiators)	
Goal	Entry into the market	Recognition in local, regional, international market	Recognized as a reputable brand of service delivery	World class leader in energy services training.

8) Shandy Carib (Caribbean)

	Now	Plans	Future	Vision
Market	o Currently USA via Miami, the USVI (St. Thomas & St. Croix). 21 US states do not specifically ban underage drinking, further 15 states have exemptions to underage consumption laws. o US levies import tax on product.	To expand into the states with large diasporic populations (currently 27 Caribbean-theme Carnivals in the USA).In any new trade agreement with the USA, negotiate for duty free access.	o Expand into rest of USA. o Removal/reduction of taxes on import of this produc	To be the leading low alcohol beverage in specified markets in the USA
Market Trends	o 20% decline in per capita consumption of heavy alcohol 1980-2000, wine consumption increased by 3.4% between 2003-2004 (12th straight year of increase). o Increasing obesity and diabetes, therefore growing health consciousness. o Increasing sensitivity to environmental issues. o Greater emphasis on leisure and relaxation (tourism is largest growth industry in world) o Increasing disposable income in US	Deepening trend in the reduction of heavy alcohol consumption.	Increasing demand for low alcoholic beverages, with health benefits. Increased attendance at Carnivals resulting in increased markets. The target market would have increased incomes.	

	Now	Plans	Future	Vision
Customers Base	Segment of US population aged 18-25.	Increase awareness of product in this segment.	Segment of population currently under 18.	To be legal drink of choice in targeted age groups.
Product	Three flavours, sorrel, lemon and ginger.	o To expand the line of flavours to appeal to fun loving, health (lower sugar content) and taste conscious consumers. o To develop the product via expert tasters.	The production of Shandy in a range of flavours that appeal to the American tastes: West Indian Cherry, Ginseng, Lime, Grapefruit, and Passion Fruit.	To be the preferred drink for the health conscious.
Technology	Automated production, labelling and packaging systems.	To get up-to-date ISO certification.	Ditto	Cutting edge technological development in low alcohol beverage production.
Competition	Companies producing similar products, e.g. Seagrams currently sell wine coolers (mixture of wine/beer and fruit juices).	Expand line to include more exotic flavours e.g. pineapple, coconut, calypso coolers.	Any brewery can produce wine coolers.	To be the leading supplier of low alcohol beverages.
Distribution	Currently through Miami.	Through several entry points in the USA.	Direct sales via internet.	To utilise most modern transportation and distribution techniques.
Marketing	Currently sold in both bottles and cans. Currently associated with Carnival in Trinidad and Tobago.	o Enhance appearance of product (colour, shape, size, labelling), including introduction of screw cap	To capitalise on the branding of Carib and its connotations of Caribbean and Carnival.	To have a product that is easily recognised and attractive to the consumer.

	Now	Plans	Future	Vision
		and sample sized bottle. o Environmentally friendly packaging & containers. o Promote Shandy in all 27 Carnivals in the USA. o Provide samples to travellers on BWIA to & from US destinations. o Sell product at competitive price.		
R&D	Information not available.	o Research feasibility of innovations, new flavours. o To acquire skills in biotechnology research.	Continue to innovate.	To be leading innovators in the low alcohol beverage industry.
Risks	A number of other low alcoholic beverages currently on the market.		o Movement away from all alcoholic drinks. o Taste not appealing. o Other firms develop technological lead. o Failure to adapt to new standards. o Price not competitive.	

9) SPARD-JEMB Associates (Training for Engineers, Trinidad and Tobago)

Vision
We are an internationally recognized technical training provider of choice.

Mission statement
We provide relevant, high-quality technical and skills training for the oil, gas and petrochemical industries.

Objectives
Provide technical training in the following skill areas:

- o Electrical/Electronics
- o Mechanical
- o Welding/Fabrication
- o Pipe fitting
- o Drilling
- o Hydraulics and Pneumatics
- o Equipment servicing and Failure Prediction/Analysis
- o Plant Operation and Processing
- o Provide Mentoring and Coaching
- o To train the trainers
- o Retraining

Industry outlook

- o Consumer demand for crude oil and petroleum products is

growing at approximately 2% per annum.

- Market growth rate expected to continue at a steady rate of 3-4% per annum over the next 15 years.

- Transportation sector is the key factor in the increasing demand - in 2001 the sector accounted for 47% of consumption.

- Next is the industry sector and petrochemicals.

- The demand growth rate is heavily dependent on technology advancements in petroleum usage and development of unconventional sources of crude such as tar sands and very heavy oils.

- Many companies are increasing their exploration and development spending. As a result the oilfield service sector is beginning to see improving margins. The industry is currently at a macroeconomic peak; the highest level in 20 years.

- Competition - emerging technologies such as solar, hydroelectric and wind power.

- Market susceptible to shocks such as natural disasters, terrorism, enabling international environment, climate change, environmental impact.

- Capital intensive; expected to provide $1.2 m for the creation of 1 job.

- Emoluments in this industry are higher and hence more attractive than other sectors.

Customers

- Local
  - Oil & Gas exploration
  - Refineries
  - Heavy Industry
  - Service providers
  - NGOs
  - Government Institutions
  - Public Sector
  - Private Sector

- Regional - in all countries bordering the Caribbean Sea, Guyana and the Gulf States of the US, Mexico and Costa Rica.
  - Public Sector
  - Private Sector
  - Civil Societies

- International
  - Africa - Nigeria
  - Middle East

Market outlook

- OPEC countries (except Iraq)
  - approx 40% of world production
  - $430 billion from exports - 27% increase from 2004
  - 27,000,000 barrels per day

- Non OPEC countries
  - approx 60 % - Middle east - 29%, North America - 19%
  - $220.9 billion from exports
  - 1.4 million barrels per day

- Trinidad
  - 34.1% of GDP is from the energy sector
  - GDP for 2004 - $11.48 billion
  - 140,000 barrels per day

Key trends in the industry

- Robust growth in demand for crude oil, natural gas and petrochemical products.
- Competitive operating environment in all industry sectors.
- Challenging regulatory environment; environmental, fiscal, legal and safety.
- Increased focus on corporate governance and risk management.
- Continuing industry consolidation and asset portfolio rationalization.
- Increasing international activities, as the pace and direction of globalization has become uncertain.
- An ageing workforce throughout many of the established oil and gas regions, struggling to attract and retain younger people in the face of increased competition from other sectors.
- Growing size, strength and international reach of state-owned companies from several of the world's resource rich nations.
- Conflict, unrest and political instability in several oil exporting countries.

Key competitors

- Universities and tertiary education institutes
  - Trinidad - UWI, UTT, John D
  - North America - Northern Lights College (BC)
  - U.K - University of Edinburgh
- International Companies
  - Noria - Consulting, education - have a franchise located at Point Lisas
  - Drillers.com Inc - drilling, exploration and field development
  - Microsoft - IT areas

Competitive strategy

- Price - will be determined through market research.
- Competitive strategy will be based on quality and reliability.

Future competitors

- International firms.
- Governments.
- Universities through franchising, joint ventures and strategic alliances.

Drivers of change

- New disruptive technologies.
- Product, Production and Process Innovation.
- Buyer behaviour and attitude towards end product.
- International terrorism.
- Natural disasters.
- Alternative availability of materials and technology.

Critical success factors

- Quality of deliverables.
- Human resources.
- Time to market.
- Accreditation.
- Ability to adapt, respond and change to market needs and changes.
- On-going market research.
- Consultation with industry players.
- Location of physical facilities must be within close proximity to the industrial base where the physical and social infrastructure is available.

Technologies required

- State of the art technologies
  - o Multimedia
  - o Laptops
  - o Online access combined with lecture presentation
- OJT concurrent with classroom training
- Skill competencies and demonstrations and its transfer to real industrial setting
- World class facilities
  - o Classroom size accommodating 15-18 trainees
  - o Controlled environment
  - o Closed-circuit monitoring
  - o State of the art equipment and materials relevant to current and future industrial practices
- Curriculum
  - o Innovative
  - o Integrative
  - o Relevant
  - o To meet and exceed existing industry standards
- Social dynamic interaction between and amongst trainees and trainers in a team environment
- Experiential learning
- Easy form of payment of fees: online
- Easy registration: online

Product description

Course	Duration	Description
Electrical/Electronics	3 m - 2 yrs	TTNVQ 1-4
Mechanical	3 m - 2 yrs	TTNVQ 1-4
Welding/Fabrication	3 m - 1.5 yrs	TTNVQ 1-3
Pipe Fitting	3 m	TTNVQ 1
Drilling	3 m - 1.5 yrs	TTNVQ 1-4
Hydraulics/Pneumatics	3 m - 1.5 yrs	TTNVQ 1-4
Equipment services & Failure Prediction Analysis	3 m - 2 yrs	TTNVQ 1-4
Plant Operation and processing	6 m	TTNVQ 1-2
Train the Trainer	40hr - 400hr	Professional

Diagram 3.5: Organogram

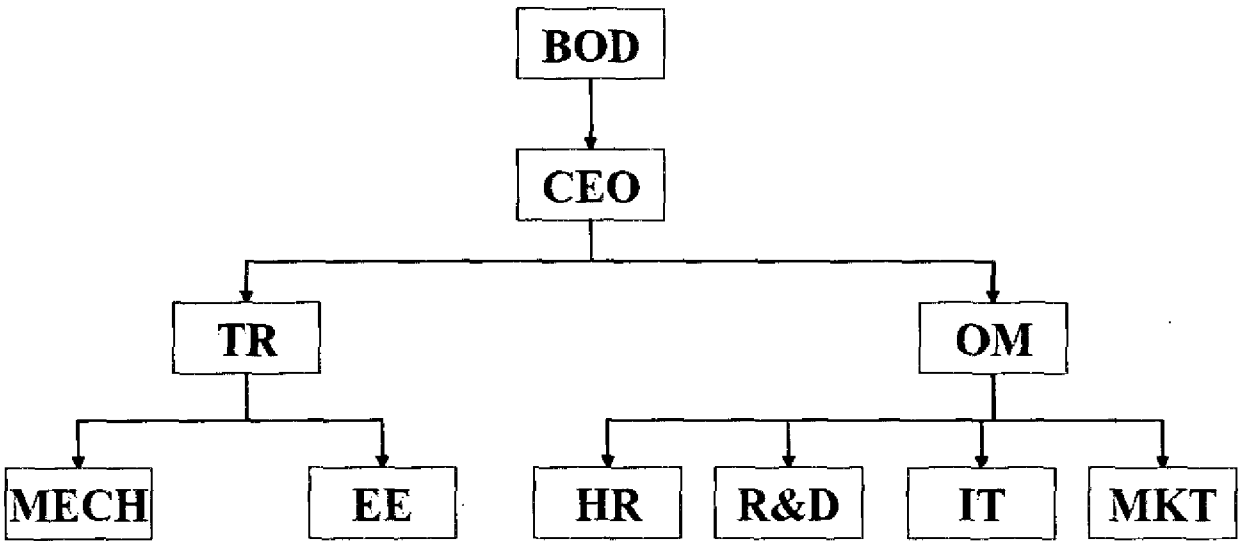
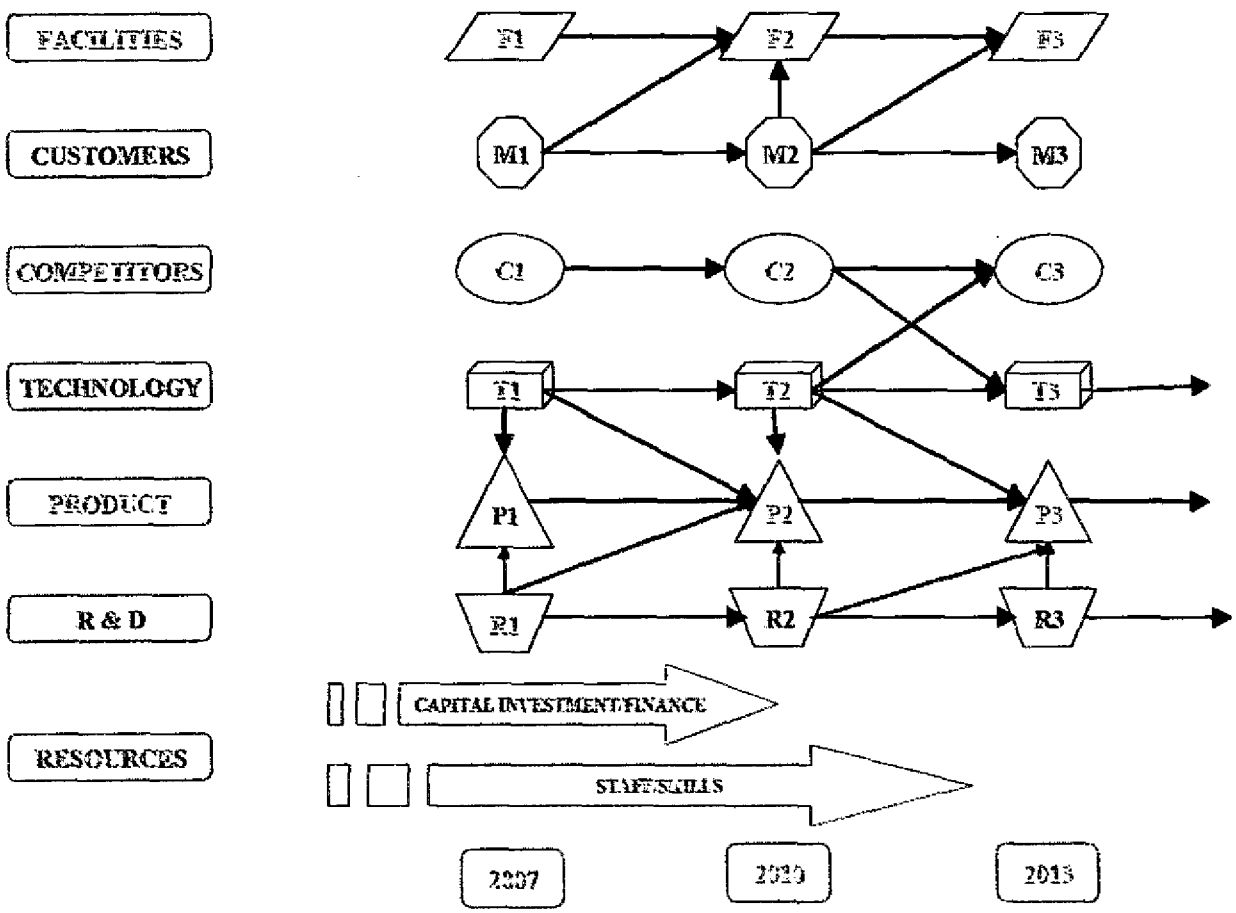


Diagram 3.6: Technology roadmap



References

[i] V Postrel. The Future and Its Enemies: The Growing Conflict Over Creativity, Enterprise and Progress. Touchstone, New York, 1998

[ii] C. Juma and L Yee-Chong. Innovation: applying knowledge in development. UN Millennium Project Task Force on Science, Technology and Innovation. Earthscan, London 2005

[iii] Article abridged from S Kettman. To the Moon in a Space Elevator? Wired News February 4th 2003. http://www.wired.com/news/technology/0,1282,57536,00.html

[iv] Abridged from S Kettman. To the Moon in a Space Elevator? Wired News February 4th 2003

[v] Williard, C. H. and McClees, "Motorola's Technology Roadmap Process," Research Management, Vol. 30, No. 5, pp. 13 - 19, Sept. - Oct. 1987.

[vi] Working Group Report Future Foods for Wellbeing: An Expert Panel's View of the Next 25 Years. Institute of Grocery Distribution, Watford, UK, 2003. http://www.igd.com/FutureFoodsForWellbeing.asp

[vii] Fundamentals of Technology Roadmapping. http://www.sandia.gov/Roadmap/home.htm

[viii] Kostoff, R. N., Schaller, R. R., "Science and Technology Roadmaps," IEEE Transactions on Engineering Management, Vol. 48, No. 2, pp. 132 - 143, May 2001.

[ix] Porter A.L. Text Mining For Technology Foresight. http://www.tpac.gatech.edu/~darius/papers/foresight-outline.html, 2000.

[x] Groenveld P. Roadmapping Integrates Business and Technology. Research Technology Management, September, 1997

[xi] Management of Accelerated Technology Innovation (MATI). An industry-university consortium review of technology management tools: http://mati.ncms.org/.

[xii] Kappel, T. A. "Perspectives on roadmaps: How organizations talk about the future," Journal of Product Innovation Management, Vol. 18, No. 1, pp. 39- 50, 2001.

[xiii] A Clayton, G Spinardi and R Williams. Strategies for Cleaner Technology: a new agenda for government and industry. Earthscan, London. 1999.

[xiv] A Tustin. Feedback. Scientific American, vol 187, no 3, September 1952, pp 48-55.

[xv] I Bellany. The Environment in World Politics. Edward Elgar, Cheltenham, 1997.

[xvi] A Clayton. Cleaner technologies: the implications for Developing Nations. In The Caribbean Economy- A Reader: The Economics of Natural Resources, the Environment and Sustainable

Development. D Pantin (ed), Randle, Kingston, 2005

[xvii] Speech 'The Roller Coaster of Change: Looking Back, Looking Forward' by Jacques Bougie, CEO of Alcan Ltd, to the Board of Trade of Metropolitan Montreal, Montreal, Canada, January 27, 1998.

[xviii] A Clayton, R Young and S Vermeylen From medicine-man to market: developing countries and the global pharmaceutical industry. Critical Perspectives on International Business. Submitted 2005.

[xix] M Parlange. Eco-nomics. New Scientist no 2172, 06/02/1999.

[xx] The Economist November 25th 2004. From Bad to Awful.

[xxi] R Murray-West, 2004. Are the drug giants in danger of bleeding themselves dry? Money Telegraph. 9th October 2004.

[xxii] Data from the IMS Health 2002 Annual Review of New Active Substances cited from IMS LifeCycle. Presented at the 9th Economist Annual Pharmaceutical Conference, London February 12-13 2003.

[xxiii] F Dyson, From Eros to Gaia. Pantheon Books, New York, 1992, pp 242-243
P Drucker, The Relentless Contrarian. Wired, August 1996, p 182
In V Postrel, The Future and Its Enemies. Simon and Schuster, New York, 1999.

[xxiv] From various sources, including the Albright Strategy Group: http://www.albrightstrategy.com/s-t_roadmap.html

[xxv] C Christensen. The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business School Press, Boston 1997.

[xxvi] B Thompson. It's an always-on, demanding world. BBC News Friday, 22 July, 2005

[xxvii] From various sources, including Industry Canada: http://strategis.ic.gc.ca/epic/internet/intrm-crt.nsf/en/rm00062e.html

[xxviii] Abridged from Kevin Done. Boeing set for design revamp Financial Times Friday June 13 2003.

[xxix] http://www.mindtools.com/crit-path.html

[xxx] The Economist. The challenge of running massive construction projects The Economist Jul 22nd 2004

[xxxi] The Economist. Blue skies thinking The Economist August 20th 2005

[xxxii] British Airports Authority: http://www.baa.com/portal/site/default/menuitem.9117dc974bda4acc0fb42410c02865a0/

[xxxiii] K Green, A Irwin and M McMeekin Technological Trajectories and R&D for Environmental Innovation in UK Firms. Futures, vol 26, no 10, pp 1047 - 1059.

[xxxiv] S Anthony. Is it Time to Shift Strategy? InKNOWvations, July 2005,

http://www.sopheon.com/inknowvations.asp?id=7-1-2005

[xxxv] Abridged from The Economist. America's airlines, flying on empty. Sept 16th 2005

[xxxvi] Abridged from G Bowes. Ryanair 'now the world's favourite airline' The Observer Sept 11 2005

[xxxvii] http://www.atimes.com/atimes/Middle_ East/GI02Ak02.html

[xxxviii] Abridged from C Recknagel. Tehran claims breakthrough. Middle East September 2nd 2005.

[xxxix] Semiconductor Industry Association, International Technology Roadmap for Semiconductors, http://public.itrs.net/, 2001.

[xl] Abridged from Unprepared. The Washington Post. Monday, September 5th, 2005 A Clayton, W Wehrmeyer, J Chenoweth and B Ngubane. Foresighting for Development. Earthscan, London, in press 2005 W Wehrmeyer, A Clayton and J Chenoweth (eds). Foresighting and Innovative Approaches to Sustainable Development Planning. Greenleaf Publishing, Sheffield, in press 2005. Economist Technology Quarterly March 14th 2002 Accuracy is Addictive.

[xli] Economist Technology Quarterly Sept 19th 2002

[xlii] Far Eastern Economic Review, cited in BBC Business News 11/11/2002.

[xliii] United States National Intelligence Council Mapping the Global Future: Report of the National Intelligence Council's 2020 Project. Dec 2004.United States Government Printing Office, Pittsburgh PA

[xliv] Brown, M Renner and C Flavin. Vital Signs 1997 - 1998. Earthscan, London, 1997.

[xlv] L Brown, C Flavin and H French. State of the World 1998. Earthscan, London, 1998.

[xlvi] World Bank projections cited in Vijay Vaitheeswaran. The Great Race. The Economist, July 4th 2002.

[xlvii] J Micklethwait and A Wooldridge, 2000. A Future Perfect: the Challenge and Hidden Promise of Globalization. William Heinemann, London.
Also reported in J Micklethwait. A Future Perfect: The Essentials of Globalization. In The World in 2000 (Business and Management). The Economist, 1999.

[xlviii] United Nations Development Programme. 2001 Human Development Report (UNDP, 2001).

[xlix] UNDP Human Development Report 2003 (UNDP, 2003)

[l] A Clayton and W Wehrmeyer. Foresighting for Development. Technical report for the Commonwealth Science Council, 2003.

[li] J A Schumpeter. Capitalism, Socialism, and Democracy. New York: Harper & Row,1950.

[lii] J Sachs. A new map of the world. The

Economist June 22nd 2000.

liii R Williams and N Markusson (2002) Knowledge and environmental innovations. Paper for presentation at the first BLUEPRINT workshop, 23rd - 24th January 2002

liv Assessing Aid. World Bank Policy Research Report. Oxford University Press, 1998.

lv Jeffrey Sachs. A New Map of the World. The Economist June 22nd, 2000.

lvi Shen, Xiaobai, 2001. China Reconstructs: the transformation of Management in two telecommunications-technology producers. In Richard Thorpe and Stephen Little (eds.), Global Change - the impact of Asia in the 21st century, Basingstoke and New York: Palgrave.

lvii W Easterly, 2002. The Cartel of Good Intentions: Bureaucracy versus markets in foreign aid. Center for Global Development, Washington.

lviii European Commission Directorate General 8 (Development) Review. The Cotonou Agreement. Available at http://europa.eu.int/comm/development/cotonou/lome_history_en.htm

lix W Easterly and R Levine. Tropics, Germs, and Crops: How Endowments Influence Economic Development. Journal of Monetary Economics. Elsevier Vol. 50 (1) January 2003 pp 3-39.

lx http://www.developments.org.uk/templates/display/text.cfm

lxi A Clayton. Cleaner technologies: the implications for Developing Nations. In The Caribbean Economy- A Reader: The Economics of Natural Resources, the Environment and Sustainable Development. D Pantin (ed), Randle, Kingston, 2005

lxii World Energy Outlook, 2004.

lxiii Evan Davies. China's magnificent historic past. BBC News 2005/03/10, citing Angus Maddison. The World Economy: Historical Statistics, OECD, Paris

lxiv E von Weizsäcker, A Lovins and L Lovins. Factor Four: Doubling Wealth, Halving Resource Use. Earthscan, London, 1997.

lxv Giarini and W Stahel. The Limits to Certainty: Facing Risks in the New Service Economy. Dordrecht, Kluwer Academic, 1993.

lxvi Interview with Sheik Yamani reported in The Observer, Sunday January 14, 2001

lxvii UN Department of Economic and Social Affairs: Population Division. World Population Prospects: The 2002 Revision (1950 - 2050), United Nations, New York 2004.

lxviii Registrar General for Scotland: Revised mid-year population estimates for 2000. November 2002.

lxix D Takehashi. The Age of Erasable Hardware. Red Herring May 1, 2001

lxx K E Drexler. Engines of Creation: The Coming Era of Nanotechnology. Fourth

Estate, London, 1996.

[lxxi] A Clayton and C Staple-Ebanks. Nutraceuticals and Functional Foods: A New Development Opportunity for Jamaica: Market-Scoping Study. Technical report for the National Commission on Science and Technology. EFJ, Jamaica, 2002.

[lxxii] P. Leighton. Up and coming markets: opportunities and issues from a Darwinian perspective. In Nutraceuticals World, October 2000.

[lxxiii] Quote from the US consumer research group HealthFocus.

[lxxiv] Leatherhead Food International. Functional Food Markets, Innovation and Prospects - an International Analysis (Second Edition) Leatherhead Food Research Institute April, 2004.

[lxxv] Datamonitor Report. US Nutraceuticals: Forging a Functional Future. Datamonitor, 1997.

[lxxvi] Datamonitor Report. European Nutraceuticals 1998. Datamonitor, 1998.

[lxxii] Abridged from A Murray-Watson. The Scotsman. Tuesday 5th December 2000.

[lxxiii] The Economist. Abridged from The Economist. Reinventing Europe. Sep 4th 2003

Printed in Austria
V.05-89320—November 2005

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Telephone: (+43-1) 26026-0, Fax: (+43-1) 26926-69
E-mail: unido@unido.org, Internet: http://www.unido.org