Thriving in a Global Market: Technology Strategies for UK Civil Engineering Exports

Michael F C Thorn, John N Bennett, Roger K Venables
Roger Flanagan and Zedi M Nyirenda

Foreword

The White Paper *Realising our potential*, published by the Government in May 1993, set in motion the UK's first Foresight programme and stated:

'*The understanding and application of science are fundamental to the fortunes of modern nations. Science, technology and engineering are intimately linked with progress across the whole range of human endeavour. They provide tools for addressing new global challenges such as those facing the environment*'.

At the conclusion of the programme, the Foresight Construction Panel published its report in which one of the key 'engines of change' for the sector was the creation of nationally competitive infrastructures which would generate significant export opportunities. These events formed the background to the present study and I am pleased to say that the Institution has demonstrated leadership on behalf of the industry in taking this issue forward.

On the future of the industry, in my Address to the Institution in November 1997, I stated that:

> '*... the need to change the culture of the industry is perhaps the biggest challenge before us. It requires everyone to accept that they can do whatever it is they do better. We have excellence in every element but we do not integrate that across all those involved in the process'*.

Part of the culture change required concerns technology. World trade is expected to double in the next ten years. There is more construction activity in Shanghai than there is in the whole of the UK. We all like certainty but the real need is for ideas that will improve the way infrastructure is provided. The use of adhesives in construction is an area which could provide huge benefits but how many firms have the equivalent of the 'technology broker' in Japan to pick up technologies from other sectors? We must start believing in ourselves, not continually producing critical reports.

Having read this report, ask yourself the following questions.

- How much does my business depend upon the application of good technology?
- Where does my business's technology come from?
- How up-to-date am I – how do I know what the latest technology is?
- How much do I – or should I – invest in the technology that underpins my business?
- What is my technology strategy to sustain and advance my business?
- What shall I do differently tomorrow as a result of reading this report?

This report encourages confident and environmentally sustainable utilisation of our wealth-creating ability through technology, doing better what our forebears did in the last century. We need to use technology to engineer a harmonious future for ourselves and the rest of the environment.

Sir Alan Cockshaw
ICE President 1997/98

Thriving in a Global Market: Technology Strategies for UK Civil Engineering Exports

Report on the ICE-led Project *Technology Support for Civil Engineering Exports*,
supported by the UK Department of the Environment, Transport and the Regions under
the Partners in Technology Scheme

Prepared by the Project Team:

Michael F C Thorn	·	Project Director (HR Wallingford Ltd)
John N Bennett	·	Institution of Civil Engineers
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Roger Flanagan and Zedi M Nyirenda	·	Department of Construction Management and Engineering at the University of Reading

Preface

The Technology Support for Civil Engineering Exports Project, of which this is the main Report, was undertaken by a Project Team comprising:

Mr Michael F C Thorn	–	Project Director Stage 2, and Senior Executive, HR Wallingford Ltd
Dr Roger D. Browne	–	Project Director Stage 1
Dr John N Bennett	–	Technical and Engineering Division, Institution of Civil Engineers
Eur Ing Roger K Venables	–	Project Manager and Director, Venables Consultancy
Professor Roger Flanagan and Dr Zedi M Nyirenda	–	Department of Construction Management and Engineering at the University of Reading.

The project was funded 50% by the Department of the Environment, Transport and the Regions (DETR) and 50% by industry. Approximately 150 representatives of industry, Government and the research community attended seven Workshops, were interviewed by Zedi Nyirenda and/or were members of the Project Steering Group (the Technology for Exports Panel). Dr Mark Mawhinney represented the DETR until late 1997, after which time the Department was represented by Ms Michelle Cameron.

The bulk of the research was undertaken by Zedi Nyirenda and colleagues at the University of Reading. The numerous Workshops held to secure comment and input from industry were organised jointly by the University of Reading and Venables Consultancy, chaired by Mike Thorn, facilitated by Roger Venables and reported by Zedi Nyirenda. The first draft of this report was prepared by Zedi Nyirenda, with contributions from other members of the Project Team. It was revised and edited for publication by Roger Venables with comment from the Project Team and the Technology for Exports Panel.

For each of the five sectors of civil engineering studied, a Project Champion was appointed to assist the Project Team with the development of their ideas for, and reporting on, each sector. The five Project Champions were all members of the Technology for Exports Panel and are indicated in the list below.

The Project Team warmly acknowledges the contribution of many members of the civil engineering profession, major companies and research centres who have contributed their knowledge, expertise and vision to this project through the programme of interviews, discussions and workshops. The contributions of members of the Technology for Exports Panel are also gratefully acknowledged. In addition to the Project Team and the DETR representative, the Panel comprised:

Mr Colin Adams	British Consultants Bureau
Mr John Britten	Building Research Establishment (until early 1998)
Dr Tim Broyd	W S Atkins plc: Project Champion for infrastructure for urban development and megacities
Mr Joe Burns	Highways Agency
Mrs Catherine Coates	Engineering and Physical Sciences Research Council
Professor Chris Fleming	Halcrow Group Ltd: Project Champion for coastal and river engineering
Mr Alick Goldsmith	The Export Group for the Constructional Industries
Mr Martin Manning	Ove Arup and Partners
Mr John McKenzie	World Federation of Engineering Organisations
Mr Paul Mullord	British Water
Mr Terry Mulroy	Transportation Planning (International): Project Champion for transport planning and infrastructure
Mr Terry Pike	Department for International Development: Project Champion for environmental improvement and sustainable development
Mr Reg Purnell	Ministry of Agriculture, Fisheries and Food (corresponding member)
Mr Peter Lee	Mott MacDonald Group Ltd
Mr Owen Simon	Institution of Civil Engineers
Professor Roy Stoner	Consultant: Project Champion for water and wastewater engineering
Mr Dominic Verschoyle	Institution of Civil Engineers
Mr Mike Winney	EMAP/New Civil Engineer

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Classification:

Availability:	Restricted to UK-based organisations and individuals
Content:	Guidance based on market research and industry consultation
Status:	Committee-guided
Users:	Present and potential exporters of civil engineering services and products, Government, clients of civil engineering, and the associated research communities.

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*Forecasts by the futurologists**

As part of the project, a review was undertaken of the literature where authors have examined many diverse trends and made predictions about the future and the review is presented in Appendix 1 in the accompanying CD. These sources are listed in the references and bibliography in Section 14. The potentially most significant predictions are given below to stimulate readers.

- Population will grow irrespective of what controls are used.
- More than 90% of the world's population growth is in developing countries.
- The need for infrastructure will increase but the means of financing that infrastructure will become more complex.
- The gap between the rich and the poor will grow.
- Crime will be the fastest growing industry in the world.
- Water will be the single most important asset for any country.
- Much of the new infrastructure in the developed world will be placed underground as space becomes a premium resource.
- A focus on the environment will be paramount on most countries' agenda.
- The 'job for life' concept will disappear and new employment patterns will evolve.
- Information technology has changed working practices, and will continue to do so.
- Technology will have no respect for international boundaries.
- Patterns of communication will change with electronic commerce and e-business becoming the norm.
- Economic cycles with traditional boom and bust will not change and the key markets for engineering infrastructure will be in Asia and Latin America.
- Africa shows no signs of being a major market for engineering infrastructure.
- Organisations from Central and Eastern Europe will emerge as major competitors in the global engineering and construction market.
- Incorporating intelligence into materials will revolutionise the use of construction materials.
- It will be possible to design a project in weeks rather than months through the use of knowledge-based engineering and object-based modelling.
- Safety will become a major issue in construction as the current level of accidents and injuries becomes socially unacceptable.
- Small and medium-sized enterprises will grow in importance in the global economy, because they are able to react quickly to change and opportunity.

*(Bhagavan M.R. 1990, Crocombe G. *et al.* 1991, Dertouzos M.L. *et al.* 1989, Easterling K. 1990, Fekiss V.C. 1977, Forester T. 1988, Freeman C. *et al.* 1978, Gandhi, M.V. *et al.* 1992, Global Outlook 2000, 1990, Guile B.R. *et al.* 1987, Hillebrandt P.M. 1988, Kennedy P. 1993, Meadows D.H. *et al.* 1988, Niosi J. 1991, Peccei A. 1981, Polak F. 1973, Rogers P. 1976, Talalay M. *et al.* 1997, Taylor G.R. 1975, and Worstenholme G. 1973.)

Why export?

Some of the reasons given by project participants were:

- to increase profitability of the business;
- to spread the risk of the boom-bust cycle across a number of markets: when the UK is down, other markets may be buoyant;
- to create jobs and continuity of employment for home-based staff;
- to provide status and excitement, for both the business and the staff, of being involved overseas;
- because UK plc has to export in order to finance imported goods and materials;
- because exposure to other markets stimulates innovation and competition.

1 Introduction

This Report, and the project that led to it, are a civil engineering industry response to the UK Government's Foresight initiative to increase the already-substantial UK success in export markets. The Report and its Appendices aim to provide a knowledge base of information on world construction market trends, to identify and define supporting technology needs, and to recommend how industry and Government should act to maintain and develop industry competitiveness overseas.

The project's objectives were to:

- assess technological and export performance trends in the major overseas markets for UK civil engineering;
- assess comparative strengths and weaknesses in UK civil engineering technologies compared to overseas competitors, and to propose measures to build on the strengths and rectify the weaknesses;
- identify technologies that are considered critical to export success in civil engineering, and their interaction with other techniques such as financial engineering;
- identify and promote appropriate research programmes to cultivate UK expertise in the identified areas;
- engender a greater export promotion culture in the UK civil engineering research community, industry and professions, and to direct the industry towards supporting R&D aimed at enhancing or strengthening civil engineering exports.

The project focused specifically on the following sectors in which the UK civil engineering industry has a strong record of success and leadership, and which are expected to offer opportunities for development and growth:

- coastal and river engineering;
- environmental improvement and sustainable development;
- infrastructure for urban development and megacities;
- transport planning and infrastructure;
- water and wastewater engineering.

In addition, the project's cross-sector workshops

(where discussion covered all of the above sectors)

generated general perspectives and conclusions which are presented as broad Recommendations and messages in Section 2.

The prime objective has not been the identification of specific technologies, although these have emerged in discussions and workshops, but to change the attitudes of those engaged in setting research priorities and allocating resources thus ensuring technical support of the UK's export potential. The interaction of 'technology push' and 'market pull', and the challenge of being able to compete in the face of increasing globalisation of knowledge and availability of skills, have been central to the project.

Success in continuing to compete in what is now a global market is vital to the continued health of the UK's civil engineering industry and the national standard of living. The industry must be able to compete in large, sophisticated markets and not depend on softer targets where technology might still be less critical. Only through sustained investment in core technology, through Innovation, Research, Development and Application (IRDA), will the industry survive and thrive, and maintain its contribution to the national economy and strong identity.

Many individual members of the civil engineering profession, major companies and research centres have contributed their knowledge, expertise and vision to this project through its programme of interviews, discussions and workshops. This report and its appendices are a distillation of the information gathered during the study, of the workshop discussions, and of the conclusions drawn at those workshops and by the Project Team. The appendices are presented on the accompanying CD.

The Project Team hopes that readers will be inspired by the vision of this report and will respond to its challenges (posed in the Foreword) by examining their own technology strategy in a rapidly changing global marketplace. Industry–Government investment in IRDA to create new technologies, products and services is essential to maintain competitiveness, profitability and jobs, and to underpin the industry's future.

2 Recommendations and messages from the project

The main outputs for the five sectors of the civil engineering industry that were studied during the Technology Support for Civil Engineering Exports Project are given in Sections 8–12 of this report. They include the recommended priorities for technology development in each sector.

Throughout the course of the project, in individual discussions and sector workshops, strong strategic issues have emerged, which were discussed and validated at a cross-sector industry workshop. These send recommendations and other key messages to the industry, to the research community and to Government about thriving in a global market, the role of technology in this strategy and about the direction of research and of research support for the future competitiveness of the UK industry in that global market. Some unattributed quotes from workshop participants have been included and are printed in italics.

2.1 Recommendations

R1 ***Global competition.*** **UK industry must compete globally by adding intellectual value. Industry and Government investment must focus on technologies that create or maintain a leading edge.**

Civil engineering design and construction markets worldwide are becoming more competitive as more players from more countries seek work overseas. The UK market for consulting, contracting and materials supply is open to international competition and major UK companies cannot survive by relying on UK work: they must maintain and grow their already-substantial international presence, and maintain their competitive advantage through substantial financial resources and a technological edge.

It is no longer viable for the industry to compete in international markets on the basis of standard technology and provision of basic engineering services – '*we cannot compete at the nuts and bolts level*'. The speed of dissemination of information, and worldwide expansion in technical education and availability of professional skills, means that standard solutions can be designed and constructed without the need for UK input. Therefore, UK industry needs to concentrate on adding intellectual value, providing original and innovative ideas and solutions. This requires constant investment in research and in the application of technologies to maintain a leading edge for the UK civil engineering industry.

R2 ***IR into DA*****. There is a great challenge to translate Innovation and Research into Development and Application. A higher proportion of industry and Government resources for technological development needs to be focused on Development and Application.**

Innovation, Research, Development and Application (IRDA) are about translating ideas into practice, and the process through which competitive technologies evolve. The key to success is to provide a climate for innovation, and then the financial means and incentive to push innovative solutions through into technology for application. '*For every £1 spent on research, £5 needs to be spent on development and application*,' but companies do not have substantial budgets for implementation of research results, and '*everyone wants new technology, but not on their project first*'. Recent initiatives such as the 'Best Practice' programme aim to bridge the gulf between IR and DA. Bridging the gulf is a core requirement if technological competitiveness is not to be stifled and competitive advantage lost.

R3 ***Population, development and society*. The civil engineering industry, its clients and suppliers must embrace environmental, societal and sustainability dimensions in their projects and their use of technology.**

Population growth and consequent pressure on natural resources are common themes and provide generic market opportunities. They create demand for environmental technology and management skills, water and water treatment, efficient use of land and buildings, provision and management of transport infrastructure, and defence against river and coastal flooding. Societal and wider environmental dimensions are becoming ever more important in development and infrastructure projects, including environmentally-orientated specification and procurement, and in the active management of a project's environmental performance. Engineering technology, and the research that underpins it, need to take this into account. Expertise in sustainable development – i.e. the engineering of the environment for the benefit of society without endangering either – is saleable. Civil engineers already have the wide-ranging skills needed to lead major, environmentally sensitive projects.

R4 ***Strategic research.* A new industry–Government partnership needs to be forged for the long-term maintenance of centres of excellence.**

Government support of research centres of excellence has been of immense value to the industry and to the UK economy by maintaining the industry's technological edge. The industry cannot replace this level of investment from its current slender profitability. However, the UK's leading edge and intellectual capital will be jeopardised unless investment is maintained. A realistic industry–Government partnership is needed for the long-term funding and maintenance of strategic centres, which provide problem-solving experience and technical know-how that underpin the industry's reputation.

To optimise the use of finite resources, the whole industry needs to be engaged in a co-ordinated and co-operative plan to work with Government through CRISP (the Construction Research and Innovation Strategy Panel), Foresight, Partners in Innovation and the Research Councils.

R5 ***Demonstration projects*. Industry has to be able to demonstrate new technology, successfully applied in high-profile projects. Clients, including Government, and the industry must develop mechanisms to enable new technology to be applied, tested and proved on 'home market' projects so that it can be offered successfully in export markets.**

Potential overseas customers are influenced by high-profile projects that demonstrate technological success but the application of new technology in the design and execution of high-profile projects inevitably carries risk. Clients tend to be increasingly risk-averse and, as the finance and procurement for public projects has moved progressively to private sector organisations, so the opportunities to prove innovative solutions using new technology are less widespread. Projects that demonstrate the successful application of innovative technology as a showcase for UK design and technology are extremely important for credibility and success in export markets. There has to be a way of valuing and, if necessary, supporting innovative first implementation of technology over and above least-cost, least-risk considerations.

R6 ***Integrated and adapted technologies*. The future lies in the integration of design and construction, with adaptation to local circumstances. The industry and the research community should seek to advance and exploit those areas where it finds it has, or can gain, real technical superiority, including the creative application of existing knowledge and research results.**

Although each sector reviewed has produced its own specific technology priorities and needs, a common theme is the need to integrate technologies to deliver whole solutions, to adapt them to local needs and circumstances and to demonstrate their ability to work as a team of infrastructure providers. This is the added intellectual value that gives the UK industry extra competitiveness. There is a wealth of existing knowledge and research to be mined, developed and applied, and such an initiative does not depend wholly upon extensive investment in new research programmes. It is

not necessary to be ahead in every aspect of industry technology: a narrow but appropriate technical advantage can be sufficient to win a broadly-based project.

R7 ***Design for whole-life value*. Long-term performance and integrity of infrastructure are key issues. The industry must deliver projects that provide good whole-life value for money by integrating techniques for risk management and value management with those for determining and costing anticipated service lifetimes. Clients, including Government, must encourage industry in this direction through suitable project specifications, evaluation and procurement policies.**

The long-term performance, maintenance and integrity of infrastructure have become key issues. This demands greater attention to asset management technologies, design for maintenance and a better understanding of deterioration rates of materials and systems. Climate variability and preparedness for extreme events are elements of the long-term sustainability of engineered projects, and offer market opportunities for relevant technologies to deal with them. The UK industry's asset management, project management and facilities management expertise need to be tailored to provide solutions to meet the needs of overseas clients. In developing countries, donors have recognised the importance of whole-life costing and appraisal, and the need to support maintenance or rehabilitation projects rather than only supporting new-build projects.

R8 ***Finance and procurement*. Financial engineering is an important part of winning projects. Industry must work harder at project integration, and Government needs to give practical assistance in international project financing.**

The growth of build–operate–transfer (BOT) and similar means of procurement, and the switch from public to private financing of major infrastructure, have introduced 'financial engineering' as a very important element in winning international business. The UK is a leading exponent of the privatisation of public sector services, and of the private financing of public infrastructure. The efficient integration of design, finance, construction and operation has brought success to some of the leading construction and consultancy organisations, but the industry must not be complacent and must seek to build on these successes. Clients are looking for better value and the industry needs to look harder at the integration of the traditional roles of the design and construction process, and further development of methods for managing projects and commercial frameworks as a 'soft' technology that will give export market edge and opportunity. Government encouragement and practical assistance is essential if the industry is to stay at the forefront of international competition.

In addition, performance specifications open the opportunity for innovative solutions where technology can give a competitive edge, particularly when supported by national accreditation. They particularly give contractors room for innovation by removing the strictures of prescriptive product- or method-related specifications.

R9 ***International standards*. Government and industry should lead the development of civil engineering-related codes and standards where they have a value in winning overseas contracts.**

Promulgation and adoption by other countries of civil engineering-related codes and standards based on UK national equivalents give a clear advantage to UK companies and play an important part in exporting of civil engineering services, but this needs to be better understood by industry and government. Nationally, the UK is neglecting standards development through a lack of resources, even though many UK engineers are still involved in this work. Many developing countries are preparing their own standards, despite resistance from the World Bank. The new Eurocodes, when finalised, will also be used increasingly worldwide. The UK needs to maintain a position of leadership in the formulation of civil engineering-related codes and standards and be active in international regulatory bodies such as CEN and ISO.

R10 ***Education of overseas students*. High quality engineering education is a UK strength and a human investment that yields future business. Overseas students are the clients of the future, and should be encouraged by Government and industry alike.**

The UK and its civil engineering industry have been helped greatly in overseas markets by the education of engineers and decision-makers from overseas in UK universities, supported by the growing ubiquity of the English language. Education of overseas students in the UK, through partnerships with UK universities, offers a big prospective return on a relatively small investment.

Technology transfer is an increasingly important element – and a strong influence – in winning projects. As other countries develop their own educational infrastructures, the UK must be proactive and create links with local academic centres to maintain its leadership and secure the links to future business opportunities. Government leadership through diplomatic and cultural channels, with industry participation, is a key to continued benefit from this inheritance.

2.2 Other key messages

M1 ***Creative swiping*. Developments in other industrial sectors can be adapted to construction through the creative transfer of technology.**

Civil engineering needs to be better informed about advances in other disciplines and to make lateral connections with technologies already proven in other applications. For example, the use in civil engineering of high-strength adhesives lags far behind some other industries. There is a general need for continued development of materials designed for specific purposes, and for the use of non-traditional materials in civil engineering applications. Examples include carbon fibre for corrosion protection of cables and stressing strands and in plate bonding for strengthening and repair; the use of plastics for structural members in conjunction with concrete and steel; and the use of advanced composite construction, with high-strength fibre-reinforced polymer materials.

The investigation of engineering properties of readily available local materials in order to achieve prescribed design strengths, and understanding the properties of common construction materials in varying climates and ground conditions of the world, would increase competitiveness. Better use could be made of aerial and satellite systems for controlling, positioning and managing installations on the ground. Technologies developed for military purposes should be examined closely for adaptation to non-military purposes. Thus, investment in bringing together diversity of knowledge, importing developments from other disciplines or countries, and so delivering holistic innovative solutions, could be an excellent investment for export success. Technology is the ‘glue’ that holds the process together.

M2 ***Application of advanced IT in civil engineering.* The industry should sustain and exploit the UK strength in artificial intelligence and computer simulation of complex systems.**

The development of innovative applications of ‘information technology’ is an area in which the intellectual powers of UK industry and academia can give added value and market opportunity. ‘Artificial intelligence’ and computer-based technologies have wide applications in analysis, in decision support systems, and in monitoring and management of systems across the whole of the industry, such as in catchment management, water resource management, infrastructure capacity management, and the virtual reality representation of structures and service systems. All these increase functional efficiency, reduce costs and add value. Computer modelling of complex systems and artificial intelligence is a UK industry strength that should be actively supported and developed to these ends, both by direct industry investment and through Government-supported research programmes.

M3 ***Technology across time zones.* In an age of electronic communication, technology crosses national boundaries almost instantaneously, and the industry must move fast to stay ahead.**

Knowledge is an instant and international commodity that can be shared, acquired and combined from worldwide sources. Competitive advantage comes not from knowledge itself, but from

harnessing and combining knowledge from many sources and disciplines. The industry needs to make more use of 'technology brokers' (a consultant or subject champion charged with acquiring technology for a business) and 'technology clusters' (physically close or electronically-linked groupings of organisations and/or individuals) to exploit knowledge that is freely available, and abandon outdated technologies and methods overtaken by technological progress. It must learn fast, apply fast and feed back experience fast to stay ahead.

M4 ***The multiplier effect*. Government and industry should recognise the extent to which projects financed, designed, managed and constructed by UK-based companies generate added value to the UK economy.**

The consequences of one firm successfully applying innovative technology to win overseas business can have far-reaching consequences for other organisations in the supply chain. When large UK civil engineering companies act as project brokers, building project teams from many sources, the value to the lead company is multiplied by all the other UK participants providing products and services. The fragmentation within the industry makes these benefits difficult to evaluate but they are believed to be real. Greater collaboration and partnership between the UK companies would help to maximise the value of international contracts to the UK economy and return the benefits of application experience to UK industry as a whole.

M5 ***The role of specialised technology companies or groups.* Technological advances often originate in specialist companies or specialist groups within large companies. Such specialists often need special resources for their Innovation, Research, Development and Application (IRDA).**

UK civil engineering is a large industry led by powerful international multi-disciplinary companies. Whatever their strengths, such companies often rely on specialist technology companies and/or specialist groups within the firm to provide leading-edge technology for major projects. Such companies and groups have the ability to work in highly specialised technical niches and to adapt quickly to changes. The industry needs them as a source of innovative technology, but such companies and groups need the financial resources to maintain their technical evolution by the acquisition of knowledge and its application in engineering practice. They should not be discriminated against on grounds of size in the allocation of government research resources. They need to be able to sell their specialist skills and knowledge at margins that enable internal investment in technological advances to continue.

M6 ***Measuring success*. Government and industry should collaborate to develop a new approach to the measurement of industry success overseas.**

Technology adds value to activities rather than delivering direct benefits and it is often difficult to establish its effect on the bottom line of company accounts. In addition, the trans-national ownership of civil engineering organisations through mergers, acquisitions and alliances obscures the true value of overseas business to the UK economy. Analysis of the published data identifies many apparent peculiarities and distortions. Measurement of the impact of this project, and the implementation of its recommendations, needs a framework for recording value returned to the UK economy from overseas projects undertaken both by UK-based lead companies and by UK companies collaborating with UK or overseas partners.

3 An overview of the international engineering and construction markets

3.1 Introduction

UK designers, engineers, constructors, and component and product manufacturers all have a world-wide reputation for working overseas. This reputation has been earned over time through their involvement in the early days of trading with the British Empire, followed by close links with Commonwealth countries. The tradition for international trading is deep-rooted.

The UK construction industry ranks as one of the strongest in the world, with output ranked in the world's top ten. It is large, not subject to rigid political control and, as with all developed countries, it has to cope with the boom–bust cycle. UK construction accounts for about 8% of the gross domestic product and provides over half of the fixed capital investment.

3.2 The world economy in context

Since 1990, the economic growth rates of industrialised and developing countries have exhibited dramatic divergence: in the former, the rates have slowed due to recessions, while the rates in the latter are increasing. In the 1980s, this growth 'gap' was modest – only 1–2 percentage points. However, in 1990, the average growth rate of industrial countries plummeted and remained low over the next three years while that of developing countries kept rising. Despite the recent difficulties in Asia, the acceleration of growth among the developing countries has been in sharp contrast to countries within the Organisation for Economic Co-operation and Development (OECD).

Among developing countries, at least four trends have emerged.

- The success of market reforms has contributed to continuing rapid growth in Asia and to improving performance in Latin America. Some commentators believe that the current Asian financial crisis will turn out to be only a blip in otherwise steeply improving performance. Whilst some in the area during the crash pulled out to reduce their losses, others are consolidating their presence by employing the now-cheaper but experienced local staff.
- A surge of infrastructure spending has fuelled growth in many regions. In countries such as the People's Republic of China, rapid economic growth has strained the capacity of power generation, roads, railways, airports, and water supply and treatment.
- Rapidly rising household incomes in many developing nations have fostered large middle classes, a new wave of consumer spending and increases in infrastructure spending. All of these have fuelled growth and reduced such countries' dependence on exports to OECD countries.
- Competitiveness in export markets has contributed to growth in many nations. The increased productivity of a number of East Asian countries has enabled them to achieve their status as top exporters as well as improving their national living standards.

3.3 Global competitiveness

The World Economic Forum publishes an index of the competitiveness of each country based on a number of characteristics including quality of infrastructure, business management and technology, plus labour market flexibility and development of financial markets. The relationship between the competitiveness index and the GDP growth per person between 1991 and 1996 is shown in Figure 3.1 (Global Competitiveness Report, 1997).

Countries that had high volumes of construction, such as Malaysia and Singapore, are those with high GDP growth and competitiveness index. High growth and high competitiveness seem therefore to be indicators of substantial future investments in infrastructure. The emerging countries, in general, have a greater competitiveness than the developed countries. However, China, where most infrastructure development in the next five years is predicted, was not included in the analysis due to the lack of reliable data.

3.4 The changing world of engineering and construction

The business environment in which contracting and consulting firms operate has undergone more change in the last five years than over the previous 40 years. Markets are expanding and changing as well as becoming more complex, and show the following characteristics.

- Globalisation has affected the way that business is undertaken. Maintaining a competitive advantage

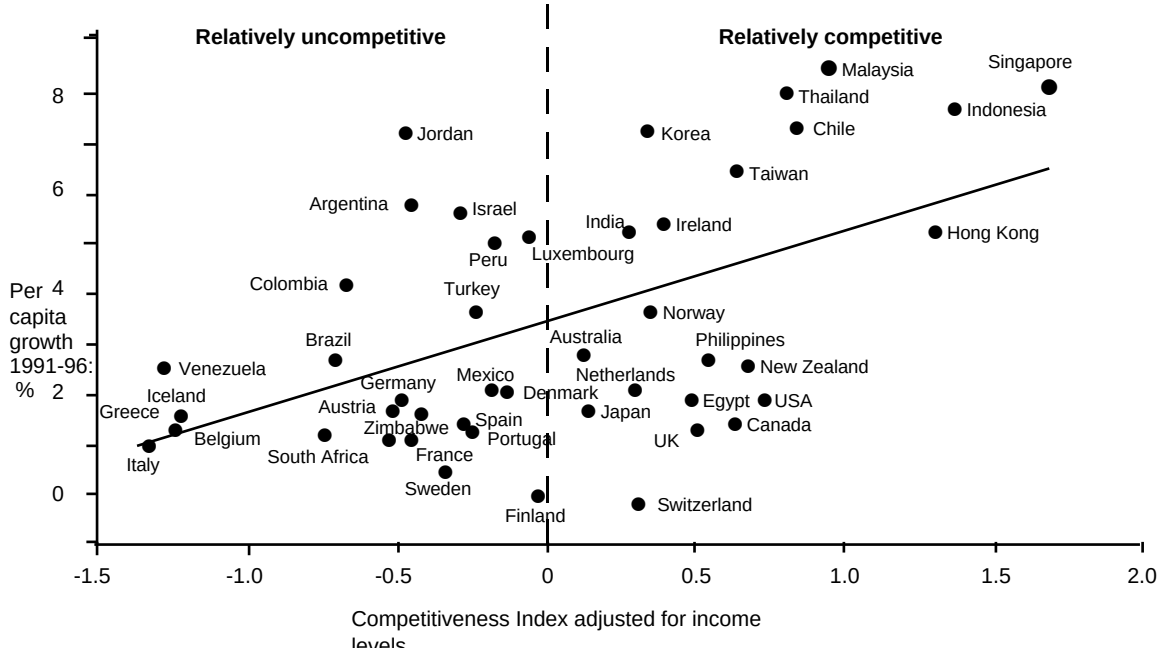


Figure 3.1 GDP growth and the competitiveness index between 1991 and 1996

is much more difficult as product and service life-cycles, and their development cycles, shorten.

- The competition to win work in overseas markets is getting tougher, with project creation, finance and financial engineering, technology, design and effective specialisation being key factors in business success.
- Technology has no respect for international boundaries or time zones.
- Most clients and engineers are in favour of innovation and new technologies, but preferably not on their project first.
- Awareness of environmental issues, of sustainable development and the influence of pressure groups are growing significantly.
- Net profit margins for contractors are not increasing, 1–3% of turnover being the norm.
- Many contractors have moved upstream into design and into design–build–manage–construct, and consultants have moved downstream into fee-based project management and facilities management.
- Some consultants have moved to take a proportion of the construction risk.
- The consultant/contractor/operator dividing lines are thus breaking down in many countries.

Markets are polarising broadly into those in developed or industrialised countries and those in developing or emerging countries.

Some developing countries are creating huge demand for infrastructure, mainly based on public–private participation or build–operate–transfer schemes. There is a new dynamism in developing countries, in which they seek to leapfrog to the most up-to-date technologies for their projects. Since these processes are at different stages in each country, pigeon-holing developing countries into one category is no longer valid. Each individual market needs to be understood and treated according to its needs and within its current culture.

There are thus great opportunities for firms that appreciate the different technological needs and the aspirations of different countries, and that are able to fulfil those needs in the most appropriate way. This will not necessarily be through labour-intensive solutions: many will require state-of-the-art solutions that can be maintained at a local level.

Design and build is used increasingly as a project procurement method around the world, as is the move from public to private financing of projects. Integration of design with production is also on the increase, along with the move away from traditional bidding and adversarial contracting towards longer-term partnering. New employment patterns and organisational structures are emerging. All the big players are re-engineering their business processes: the 1990s are about core competencies and service for the customer.

3.5 New approaches

The traditional approach of a general consultant or contractor for winning projects based upon the lowest tender bid is less viable on overseas projects because the risk:reward ratio is very high. Many companies are seeking overseas work as part of a consortium, as part of a strategic alliance, or as specialist niche players.

The growth of the civil engineering industry overseas has been such that UK firms now find it difficult to compete at the production and assembly level, since local firms will always be able to provide competitively the labour and basic resources required. There is a need for a balance to be struck between 'big-plant' and 'labour-intensive' solutions. There should therefore be an increasing focus on competing in the intellectually demanding areas, such as:

- project evaluation;
- project management;
- operational management;
- management of change;
- asset management;
- risk management.

Competing at the intellectually demanding level will also allow young engineers to continue to gain experience from overseas projects.

Many developing countries are protective of their domestic construction markets. They want to develop their local companies by insisting on technology transfer arrangements and/or requirements for a local shareholding of companies set up in the country. There is also increased competition from engineering firms from the newly industrialised countries. They have lower wage bills, are becoming ever-more sophisticated, and are beginning to compete in developed countries.

Continued export success therefore depends upon the integration of local personnel and their skills in project implementation and, to keep costs competitive, it is necessary to make the maximum use of local staff. UK industry can no longer compete on the basis of providing a complete team of expatriate engineers to carry out all the functions of design and construction supervision to an artisan economy.

The UK can trade on the expressed wish for local participation by building education and training opportunities for indigenous engineers into project plans. The very specialised nature and availability of high-quality, technically skilled manpower among consultants in developed countries give them a competitive advantage at present. A good appreciation of client expectations and needs, and a reputation for applying advanced, but appropriate technology are the keys to success.

An additional and significant facet of these markets is that not everybody is playing by the same rules. There are suggestions that some governments have very generous export support packages whilst others offer little or no support. Regrettably, corruption seems to be rife and increasing.

There is a substantial market for 'soft technologies' or 'know how', and for technology transfer, which are increasingly the route to the provision of hard technology and products. The training of overseas students in British methods is of immeasurable value in developing the global market for British technology.

Clients will also look for best value and it will be important for companies to find improved ways of presenting design solutions in a new and innovative way, using virtual reality linked to CAD and object-based models.

3.6 Private finance and procurement

There is a growing movement for both privatisation and the introduction of private finance to public-sector projects, in developed and developing countries alike. Although these changes in organisation and funding are different and do not necessarily need to be combined, many UK firms have experience of how to effect both. There is a significant opportunity to market the skills and experience resulting from private financing of projects and the UK's privatisation of the public utilities and incorporate these within the institutional or planning frameworks in overseas countries. For many developing countries, the initial effect of privatisation has been better economic performance. This has led some of the international aid agencies to insist on the privatisation of publicly-owned comp-anies in developing countries as a condition for loans.

Recent UK experience of how to privatise, how to regulate and how to structure projects to attract private finance, plus a long history of effective local management of such utilities and of local municipalities, is all 'know-how' that is internationally exportable.

There is much scope for developing partnerships with clients, especially as the UK civil engineering industry operates through a variety of frameworks and has a diversity of technical, geographical and organisational experience. Client requirements and new forms of finance and procurement change project culture, drive design philosophy, and can significantly shift the emphasis towards design for whole-life costing, minimising environmental impact and delivering project sustainability.

4 UK civil engineering exports

4.1 Definition of exports

For the purpose of this report, civil engineering exports are defined as:

- the capital value of overseas construction activity undertaken by UK-based civil engineering enterprises, plus
- the value of materials and components, plant and machinery purchased from UK manufacturers and suppliers (including distribution), together with
- all other associated income including insurance premiums and interest payments from loans made by UK financial institutions (commercial or otherwise) to fund projects, and
- the transfer of appropriate technologies in direct and indirect forms.

4.2 Major features of civil engineering exporting

Major UK civil engineering consultants and contractors earn a large proportion of their annual turnover from overseas work. A few have their annual turnover made up entirely from overseas work. Exports are therefore very important for the future prosperity of civil engineering companies.

The presence of UK consulting firms on overseas projects will encourage the participation of UK contractors and manufacturers. The resultant benefit to the UK balance of payments can be significantly greater than the design fee alone. Other direct benefits from UK consultants working overseas include:

- the use of international standards which are compatible with UK standards;
- the use of UK products and services;
- the use of UK sub-consultants and contractors.

Up to 80% of the value of a construction contract can be in the materials and equipment supplied. For most overseas construction projects in which UK contractors are involved, a considerable proportion of these resources are obtained in the country in which the work is carried out. Although this varies, research suggests that when the lead contractor is British, the proportion of British supplies is likely to be much higher than when the lead contractor is

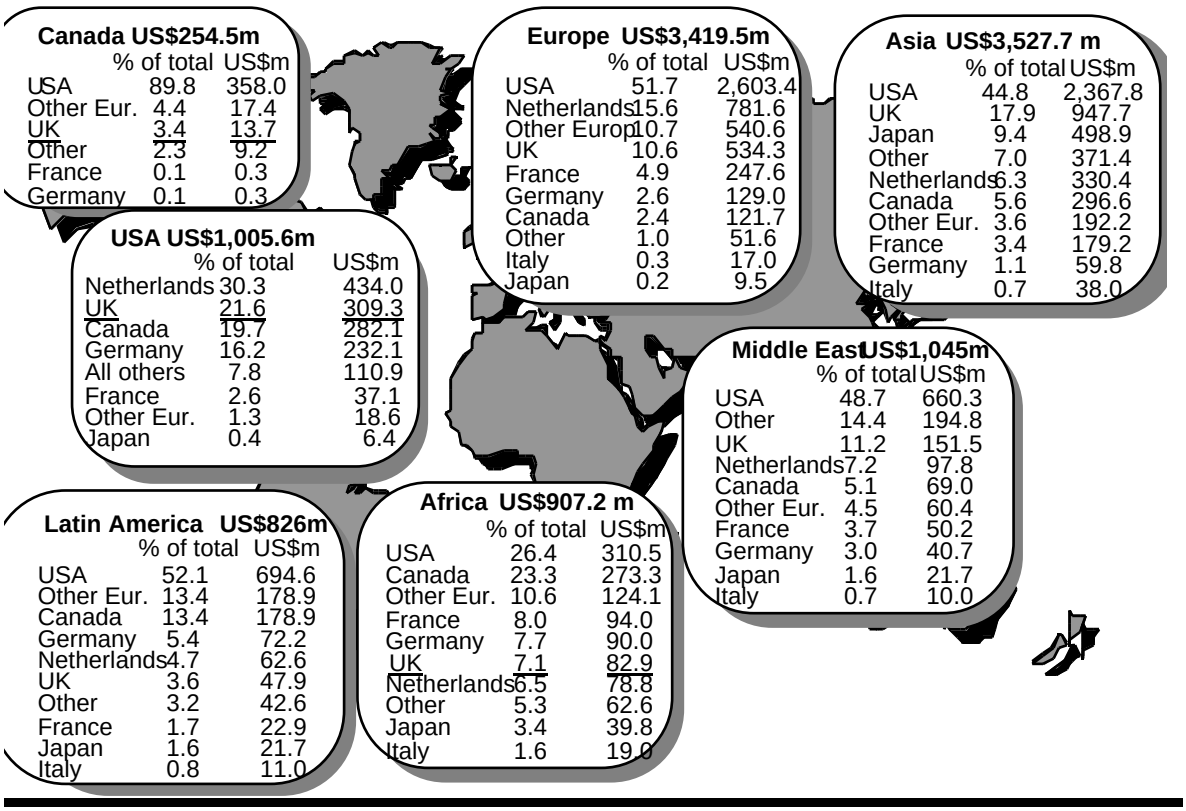


Figure 4.1 World market share by the top 200 International Design firms *Source: ENR (1996)*

foreign. This is also likely to attract smaller UK suppliers who would lack the resources to export on their own account. Building materials and components of high value and low weight may be bought in the UK. Plant may be bought from the UK, but in view of the high transp-ortation costs, it may be cheaper to purchase it closer to the project location. Thus, the contribution to exports often consists of UK-based management, high value components, overheads and profit.

Exports in the form of package deals (eg finance, design, supply, construction and operation gathered together in one contract) may also provide an opportunity for the sale of UK products. Potential benefits for the client arise from reduced administration and the single point of responsibility. However, the client loses the ability to specify the best value component in each individual case, a factor that dissuades some more experienced clients from taking this route. Despite this, the role of the consultant is crucial in assembling a competitive package deal including UK contractors and manufacturers. Major UK clients also have an important role to play in promoting UK manufacturing exports. Through the alignment of UK and international standards and specifications for equipment, it is often possible to ensure that the same product can be used abroad.

4.3 The global standing of UK civil engineering companies

Each year, EMAP Construct (Contractors File and Consultants File) and Engineering News Record (ENR 1997) prepare lists of the top 100–200 contractors and consultants. Analysis of the recent listings, together with information from the Association of Consulting Engineers, are provided in Appendix 4 on the accompanying CD. Identifying the leading UK exporters from the data is notoriously difficult. For example, the turnover of a US-based company that is working in the US but owned by a UK company is included in UK exports data. Exports are thus not confined only to work won by bidding from the UK.

Nevertheless, ten British companies were among the top 200 in the ENR survey of international design companies, which included consultants, contractors and process engineers (ENR, 1996). In a similar survey of international contractors (ENR 1997), 11 British contractors were listed in the top 225 in the world, with the UK in fifth position overall.

From the same surveys, the share of world markets among the top 200 international design companies is shown by country of origin in Figure 4.1 (design includes engineering, architectural work and environmental engineering). ENR calculate the percentages shown from the activity of the firms on

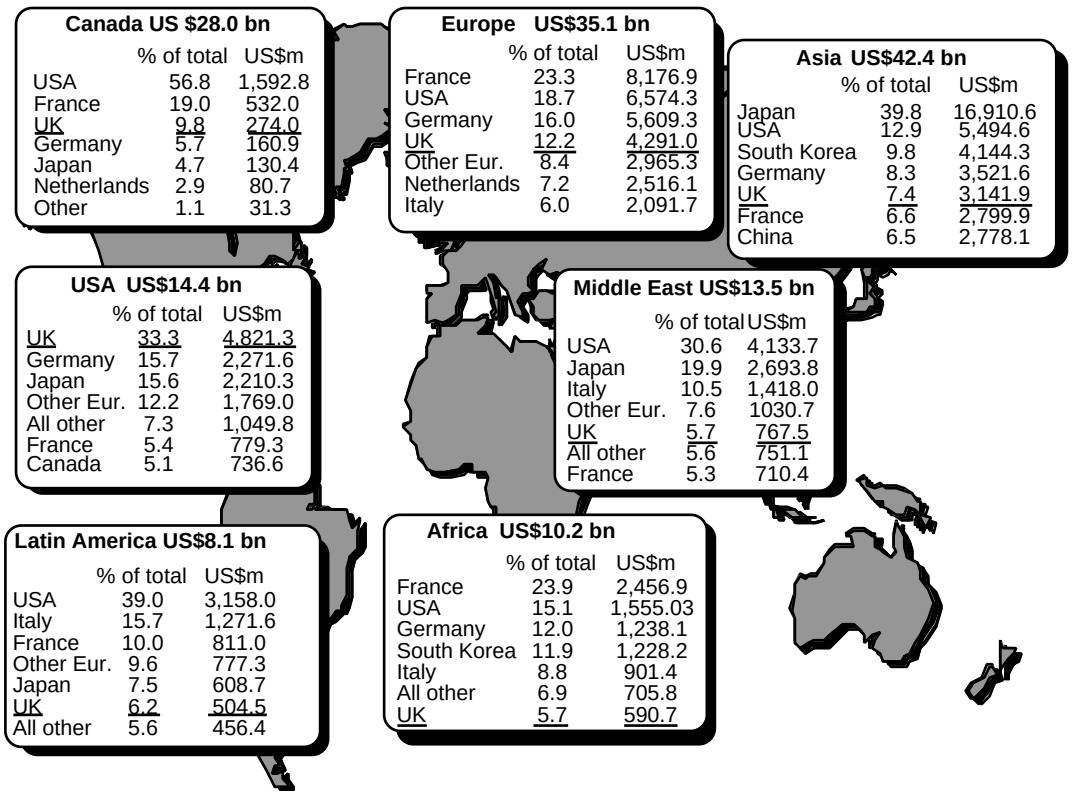


Figure 4.2 World market share by the top 225 International Contractors *Source: ENR (1997)*

their lists. For example, Figure 4.1 shows that, in Canada, the US firms on the list have 94.4% of the total turnover of the top 200 firms. It does not mean that they have 94.4% of all design work in Canada that is undertaken by non-Canadian firms.

Figure 4.1 shows that UK design companies have room for improvement. UK international contractors, on the other hand (Figure 4.2), have made great inroads into the USA (33.3%), Canada (9.8%) and Europe (12.2%), although it must be stressed that some of those 'imports' arise from UK ownership of local firms.

The global distribution of civil engineering exports from UK consultants can also be indicated by the exports of the members of the Association of Consulting Engineers (ACE). Since 1985, UK engineering consultants' overseas fee income has been:

- 1985 – £562m;
- 1988 – £400m;
- 1992 – £230m, the reduction being due primarily to the Gulf crisis and the world-wide recession;
- 1996 – £878m.

The estimated invisible export earnings by the members of the ACE (ACE, 1997) maintained them as leading export earners in the UK services sector. The balance of accounts for trade in services is in credit compared with the trade in goods, as shown in Figure 4.3, with over 15% of the credits due to civil engineering exports. The financial crises in the Far East are likely to cause significant reductions in earnings unless the sector diversifies to other regions of the world. In 1996, British engineering consultants were engaged in projects in 140 countries. (Britain 1997).

ACE report a comparative lack of activity in South America (ACE, 1997). However, the project value of new work for ACE members in Africa increased from about £1bn in 1995 to just under £7bn in 1996.

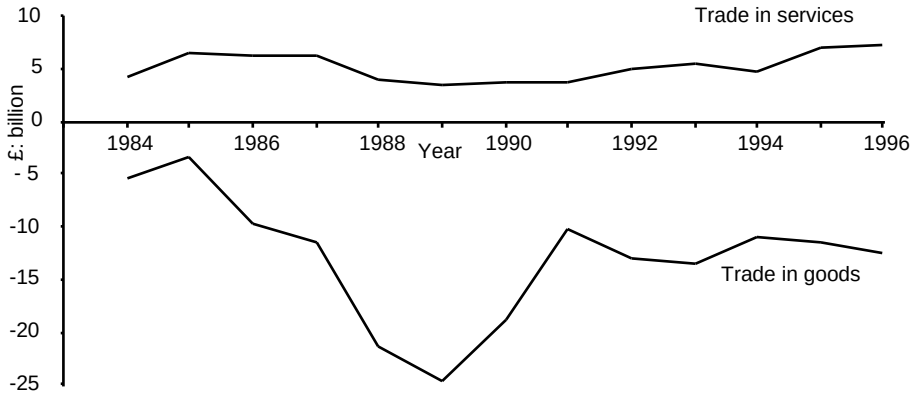


Figure 4.3 UK balance of payment for goods and services *Source: The Pink Book 1998*

5 Engineering the finance for overseas projects

Many of the large infrastructure projects in the world are supported financially by the international agencies: they are a key source of work for UK companies. The destinations of the funding by these agencies such as the International Bank for Reconstruction and Development (IBRD) and the International Development Agency (IDA), shown in Figure 5.1, provide a current picture of global markets. Lending in 1997 showed that the Far East and Latin America are the areas where most civil engineering work funded by the World Bank is taking place or planned.

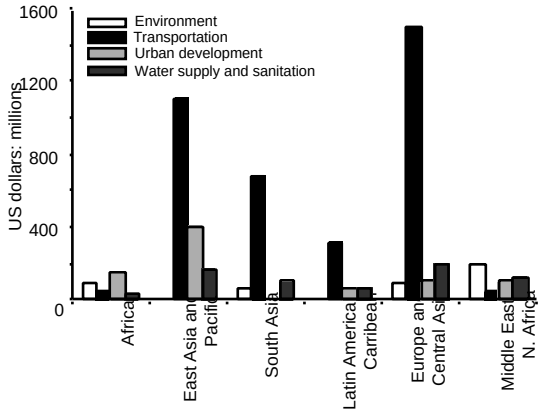


Figure 5.1 IBRD and IDA lending for 1997
Source: World Bank, (1997)

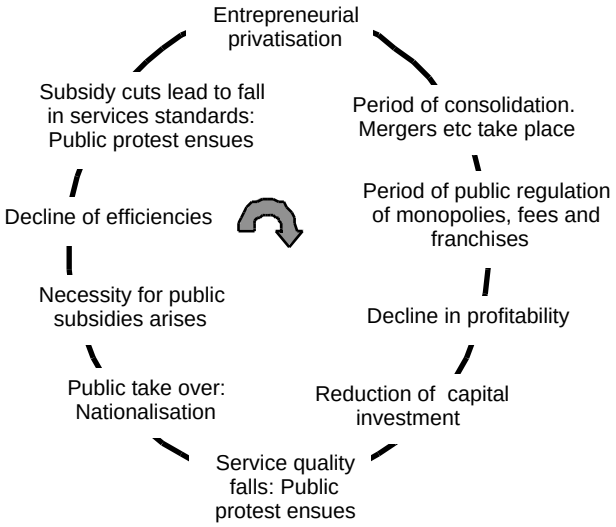
Despite being a high-risk strategy for project participants, the use of BOT is growing in extent and importance. It is expensive for prospective participants to secure such work and the guarantees expected can be a substantial burden to them. Some international companies see investment in BOT as a means of beating the competition while others see it as a means of maintaining their level of construction activity. Nevertheless, UK firms are well placed to win work through the BOT route.

As Engineering News Record (1997) reports: 'International contractors are finding that size and financial clout are distinct advantages in the market, sparking increasing numbers of mergers'. Being able to finance a project, or to arrange its finance, is clearly where most large international construction companies are moving and, slowly, financial and other institutions are also beginning to realise this potential and taking initiatives to instigate projects in this manner. BOT, and other similar procurement methods that require financial engineering, have so far been prerogatives for the large construction companies. This need not be the case because small companies can have the same access to such investments if they work in consortia with other small companies.

BOT and similar forms of project procurement have come about as a result of a wave of privatisations around the world. The World Bank and the International Monetary Fund (IMF) are increasingly insisting upon 'market-friendly domestic policies and operational environments in which the private sector is increasingly the engine for growth', as a condition for loans to recipient countries. The World Bank suggests that it makes good sense to insist on creating business environments where the private sector can compete or take over public utilities when there is disenchantment with the performance of state-owned companies.

However, as the privatisation cycle in Figure 5.2 indicates, when profit margins decline and the private sector begins to withdraw some services to improve profitability, public outcries may arise and public take-overs may become inevitable. It therefore helps to understand the point of the cycle where a utility is, and therefore what are the major associated risks, before becoming involved in its private ownership.

Figure 5.2 Privatisation cycle (after D Suratgar 1998)



6 Technology for competitive advantage

6.1 The use of technology in civil engineering

Civil engineering practice in the UK covers a very wide range of activities in many different sectors involving 'soft engineering' (management techniques, engineering software, project finance etc.) and 'hard engineering' (project design and construction). Therefore the technologies needed to enhance civil engineering exports will also need to be both hard and soft. Currently, the technologies being used in the industry are generally of the mature type on the technology s-curve (Figure 6.1). This is mainly due to widespread conservative attitudes to technology within the industry, where many will only accept tried and tested technologies.

In order to maintain and develop its competitive advantage, the industry needs to search for and incorporate new ideas. Research output from a wide variety of disciplines needs to be developed into applications that will keep the industry at the leading edge of technology. Such continuing advancement, depicted by Figure 6.2, is necessary to maintain competitiveness.

The growing importance of technology is now crucial, with knowledge technology and knowledge management becoming central to all businesses. The level of performance of the world's best companies is constantly being raised as a result of innovation in communications technology and learning. Industrial development has moved from being labour-intensive to capital-intensive to knowledge-intensive. Technology has been the vital ingredient in this development. The centre of gravity in business success is shifting from the exploitation of physical assets to the realisation of the creativity and learning potential of people. More than ever, people and relationships are one of the important keys to sustainable success.

6.2 Barriers to innovation

Three barriers to innovation were confirmed during this project.

- Technology adds value to activities rather than delivering direct benefits but it is often difficult to establish the economic benefit of applying technology.
- The consequences of one firm applying innovative technology may have far-reaching consequences for other organisations in the supply chain. Fragmentation within the industry means that these benefits are not always accounted for within the evaluation process.
- Construction is a project-based industry and innovations are frequently undertaken on an individual project basis. Apart from such innovation, it is often difficult for construction organisations to justify investments that do not provide a return within the short term.

6.3 Innovation, Research, Development and Application (IRDA)

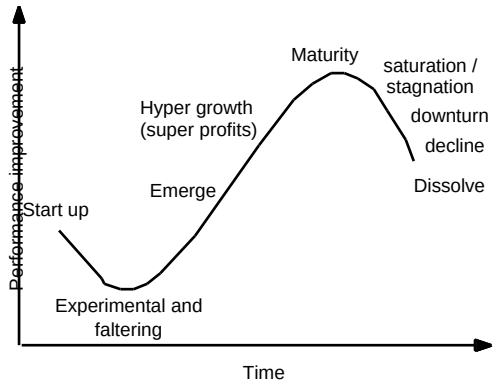


Figure 6.1 Technology s-curve

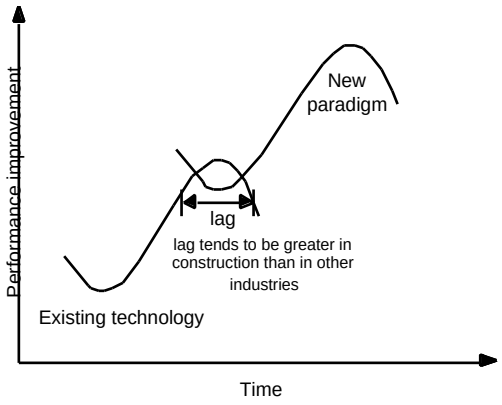


Figure 6.2 Maintaining technology advantage

Everything that has been invented started off as an idea, which was initially researched and the results then developed so that they could be applied to real life products or services. At present, there is much innovation and research (I & R) being undertaken in academic circles and industry, much of it fully or part-funded by the UK Government or the European Union. A common theme from industrial and academic participants in this project was, however, the comparative lack of development and application (D & A) of the research results, such that there is an under-realisation of the potential of research results.

Researchers disseminate their research results and industry is expected to carry out the D & A, even though it has been estimated to cost five times as much as the I & R. With low profit margins in the industry, however, much of the industry is unable to carry out as much development as it would wish. As a result, much potential application never happens. Financing this whole process more effectively than at present may be a key to using technology for competitive advantage.

6.4 The Foresight Programme

The UK Government's Foresight Programme has been aimed at stimulating innovation backed up by research, embracing the dual themes of partnership and wealth creation. The purpose has been to help industrialists and scientists to become well informed about each other's efforts. It seeks to bring these communities together in networks – 'looking forward to partnership' – that will help to identify emerging opportunities in markets and technologies. Helping to ensure that resources are used to best effect, in support of wealth creation and improving the quality of life, has also been a major theme. The results of Foresight have been directed at enabling informed decision-making on spending by Government and industry.

The first Foresight Programme, called Technology Foresight, was undertaken through 16 Foresight Sector Panels, co-ordinated by the Office of Science and Technology. Each Panel published its findings in a separate report and the details are given in Appendix 6 on the accompanying CD. Most of the reports considered possible trends over the 20 years to 2015, focusing on what each Panel considered to be technologies that would either create wealth or improve the quality of life.

6.5 Key points from Foresight Reports

The Foresight Reports highlighted some important points for the civil engineering industry.

- The Construction Foresight Report noted that the UK construction industry had a high potential for creating a competitive infrastructure. Wealth creation, quality of life improvement, and likelihood of success were all rated high, but current capabilities were rated only medium to high. The UK construction industry therefore needed to continue to sharpen its technological base together with that of its allied disciplines and industries in order to compete with the best in the world and win.
- The majority of the UK's civil engineering exports will be to developing or emerging countries that will not have the capacity, even though they may have the technology, to fulfil the demands of the rapid developments in their countries.
- There are export opportunities associated with all new technologies developed for UK markets because the less mature markets, to which the UK will export, will be looking to obtain the best available technology.
- Innovation in the construction industry has largely been project-related and/or focused on solving specific problems.
- Developing countries may not remain behind the developed world for long. They are catching up fast, as has been seen in the Far East, with the expertise available in these countries often being of as high a calibre as can be found in the UK. They may not have the required numbers of experts for a particular project, so a market posture that persuades them to use UK companies rather than the competition will be needed.
- Civil engineering designers are the main 'vehicles' for exporting civil engineering related technologies.
- Development of technologies such as remote control, automation or robotics for use in the construction industry may help reduce output costs and may improve the perception of high quality UK companies.

7 Introduction to the sector outputs

The following five sections present the main outputs from the five sectors of civil engineering that were studied as part of the Technology Support for Civil Engineering Exports Project. They are a distillation of expert views from dedicated sector workshops, refined and agreed at a whole-industry cross-sector workshop, with wide representation. Each is supported by more-detailed information and findings in the corresponding Appendix in the supplementary documents on the accompanying CD. The strategic and cross-sector issues arising from the discussions are presented in Section 2 of this report.

Each of the Appendices on the CD comprises three main parts:

- a Sector Overview that presents the workshops' views of the most important market and technology facets of the sector;
- a review of the main points arising from responses to the project questionnaire, related to the sector under discussion and covering issues such as the importance of technology, how technology is acquired, the types of research and development required and the sources for funding of the required research and development;
- outputs from the project workshop 'foresight' research in this sector under five headings explained below.

Each of the following sections in this report comprises:

- a summary of the Sector Overview, including selected comments based on the market-orientated parts of the project workshop foresight process;
- an outline of the key services and technologies identified in the project workshop foresight process.

Inevitably, there is some apparent repetition between the sections but this is limited to coverage of factors that apply to more than one sector.

Readers wishing to study further the findings in any particular sector are directed to the supporting Appendix of the same number as the relevant section below.

The five headings under which the foresight outputs are reported stem from the structure of, and the approach to the project foresight process, adopted and amended for this project from the original Technology Foresight. That structure was to:

- identify the market, technical and social ***trends*** that may affect the sector's technology needs and to identify the ***main drivers*** for market and/or technology development and adoption;
- identify the main ***market opportunities*** that could arise from the trends or driving causes;
- identify the ***new or enhanced products or services*** that might be needed to exploit the identified market opportunities;
- identify the ***new or enhanced technologies*** needed to enable the identified products or services to be developed and/or offered to the identified markets;
- identify any ***research and development policy issues*** arising from the technology needs or elsewhere in the analysis;
- work through the sequence in reverse order (if possible) – to identify products and services, market opportunities and even trends that might arise from the creation of a technology (for example smart cards) for which no civil engineering application was originally envisaged when it was being developed.

In presenting the outputs, the authors have sought to avoid the 'shopping list' approach to identification of technologies and/or research and development needs. Nevertheless, it is important that researchers and industry-based development managers study the results, including the detail in the Appendices, to identify opportunities for their own work and for the creation of new technologies, products or services for commercial gain.

8 Coastal and river engineering

8.1 Sector overview

Coastal and river engineering consists of much more than conventional civil engineering design and construction. It demands a wide range of skills and technologies, including environmental sciences, environmental economics, socio-economics, risk evaluation, legal structures and consultation procedures. To be successful in this sector, engineers must be able to take a broad view, bringing together and managing a team of specialists to drive the whole project, of which classical 'civil engineering' may be no more than 10%. The civil engineering industry has to adapt its capability and approach a wide variety of projects. It needs to offer the whole spectrum of expertise, which will allow it to participate in projects at their inception when engineering content is small, so as to be able to secure the engineering content at the downstream end of project implementation.

Data collection, synthesis and interpretation are key elements of success in this sector. They are high-cost activities, and advanced technologies that reduce the time and manpower involved provide a significant competitive advantage. Thus investment in developing 'smart' ways of collecting data over large areas, exploiting remote sensing and satellite systems, underpinned by application of computer technologies for integration with information databases and systems, is a route to success in export markets. The UK has produced many innovative ideas and prototype systems for data acquisition, but they are not being fully exploited through lack of focused ownership and investment.

It is now realised that engineering works in coastal and river environments often have very far-reaching and complex impacts. There is a need to be able to simulate very large physical systems, and make well-founded predictions of the impact of imposed changes. This capability has given UK industry leaders a strong competitive edge, and needs to be maintained. It is linked with increasing awareness of the concept of 'risk analysis' in natural situations. Risk analysis, prediction and acceptance, and the inter-relationship between innovation and risk, presents a large area for development and innovation in the context of coastal and river engineering projects.

In addition to the general issues covered in Section 3, the key issues driving market opportunity, product and service development, and technology needs in the sector include:

- the increasing population in coastal zones – due both to the land needs of growing populations and to the development of tourism – which is at risk from climate change, increasing storminess and uncertainty of sea level predictions;
- asset management and maintenance systems, needed at appropriate technological levels in areas such as irrigation and coastal defences;
- a particularly strong conflict in this sector between the demand for development and pressure to protect the environment, coupled with 'sustainable development';
- the perception of the UK industry, with a wide range of coastal and river engineering experience world-wide, as a market leader, a position which UK companies need to build and maintain.

8.2 Key services and technologies

Technology is the foundation of the UK's already-high reputation and competitiveness in this sector. The understanding and experience of complex river and coastal processes has given the UK industry a global reputation for advanced knowledge and technology, but this is not static and has to be maintained. Other countries are becoming more active in this sector, and improving their technical competence. The UK lead in this sector can be sustained only by continued and substantial investment in application of new techn-ologies to increase the efficiency and breadth of our technical capability. Although the developing world has been a strong market for the UK industry, there are now substantial opportunities arising from increased leisure investment in waterside locations in developed countries. This is a truly global market sector in which application of technology will win business.

The key services and technologies to be exploited in increased exports in the coastal and river engineering sector have been identified as:

- the need for models to evaluate the effects of sea level rise and climate change, for future planning and design;
- the analysis of river and coastal processes, which offers considerable scope for the application of neural network technology; (To date, the emphasis has been on increasingly detailed understanding of the physical processes that make up these natural systems, but their complexity defies definitive analysis. Application of neural network techn-ology to the increasingly large data sets that can now be

obtained by remote measurement reduces the need to understand the detail of the physics, and offers the opportunity to analyse data without imposing pre-conceived ideas or structures. This is an advanced technology in which the UK industry could excel and gain a significant competitive advantage with serious investment.)
- further research to understand the physical, chemical and biological processes of sediment transport in coastal zones and rivers, to be developed into full ecosystem models;
- durable products, materials and coatings for structures in fresh and saltwater environments, which would provide competitive advantage in a market now sensitised to whole-life costs;
- better intertidal construction techniques, including stabilisation of underwater slopes;
- methods of risk assessment, which will be increasingly necessary for coastal and river works;
- technology of large control structures applicable to rivers and canals with high sediment loads and a wide range of potential flows and founded on permeable foundations;
- advanced ship-handling facilities, thus reducing the need for large port and breakwater construction in response to changes in ship design;
- the strong need for new, remote methods of data acquisition and interpretation in rivers, ocean currents, wave climates, land use, erosion and sediment transport;
- innovative designs for coastal and river structures, which should evolve to respond to concerns about environmental impact both during service life and at abandonment or demolition.

9 Environmental improvement and sustainable development

9.1 Sector overview

Concerns about environmental quality and sustainable development are already influencing significantly how businesses and governments think and operate. There are changing perceptions in developing countries, which have often cut into world markets by ignoring environmental issues. There is growing pressure for ethics in world trade, for conformity with international norms such as the International Labour Organisation's recommendations and requirements and the international standard for environmental management systems, ISO 14001 (1996). Initial growth by exploitation of cheap labour and resources, while ignoring environmental degradation and pollution, has led to a realisation that this cannot be sustained and there is a political reaction against a poor living environment.

The western world – and the UK in particular – has a long head start in this developmental process, which should be transferable and marketable to emerging and already-developed economies alike. The UK, through its experience and Commonwealth connections, has a much better rapport with the developing world's problems than many other Western nations.

Some of the key issues driving market opportunity, product and service development, and technology needs in the sector include:

- increasing environmental law and regulation;
- the drive towards sustainable development, the implications of Agenda 21 (the action plan for sustainability generated at the 1992 Rio UN Conference on the Environment and Development) and the alignment of business ethics with cultural and social ethics;
- population growth, urban growth and related problems, including urban regeneration and remediation and re-use of urban land to reduce the pressures to develop rural land;
- increasing environmental awareness by the population generally, especially the young, and thus the influence of non-commercial stakeholders on clients and construction firms;
- the increasing use and demand for whole-life costing and for formal, demonstrable and effective environmental management systems, with or without accreditation to ISO 14001;
- pressure on land use and the need to halt the reduction in biodiversity;
- striking an appropriate balance between increased economic activity, including development, and the environmental impact of that activity;
- pressure to reduce pollution – for example reducing greenhouse gas emissions and pollution of water courses – and to reduce the consumption and waste of existing finite resources;
- recovery of irrigation schemes, especially in relation to soil salinity, and recovery of reservoir capacity where they suffer from siltation;
- adaptation of existing infrastructure to meet changing needs and circumstances.

These all offer opportunities for UK industry to assemble and adapt its technology and expertise to meet market demands. A whole-system, whole-life-costing approach is, however, required. Technology for this sector must be defined not only in terms of widgets, but also in terms of the processes that bring together a wide variety of widgets to produce cohe-rent, economic and sustainable solutions. In this respect, the

integration of societal research into engineering and technology solutions is an impor-tant factor in identifying and serving market needs.

The 'environmental' markets can usefully be divided into four distinct sectors where there are different technology requirements and different export opportunities:

- ***overtly environmental projects*** – for example remediation of contaminated land – in which the UK has excellent skills and a strong presence in many export markets;
- ***active management of the environmental performance of the construction process***, where the UK is at the leading edge of best practice and should be well-placed to win construction and consultancy work where environmentally-aware contracting is required;
- ***services related to environmental management*** generally, where the UK is quite strong and getting stronger, although ISO 14001 is also being taken up strongly overseas;
- ***integration of a positive environmental, or sustainable development, approach to otherwise non-environmental projects*** to improve the long-term environmental performance of the project such as arises from reduced energy or water consumption – in this market, UK *best* practice is on a par with world best practice.

In addition to the issues raised in Section 3, the ability to secure private investment is a very important factor in the development of business in this sector. It changes project culture, drives design and can, if the client or consortium partners are so inclined, significantly shift the emphasis towards whole-life costing, minimising environmental impact and delivering project sustainability.

The UK has also developed the skills needed to liaise with, and involve in the project development process, the many stakeholders now associated with construction projects, including environmental protest groups. It also has one of the most sophisticated environmental legislative regimes, and a civil engineering industry that, at best, has learnt the implications of this regime and how to deal with environmental legal liabilities. As environmental pressures grow in the UK's export markets, integration of these skills into the project team should improve its competitive advantage.

There are thus major opportunities to influence development trends. Civil engineers can lead the multi-disciplinary project development stages (although the industry could be more pro-active in achieving this status) and should actively seek this role. At a minimum, civil engineers should seek to become involved earlier in the evolutionary chain, rather than simply being suppliers of an end product within a solution prescribed by others. There is a need to improve our (internal) industry communication skills and to build on the communications strengths evident elsewhere in UK business. Civil engineers already have the wide-ranging skills needed to lead major, environmentally sensitive projects.

Civil engineering is, and always has been, about environmental change. Social awareness and responsibility in engineering is increasingly a market demand, a market opportunity and an exportable skill. Success in this sector will come from a greater emphasis on, and integration of, sustainable development thinking, whole-life costing, social acceptability of projects and minimisation of the environmental impact of projects into the conventional engineering process, as well as from particular, individual environmental technologies.

9.2 Key services and technologies

Key services and technologies to be exploited in increased exports of environmental skills include:

- integrated, whole-life based project development covering finance, procurement, contractual arrangements, environmental performance, engineering, social acceptability, management and long-term maintenance solutions;
- whole-life costing analysis tools, and tools for measuring environmental indicators;
- the use of IT-based systems such as GIS to improve understanding of the environment and to reduce the environmental impact of civil engineering works;
- the use of virtual reality techniques to predict the environmental impacts of projects during design and before construction – and to demonstrate 'completed' projects to clients before construction – to reduce changes and therefore waste and cost;
- clean-up of polluted and abandoned industrial sites;
- environmental management of projects, sites and/or organisations;
- techniques for renovating works subject to past bad design, such as de-silting of reservoirs.

10 Infrastructure for urban development and megacities

10.1 Sector overview

In developing countries, there are often massive institutional barriers to infrastructure development because of the plethora of authorities that need, or believe they need, to be involved. Clients will therefore favour those with the ability to provide a complete infrastructure solution (i.e. concept, co-ordination with local authorities, design, construction, management, funding). A key to export success is therefore the ability to be able to assist those at the top of a country's political structure to achieve solutions. Those who understand the needs, concerns and cultures of the people, by involving all interested parties in the infrastructure that is planned, will be the winners in overseas markets.

To do this, it is vital to have a long-term presence in the country concerned, and to understand fully the culture, customs, personalities, and politics. Particularly important is the ability to deliver solutions with both private and public sector funding, to bring together an appropriate mix of disciplines at a strategic level, to bring in a range of non-technological skills including financial engineering and management of urban development. The integrity of UK firms is still a positive aspect in overseas markets, but set against this is the trend among UK multi-disciplinary organisations to form teams that are nevertheless based around separate individual disciplines.

Major trends in urban development include making better use of existing infrastructure, stronger traffic management and traffic restraint, the development of light rail systems, development of water resources, enhanced leakage control, changing institutional structures such as the reform of the utilities, and greater public/private partnerships.

The UK must endeavour to improve its ability to deliver projects that provide good overall value for money. Project management skills are vital to success in overseas markets, including risk management, whole-life costing and value management, which need to come together in one seamless package. This will minimise risk, speed up construction, maximise productivity and reduce costs.

The UK's experience with privatisation of utilities, private finance and with development on brownfield sites will be important weapons in winning overseas contracts. However, the traditional commercial framework for construction in the UK can inhibit the contracting parties from achieving best value for the client. For example, a much earlier involvement by the contractor with the client and designers would facilitate the introduction of engineering innovation and cost reduction. Greater interaction between consultants and contractors will be increasingly important in bidding for overseas contracts.

It is envisaged that there will be much greater use of IT systems to enable the establishment of a common project database that will also enable design work to be conducted at several sites simultaneously, and also much greater use of GPS and GIS for infrastructure development.

In this sector in particular, there is a need for structured, industry-relevant research with fewer themes than at present and with assured long-term funding.

The trend towards increasing urbanisation in many parts of the world will lead to a further need for new underground facilities. This will include using more trenchless technology and more cost-effective solutions to the problem of contaminated land than the remove-and-dispose option.

10.2 Key services and technologies

The key services and technologies to be exploited in increased exports in the urban development infrastructure sector have been identified as:

- development of methods for resolving the conflict between the demand for development and the need to protect the environment, leading to radical strategies for environmentally acceptable infrastructure to support existing major conurbations, for example, transport corridors, service corridors and inter-modal interchanges (for both passengers and freight);
- development of an understanding of social conflict, the implications of sustainable development and the realisation that sustainable development could be a key to the future success of engineering projects;
- development of more effective systems for treating contaminated land *in situ*;
- development of integrated modelling technologies and improved monitoring systems for real-time control of the built environment, and more accurate models for predicting the in-service use after completion;
- greater understanding of the performance of reinforced concrete structures in extremely severe environments;

- development of climate prediction and disaster management methods that can be incorporated in the models for civil engineering works;
- development of integrated transport systems in cities;
- development of advanced composite technologies, and new lightweight, high-strength, low-creep tensile and/or compressive materials to replace or complement steel and/or concrete at comparable prices;
- development of an integrated approach to tunnel design and construction;
- development and use of reliable and smart materials with built-in intelligence, the use of adhesives for joining instead of bolts, the use of porous asphalt on roads and the development of high strength concrete (100 N/mm^2);
- better understanding of soil–structure interaction between sprayed concrete structures and the ground, leading to better control of the application of sprayed concrete to ensure safety and predictability and refinement of methods for predicting ground movements as tunnelling work progresses.

11 Transport planning and infrastructure

11.1 Sector overview

The world's demand for transport planning and infrastructure will not diminish. The increase in population, coupled with increases in disposable incomes, will fuel an increase in private cars, which in turn will cause or increase congestion in cities if not checked.

Increased city populations have a wide-ranging impact on transport planning and infrastructure. There will be a need for more airports or improvement of existing airports to account for the increased traffic, and more ports or improvement of existing ports to take increased traffic both in cargo and people. There will also be increases in traffic in other forms of transport such as bus and rail.

Planning for the infrastructure to cater for these increases in traffic and their effects are among the greatest potential export earners for the sector. The need for integrated transport systems using advanced information systems will become evident and will lead to improved transport for the inhabitants of the cities of the world. With the increased awareness of environmental, health and safety considerations, designs will also increasingly be required to consider these issues, together with whole-life design and costing of projects at the outset rather than bolting them on at a later stage.

The emerging project procurement methods, such as design–build–finance–operate (DBFO), build–operate–transfer (BOT), private finance initiatives (PFI) and Partnering, will not only provide a good platform for innovation, but will also lead to an increase in the integration of design and construction. The decreasing cost of information technology and the advancements in soft engineering technologies, such as management techniques and computer software for engineering use, will have considerable influence on transport project construction. Together with the emerging procurement methods, soft technologies in civil engineering will provide continuing opportunities for transport-related exports.

Transportation schemes, like all other civil engineering schemes, will be influenced by Agenda 21. Sustainability includes societal issues, for which many engineering companies do not have the expertise. The requirement for social scientists in engineering projects may be another reason why companies should combine forces and become larger, multi-disciplinary players.

There are two key market issues particularly relevant in this sector, in addition to the issues raised in Section 3.

- Increased use of performance specifications so that innovative technologies can find easy ways into the mainstream of the civil engineering process. Giving the contractor room for innovation will also encourage the use of technology appropriate to the project.
- Nurturing the market for the future has to include grant-aided training for overseas students. The UK government needs to prioritise this issue with urgency.

11.2 Key services and technologies

The technologies that can enhance exports are listed below. They may need first to be demonstrated on projects in the UK before they can be exported. Being able to demonstrate a technology in a target country is also very competitive, but runs the risk of rejection if not proven in the home base.

The main issues and technologies lie in the following areas.

Access – This includes technologies and issues relating to:

- integrated transport and demand management systems;

- national transport information systems to improve reliability and connectivity for all modes of transport;
- information technology-based systems such as intelligent transport and asset management systems;
- integrated planning, design and virtual reality visualisation systems;
- advanced information systems to increase capacity of highway and railway networks, and cargo and passenger handling at ports and harbours.

Reduction of accidents – This includes technologies and issues relating to:
- advanced signalling methods for railways;
- embedded intelligence systems in products such as smart highways or bridges, and electronic traffic calming and congestion control systems for vehicles;
- collision avoidance systems for all modes of transport.

Environmental and health – This includes technologies and issues relating to:
- reduction of traffic noise in built-up areas from all modes of transport;
- energy efficiency;
- combustion and pollution control from land, sea or air transport.

General – This includes technologies and issues relating to:
- determination of technology needs for the specific target export countries, rather than making inappropriate generalisations for whole regions;
- rail infrastructure including maintenance, noise control, pre-fabrication, signals and/or miniaturisation of signal systems, and for improving railway switching durability and reduction of railway track noise;
- improving the durability of traditional construction materials or developing alternatives together with understanding engineering properties of local materials in target countries;
- development of expert systems for knowledge engineering and better networking support for small to medium sized engineering enterprises (SMEs);
- development of technologies that capitalise on intellectual skills and 'technology pots', for example from people and projects accessible on intranets.

12 Water and wastewater engineering

12.1 Sector overview

The global population will continue to grow and concentrate into urban areas, which provides a great opportunity to meet the needs for large-scale development of water resources, bulk transfer and treatment of water supply and wastewater. UK experience in overseas markets has drawn UK companies into international alliances that enable them to compete more effectively in this global market. Most governments now want the most up-to-date technologies for their infrastructure, but poor maintenance and robustness of installations remain key issues. A small footprint and low power consumption for process plant are high priorities. Water is an increasingly valuable resource, and accurate methods of measurement for both resource management and recovery of investment through charges are urgently needed.

UK water and wastewater engineering is well regarded but the whole industry needs to overcome its innate conservatism and inter-company defensiveness to increase its success in global markets. The future major players will be project initiators and innovators. The industry needs to offer distinctive, leading-edge technologies that contribute to whole solutions including project finance, construction and management.

The different characteristics and demands of regional markets for water and wastewater engineering need to be recognised. A good appreciation of client expectations and needs, and a reputation for applying advanced but appropriate technology are keys to success.

In addition to the general issues raised in Section 3, the main influences on the markets in this sector are:

- the influence of standards and performance specifications, which cannot be overemphasised because performance specifications open the opportunity for innovative solutions where technology can give a competitive edge, particularly when supported by national accreditation;
- UK expertise in the resolution of conflict between the demand for development and the demand for protection of water environments, which offers a growing opportunity especially with evaluation of the true cost of water becoming a strategic planning necessity;
- the increasing control of the disposal of wastes, which offers a global market opportunity for innovative solutions and technologies;

- accurate measurement of water quantity and quality in pipe networks as a means of management and charging, especially as privatisation spreads;
- the potential for the water and wastewater sector to learn from other utilities – such as power and telecommunications – that have relevant experience of successfully developing overseas projects.

12.2 Key services and technologies

The water and wastewater sector needs a 'step-jump' in technologies to give improved performance and a competitive lead. The industry is constrained and conservative and needs to work collaboratively, rather than adversarially, in achieving best practice against defined benchmarks and standards as a basis for export success. The water and wastewater industry needs to increase awareness of research results, and resolve the conflict between commercial secrecy and sharing knowledge for common benefit. There is a strong need for constructive lateral thinking.

The key services and technologies to be exploited in increased exports in the water and wastewater engineering sector have been identified as:

- robust and sustainable waste treatment solutions, including ways of handling large contaminated volumes of sludge, and the fundamentals of waste microbiology, which are needed for different environments and for treating contaminated water to high potable standards or for re-use elsewhere;
- data capture and analysis as an input to resource management and risk assessment, which is increasingly important, but for which traditional methods of field data acquisition are cumbersome and expensive;
- a greater use of aerial and satellite imagery combined with GIS, which would have great potential, particularly in arid and sparsely populated areas, as non-intrusive, remote-reading methods of hydrological, hydraulic and water quality data with electronic data capture are needed for water management and regulation;
- accurate automatic measurement of water quantity and quality in water distribution and

  wastewater networks, a high priority for the management of revenue-based utilities;
- neural network technologies, which need to be developed for the analysis of operational data, and for monitoring network efficiency and which will become a key issue for successful investment in water utilities as privatisation spreads to other markets;
- design and performance of materials, and understanding of the physical, chemical and electro-chemical processes of deterioration, in a wide range of climates and water chemistries;
- development of alternative materials for concrete reinforcement, such as plastics or fibre-reinforced plastics, which would help to circumvent corrosion and deterioration;
- an underlying aim to 'shrink-down' the size of process plant, as has been achieved in the chemical industry, so as to reduce plant volumes and footprints;
- technical solutions for the loss of reservoir capacity through sediment accumulation, which is becoming a serious problem in some countries where alluvial rivers carry a high sediment load, including modelling technologies for the design of affordable and sustainable solutions;
- the application of genetic engineering of purpose-specific organisms for biological treatment, a science in which the UK has international leadership;
- repair or replacement methods for underground pipes, which are a high priority, and where 'keyhole' technology for accessing and repairing underground services, fitting in-line meters, plus shallow soft ground tunnelling methods and machines all have wide application for urban pipe systems;
- in-line wastewater treatment technologies and alternatives to solid sludge disposal from wastewater plants;
- technologies and management systems to increase value added by water for agriculture, and a general improvement of productive and allocative efficiency of large-scale water resource development;
- development of water and wastewater treatment techniques, and water-recycling processes that have low energy consumption, or can be run from renewable energy sources allowing even the remotest areas to have treated water and wastewater;
- technology to reduce the power and cost of desalination, which would make almost unlimited supplies of water available in many countries of the world.

13 Regional Profiles

The following brief regional profiles were derived from the annual reports of the World Bank (1997), the European Investment Bank (1997) and the Asian Development Bank (1996) and from the Global Competitiveness Report (1997).

13.1 Africa and the Middle East

Characteristics

- Although aid dependency remains high and domestic savings low in the majority of countries in the region, private investment and foreign direct investment levels are beginning to improve.
- The economic performance of the region of Africa south of the Sahara is improving.
- Accelerated economic recovery spread to more countries in 1996 and the region's GDP grew faster than its population two years in succession across the region. Countries with structural adjustment programmes are generally doing better than those without.
- The entry of South Africa as an active participant in the continent's development contributes to the recent optimism in Africa.
- Private investment and foreign direct investment have begun to increase.

Growth markets

- Airports, roads, bridges and tunnels.
- Coastal protection and ports.
- Harbours, docks and sea defences.
- Irrigation to alleviate drought.
- Power plants, transmission and rural electrification.
- Residential and commercial development.
- Water supply and wastewater treatment.

'Africa is changing. A new dynamism is taking hold. Political systems are opening up....Reforms are energising trade and opportunities for investment are increasing. Privatisation is under way as well as a new competitiveness. The gross domestic product of 24 countries has tripled in size. By encouraging open investment and trade, Africa will achieve stability and growth .'

A World Bank minute, (1997)

13.2 Asia and Pacific

Characteristics

- Strong economic growth across almost all regions until the 1997/1998 financial crises.
- China recorded 8% growth in GDP in 1997.
- *'There has been an East Asian miracle.'*
- Major investment in infrastructure is needed to support growth.
- China is the giant, India is emerging.
- Environmental management is of increasing importance.

Growth markets

- Airports, roads, bridges and tunnels.
- Environmental work of all kinds.
- Harbours, docks and sea defences.
- Health care facilities.
- Land use planning and development.

Growth markets continued

- Power plants and transmission systems.
- Railways.
- Residential buildings and infrastructure.
- Telecommunications.
- Water supply and wastewater treatment.

'East Asia is in financial crisis. But let us not forget that no group of countries has ever reduced poverty so much so fast in human history. Living standards quadrupled in a generation. We must help protect the success story and its fortunes: engaging in the world, hard work and high savings rate. We know what went wrong: too many cases of weak banks, flawed policies, poor regulation and lack of openness. These mistakes must be corrected and the investment in people must be saved...'

A World Bank minute, (1997)

13.3 Central and Eastern Europe

Characteristics

- Total output in Central and Eastern Europe and the Baltic countries continues to grow and there is evidence that it is being sustained.
- Environmental issues taking on a high level of importance.
- Output continues to decline in some of the former Soviet Union countries.
- Privatisation and private–public partnerships are becoming common for infrastructure.
- Some countries have yet to make progress towards sustained stabilisation.
- Many countries are experiencing rising unemployment.

Growth markets

- Environmental work of all kinds.
- Oil and gas.
- Power plants and transmission.
- Residential buildings and infrastructure.
- Roads, airports, railways, bridges and tunnels.
- Telecommunications.
- Upgrading existing stock.
- Water and wastewater plants.

13.4 North America

Characteristics

- The USA and Canada are among the most developed countries in the world.
- Consistent growth.
- A growing environmental awareness.
- The USA's and Canada's competitive advantages are in highly specialised construction services.

Growth markets

- Airports.
- Environmental e.g. solid waste handling, air pollution control, biotechnology, renewable energy.
- Infrastructure for advanced telecommunications.
- Roads and bridges.
- Upgrading existing stock.

13.5 Latin America and the Caribbean

Characteristics

- The aggregate regional economy grew by 3.5% in 1996.
- The region succeeded in containing the financial repercussions of the 1994–1995 Mexico peso crisis.
- The stronger growth reflected resumed positive growth in Mexico (5.1%) and Argentina (4.4%).
- The general trend is towards privatisation and the removal of trade barriers.
- The region is emerging as one of the fastest growing regional economies in the international market.
- The economies of the region are now sufficiently differentiated that adverse developments in one country do not significantly affect any of the others.
- Chile's consistent growth continued at 7.1% while Brazil, the region's largest economy, slowed down.
- There are serious development challenges such as poverty, inequality and unemployment.
- The Dominican Republic and Guyana began to recover from recession and grew at more than 5%.

Growth markets

- Airports, roads, bridges and tunnels.
- Environmental work of all kinds.
- Health care facilities.
- Land use planning and development.
- Power plants, transmission and rural electrification.
- Residential buildings and infrastructure.
- Water supply and wastewater treatment.

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What next?

Having read this report, ask yourself the following questions.

- How much does my business depend upon the application of good technology?
- Where does my business's technology come from?
- How up-to-date am I – how do I know what the latest technology is?
- How much do I – or should I – invest in the technology that underpins my business?
- What is my technology strategy to sustain and advance my business?
- What shall I do differently tomorrow as a result of reading this report?

If by chance you have arrived at this concluding box without having read Section 2, that is where you will find the conclusions and recommendations. The project team hope you take up enthusiastically the challenges that the recommendations and the above questions present.

THE INSTITUTION OF CIVIL ENGINEERS

Research and Innovation Activities

The Institution's Research and Innovation Committee, composed of representatives of the ICE's Engineering Boards and the major research establishments, has published many reports resulting from its strategic studies. The aim of these reports has been to examine fundamental issues related to construction research, to identify research priorities as seen from the practitioner's viewpoint, and to influence the practice of industry, and the policies of government and the research councils as they affect construction.

One of these reports found that much construction research was published in learned journals but was not being disseminated effectively to construction professionals. The Committee was particularly pleased, therefore, to collaborate with the industry, government and research establishments to launch a new research newsletter in 1990. This newsletter, *Research Focus*, is published 4 times a year by the Institution and is funded jointly by 3 professional institutions, 8 research establishments, the DETR, and consultants and contractors. It has a circulation of some 55,000 copies, including all corporate members of the ICE worldwide.

The Committee responds on behalf of the profession to public consultation papers and participated strongly in the Government's Foresight exercise. More recently, the Committee has taken forward one of the recommendations of the first Foresight exercise and, with the support of the DETR, has undertaken this research project designed to enhance the technological capability of the UK's civil engineering industry in overseas markets.

In 1992, the ICE established an R&D Enabling Fund in order to allow the Institution's own members to support or initiate projects which will enhance the technical development of the civil engineering profession. It is governed by a Board of Trustees and, up to June 1998, support totalling £400,000 has been given to 58 projects. Most of these have been successful in attracting additional funding from other bodies, such that the total value of research initiated is £2.7 million. The Enabling Fund is intended to support practitioners who have sound proposals for innovation or development who would not otherwise be likely to gain support by the established funders such as the research councils. It is therefore a potential source of funding for individuals or organisations wishing to pursue an idea which perhaps needs a feasibility study completed, before others can be approached in a collaborative venture. As a condition of an award, all recipients have to publish their results to enable the benefits to be disseminated to the profession at large.