

# STATE OF THE WORLD

## FIDIC Infrastructure Report 2009



*Representing globally the consulting engineering industry*



FIDIC is an international federation of national Member Associations of consulting engineers.

FIDIC was founded in 1913 by three national associations of consulting engineers within Europe. The objectives of forming the Federation were to promote in common the professional interests of the Member Associations, and to disseminate information of interest to their members. Today, FIDIC membership covers more than 80 countries from all parts of the globe and encompassing most of the private practice consulting engineers.

FIDIC is charged with promoting and implementing the consulting engineering industry's strategic goals on behalf of Member Associations. Its strategic objectives are to: represent world-wide the majority of firms providing technology-based intellectual services for the built and natural environment; assist members with issues relating to business practice; define and actively promote conformance to a code of ethics; enhance the image of consulting engineers as leaders and wealth creators in society; promote the commitment to environmental sustainability.

FIDIC arranges seminars, conferences and other events in the furtherance of its goals: maintenance of high ethical and professional standards; exchange of views and information; discussion of problems of mutual concern among Member Associations and representatives of the international financial institutions; development of the consulting engineering industry in developing countries.

FIDIC members endorse FIDIC's statutes and policy statements and comply with FIDIC's Code of Ethics which calls for professional competence, impartial advice and open and fair competition.

FIDIC, in the furtherance of its goals, publishes international standard forms of contracts and agreements for works and for clients, consultants, sub-consultants, joint ventures and representatives, together with related materials such as standard pre-qualification forms.

FIDIC also publishes business practice documents such as policy statements, position papers, guides, guidelines, training manuals and training resource kits in the areas of management systems and business processes.

FIDIC organises an extensive programme of seminars, conferences, capacity building workshops and training courses.

FIDICs contracts and agreements are recognised internationally as the industry standard for infrastructure, civil engineering and construction. They have been adopted by the multilateral development banks, by bilateral aid agencies, national governments, procurement authorities, and by private clients in all sectors.



FIDIC works contracts cover the full range of infrastructure projects – from relatively short construction-time projects to design-build-operate projects combining design, construction and long-term operation and maintenance.

FIDIC professional services agreements are based upon the FIDIC Client/Consultant Model Services Agreement. Together with agreements for joint ventures, and subconsultants, they are widely used in the public and private sectors.



FIDIC is the authority on business practice for the consulting engineering industry. The federation develops and disseminates policies, guidance and training materials for firms supplying technology-based intellectual services.

- Procurement
- Consultant selection
- Risk management
- Scope of services
- Quality management
- Quality of construction
- Business integrity
- Environmental management
- Project sustainability
- Transfer of technology
- Professional liability and insurance
- Project management

# STATE OF THE WORLD FIDIC



## Infrastructure Report 2009

The world currently faces a number of serious issues simultaneously. The uncertainties relating to the sustainability of today's lifestyles, the current difficult economic situation, and the impact we are having on our planet and its climate all mean that urgent action is required.

What has become increasingly clear is that this urgent action cannot aim merely to recreate the world as it was just a few years ago. The recent financial crisis has demonstrated that the core processes on which society has come to depend are not robust enough to cope adequately with the pressures introduced by globalisation.

The trend towards increased urbanisation is likely to continue and may well accelerate. This is an ongoing and developing reality that will require consulting engineers to provide the necessary infrastructure so as to improve significantly the quality of urbanisation.

As the custodians of existing infrastructure and the developers of future infrastructure, consulting engineers recognise a responsibility to innovate and improve the products of their efforts and to understand the importance of instituting a dialogue with the rest of society on these subjects. The industry and its professionals need to be more vocal about the things that are considered to be mistakes, and equally vocal about those things that are considered to be advances if improvements are to be made promptly and effectively.

FIDIC, the International Federation of Consulting Engineers, is uniquely placed to help consulting engineers and society address the issues facing the world as a whole. It uses its worldwide network to bring best practice in one geographical area to the attention of everyone, and seeks to ensure that projects are carried out in a manner that ensures professionalism and high standards for sustainability, integrity and quality.

The *FIDIC Infrastructure Report 2009* was commissioned by the FIDIC Executive Committee, comprising: Dr John Boyd, Golder Associates, Canada (President); Gregs Thomopoulos, Stanley Consultants, USA (President-Elect); Adam Thornton, Dunning Thornton Consultants, New Zealand (Treasurer); Patrick Batumbya, MBW Consulting Engineers, Uganda; Pablo Bueno Tomás, Tyspa, Spain; Geoff French, Scott Wilson, UK; Andreas Gobiet, Gobiet & Partner, Austria; Subhash Mehrotra, Mehro Consultants, India; Xie Shaozhang, Chelbi Engineering Consultants, China.

The report was compiled by Geoff French based on contributions by: Bill Wallace, Wallace Futures, USA; Professor Roger Flanagan, Reading University, UK; John Ritchie, Hatch Energy, Canada; Michael Snow, Golder Associates, Canada; Tony Shum Chun Kin, AECOM, Hong Kong; Jerome Munro-Lafon, Scott Wilson, UK; Subhash Mehrotra; John Wotton, Halcrow, UK; Adam Thornton; Dr Ike Van der Putte, RPS, The Netherlands; Dr John Boyd.

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The *FIDIC Infrastructure Report 2009* aims to provide an overview of the main infrastructure issues that the world now faces. Having established the overall challenges, and the need to address these challenges in a way that is sustainable, each aspect of infrastructure is addressed individually.

In each section of the report the issues that are most important have been identified, not only the challenges which have to be addressed but also examples of constructive solutions. The report has deliberately been produced in a form that provides the opportunity for future updates and for progress to be addressed repeatedly within each aspect of infrastructure.

The report starts with a section on **Sustainable Development** as this aspect has to be considered within every element of infrastructure if the world is to have a viable, long-term future. The need for the consulting engineering industry to take more of a leadership role is clearly identified – a role it is able to fill because of its experience in many sectors of the economy and its ability to identify both the cross-sector opportunities and the potential mistakes society should avoid.

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**Economics, Urbanisation and Infrastructure** reviews the importance of construction in the world economy, the rapidly rising world population and the significant increase in urbanisation over the last century, and its likely continuation in the future. All of these factors lead to an increasing demand for infrastructure to be provided and maintained – infrastructure that helps alleviate poverty and improve the quality of life. Consulting engineers understand the different perspectives for these issues around the world and will need to be innovative in their project delivery models and the methods of financing vital projects.

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Within almost all sectors, and discussed initially in the section on **Energy Resources**, the report makes clear that the problems associated with each aspect of infrastructure vary according to the stage of economic development of a particular country or group of countries. This is demonstrated by part of the world taking energy for granted while almost one-half of the world has no access to reliable energy sources. The elevated CO<sub>2</sub> levels from energy generation have contributed significantly to global warming. The challenge will be to provide energy to those that do not have it at present while implementing measures to reduce CO<sub>2</sub> levels worldwide.

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**Waste and Waste Management** addresses the waste that we generate and in particular the need to move waste diversion practices towards the 3R's of 'reduction', 're-use' and 'recycle'. The opportunities presented by waste-to-energy developments are identified. There is no doubt that the challenge of providing effective and sustainable waste management services will also offer a fertile ground for the development and application of innovative solutions.

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**Water and Wastewater** highlights the crucial importance of water and the great advances that have been made in sewage and water treatment. It will be up to engineers to continue finding ways to maximise water capture, ensure conservation of this vital resource and increase usage before final disposal. The huge difference between the current and required capital expenditures is clearly set out. The shortage of engineering graduates, particularly in developing countries and also in the water sector, needs to be addressed if we are to ensure the widest possible access to potable water in the least damaging way possible across the globe.

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**Transport** addresses a fundamental element of human existence. It identifies the roles played by all of the main transport modes before discussing each individually. The continuing development of rail, both high-speed lines and metros, is identified together with the innovations currently being considered which will help maintain rail as an increasingly important mode of transport. Roads are the most widespread means of transporting goods and people and there is a strong association between established road networks and socio-economic development, especially in the least economically developed countries. Aviation both facilitates, and is driven by, global trade and has arguably contributed more than any other form of transport to the globalisation of the world economy. The section on maritime transport clearly identifies the tremendous impact of the recent global economic downturn and the way that the industry is responding. It is not clear how long it will take for the market to return to the volumes seen in early 2008, but there will be an ongoing need for consulting engineers to continue providing cutting edge solutions to the infrastructure and logistical challenges.

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**Buildings and the Built Environment** makes it clear that consulting engineers will need to create innovative building solutions that meet the required social and planning objectives while being energy efficient, sustainable, of high value, and cost effective. As with all elements of infrastructure, there is also a need for ongoing and effective technology transfer from the developed to the less-developed world.

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**Disaster Risk Mitigation and Adaptation** shows how new challenges lie ahead for societies and the engineering community owing to climate change and the increase of extreme weather-related events. Dealing with these challenges will need a number of paradigm shifts, including the introduction of more decentralised concepts for wastewater and a different approach for tackling flood protection.

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A final section titled **Trusted Advisers** summarises how FIDIC's governing principles of sustainability, integrity and quality ensure that consulting engineers act in their clients' and society's best interests in providing the essential infrastructure needed to nurture and sustain mankind.

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# Sustainable Development



The quality of life of the world's societies is based to an overwhelming degree on their ability to convert natural resources, both renewable and non-renewable, into products and services that meet their needs and wants. Throughout history, the goal of these societies has been to continually improve their quality of life through growth and development. In that regard, improvements over the last two centuries have been astounding, particularly in the developed world. This has been made possible not only because of the Earth's large amount of resources, but also by the ingenuity of societies to utilise these natural resources, transforming them efficiently and effectively into a wide and ever-changing variety of products and services, and distributing them to consumers. Here, engineers play a key role by conceiving, designing, constructing, and maintaining the essential frameworks, namely the processes, systems and infrastructure necessary to extract, harvest, produce, and deliver the products and services that societies need and want.

All of this works as long as there are enough resources to go around, and throughout history that has normally been the case. But today the situation is changing dramatically. Populations of the developing nations are increasing at an alarming rate, creating enormous demands for products and services, and as a consequence, enormous demands for resources. Making matters worse, the demands of these nations are increasing disproportionately, driven by their aspirations to reach quality of life levels enjoyed by the developed nations. The result has been a spike in the demand for resources, challenging, and in some cases overwhelming, the capability to meet that demand, or identify and develop substitutes soon enough to make a difference. Moreover, overharvesting and pollution of the world's ecological resources has not only reduced resource supplies but also diminished ecological carrying capacity – the ability of the environment to deliver the essentials



of life and to absorb and process wastes.

Over the last decade, the notion that society's current model for growth and economic development is not sustainable has moved from extremist thinking into mainstream opinion. Driven largely by what appear to be symptoms of global climate change, the public is beginning to question the current assumptions and approaches for achieving economic



growth and prosperity. Society is now experiencing the results of decades of expanding resource demands and relatively unchecked pollution. Soaring energy prices, spreading water shortages, overtaxed electrical power grids, mounting traffic congestion, urban sprawl, devastating forest fires, unprecedented flood damage, dead zones in the world's oceans, loss of fisheries resources, reduced food security, global climate change – incidents once seen as disturbing but manageable are now viewed as contributors to a rapidly-declining quality of life.

Viewed individually, these trends and events might be dismissed as the inevitable consequences of an increasingly complex world, where problems need to be addressed in order to maintain a high standard of living. Viewed collectively however, they can be interpreted as the perilous consequences of society's current approach to economic development. This is an approach that uses resources without much restraint, burdens our ecosystems with waste and pollution, neglects the care and upgrading of our supporting infrastructures, and disrupts the social fabric of societies. These events are evidence of a flawed economic development model, one which treats materials, energy and fresh water supplies as if they were inexhaustible, and the environment as if it was infinitely repairable or self-healing.

## What makes economic development sustainable?

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The 1987 Brundtland Commission report, *Our Common Future*, contains the well-accepted and often quoted definition of sustainable development: “... development that .... meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Addressing this challenge effectively requires more than ‘becoming green’ or other token gestures common today. Recycling office paper, replacing incandescent light bulbs with compact fluorescents or achieving some level of green building certification are clearly beneficial, but not particularly meaningful by themselves given the scale of the overall problems. Furthermore, these efforts can in themselves be damaging, as they perpetuate the illusion that something important and substantial is being achieved.

To reach conditions in which our economic development becomes truly sustainable, resources

cannot be used faster than they can be replaced or replenished. Moreover, the availability and use of resources and environmental carrying capacity must be shared fairly and equitably, recognising the needs and aspirations of the developing world. Lastly, the use and substitution of resources must be viewed holistically, making sure that the development and deployment of a renewable substitute (for example, ethanol for fossil fuel) does not deplete another scarce resource such as water, and delivers more energy than is required to produce it.

Conspicuously absent in today’s dialogue on sustainability is benchmarking – an understanding of where society stands in regard to achieving conditions of sustainability and what level of effort will be required to make development sustainable. Measured against this backdrop, today’s efforts are trivial compared to what is really required to achieve conditions of sustainability.

## The situation today

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The situation regarding sustainability varies considerably around the world depending on the current level of development.

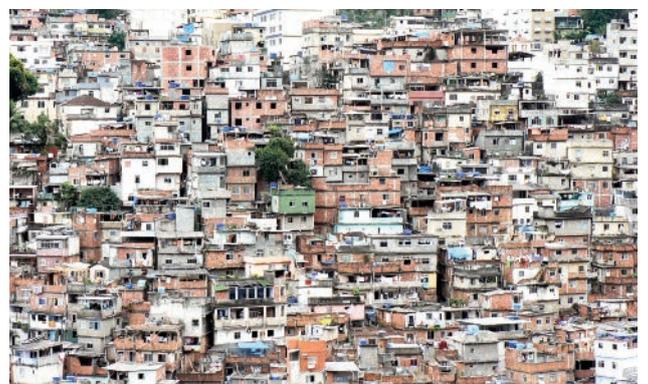
### **1st world nations: acceptance more or less, but limited action**

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For the developed nations, organisations in both the public and private sector are beginning to understand and accept, albeit reluctantly, the idea that their operations are not sustainable. Driven largely by public opinion, these organisations first sought to improve their image and reputation as being socially conscious protectors of the environment. As a result, many organisations are conducting internal evaluations across sustainability dimensions, benchmarking themselves against competitors and other relevant entities, and publicising the results. Many are also following up with investments in the form of engineering projects focused on improving sustainable performance. Others have recognised that improvements in sustainable performance can make them more competitive: their investments are more strategically focused, seeking to meet customer needs and wants while at the same time reducing costs and improving sustainable performance. Finally, there are a number of organisations which are discovering that the symptoms of non-sustainability are entering their planning horizon. They are now realising that these problems, if left unattended, will soon have significant consequences for their operations. These organisations are taking action out of necessity, investing in changes that are absolutely essential to their success in the immediate future.

While this understanding and acceptance is encouraging, there are still many organisations and interest groups that either purposefully ignore or strongly question the view that existing or projected resource shortages, extreme weather events and ecological damage are serious enough to warrant attention. They continue to be highly resistant to change, preferring instead to continue with business as usual.

Engineering firms working in the developed world therefore encounter clients with a wide range of attitudes and beliefs about sustainable development, both in terms of its impact and urgency, and in terms of the response. Accordingly, firms can expect a wide range of project opportunities. At one extreme, clients who do not see (or do not care to see) any significant impacts or urgencies will initiate projects geared to defending the status quo, maintaining their conventional systems and infrastructure. At the other extreme are clients who not only understand the problems associated with non-sustainability, but are altering their operations to accommodate the corresponding changes and gain competitive advantage. These organisations are investing in projects to reduce costs, change their product lines, and/or revamp their facilities and



infrastructure in response to a changing business environment. In between are clients with a variety of needs related to sustainability, including education, assessment and benchmarking, sustainable performance reporting and improvement, cost improvement, and strategy and programme development.

## 2nd world nations: economic growth is what matters

For the developing nations, rapid population growth combined with equally rapid urbanisation is straining their infrastructure beyond breaking point. Megacities – urban areas with burgeoning populations of five million or greater – are now being formed as people living in rural areas flock to cities in search of the means to earn a living. Severe traffic congestion, widespread power outages, and the lack of clean water and sanitation are commonplace. In many instances, these cities lack even the most basic infrastructure and thus are highly vulnerable to disasters, natural or man-made.

As they try to modernise in the face of high population growth rates, the developing nations are using whatever technology is available without sufficient regard to its impacts. For example, to support its growth and corresponding energy needs, China is adding one new coal-fired power plant every 10 days. Combined with their increased use of automobiles, China has now outstripped the USA in total greenhouse gas emissions.

Engineering firms working in the developing world are finding that keeping pace with the needs of a growing population is the primary determinant for the design and construction of new facilities. Given the choice between conventional and newer designs that could deliver more sustainable performance, project owners will select the conventional – a choice with much less implementation risk than a sustainable solution. Owners may elect to add features that reduce resource consumption and pollution, but only if they are well proven and add little or nothing to the cost of the project. When told of the consequences of employing conventional technologies in an effort to spur the use of technologies that are more sustainable, the owners' response is revealing. They ask, "How can you ask us to spend money on relatively untried technologies, when you have done nothing of the sort? Your growth and development are based on the same polluting and resource-wasting technologies you are asking us to abandon."



There are notable exceptions. Seeing an opportunity to lead by example, several nations in the developing world are building 'sustainable' cities – cities that are designed to deliver exceptional sustainable performance. For example, Masdar City in Abu Dhabi is being designed as a low-energy, zero waste, zero emissions community. China is building Dongtan, a city situated on an island off the coast of Shanghai which is intended to be "... the first truly environmentally and economically sustainable city." While these cities may turn out to be useful demonstrations of what is possible, by themselves they will barely make a dent in the deep structural problems inherent in society's current model for economic development.

## 3rd world nations: survival

For the poor nations of the world, the issue is survival. Today, 1.1 billion people do not have access to safe water, and over 2.6 billion do not have access to anything more than basic sanitation. Food shortages are widespread. Approximately 1.2 billion people suffer from hunger (deficiency of calories and protein); some 2 to 3.5 billion people have micronutrient deficiency (deficiency of vitamins and minerals). Most people live below subsistence levels on a day-to-day basis. In general, governments at all levels lack the resources or capacity to establish the framework conditions necessary to move their countries out of poverty. Corruption is also a major problem.

Engineering firms working in third-world nations are for the most part delivering projects for international aid organisations or for multinational companies. Projects for the aid organisations are usually focused on infrastructure by providing water, wastewater treatment, transportation, communication, and other essentials; projects for multinational companies are usually focused on the extraction or harvesting of resources or taking advantage of low-cost labour. At first, facilities were designed and operated so that they just complied with local laws and regulations, if there were any. However, now many governments in these host countries require multinational companies to design their facilities so that they meet first-world standards.

While these sorts of projects and policies create jobs and some economic benefit, they do little to enable the bulk of the population to move out of poverty. For third-world countries, most of the population is either concentrated in cities or dispersed



in rural communities, each with little or no infrastructure. What is needed most is the application of technologies to raise the population above the poverty line, appropriate in both scale and complexity for the capacity and capability of the community.

Unfortunately, this sort of technology is not generally known or applied owing to the fact that the communities that would receive these technologies do not have enough money to engage the engineering industry. Furthermore, the design and application of these technologies is not part of the mainstream of engineering education. As Paul Polak points out in *Out*



*of Poverty*, “The majority of the world’s designers focus all their efforts on developing products and services exclusively for the richest 10% of the world’s customers; nothing less than a revolution in design is needed to reach the other 90%.”

## The sustainability tipping point

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Making progress towards sustainability is not a single long journey but requires multiple journeys down multiple pathways. Creating the environment under which sustainability can be achieved requires that the nine ‘concurrent requirements for sustainability’

depicted in Fig. 1 be met. Not satisfactorily achieving any one of these conditions puts the success of the journey in jeopardy.

# Economics, Urbanisation and Infrastructure



Construction serves a growing world population; it is at the core of all development. Estimates are that the Earth's population will reach just over nine billion by 2050 with virtually all growth occurring in developing countries (see Fig. 2 below). Future world population growth will differ from previous

decades as humans are living longer and having fewer children, creating an ageing society, particularly in the developed world, with more older people (age 60 and above) than very young people (age zero to four). Nearly all population growth will take place in urban areas.

## Construction worldwide

### Global construction output

In 2007, the annual global output of construction work put in place was estimated at US\$4.8 trillion and this does not include the work undertaken by professional construction service firms. The global output figure can only be an estimate, partly due to the accuracy/availability of national statistics, and partly because of the size of the informal economy, particularly in developing countries. The majority of construction output is in the developed world with around 72% of the output; yet the growth in the world population is predominantly in the developing world. To put the

output into context, global Gross Domestic Product (GDP) output in 2007 was US\$54.35 trillion at current prices (The World Bank, 2009). Hence, construction represents around 10% of global GDP, making it one of the most important industry sectors in the world.

### Global economic crisis

Economies around the world are dealing with the global shock waves of the credit crunch, which produced drastic falls in stock markets that have become much more volatile. Most world currencies have fallen against the US\$ and the Euro, and risk premiums, on a broad range of debt, have increased by more than 600 points. The International Monetary Fund's latest forecast predicts global GDP growth will decelerate to a meagre 0.5% in 2009, the weakest showing since World War II.

The 'waves' have spread far more rapidly than in any other recession in history. The slump and depression of the 1930's was restricted to the developed world; its impact was felt less widely than the global economic turmoil in 2009. The emerging interdependency of economies, banking systems and markets feeds the spread of the contagion.

Being able to use and share each others' money was one of the huge innovations of the Renaissance – an idea developed by Italians that transformed society. Even countries with good economic growth such as China and India are faced with a reduced demand for their goods by their main export trading partners. However, the BRIC countries – Brazil, Russia, India and China – are maintaining reasonable growth rates, as illustrated in Fig. 3 on the opposite page.

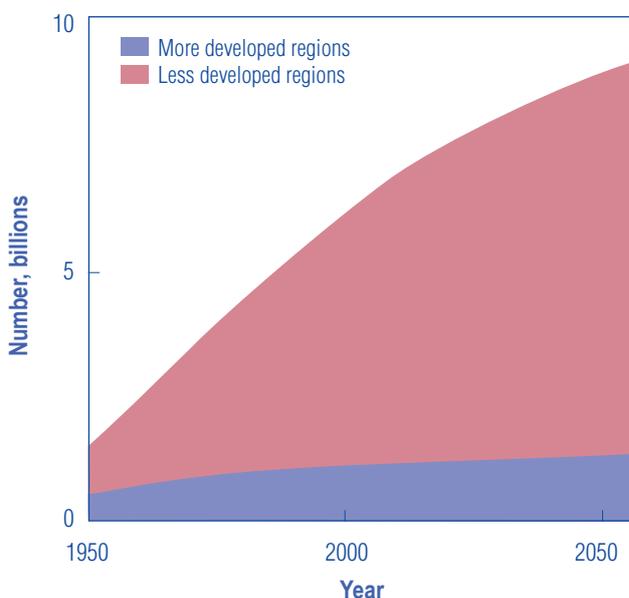


Fig. 2 - World population, 1950-2050.

The McKinsey Global Institute reports that the “new power brokers of global capital markets” are increasingly going to be Asian central banks and oil investors (both loosely categorised as sovereign wealth funds), private equity and hedge funds. The capital from these sources is set to overtake the traditional sources of mutual funds, pension funds and the banks. Engineering and construction companies are facing the challenge of both a decline in the access to capital, and the limited availability of insurance and bonds for their projects. The whole world is a closed economy.

Fiscal stimuli will not work if they are not co-ordinated: current packages are inherently nationalistic, representing virtual subsidies to domestic industries, but they may be the only option in the short term, stimulating demand at a time when interest rates are at or near zero in many countries. China’s 2009 two-year plan equates to 16% of the country’s GDP, to be used to subsidise housing, railway construction and other infrastructure projects.

In the late 1980’s and early 1990’s the economies of China and India were similar in terms of the size of GDP, per capita income and foreign trade. In recent years, however, the Indian economy has lagged behind whilst China has made giant leaps through foreign direct investment, rapid industrialisation, and export expansion. In an effort to emulate the Chinese success, India is beginning to shift the structure of its economy, with greater emphasis on industry and the services sector. However, poor infrastructure and the low level of educational attainment of the general population will be significant impediments to India’s growth strategy.

*“We can’t solve problems by using the same kind of thinking we used when we created them.”*  
Albert Einstein

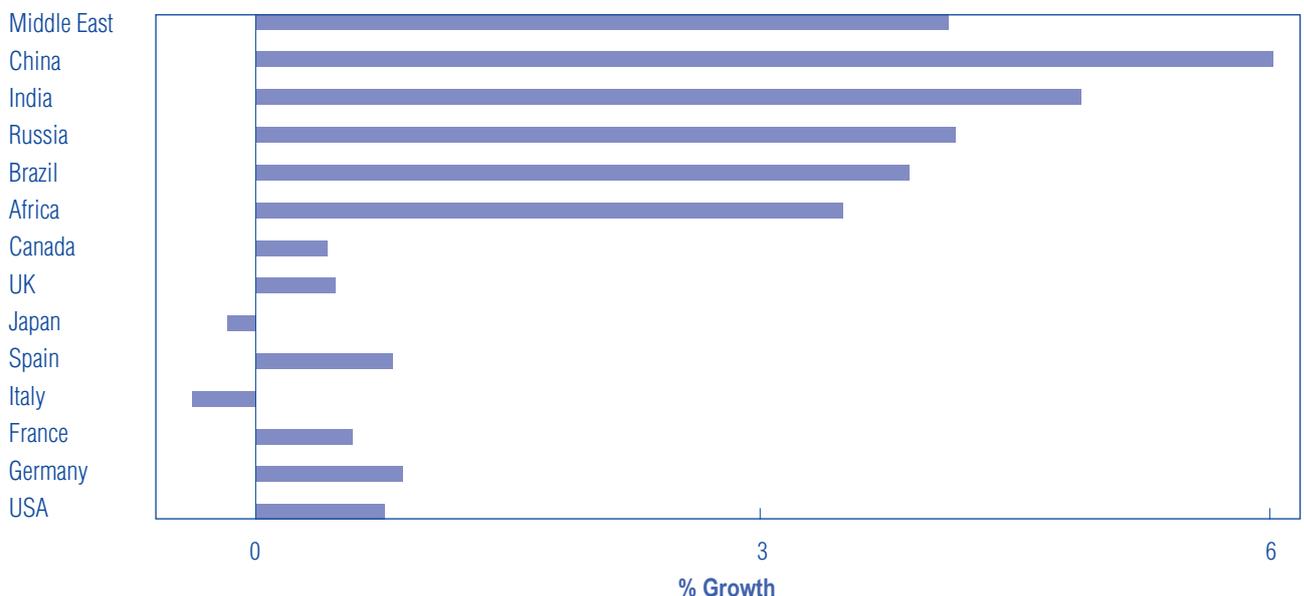


Fig. 3 - Growth rates in global output by country. The World Bank, 2009,

## Globalisation

Globalisation has created markets and economies that are interlinked and interdependent, with labour becoming much more mobile and goods and services being sourced from around the world. Although globalisation has created vast wealth and lifted millions out of poverty, progress has been uneven, inequitable and unsustainable, reflected in the lack of, or poor, infrastructure in the developing world. The impacts of globalisation on the construction industry are broad and very deep:

- Transfer of capital: foreign investment is on the rise and firms can access skilled labour across borders through outsourcing and migration.
- Increased competition: foreign firms place pressure on domestic firms by underbidding on local projects.
- Vulnerability: as marketplaces become more global, firms are subject to the fallout of financial crises and economic recessions that occur in other countries.
- Risk: as firms expand to work in emerging and transitioning economies, they need to understand region and country-specific political risks and find ways to work around these obstacles. However, with more partners and stakeholders on projects, globalisation provides new and much expanded opportunities for risk-sharing.

## Global drivers

Global drivers such as globalisation, global warming, sustainability, water scarcity, energy shortages, and urbanisation affect everybody. They shape the world in which we live; they transcend national boundaries. The challenge for all enterprises is ensuring profitability and maintaining customer satisfaction, while at the same time facing, managing and implementing change. Many business leaders are compelled to focus on their short-term profitability and growth, yet many of the

global drivers are of a long-term nature; there is a fundamental difference between the time horizon of most enterprises and the long-term nature of the drivers.

Global drivers are connected by a complex web. Some connections are obvious, such as the links between urbanisation and the need for better transportation, healthcare and education in cities. Drivers can be defined as those forces that cannot be changed. They involve social, technological, economic, environmental, and political forces and include:

- speed of change
- globalisation
- increasing governance
- communications revolution
- move from public to private financing for infrastructure
- environmental pressures/sustainability
- new technologies
- urbanisation
- water
- demographics
- climate change
- pandemics

Rapidly converging geopolitical drivers are changing the nature of the construction marketplace. Recent shifts in the global environment, ranging from climate change to evolutions in technology, have altered the world in which the construction industry operates. These changes are widespread, complex and mutually interdependent. Shifts in demographics, governance, technology, and climate can cause fluctuations in global levels of supply and demand and materials prices, which cause ripple effects throughout the construction industry and beyond.

As these global drivers shift and evolve, they create a climate of volatility in the market. There is increasing pressure for consulting engineering firms across all specialities to keep abreast of these changes and plan accordingly. In this operating environment knowledge is invaluable. Engineering firms of all specialties and size need to understand how these global drivers are interacting with industry trends, and how they can integrate this information into their business strategy for today and the future.

## Urbanisation

Of the three megatrends that dominate today's world – globalisation, information and communication technology and urbanisation – urbanisation is the one least covered by the media. Cities, on one hand, offer an opportunity to create wealth and prosperity as the hub for global trade, the home of financial markets, and acting as service centres. On the other hand the concentration of humans in cities is putting pressure on infrastructure, natural resources and the environment. Cities consume 75% of the world's energy and generate 80% of the world's carbon emissions. They can harbour areas of social deprivation and exclusion; an estimated one billion people are currently living in city slums throughout most of the developing world.

United Nation's statistics show that one-half of the world's population now lives in urban areas, a figure that is expected to rise to 60% in 2030. Some two billion more people are expected to live in cities in developing countries by 2030; these two billion will require the equivalent of the planning, financing and servicing of facilities for a new city of two million people every week for the next 20 years. There is a continuing growth in services in economies around the world, moving away from a dependency on manufacturing and agriculture. The rate of urbanisation differs significantly between developed and developing countries, as shown in Fig. 4.

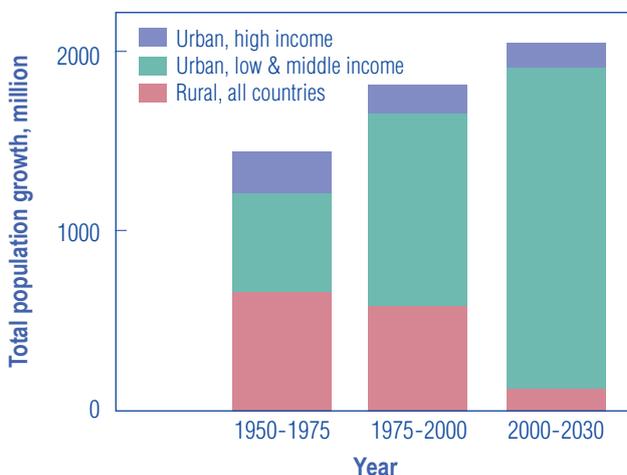


Fig. 4 - Population growth – rural/urban/income split.

## Impacts and issues

There are a number of impacts/issues emanating from urbanisation in both the developed and developing world, particularly the sociological, economic, environmental, and technical impacts of growing cities.

### Gap between rich and poor

The gap between the rich and the poor is getting wider. This polarisation is particularly evident, and more destructive, in the growing urban areas of the world where food and water provision as well as water and sanitation infrastructure, are not meeting demand.

### Climate change and sustainability

Climate change is fundamentally affecting the way we live. People in developing countries will



suffer the most – a huge injustice as they are not responsible for it. National policy frameworks must be overhauled to halve carbon emissions from the current level of 28 gigatonnes per year to 14 gigatonnes.

The world has experienced an increasing frequency of natural disasters driven by climate change, such as tropical cyclones, flooding and landslides. The Low Elevation Coastal Zone, the contiguous area along the coast that is less than 10 metres above sea level, makes up 2% of the world’s land area but contains 10% of the world’s population. In addition, many informal settlements are located in other high-risk areas such as steep hill slopes, deep gullies and flood-prone areas.

Sustainability and its associated environmental pressures is changing construction. There are push-pull elements with legislation and taxation providing the push, with the pull coming in the form of business motivation to achieve less waste and greater energy efficiency, thus reducing costs.

**Megacities**

It is estimated that by 2015 there will be as many as 60 megacities (cities with more than five million inhabitants), together housing more than 600 million people. Megacities require human and natural resources for energy, industry, construction, infrastructure, and maintenance, and the ‘ecological footprint’ they create has a huge impact, both locally and globally. The consequences of high population densities include pollution, energy consumption and waste. Ignoring any one of these will compromise a city’s sustainability, but they all require planning, finance and delivery. Public-private partnerships are seen by many as the only way to achieve improvements in urban areas.

**Lack of water and sanitation**

More than 1.1 billion people lack access to safe water, and 2.6 billion lack access to anything more than basic sanitation, putting people’s lives at risk. Fig. 5 shows that the problem is increasing in urban areas. The world’s water resources are under increasing

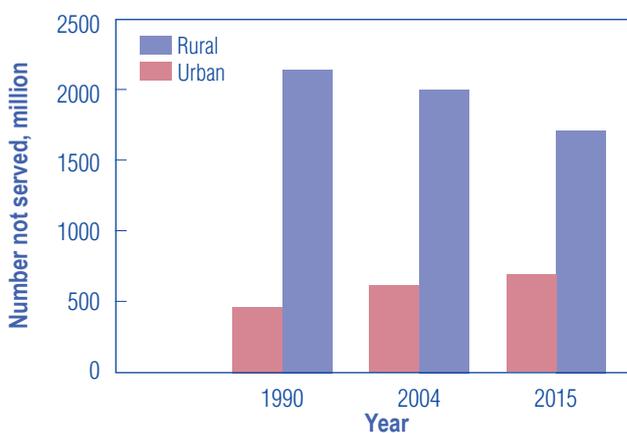


Fig. 5 - Global population without access to improved sanitation (2015, projected). Source: WHO/UNICEF Joint Monitoring Programme.

pressure due to intensive farming, increasing population, and political tensions. This situation is exacerbated by climate change and environmental degradation. Most of the water used is for agriculture; irrigation accounts for nearly 70% of total global use. Growing food is water-intensive; every kilogramme of potatoes we eat uses 1,000 litres, wheat 1,450 litres and rice 3,450 litres. Industry uses 20%, and nearly every industrial process needs some water; it takes 477,750 litres of water to make a single car for instance. The remaining 10% is for everyday use – for drinking, washing, bathing, and cooking. Each person in the world should have a minimum of 2-3 litres of water to drink every day.

- In 2007, British Medical Journal readers were asked to vote for the biggest medical milestone of the last two hundred years. Their choice was wide: antibiotics, penicillin, anaesthesia.... They chose sanitation.
- Modern sanitation has added 20 years to the average human lifespan.
- Where good sanitation exists, people are wealthier, healthier and cleaner..... it is engineers and the construction sector that have delivered this.

**Poverty**

About 25,000 people die every day of hunger or hunger-related causes (Food and Agriculture Organization, 2008). Of the three billion that live in cities, one billion are in slums and the majority of these slum dwellers live on less than US\$1 per day. Poverty in urban areas is different in character from rural poverty. Towns and cities are part of the monetary economy and people living there are completely dependent on a stable income base in order to be able to pay for necessities such as food, shelter and fuel.

**Congestion**

Increasing congestion owing to increasing urbanisation and vehicle ownership has an economic, social and environmental impact. In China, national vehicle ownership is forecast to rise from 30 million to 140 million by 2020. Tackling congestion is high on the agenda of many countries; investment in transport infrastructure is crucial. Governments are faced not only with the need for new facilities but also have to finance the replacement, modernisation or refurbishment of existing ageing stock. Many city governments are looking at building underground, to lessen the environmental impact and also because of land availability issues.

**Housing shortages**

The emerging economies, notably the BRIC countries – Brazil, Russia, India, and China – are undertaking market reforms that are prompting the

expansion of a 'middle class' in need of housing. People with an annual income of over US\$3,000 (part of The World Bank's definition of 'middle class') in the BRICs has nearly doubled in the past three years. These countries need 22 million housing units every year until 2030.

## Demographics and ageing

The design of cities must take account of the changing age profile of the inhabitants. This is of particular importance for healthcare, accessible infrastructure and leisure facilities.

## Demand for infrastructure

Good infrastructure is a pre-requisite for economic growth and the ability to be competitive. The development of a country is measured by its level of infrastructure providing transport, communication networks, and educational and healthcare facilities. There is a growing demand for infrastructure in the face of rising urbanisation and population growth. Countries such as China, India and the UAE are growing their

infrastructure provision. In the developed world, Canada, USA and Australia are focusing on the maintenance of existing provision rather than major development, whilst Spain, the UK, and Germany are having to replace/improve infrastructure to remain competitive. Russia, Brazil, Mexico, and the Czech Republic suffer inadequate investment, with much of the existing infrastructure under-performing.

Fig. 6 shows the global infrastructure gap and the projected infrastructure investment needs in various countries and regions. The crux of the challenge of bridging the infrastructure gap is money. Whatever the financing structure, the public sector is the final funder. New forms of procurement, particularly public-private partnerships (PPP), Private Finance Initiatives (PFI) and Build-Operate-Transfer (BOT), are involving the private sector in the provision of public goods and are providing much needed facilities, but the integration (and thus the sustainability) of transport must remain a high priority, a challenge when different organisations are involved in each of the one-off projects. The credit

**CANADA:** plugging Canada's infrastructure gap requires an investment of six to ten times the level of current annual government infrastructure spending. Canada's local governments alone face a US\$60 billion annual infrastructure deficit, a number growing at a rate of US\$2 billion a year. Investment needs for urban roads and bridges are US\$66 billion over 10 years.

**EUROPE:** the infrastructure needs for the European Union run into trillions of US dollars. The energy sector alone requires US\$1.2 trillion over the next 20 years. Approximately US\$90 billion is needed for infrastructure investment in Germany alone each year.

**EAST ASIA:** the developing economies in East Asia need to invest US\$65 billion per year over the next five years for electricity, telecommunications, major inter-urban roads, rail routes, water, and sanitation. This amounts to nearly 6.2% of GDP for the region (4% for investment and 2.2% for manufacturing). China with its enormous electricity needs is expected to account for 80% of all regional infrastructure expenditures.



**USA:** the US infrastructure deficit totals US\$40 billion a year in the roads sector alone. Overall, the American Society of Civil Engineers estimates total US infrastructure investment needs over the next five years to be US\$1.6 trillion, an amount that is nearly equivalent to Italy's GDP in 2004.

**SOUTH ASIA:** India spends just 6% of its GDP on infrastructure, compared to China's 20%. To achieve its targetted growth rates, the country will need to invest some US\$250 billion over the next five years.

**SOUTH PACIFIC:** a survey by Econotech and the Australian Council for Infrastructure Development puts Australia's infrastructure deficit at US\$9 billion. Meanwhile, the infrastructure deficit in New Zealand is estimated as 5% of GDP (around US\$5 billion).

Fig. 6 - The global infrastructure gap – projected infrastructure investment needs. Source: Deloitte, 2008.



crunch has further tightened the public purse and the necessary securities such as bonds, insurances and sureties have become increasingly difficult to secure.

Fig. 6 only refers to the initial capital investment required; it does not include the maintenance and operating cost requirements that carry on through the life of a project. The estimates vary significantly. For example, the Africa Country Infrastructure Diagnostic (2009) study estimates that annual infrastructure investment needs in Africa are in the region of US\$40 billion per year, with maintenance and operating costs adding a further US\$40 billion per year. Whereas the United Nations World Investment Report (2008) puts the infrastructure financing gap (investment plus operation and maintenance) for Sub-Saharan Africa at US\$23.5 billion per annum. Whilst governments recognise the need to invest in infrastructure, they have yet to face the big issue of funding ongoing maintenance, upgrading and asset management.

The scale is vast, but the consequences of not making the investment can be catastrophic, as shown recently with the collapse of the Interstate 35 West bridge in Minneapolis, USA (see photo above). A survey by the American Society of Civil Engineers (ASCE) produced a 'report card' on the state of America's infrastructure with a five-year investment need of US\$2.2 trillion and items ranked on a scale of A+ to D-. Other countries would probably report a similar situation. The ASCE report card gave:

- |                           |                   |
|---------------------------|-------------------|
| C+ Solid Waste            | D Aviation        |
| C Bridges                 | Dams              |
| C- Rail                   | Hazardous Waste   |
| Public Parks & Recreation | Schools           |
| D+ Energy                 | Transit           |
|                           | D- Drinking Water |
|                           | Inland Waterways  |
|                           | Levees            |
|                           | Roads             |
|                           | Wastewater        |

**The global infrastructure market**

The public purse cannot afford to deliver all the necessary infrastructure; new forms of public-private partnership will probably have to evolve, in which the private sector will be responsible for delivering the infrastructure so important to a nation's growth and well-being. Infrastructure can be traded just like any other physical asset, but there need to be caveats stopping exploitation. Innovation will be at the hub of the new project delivery systems. There is increasing investor interest in infrastructure funding which has become an emerging asset class, once considered the domain of municipal government.

The various global infrastructure indices (such as Standard & Poor's, Macquarie and UBS) are showing good performance. As governments around

the world start to spend heavily on infrastructure, particularly with the fiscal stimulus packages being implemented, there are many opportunities for investors in global infrastructure stocks. Global expenditure on infrastructure spending and maintenance, estimated to be around 2% of global GDP each year, or US\$1 trillion currently, could reach a cumulative US\$41 trillion by 2030 given the need for countries worldwide to build and repair their nations' respective infrastructure (Morgan Stanley Investment Management, 2009).

**Changing forms of procurement**

Globally, there has been a blurring between building and civil engineering contractors towards service providers. There is now more design and build/single point responsibility, with information technology developments acting as the 'glue' to integrate design and production and to manage information flow. Financial engineering has brought innovative approaches to procurement with more concession agreements such as PPP, BOT and PFI. Asset management has become an important part of the maintenance and operation of infrastructure.

The nature of these procurement approaches means that the long-term financing arrangements are affected by economic changes over their whole life. In the current economic crisis, debt has either become more expensive or very difficult to obtain. Under a recent UK government 'rescue' plan, up to 110 major PFI infrastructure projects (worth £13 billion) currently in the pipeline will be able to secure public cash to save them from collapse owing to a lack of private money.

**The engineer's response**

Infrastructure helps to alleviate poverty and improve quality of life; it also has proven to be the bedrock for growth in the developed world as evidenced by the recent national economic stimulus packages that have invested money in infrastructure. There is no shortage of data and information about the effects of climate change, urbanisation, globalisation, and changing demographics on the environment, society and the world's economies. Consulting engineers understand the different perspectives of these issues as we live in a variable speed world. The infrastructure crises in Africa are very different to those in Europe and America, and different again to infrastructure gaps in Asia and Latin America. The way forward is to provide infrastructure that improves the quality of life for everyone. Engineers will need to be innovative in the project delivery models and the methods of financing projects.

# Energy Resources



Energy is a fundamental requirement for meeting the basic needs of society, and the ability to harness energy efficiently and put it to beneficial use has been a key element of economic development over the past century or more. Energy drives industrial, commercial and agricultural output, provides lighting, heating and cooling for homes and for workplaces, powers our transportation systems, and is the backbone of our complex communications systems. Despite the fact that energy systems work well in many countries, they are exceedingly complex and they are poorly understood by the public at large.

Whereas societies in developed countries take readily available low-cost energy for granted, almost one-half of the world's population has either no access to commercial energy or has access only to unreliable and unsatisfactory energy sources. Awareness of the close correlation between the level of per capita energy consumption and economic development as represented by per capita GDP has provided the impetus for ambitious programmes over the past 60 years to develop energy resources, especially electric power, as a means of stimulating economic growth in developing countries and alleviating poverty. In spite of these programmes, there remain wide gaps between the per capita use of energy in developed and developing economies, as shown in Fig. 7 .

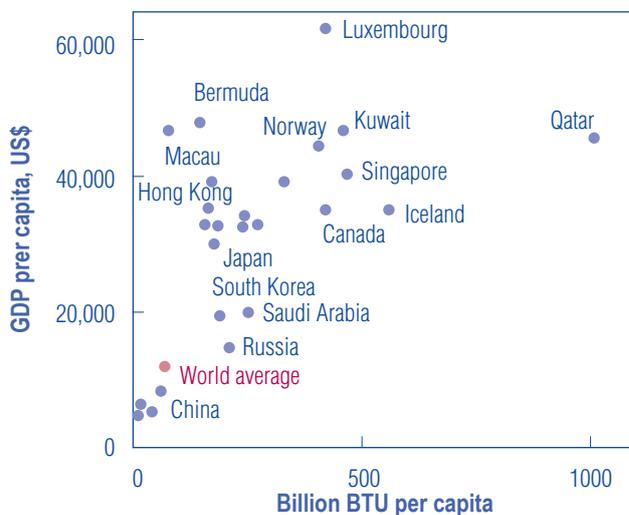


Fig. 7 - Energy use per capita versus GDP per capita, 2006 (GDP in purchasing power parity). Sources: EIA; International Energy Annual, 2006; IHS Global Insight.

It is now apparent that the pursuit of increased rates of energy use over the past 100 years has led to unintended consequences in the form of elevated CO<sub>2</sub> levels in the atmosphere and consequential impacts on global warming. The key question then becomes – how can access to energy be improved for the very large numbers of people living in poverty, while reducing the consumption of the fossil fuels that are contributing to global warming? These challenges affect all of us, and all segments of society have a role to play in meeting them. As the developers and implementers of technology innovations, engineers formulate and implement technological solutions to our complex energy problems, and need to provide wise advice to policy makers on problems that cannot be solved by technology alone.

## The present situation

Rapid economic development throughout the world over the past 100 years, accompanied by the increasing energy intensity of much of the world

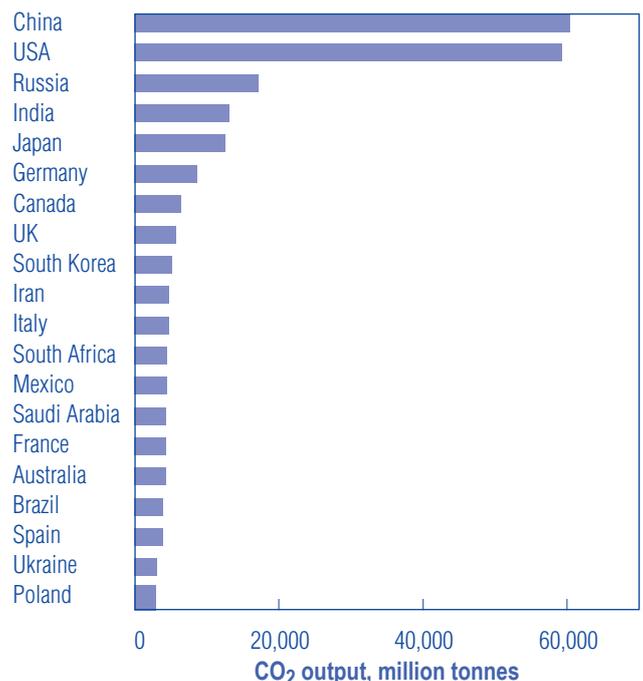


Fig. 8 - National CO<sub>2</sub> contributions for major producing countries, 2006. Sources: Energy Information Administration (EIA), US Department of Energy.

economy, has led to dramatic increases in the consumption of fossil fuels – 85% of global energy demand is currently being met by fossil fuel sources. The remainder is met primarily by hydropower and nuclear energy. The burning of fossil fuels now contributes about 30,000 million tonnes of CO<sub>2</sub> to the atmosphere, compared to an estimated 5,000 million tonnes in 1950. Over the past several million years, the concentration of CO<sub>2</sub> in the atmosphere has varied between about 170 and 270 ppm. Over the past century, the concentrations of CO<sub>2</sub> and other greenhouse gases have risen sharply, resulting in the current CO<sub>2</sub> concentration of 385 ppm, a level which is rising at the rate of approximately 2 ppm per year.

The developed economies represent high per capita use of energy and production of CO<sub>2</sub>; the top 21 countries account for 83% of emissions and the USA generates 20 tonnes of CO<sub>2</sub> per capita per year, China generates 4 tonnes per capita, and India generates only 1.2 tonnes per capita. However, the rate of increase of CO<sub>2</sub> generation by the developed economies has slowed dramatically in recent years and in some cases the rate has declined, but the rapid development of some coal-dependent economies (especially China and India) has led to rapid increases in CO<sub>2</sub> generation from these countries. China overtook the USA in terms of total CO<sub>2</sub> generation in 2006 (see Fig. 8 on the opposite page).

Concern over the consequences of increasing levels of CO<sub>2</sub> released into the atmosphere is accompanied by concern over the other consequences of fossil fuel extraction and use. These include water pollution from the production, refining and transportation of fossil fuels, and air pollution that is causing damage to human health and ecosystems. Furthermore, the dramatic crude oil price fluctuations recently have caused economic uncertainty and arguably contributed to the current global economic downturn.

Despite the continued growth of demand for energy throughout the world, there has been a general slowing of investment in new energy infrastructure owing to the many barriers to such development. These have included complex and time consuming regulatory hearings, public and political opposition and excessive regulation, all supported by a general lack of understanding of energy systems by the public. The situation has led to a progressive tightening of the supply-demand balance, with utilities at times resorting to very expensive options to meet urgent short-term supply needs. It has also been one of the key drivers for the recent escalation in the market price of energy commodities – including the price of oil and natural gas, and also the price of electricity in some jurisdictions. In addition, CO<sub>2</sub>-emitting thermal power projects are being planned and built in many locations owing to a lack of viable alternatives to meet growing energy demands. This is aggravating our already severe CO<sub>2</sub> emission problem.

### Challenges for the future

The increasing global demand for primary energy since 1980 is shown in Fig. 9, together with the projected increase to 2030. Much of the increase will occur in developing countries, especially in Brazil, Russia, India, and China. Per capita energy use is projected to increase in all countries, but at a significantly faster rate in developing economies, as they become more energy intensive. Without major initiatives to reduce CO<sub>2</sub> emissions in developed countries and reversing current trends elsewhere, the increase in energy use will be accompanied by equivalent increases in CO<sub>2</sub> emissions (see Fig. 10), with 97% of the increase between now and 2030 estimated to come from non-OECD countries.

However, research has shown that unless we are able to stabilise CO<sub>2</sub> emissions at little more than present levels, greenhouse gas concentrations will rise to levels at which irreversible and catastrophic climate change will occur. This means that major efforts must be devoted to reducing our demand for energy where possible, and moving towards non-CO<sub>2</sub> emitting energy sources as well.

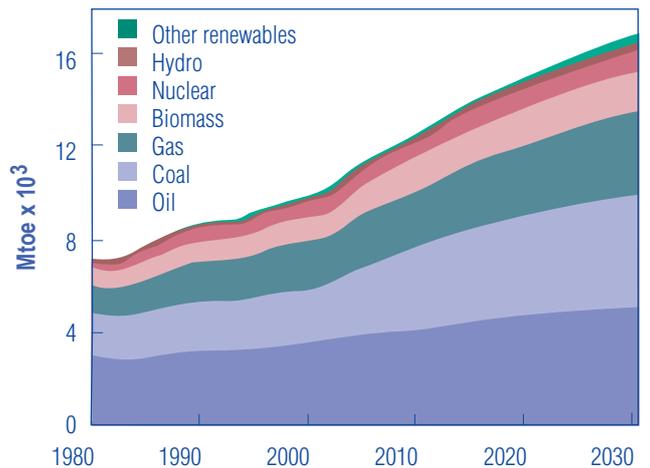


Fig. 9 - World primary energy demand in the Reference Scenario. Source: OECD/IEA, 2008.

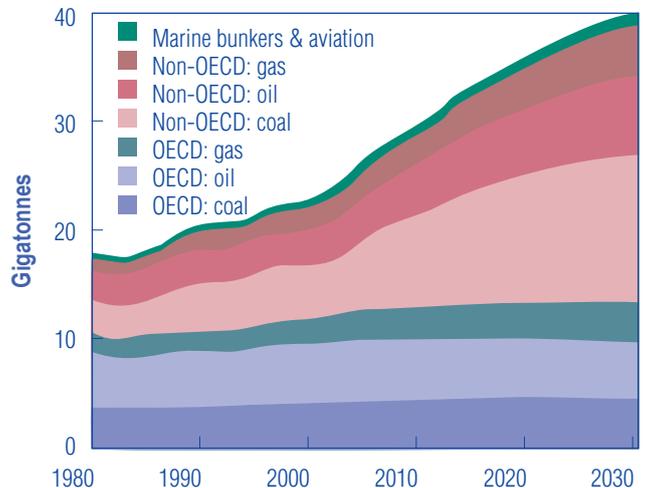


Fig. 10 - Energy-related CO<sub>2</sub> emissions in the Reference Scenario. Source: OECD/IEA, 2008.

These realities mean that engineers and society at large need to work together to:

- Continue to improve the energy efficiency of buildings and industrial processes.
- Encourage energy efficiency through use of smart meters, smart grids and smart infrastructure.
- Re-define our cities to encourage efficient energy use through increased population densities and energy-efficient services, including transportation.
- Eliminate energy subsidies and ascribe financial values to CO<sub>2</sub>-related externalities through carbon pricing systems, to motivate consumers to move away from fossil fuels and encourage efficient use of energy.
- Foster greater reliance on non-fossil fuel sources (hydro, nuclear, wind, solar, and wave power) for primary energy supply.
- Develop a larger role for electricity in our global energy mix, to curtail the use of fossil fuels. Since over 50% of global oil production is consumed by transportation, a special focus on public transit and electrification of transportation modes is needed.
- Make more effective use of fossil fuels for energy supply, including improved efficiency in energy conversion, combined cycle generation, cogeneration, district heating, and waste-to-energy.
- Pursue measures to capture and store CO<sub>2</sub> (carbon capture and sequestration, or CCS).



### The engineer's response

Implementing measures to reduce CO<sub>2</sub> emissions while fostering global economic growth and poverty alleviation will present both technological and social challenges. The measures outlined above have substantial technological components, and engineers can and must play lead roles in bringing them to reality, both through R&D activities and through effectively engineered and managed projects.

However, implementing these measures will also present social and economic challenges. Here the role of engineers must be to continue developing convincing arguments for the implementation of effective emission-reducing measures, and designing projects that will gain acceptance by a public that too often sees the world in narrow and local terms. The problems of energy use and implications for climate change are global in nature – engineers must ensure that this global context is brought to each of their projects.

# Waste and Waste Management



Waste generation and, correspondingly, its effective management remains a serious concern for communities around the world, be they within developed or developing countries. The growing human population continues to generate large quantities of hazardous and non-hazardous wastes. To understand

the waste challenge it is also important to consider those key attributes which differentiate the challenge on a regional basis.

## Waste

Waste generation trends indicate a correlation between the United Nations Development Programme's Human Development Index (HDI) and waste generation per capita (see Fig. 11). In recent years the urbanisation, population growth and growing affluence of major population areas such as India, China and Indonesia have led to increased waste generation trends on a per capita basis. The UN indicates that the urban population ratio was 29% and 42% in India and China in 2007, respectively, and is expected to grow to 37% and 57% by 2025. In India where the HDI is typically about 0.62, the municipal waste generation rates are about 0.4 kg/capita/day. Conversely, in Western Europe and the USA where the HDI is typically around 0.95 the municipal waste generation rates are in the range of 1.6 to 2.1 kg/capita/day.

Efforts to move waste diversion practices towards the 3R's (reduction; re-use; recycle) show varying degrees of success across the world. The UN Agenda 21 agreement emphasised that reducing waste and maximising environmentally sound waste re-use and recycling should be the first steps in waste management. The current degree of success appears related to the cost of diversion and the level of the regulatory framework in place to mandate these diversion activities. The positive effects of waste diversion regulations are evident amongst the European Union (EU) states where several countries report diversion rates in excess of 50%. Conversely, some developed countries such as the USA have not yet been as forceful with waste diversion regulations

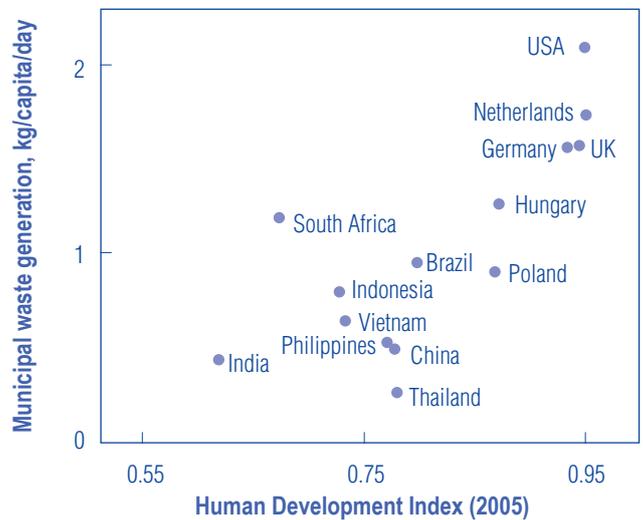


Fig. 11 - Municipal waste generation. Source: UNDP.

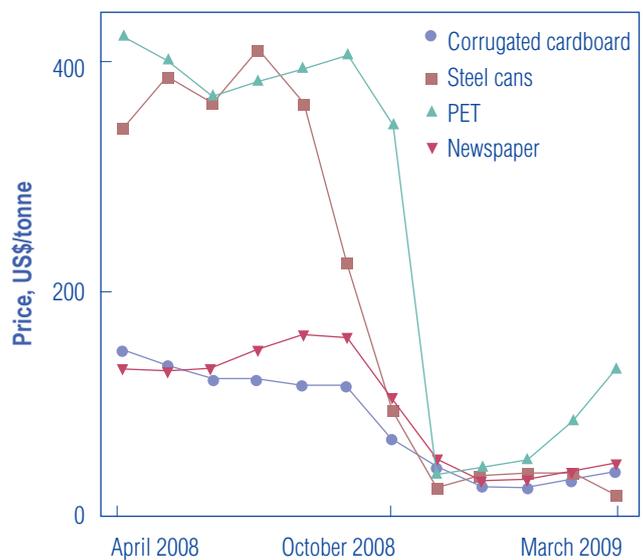


Fig. 12 - Value of recycled commodities. Source: Corporations in Support of Recycling.

(although several US states are now moving forward with regulation) and the diversion rate remains relatively low at about 25%. In 2007 and the early part of 2008 the values of recycled commodities were at historically high levels. However, as shown in Fig. 12, these commodity prices have fallen dramatically, with the result that materials are currently being stockpiled to await better market conditions.

The Basel Convention, an international treaty that came into effect in 1992, governs the transboundary movement of hazardous wastes amongst its 172 member countries. The convention outlines a list of banned substances, undertakes annual reporting of its members, and provides specific programmes to assist member countries, such as the 2008 Partnership for Action on Computing Equipment (PACE). The reporting through the Basel Convention provides an indication of the trends in hazardous waste generation. For the period of 2000 to 2005 the total amount of hazardous waste generation reported grew from 51 to 94 million tonnes. Fig. 13 shows the total reported hazardous waste generation for selected countries and clearly indicates an increasing trend, particularly for the heavily industrialised countries.

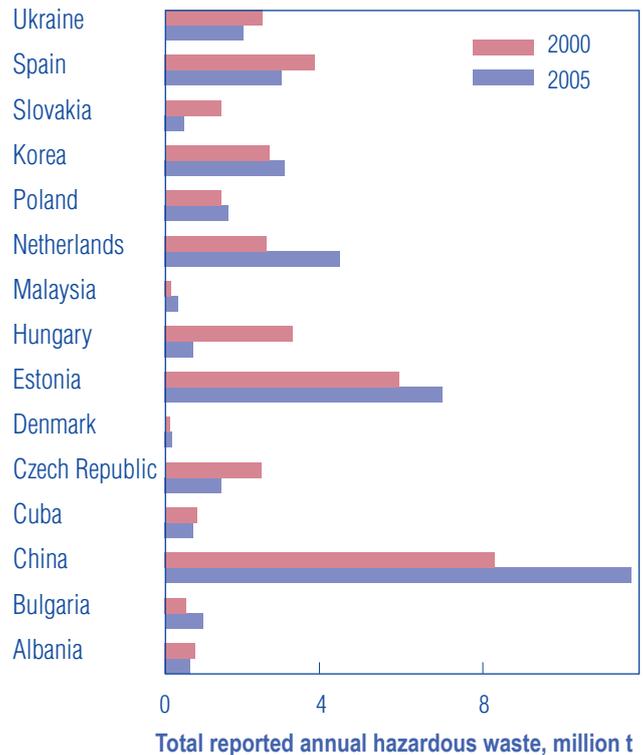


Fig. 13 - Hazardous waste generation. Source: Corporations in Support of Recycling.

## Innovative approaches in waste management

### Mechanical and biological treatment

The European Union (EU) Waste Framework Directive came into force in 2006 promoting the 3R's, a move favoured option, rather than incineration and landfilling as illustrated in Fig. 14. These priorities led to the EU Landfill Directive, which requires the pre-treatment of municipal solid waste and encourages the diversion of biodegradable wastes. For the UK, which has been heavily reliant on landfills, this has led to investments in mechanical and biological treatment and other innovative technologies to bridge the current capacity gap; this will require some £6 billion of investment in the UK to meet the level of diversion required by 2013.

Given the scale of this investment, many municipalities have sought to fund the up-front costs using Private Finance Initiative (PFI) contracts, whereby the contractor finances the capital and operational investment and then recoups this on a tonnage payment basis over the (typically 25 years) life of the contract. Whilst this is attractive, PFI is typically more expensive over the project life-cycle when compared to traditional public finance schemes. Furthermore, the recent turmoil in financial markets has made PFI more difficult at present and municipalities may also need to consider procuring the necessary infrastructure directly. Another key area of uncertainty is the ability to identify and secure suitable sites on which to develop the infrastructure. In many cases, this risk is such that it is

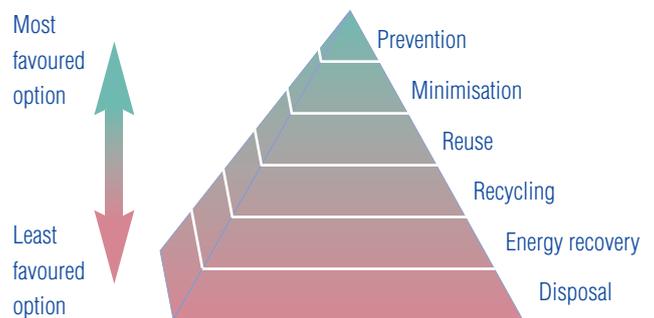


Fig. 14 - Most favoured option.

becoming increasingly common for municipalities to secure suitable sites (and possibly planning consents) before tendering projects, such that the bidding process can be as equitable as possible to all potential bidders.

### Waste-to-energy developments

The key drivers leading to innovation in the waste-to-energy (WTE) industry are the improvement of energy efficiencies, the reduction of air emissions, and the improvement of ash quality. Air emissions regulations are common in developed countries, and have driven innovation in the industry. In certain countries in Europe, such as Sweden, Denmark, France, and The Netherlands, WTE is used to handle larger percentages of the waste stream. Overall it is estimated that 400 WTE facilities are currently operational in Europe, with another 100 in different stages of planning. In North America there are approximately 90 facilities

operational and approximately 20 to 30 planned. In Europe, the EU has taken the step to classify 'incineration' as recovery rather than disposal if the facilities meet certain environmental and energy efficiency standards. This has driven innovation in the design of combustion chambers. In North America, WTE facilities are considered disposal and therefore much lower in a waste hierarchy that favours systems or technologies that recover materials. With the growing emphasis on



alternative energy sources worldwide, WTE will begin to play a larger role in waste management strategies.

## Areas needing improvement

### Introducing technology in developing countries

In developing countries there is a general lack of financial and equipment resources and a lack of understanding with regard to waste management. There is also an absence of legal and policy frameworks and administrative systems relating to waste management. This is generally manifested in the poor siting, design and operation of disposal facilities and inefficient collection services. Such situations translate into environmental and social problems. In formulating and implementing solid-waste management solutions in developing countries, sustainability achieved through appropriate technology and training is needed.

### The necessary steps

Assuming that requisite resources are available, say from donor funding, the following steps should be considered:

- Understand the local situation and politics, and have input from the local population, before trying to define a problem or formulate a solution.
- Set achievable objectives and develop simple, effective solutions that make use of 'appropriate technology' in the form of a locally developed solution, rather than a developed country solution that has been tailored to fit developing country conditions.
- The solution widely considered to be the 'best technologically' and 'most sustainable' may often be unsustainable and inappropriate (as shown in Fig. 15).
- 'Appropriate technology' goes a long way to promoting sustainability since it can be maintained under local conditions using locally available resources (for example, local skills and readily available parts). Thus appropriate technology has significant advantages in the long term.
- Training is indispensable in the implementation of sustainable waste management systems in developing countries and must include political and technical decision makers and operators.

## Balancing society's needs

### Energy from waste: a renewable energy source

The global focus on increasing our reliance on renewable energy sources rather than on fossil fuels continues to provide a strong context for the further development of energy from waste alternatives. Furthermore, as the global economy recovers from the

current crisis, a return to high energy costs is anticipated. As a result, interest in renewable energy from waste is expected to increase. In developing renewable energy from waste technologies two different approaches appear to have been favoured: (1) regulatory drivers to reduce the dependence on landfill disposal; and (2) regulatory drivers to increase the production of renewable energy.

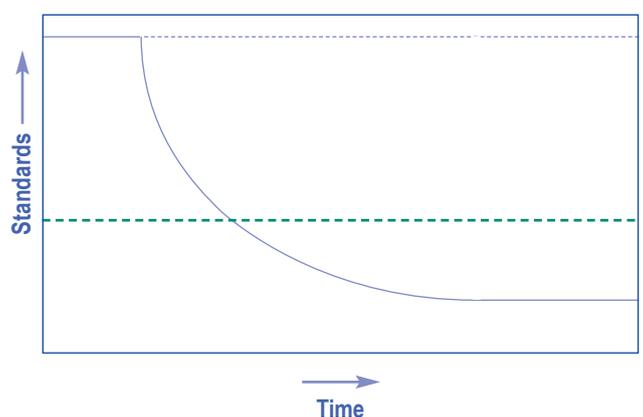
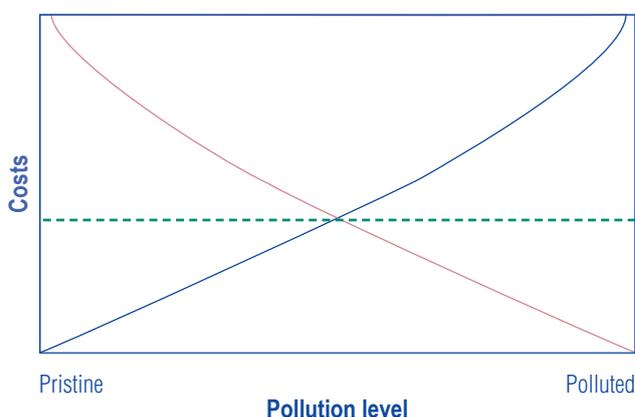


Fig. 15 - Appropriate solutions for waste management.

## Life-cycle assessment: a robust approach to decision analysis

Life-Cycle Assessment (LCA) is becoming a common tool used to help decision makers during the strategic planning of all technologies, including waste technologies for local and regional needs. LCA works at a higher level than permitting and local environmental impact assessment and allows a more global impact assessment to be carried out. Critically, it allows a scenario comparison (or 'what-if options') to be investigated, enabling waste managers to compare the environmental impact of many of the new innovative waste technologies that are available today. LCA requires an in-depth knowledge of the entire life-cycle of a facility, and should consider the capital burdens (namely, emissions and energy used in building the plant), operational and maintenance burdens, as well as the direct process emission (from both the process and the energy needed to run the system), through to plant decommissioning. Many countries and municipalities, including municipalities in the UK, Sweden and Finland, as well as some Australian states and Canadian provinces, are now using, or considering using, LCA to assist in technology selection for waste management.

## The engineer's response

The challenge of providing effective and sustainable waste management services will be fertile ground for the application of innovative solutions. The next 20 years will see a tremendous growth in waste generation as population growth and more importantly urbanisation create significant challenges in both the developing and undeveloped parts of the world. The focus on formulating sustainable solutions within the context of climate change and the growing global energy demands will create opportunities in all regions for the engineering community to clearly outline the solutions and technologies which can meet the needs of the local and regional stakeholders.

The engineering community will also continue to be at the forefront of discussions to improve the efficiency of energy-from-waste systems, and to develop designs that provide some security to society that these plants will not have significant adverse impacts on the environment. Moreover, the engineering community has to be engaged with the public to provide an understanding of the life-cycle impacts and costs of such systems and to help negotiate the necessary long-term contracts that these systems require.

# Water and Wastewater



Mankind is dependent on the availability of fresh, potable water for health and economic activity. Today, this issue is more important than ever. Inadequate water supply is a major constraint for development and, in some cases, is at the heart of economic survival. Water stress and the continuity of supply will become increasingly more strategic issues for political planners and communities around the globe.

The challenges that we will face are already clearly visible. It is crucial that future generations follow the example of our forebears by working to adapt to changing circumstances to ensure the widest possible access to potable water in the least damaging way possible across the globe. Global leaders will need to recognise the value of water and support appropriate programmes and strategies.

## A source of conflict

It is often asserted that the availability of water supply for human use will become one of the most likely flashpoints for strife in the future. Much of the world is already experiencing water stress, and this is becoming an increasingly urgent issue as population growth in urban centres and climatic change increase the demand for water and limit access to supply. At the present time, water stress is largely confined to local disputes over access to water, which on occasion turn into violent confrontation. There have been examples in the past year, particularly in Africa, where tension between local communities and commercial agricultural operations has exploded into loss of life and property.

People are realising increasingly that water issues have the potential to rapidly escalate into regional tension, and, if climate scenarios are correct, could hold the key to the viability of cities, economies, food security and even, in some areas, nation states themselves.

Advances in sewage and water treatment for municipalities in the second half of the 19th century constituted one of the greatest advances of our modern civilisation, making possible much of the world's economic infrastructure and our current health and lifestyle standards. However, much remains to be done in order to provide access to basic health standards for a large part of the world's population. By 2050, it is anticipated that 75% of the global population will face a noticeable degree of water scarcity, up from the figure of 40% today (for projections based on minimal climate disruption). The intensity and distribution of this scarcity will also increase. In addition, the historical legacy of neglect in our existing water infrastructure systems is coming to a head, with under-investment over many decades beginning to threaten the viability of existing supply and disposal regimes in many regions.

**Table 1 - World water investment shortfall, US\$ billion**

	Current capex spending p.a.	*Total capex 2006-25 required
Western Europe	29.5	502 - 810
EU Accession Europe	1.7	44 - 78
Rest of Europe	1.0	20 - 42
USA	20.5	435 - 820
Canada	2.0	42 - 115
Mexico	0.9	18 - 26
Brazil	1.5	33 - 56
Chile	0.3	3 - 4
Other Americas	1.5	32 - 54
Japan	14.2	175 - 370
South Korea	3.5	73 - 92
Australia	2.1	42 - 60
Singapore	0.3	6 - 8
New Zealand	0.2	4 - 5
China	5.0	395 - 535

Source: Envisager Water Analysis, 2009.

\*These figures are based on meeting the applicable national water quality standards.

Along with the water demands of an increasingly urbanised world and the requirements of agriculture struggling to keep pace with ever greater population levels (food production currently takes up around 70% of human water use), the problems are exacerbated by climate change and what this could mean for water availability on an already overloaded planet. The signs are that climate change will not only make it harder to achieve improvement, but also potentially threaten much of what has been achieved to date.

Although broad-based statistics such as those in Table 1 are mainly an illustrative tool, by any



measure the difference between the current and required capital expenditure gives some idea of the scale of the problem, even to meet existing national criteria of water quality. Meanwhile, many parts of the world are struggling to measure up to the current developed country scales of water investment indicated in the table. The investment required on a global scale to meet United Nations water access goals for 2015 is already a considerable challenge, even without factoring in any possible climate change.

## An uncertain future

### Climate change

Some areas of the world are providing examples, even now, of what may be in store for us as a species. Water scarcity, or drought, although commonly experienced in the sub-Saharan and tropical regions of the world, is now imposing itself on more economically developed regions. Their ability to cope with or adapt to the changing water base is proving instructive, particularly for regions where the human population exceeds the carrying capacity of watersheds. Sydney in Australia, for example, is a city which has historically experienced significant climate variability: its infrastructure and civil engineering have been developed to meet this issue. This is why, at full capacity, the current water supply available to the Sydney metropolitan area could provide the city with four years' water, whereas New York City's equivalent capacity is only two to three months.

The Australian experience also highlights several other aspects of what happens when a region runs out of water. For example, a large volume of water is consumed by power stations serving the area. In these circumstances, the value of desalination plants is reduced when the energy-hungry desalination plants obtain power from power stations that are drawing from the local potable supply at the same time. Eastern Australia's recent record drought also provided a notable example of agricultural needs becoming a secondary priority to potable water needs, resulting in the loss of large tracts of agricultural land.

### Economic and political issues

A key component of the constraints to be addressed relates to the economic and political instruments imposed or used by society to manage its water supply and distribution systems. Table 1 indicated the infrastructure investment gap for achieving water quality requirements (assuming that the water is available for use). But what is equally important is the availability of funds to finance continuing and improving access to water. Table 2 summarises capital spending shortfalls in the water sector in several regions for the period 2006 to 2025 after removing the investments

already programmed.

How this shortfall is to be addressed is a key issue for politicians and societies to agree, since the outcome will form the platform from which investment programmes will spring. The current world financial situation further complicates the outlook for the water sector (as well as for everyone else) with the credit crisis affecting the development of new concessions by private concessionaires. An important model for water sector investment from 1993 until 2000 was largely based on concession finance, but foreign exchange risk has made this approach problematic until political, operational and financial risks can be overhauled. Consequently, other scenarios for water finance are being developed, ranging from private equity and structured finance to sub-sovereign structured finance and debt and loan issuance models. However, the water sector has to compete for investment with many other sectors, and the demand and the outcomes are often long term and not particularly 'glamorous'. If the world is to improve the security of water supply and minimise the potential for future conflict then issues of ownership, payment flows, provision levels, and investor returns will need to be considered in the light of the fundamental importance of water provision.

### Technology

The human race has always placed a great deal of faith in its ability to innovate and improve using technology, and the future of water supply is no exception. Desalination and water recycling plants are at the high end of water infrastructure in terms of expense and the complexity of the technology involved.

**Table 2 - Global revenue - capital investment gap 2006 to 2025 (\$US billion)**

Region	Low	Medium	High
Europe	267	399	522
North America	65	98	428
Latin America	57	80	101
Developed Asia	589	658	730
Rest of World	369	448	522
Overall	1,350	1,683	2,303

Source: Envisager, UK.

Desalination offers flexibility, particularly where an increasingly arid climate is encountered by a community with access to sea water – a seemingly limitless resource in the medium- to long-term. Pre-treatment and reverse osmosis systems can now be built to supply increasingly intense population levels, and the support infrastructure for seawater intake and screening can be extensive. The corollary is that these approaches provide solutions for a society with access to finance, energy and the capability to maintain infrastructure.

Increasingly, water supply facilities are being linked in 'water grids'. This approach aims to achieve additional flexibility and better matching of water storage and supply infrastructure to the location of demand. Grids are controlled using sophisticated management programmes and linked infrastructure networks to enable efficient use of resources across a catchment area or region.

Water recycling and the increasing use of 'grey' water are also climbing up the agenda. While there remain issues surrounding the quality and acceptance of this resource by the user community, these approaches will become increasingly more important to supplement traditional catchment sources. The key will be to apply more advanced screening and treatment processes to extend the application of these types of resources beyond current possibilities (in, for instance, sanitation, agriculture and landscaping) to eventually become a component of human consumption. This goal, although technologically feasible, still has many psychological hurdles to overcome in many areas. Where water recycling has been attempted on a small scale (in Barcelona in Spain, for example) an extensive and comprehensive public information programme together with incentives was required.

The downside to this technological progress is that all these approaches require copious amounts of 'cheap' energy, which further exacerbates climate change through greenhouse gas emission. Moreover, the availability of energy for such activities is likely to become more constrained.

### **The energy issue**

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The energy issue is an essential element of all future developments for maintaining and improving

## **Some promising solutions**

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### **Alternative sources of supply**

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Alternative supply sources are also becoming mainstream design elements for many developments and facilities. These include items such as rainwater tanks, desalination (groundwater and seawater), storm water harvesting, and the recycling of sewage effluent and greywater. The essential point is



water access. Water is a heavy commodity to move around (in many areas without infrastructure it is still transported from sources in pots or other vessels by humans and animals) and power for pumping and treatment is a major component of ongoing operating costs (and a major component of carbon footprints). Water systems are typically a municipality's single most important energy consumer, accounting for between 20 and 30% of municipal energy needs. With likely future constraints and cost increases in fossil fuels, water companies worldwide are starting to concentrate their efforts on techniques to minimise energy dependence and reduce their carbon contributions. Such efforts should have a positive impact on both balance sheets and the achievement of goals for sustainability.

Of particular concern are centralised waste water treatment facilities. As water is used to transport the wastes, these systems consume much energy and have a high water consumption, making them unsuitable in the long term for regions with water scarcity. In many places this has already led to an over-exploitation of the limited renewable water resources. A far more fundamental problem is that the conventional centralised systems do not facilitate the re-use of macro- and micro-nutrients present in excreta and wastewater. This lack of nutrient recovery and re-use leads to a linear flow of nutrients from agriculture, via humans, to recipient water bodies.

New systems include various forms of recycling of nutrients based on separated wastewater, close to the source at individual houses or at decentralised units covering a number of houses. An increasing number of projects in developing countries as well as in industrialised countries facilitates the application of decentralised systems with re-use and recycling of nutrients and less use of water.

that water supply is increasingly seen as comprising a 'portfolio' of opportunities and techniques rather than the traditional demand and supply models of provision. Aquifer storage and recovery and aquifer recharge are also being used in suitable locations for the temporary storage ('banking') of treated storm water and recycled effluent. Such approaches which localise integrated water management issues have reached an apogee with

the introduction of Water Sensitive Urban Development (WSUD, an acronym which will surely become more and more familiar worldwide).

### **Rethinking catchments**

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From a catchment perspective, the improved understanding of ecological requirements and values in freshwater systems has been translated into requirements for the maintenance and return of 'environmental flows' to river systems. The environmental flow needs to be carefully balanced against human use to prevent over-exploitation and to enable systems to regenerate from prior over-extraction.

Climate change is making the consideration of balancing more and more essential as stresses grow on ecosystems and the size of stored water reserves required to mitigate the increased risk of prolonged drought increases. Much of the world's human population depends on a finite range of water supplies which are under increasing climatic and ecological pressure. The Himalayan and Colorado River watersheds are two major examples; the River Jordan water catchment is another potential regional flashpoint (Israel, Syria, Lebanon, and Jordan all draw water from the catchment area).

There is a further possible link between catchment management and climate change relating to the protection of natural vegetation in lands adjacent to significant water supply reservoirs and dams. As well as contributing to improved water quality, natural vegetation can store carbon, dampen the heat island effect in urban areas and contribute to run-off capture and the maintenance of ground water systems.

It is also possible to think in terms of 'micro-catchment' treatments – a move away from a large, centralised water supply approach towards the possibility of 'off grid' houses, institutions and communities. The use of water metering is also predicted to increase dramatically over the next 10 years, and some of it will be compulsory.

### **Conservation and regulation**

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Aside from supply and management operations, consumer conservation measures and the application of energy efficient domestic technologies can be just as important as major investments. For example, one of the most important technologies available in the developed world for reducing greenhouse gas emissions in the water industry could be the mass installation of highly efficient domestic showers. It will be up to integrated policy decisions between the water utilities and governments to ensure that these types of measures can be implemented. For some water supply companies the reduction of unaccounted water loss by leakage from the system is the single biggest conservation gain that can be achieved.



Design decisions made outside the water supply arena will also be crucial in ensuring that the maximisation of catchment and conservation opportunities becomes more highly integrated with plans to develop and upgrade systems. Water conservation techniques and considerations are now being built into infrastructure and planning proposals that increasingly take account of potential climate profiles for the longer term as well as consideration of maintenance and operational demands. Such approaches are now being enforced by legislation in areas suffering availability constraints. In many parts of Australia, for example, any new residential development must demonstrate a 40% water saving compared to previous designs simply to meet the planning approval requirements that are in force.

### **Coupled to disaster management**

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Climate change is not just about drought and scarcity; it is also about increases in the frequency and intensity of precipitation. The latter increase the risk of localised and regional flooding which can cause significant infrastructure damage and lead to major recovery costs in areas where the storm water and river management systems are overwhelmed. Northern Europe, in particular, has been experiencing flood events which were beyond the current capability of the infrastructure to cope. As the floods in western England in 2006 illustrated (see the photograph above), flooding can also damage elements of the fabric of modern life from power to clean water supplies. Across Europe, previous assumptions are being revisited, notably the density of building development, proximity to flood plains, design standards, river containment, and storm water runoff measures.

### **Local solutions**

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Most of the issues discussed so far are concerned with the large-scale delivery of water from source to user. This reflects the priorities of the economic and connected world of business, urbanisation and politics. However, it is arguable that the considerations do not address a considerable proportion of the world's population. These are the people who are not in reach of an organised water policy and who also face scarcity and water hardship in a climate-challenged world.

Aside from multilateral donors, innovation

and problem solving are being applied around the world to local, small-scale solutions where finance for major infrastructure is unavailable – from well development and solar powered pumping systems with minimal moving parts to save on maintenance to ground water protection education and programmes to recharge groundwater aquifers.



### The engineer's response

Engineers have always been essential for ensuring that societies can access water supplies, distribute water to consumers and dispose of the sewage and waste. It is clear that there will continue to be a demand for skilled individuals who will be the engineers of tomorrow. They will have to provide the leadership and solutions which are needed if water is to be conserved and water use systems improved. At the moment, however, there is a global shortfall in engineering graduates, particularly in developing countries and it is projected that the water sector will also suffer from this.

Engineers will have to be at the forefront of developments. Whether finding ways to maximise water capture, ensuring conservation of the resource from supply through to distribution, or increasing usage before final disposal, the issues of innovation, technology, design, and management will be crucial for the engineer in meeting the challenges.

Whatever the investment framework, consulting engineers worldwide are delivering improvements and are thinking through the most effective management scenarios for each particular situation. Their work encompasses both high and low technology solutions, where practitioners aim to implement the most appropriate and economically feasible solutions.

Engineers are not just working with the supply and management operations: consumer conservation measures and the application of energy efficient domestic technologies can be just as important as major investments.

Design decisions made outside the water supply arena will also be crucial in ensuring that maximising catchment and conservation opportunities are increasingly integrated with development plans. Engineers worldwide are designing-in water conservation techniques and considerations into fundamental infrastructure and planning proposals.

These examples are not just cases of engineers taking on board green ideas – it is about ensuring the use of technology and design to maximise the efficiency of the natural systems, working in concert with local conditions to ensure sustainable management and resource capture for the existing system as well as increasing capacity potential and efficiency.

Finally, engineers are also working hard to reach out to the people affected by water stress, with many giving their time and skills on a volunteer basis through international organisations such as WaterAid, RedR and Engineers Without Borders.

# Transport



Transportation has always been, and remains, a fundamental element of human existence. The major breakthrough, the invention of the wheel, took place over 5,000 years ago in what is now Iraq. After this progress was very slow until the 18th and 19th centuries when improved roads started to appear, initially as turnpikes which travellers had to pay to use. At the end of the 18th century canals also started to appear and in the mid-19th century travel was revolutionised by the appearance of railways. The steam engine that produced the rail revolution also had a similar impact on sea journeys. The first urban underground railway was built in London in 1863 with steam locomotives pulling the carriages; the first electric underground trains ran in London in 1890.

The private car first appeared at the end of the 19th century and became more common as it became cheaper, with the growth in private car ownership accelerating significantly after 1945. Aeroplanes began scheduled flights within Florida in 1914 and internationally between London and Paris in 1919, and air travel accelerated rapidly after the introduction of jet passenger aircraft in 1949 and the Boeing 747 in 1970.

Table 3 compares both passenger and freight transport based on available transport statistics for some of the major and emerging economic blocks. In the USA, cars account for 85% of passenger-km compared to 74% in the European Union (EU), 56% in Japan and 53% in China. Conversely, rail's share of passenger-km in the USA is negligible while in Japan it is 30% and in China 34%. Domestic and intra-EU member state air travel accounts for around 10% of passenger-km in each case. For freight transport the figures are significantly different with road accounting for only 30% in the USA and 46% in Europe. Rail takes almost one-half of the freight in the USA and sea and inland waterways account for over 60% of the total in mainland China.

In recent years the environmental performance of the various transport modes has become a very important consideration. While there is a debate about the precise levels of carbon footprint left by each mode of transport there is little doubt that greenhouse gas emissions produced by a railway system are notably lower than those produced by road and air travel per passenger-kilometre.

**Table 3 - Passenger and freight transport**

	EU27 2007	USA 2006	Japan 2006	China 2006
<i>Passenger transport, billion passenger-km</i>				
Passenger car	4,688.0	[1] 7,317.1	[2] 724.0	[3] 1,013.1
Bus + trolley-bus + coach	539.0	275.4	89.0	-
Railway	394.6	23.7	396.0	662.2
Train + metro	85.4	19.7	-	-
Waterborne	41.0	0.6	3.8	7.4
Air (domestic/intra-EU27)	571.0	950.5	86.0	237.1
Total	6,319.0	8,586.9	1,298.8	1,919.8
<i>Freight transport, billion tonne-km</i>				
Road	1,927.4	1,889.9	347.0	975.4
Rail	452.2	2,705.1	23.0	2,195.4
Inland waterways	141.1	486.0	-	1,290.9
Oil pipeline	128.9	853.6	-	166.4
Sea (domestic/intra-EU27)	1,575.0	331.6	208.0	4,257.7
Total	4,224.6	6,266.2	578.0	8,885.8

Sources: Eurostat; Japan Statistics Bureau; US Bureau of Transportation Statistics; National Bureau Statistics of China; International Transport Forum.

Notes: [1] USA: including light trucks/vans; [2] Japan: including light vehicles; [3] China: including buses and coaches.

Safety is another very important consideration, especially as in 2007 more than 1.3 million people died in road accidents around the world, and another 15 million people were injured. To date there have been no fatal accidents of high-speed trains running exclusively on high-speed lines. Thus high-speed rail can be seen to be the safest means of transport at present.



Given the very different characteristics of the various modes of transport, rail, road, air and maritime

transport are examined individually in the remainder of this section.

## Rail transport

Since the railway first appeared, it has been a major factor in mankind's progress and quality of life. When it emerged at the beginning of the 19th century, it represented nothing less than a revolution in passenger and freight transport.

### High-speed trains

In the last 40 years, the railway has taken another very significant leap forward (at least in some countries) with the development of high-speed trains (see Fig. 16). This change is perhaps not as dramatic as that of the 19th century from a quantitative point of view. Journey times have not been reduced by a factor of 7 to 10, as happened then, but rather by only a factor of around two if we compare them with normal railway lines or motorway travel.

The high-speed railway lines represent a notable improvement in quality, comfort and safety of travel, not only compared with the conventional railway, but also when compared with road and air travel. Japan forged the way with the Tokyo-Osaka line in 1964, followed by France with the Paris-Lyon line in 1981. The market share of rail and air travel against rail journey time is shown in Fig. 17.

The total length of high-speed lines is expected to double by 2025 (see Table 4). Proof of how efficient and useful the high-speed rail lines are is that, despite the high cost (owing to the demanding design requirements of their lines and their strict conditions of construction), their development has been spectacular.

Spain provides a clear example. The first high-speed line, covering the 471 kilometres between Madrid and Seville, came into service in 1992. Construction on other lines started around 1996, and by the end of 2007 more than 1,500 kilometres of high-speed railway lines were in service. Currently, construction is underway on more than 2,000 km of

**Table 4 - 2010 and 2025 forecast high-speed rail network**

Kilometres of high-speed lines in the world

	Europe	Asia	Other	World
In operation	5,174	3,168	362	
Under construction	2,417	3,860	0	
Planned	7,765	5,595	2,570	
Total, 2010	7,591	7,028	362	14,981
Total, 2025	15,356	12,623	2,932	30,911

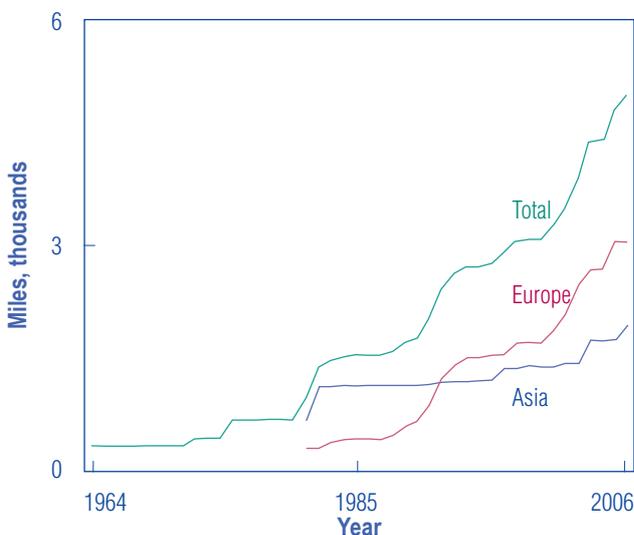


Fig. 16 - Length of high-speed railway lines.

Source: Jean-Pierre Loubinoux.

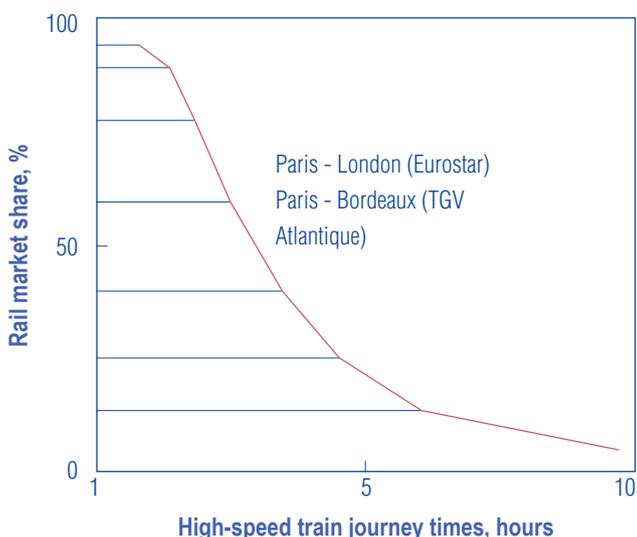


Fig. 17 - Market share: rail/air versus rail journey time.

Source: Jean-Pierre Loubinoux.

new lines. By 2012-2015 the lines in service will extend to some 5,000 km.

Railways have thus contributed to the progress of society, with two momentous leaps in a relatively short space of time, and the prospects for the future are excellent (see Table 4).

The impressive safety record of the new high-speed lines is not a question of luck. It is the result of the determination, effort, intelligence, and hard work of many engineers, technicians and operators, whose guiding principle, above any other consideration, is safe rail transport.

## Metros

Metros continue to offer an essential mobility system for large cities, a role that they have played since the late-19th century. Today, no citizen living in a city with an urban rail system could imagine life without it, even if metro projects may have generated controversy at the outset. With time, metros help cities to establish their configuration and remain attractive for citizens and businesses.

Metro systems around the world have a total length of almost 9,000 km with 8,200 stations, and carry some 155 million passengers each day. The growth experienced by many of these networks in the past few years has been considerable. Cities such as Copenhagen, Bilbao, Brasilia, Dubai, Seville, Santo Domingo, New Delhi, and Guangzhou that had no metros have created new networks. Other cities that already had a metro system have extended their networks significantly. Madrid has tripled the size of its metro network, building more than 200 km, in the past 12 years.

Construction methods have been developed that can deal with issues related to safety while minimising construction times. Tunnel boring machines allow the secure and quick construction of metro lines under practically any conditions; diaphragm walls are usually used to develop stations. There are many procedures that allow works in more difficult conditions such as compensating grouting, jet grouting, freezing soil, and compressed air. Moreover, there are many devices to monitor and control movements and ground stresses in real time.

Electromechanical devices make travelling more comfortable; lifts, escalators or platform doors are frequent solutions in new extensions, even when they are implemented in networks already in operation. Electrical and electronic aids such as Wifi, cellular phone reception, TV screens, CCTV and heating, ventilating and air conditioning (HVAC) plant also contribute significantly to improved comfort.

The Reliability, Availability, Maintainability and Safety (RAMS) culture provides reliable and available systems based on appropriate maintenance



and safety programmes. Today, it is possible to provide a high-quality service to passengers, with a minimum headway based on system integration, rolling stock, SCADA (Supervisory Control and Data Acquisition), operation control centres, expert control systems, signalling, automatic fare collection, traction power, ventilation, and emergency management.

Good station and interchange design makes the passenger's journey more efficient and comfortable. Fares integration and contactless cards also make life easier for urban transport system users.

New and existing networks are developing solutions based on sustainability. Examples include: using braking energy from the train; using the ground around the built infrastructure to cool water for HVAC systems; using water drained in tunnels and stations for irrigation; vibration and noise mitigation solutions.

The systems and methods that are used today will also be improved and developed, adapting them to new and more demanding safety, quality and risk-reduction requirements. In this sense, closer attention will be given to soil modelling, calculations defining the tunnel-soil interaction, monitoring in real time the soil movements and the structures located around tunnel and caverns, as well as the precise modelling of passenger movements (both in day-to-day and emergency operations) and the risks associated with fire and smoke. Signalling and traffic control systems will also be improved, as will train maintenance cycles.

Looking to the future of metros, the International Association of Public Transport (UITP) highlights unattended train operation (UTO). Hans Rat, UITP Secretary General, has stated that, "We predict that, by 2020, 75% of all new metro lines will be

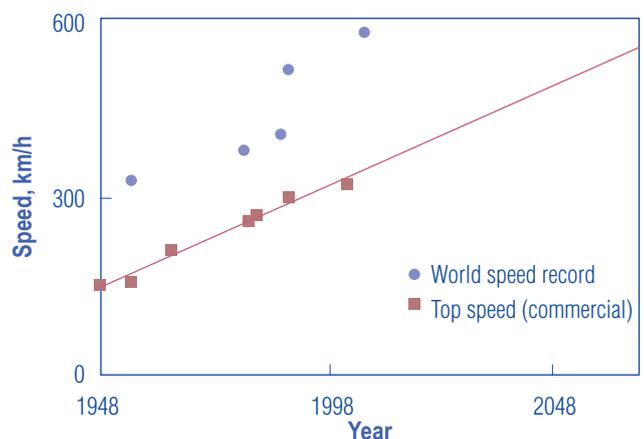


Fig. 18 - Commercial rail top speeds. Source: Oskar Fröidh.

designed for UTO, and that 40% of all lines undergoing refurbishment will be upgraded to UTO operation.”

## Many new challenges

With regard to high-speed rail transport, Fig. 18 shows how the top speeds for commercial operation have increased over the last 60 years – and how they may increase in future decades. If speeds are to increase above current levels there are a number of technical issues to be addressed, that involve braking, track loading and ballast behaviour, maintenance, stability/vibration/comfort/air-tightness, aerodynamics, and environmental noise and acoustic comfort.

The alignment requirements of high-speed railway lines result in more and lengthier tunnel sections. Going through tunnels means putting passengers under significant changes of pressure. This feature has highlighted new challenges concerning the air-tightness of rolling stock and variable cross-sections depending on the speed.

There are other technological advances that have not yet taken root. For example, there are trains that use magnetic induction (the ‘maglev’ system and others) that have been under development for more than 40 years (long stretches of experimental lines have even been constructed, mainly in Japan and Germany). However, magnetic levitation has not yet been generally accepted, and currently the only line with passenger traffic is that which links Shanghai to its airport. The trains cover the distance of more than 30 km in some eight minutes, at a maximum speed of 430 km/h.



Although it is run as a demonstration, it has been in use commercially since January 2003, with trains every 15 minutes in both directions at peak times. This technology suffered a serious blow in Germany, one of the countries which had made most progress in the field, when construction on a line joining Hamburg to Berlin was stopped because of its high cost, with consequential doubts as to its profitability.

Another challenge is interoperability. The diversity of systems and regulations is a serious obstacle to communication between the networks of different countries. The European Union has tackled this problem by implementing Technical Interoperability Specifications (TIS) for the high-speed trans-European rail system. The result of this is the unified control-command and signalling subsystem called ERTMS (European Rail Traffic Management System), which is already, or is becoming, a reality on several high-speed lines such as Austria-Hungary, Holland-Belgium and Spain-France.

These technological innovations, and others yet to be developed, will help maintain rail, with its low energy consumption and CO<sub>2</sub> emissions, as an increasingly important mode of transport in the decades to come.

## Road transport

As the most widespread means of transporting goods and people, roads are the dominant facilitator of intra-national travel and continue to play a highly significant role in travel between continents.

As captured in Table 5, the strong association between established road networks and socio-economic development is evident, especially for

the least economically developed countries (LEDC's). As the most accessible transport mode for the poorest people, roads provide vital links for trade, healthcare and education. However, the construction of road networks in developing nations, where there is much competition for infrastructure funding, warrants a similar level of consideration to that mandated by the planning process in economically developed nations.

**Table 5 - Road development by nation**

Country	Human Development Index 2005	Land area km <sup>2</sup>	Population million	Length of paved road km	Length of paved road per capita m	Length of paved road per km <sup>2</sup> km
Democratic Republic of the Congo	0.411	2,267,600	66.5	2,794	0.04	0.001
Bangladesh	0.547	133,910	153.5	22,726	0.15	0.17
India	0.619	2,973,190	1,148.0	1,449,560	1.26	0.49
China	0.777	9,326,410	1,330.0	1,575,571	1.18	0.17
UK	0.946	241,590	60.9	398,366	6.54	1.65
USA	0.951	9,161,923	303.8	4,209,835	13.86	0.46

Source: IRF World Road Statistics 2006.

For countries with fast-growing economies and burgeoning foreign investment it remains vital that the road infrastructure keeps pace and does not throttle development; hence high capacity, high-speed national networks are the priority. Whilst these national roads form the main political showpiece for a country's success they must be integrated into the rural road network in order to maintain the large, agile labour market on which growing economies thrive.

Economically developed countries are characterised by extensive road networks, from local roads which are typically paved and accessible in all weathers, to large national and trans-national motorway networks. Road building tends to have levelled off, and energy is now focused on managing the road network, demand for which does not tend to be evenly distributed over time. In parallel with this challenge, significant work is underway to mitigate the effect of road transport on climate change.

Multi-modal connectivity and a 'joined up' integrated approach to transport development is required to enhance the sustainability of future networks, and this must continue to recognise the economic and social benefits of roads.

## Least economically developed countries

Road development in the least economically developed countries may be limited by a number of factors, summarised by The World Bank as: poor cost recovery; corruption; insufficient competition; poor credibility of institutions.



### Africa: Trans-African Highways

The Trans-African Highways project consists of nine primary corridors totalling approximately 52,450 km of road with 2015 as the target date for substantial completion. Key objectives are to provide all-weather links between capital cities, to link regions of production and consumption, and to increase regional and continental cohesion. Roads in Africa account for approximately 80% of freight and passenger traffic but developing a trans-continental road network has highlighted many national discrepancies in road design. For instance, carriageway widths vary between 6 and 7.5 metres and design axle loads vary between 8.2 and 13 tonnes. In spite of the road network's continuing physical development, its use (and associated economic growth) has been stunted by political issues such as slow border crossings, local taxes, road blocks (sometimes legitimate, but usually often not), and the harassment of passing traffic.

Some of the most high-profile road projects are promoted or funded by commercial operations. For example, roads in Libya have been developed to serve the oilfields and are now being extended to serve coastal tourism; this also creates infrastructure for use by the general population. The *Trans-African Highways* (see insert) highlights the scale of development required to connect a continent.

The availability of skilled resources and knowledge of design codes is a fundamental consideration when constructing and maintaining roads in developing countries. Where foreign contractors are involved there is a knowledge transfer opportunity (see insert *Bangladesh: The UK Friendship Bridge*). This need not be limited to technical details but can cover management aspects, techniques for operating and maintaining the road, and corporate and social responsibility.

Key issues for future roads in the least economically developed countries are:

- Import the latest advances in high quality mechanised construction, to overcome skills gaps.
- Develop codes and standards for roads to ensure that designs are robust and able to resist unforeseen climatic events.
- Improve the management and the dispersal of aid and commercial revenue, using established techniques such as the Highway Development and Management Model developed by The World Bank.
- Progress the development of all-weather rural roads to extend the benefits of national highway projects to a wider community.



### Bangladesh: The UK Friendship Bridge

Built between 1999 and 2002, the 1.2km UK Friendship Bridge replaced ferry services across the Meghna River to connect the capital Dhaka to the Sylhet region. Funding came from the Bangladesh government, a bank loan and a UK Department for International Development grant. A toll charge will repay the bank loan and fund maintenance. Design and construction used both British and Bangladeshi expertise. Toll collection has been subcontracted to a Malaysian firm and maintenance is carried out by a Bangladeshi contractor. In addition to improving local connectivity, the bridge has facilitated knowledge transfer (for example, maintenance contractors follow an inspection model based on that of the UK Highways Agency). Social impacts were mitigated by providing appropriate inspection manual compensation under a broad approach that has educated local highway staff in several critical areas such as resettlement management.

## Emerging economies

The rapid development of the emerging economies has led to dynamic funding and procurement programmes. Capital projects may be facilitated by development grants, the national roads budget or private finance, although development funds normally diminish as economies strengthen. The *Golden Quadrilateral Highway* project in India (see insert) uses government spending for both capital and maintenance to stimulate the economy while China has encouraged private investors to build and operate its rapidly expanding expressway network (see insert).

Improvements to the quality of the road network are echoing increased mobility in the economically emerging nations. For example, the planned US\$2,500 Tata Nano car will make motorised transport available to a new generation of India's middle class, but inevitably raises sustainability considerations. However, the impact of road development goes beyond the traffic levels generated. For example, in Brazil in 2008 paving of the BR319 highway into the Amazonia region had to be suspended while adjacent forest areas were granted protection from deforestation.

The number of road deaths occurring in emerging economies is a serious cause for concern; fatality rates per 10,000 vehicles are around 1-2 in developed nations but may be as high as 25-30 in poorer nations. There are a wealth of approaches to tackling this. Of particular note from developed economies is the emphasis on raising driving standards through improved education as well as promoting the use of seatbelts and safety helmets. Road design also plays a significant role: sufficient space and segregation for the different traffic user types are undoubtedly the most important parameters.

Key issues for future roads in emerging economies are:

- Development should be timed in accordance with economic growth and positioned to maximise reach.
- The scale of development should not outstrip the future ability to manage and maintain the asset, particularly with respect to securing revenue streams.
- Rapid growth in networks and traffic demand a proactive approach to road safety through appropriate governance.

## Economically developed countries

Where a well-developed road network has been established, managing and optimising use is a key issue. Demand can be managed through both pricing mechanisms and the control of infrastructure. Advances in technology have increased the options available for controlling road space via remote changes to speed limits and the opening and closing of lanes. Hard



### India: Golden Quadrilateral Highway

The Golden Quadrilateral Highway (GQH) is a US\$30 billion project linking the cities of Delhi, Kolkata, Mumbai and Chennai with approximately 5,500 km of dual carriageway. Begun in 2000, the network aims to strengthen India's economic development by bringing millions of people within easy reach of urban centres. In addition to social ambitions, the GQH is designed to be compatible with electronic tolls and incorporates sensors in the road surface to relay maintenance information.

The project has not been without its difficulties. Construction has over-run by two years owing in part to land ownership wrangles at the state level. The project is also over-shadowed by recriminations of poor performance by some contractors. The usage pattern, which envisages pedestrians and ox carts sharing the road with tourist coaches and large goods vehicles, as well as private cars, has led to the GQH accounting for one-third of India's traffic accidents. Nevertheless, the GQH's dual carriageway arrangement is typically safer than the single carriageway roads it supplements.



### China: rapid road development

China's National Trunk Highway System is now second in length only to that of the USA. The expressways making up the heart of the network tend to be privately financed and operated and are funded by toll revenues. These roads have been constructed at a fast rate, with 4,000 km added to the network in 2005 and over 3,000 km in 2006. To complement the network, rural roads connect villages and communities to the expressways.

The Minister of Transport has declared that over 300,000 km of rural roads will be built or renovated in 2009. Fuel tax reforms in 2008 brought an end to tolls on government roads and to motorists contributing directly to maintenance funds; revenue is now raised through taxes on the (government controlled) price of petrol and diesel. Chinese authorities see this as a positive step towards the 'polluter pays' principle.



## Europe: hard shoulder running

The Netherlands and Germany have well-established semi-automated hard shoulder running programmes. Capacity improvements of approximately 20% are claimed using the system, with no reduction in road safety and continuing strong public support. However, both countries view hard shoulder running as a short-term solution. In The Netherlands, it is part of the overall Intelligent Transportation System and is supported by other traffic management schemes such as ramp metering and tidal flow lanes.

In Germany, hard shoulder running is viewed as a stop-gap until over 2,000 km of conventional widening projects are delivered (it should be noted that over 1,200 km of traffic management on existing motorways is also planned). In the UK, hard shoulder running has been judged a success on a pilot project and the government has announced a wider roll-out to realise capacity improvements, with lower fiscal and environmental costs compared to conventional widening.

shoulder running shows how these changes have been deployed (see insert). Congestion charging uses the market as a lever to control demand, and whilst it generally covers urban centres, application to inter-urban routes is already underway for freight traffic in Germany and Austria.

Developed countries are beginning to address climate change through their roads programmes. Emissions from road transport account for over 10% of total greenhouse gas emissions. Demand management leading to improved traffic flow plays a part in reducing emissions; developed nations are looking increasingly at congestion pricing models as ways to reduce both use and emissions. In addition to shaping traffic patterns to contribute to climate change mitigation, construction and maintenance standards may need adapting to maintain the road network's integrity in the face of future climatic trends. The roads of the future must be resilient to environmental and technological change in order to minimise their whole-life cost and maximise sustainability.

Private sector finance is used increasingly for roads, both to manage and maintain the asset and to enhance the network. There are many examples of well-executed privately funded projects which enhance national road infrastructure. Funding gaps for



## USA: under-investment

The tragic failure of the Interstate 35 West bridge over the Mississippi River in 2007 symbolised the under-investment in US highways. These main roads support up to three trillion vehicle miles annually, although journeys have fallen in recent years. While built with largely federal funding, the majority of operating costs and management decisions are now met at state and local levels. It is recognised that the USA has under-invested in roads.

The current annual maintenance spend is US\$70.3 billion, but the American Society of Civil Engineers estimates that US\$183 billion is required to return the asset to a good condition. The USA has committed 2.3-2.6% of GDP for spending on infrastructure, whilst the European Union spends 5%, and Japan 10%. The fiscal stimulus package announced in early 2009, although focused on a large number of relatively low-key projects, is anticipated to go some way towards improving the condition of the USA's road network.

maintaining roads from the public purse have led to some high profile deficiencies; the insert on road maintenance in the USA illustrates this.

Knowledge gained on innovative solutions engineered for developed countries must continue to be incorporated into the expansion of the growing road networks in the developing world.

Key issues for future roads in economically developed countries are:

- Roads are much more than the physical asset (for example, aggregates and asphalt); technology systems facilitating improved management are now central to optimising their use.
- The demand for finance to build and maintain roads is increasingly being met by the private sector.
- Inter-connectivity of roads with other transport modes is central to efficiency; better integration of urban and national traffic control is required and multi-modal journeys need to be facilitated.

## Air transport

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Aviation both facilitates and is driven by global trade. Air transport has arguably contributed more than any other form of transport to the globalisation of the world economy and helped create a global village.

Much of the last decade saw sustained growth for air transport as economies worldwide expanded rapidly with particular focus on the Asia-Pacific region and China. As recently as 2007 the International Civil Aviation Organisation (ICAO) predicted an annual average world growth in GDP to 2025 of 3.5% driving an annual growth of 4.6% in passenger demand.

After this sustained period of growth air transport is facing uncertain times. Falling passenger numbers are weakening balance sheets and removing the imperative to expand. Airlines are significantly loss-making and a number have failed. Airports are struggling.

While long-term forecasts inevitably envisaged variation around a long-term trend, the speed with which the short term has varied from the trend was not foreseen by most within the industry. The International Air Transport Association (IATA), the worldwide airline trade body, has predicted that passenger demand will be 8% down in 2009 on 2008, and cargo volumes are reported to have fallen by over 20% compared to the same month a year earlier for five consecutive months.

The short term is directed towards reducing over capacity and making efficient use of existing infrastructure. However, underlying forecasts continue to predict medium-term growth and a long-term shortfall in airport and airspace capacity in particular. For example, updating its 2007 forecasts in June 2009, ICAO predicted a global contraction of 3.8% for 2009 followed by 3.3% growth in 2010 and an above trend growth of 5.5% in 2011.

Thus while the current difficult economic climate is presenting challenges to both airports and airlines (who made a collective US\$ 9.8 billion loss in 2008, with 2009 forecast to be worse still, compared with a record US\$ 19.7 billion operating profit in 2007), the trend remains for long-term growth.

A number of interrelated key issues face the industry including:

- rising costs (e.g., fuel for airlines, security for airports);
- lack of system capacities (airport and airspace in particular) and restrictions on their expansion either from planning systems or environmental concerns;
- changing airline markets, at least partially driven by the rise of the low-cost carrier;
- environmental pressures.



Whilst the current reduction in demand has relieved the pressure on some of these aspects, perhaps airport capacity in particular, these issues will still confront the industry for many years to come. Most importantly, aviation faces ever mounting challenges over its environmental impact.

Climate change, and the industry's growing contribution to global carbon emissions, is focusing world attention on the industry and highlighting the balance to be created between air transport's facilitation of globalisation and its impact on the environment.

In the developed world, airport expansion is increasingly contentious with tighter environmental constraints forcing ever greener development proposals. For the developing world the construction industry's capacity to deliver the demanded additional capacity is perhaps the most significant constraint to further growth.

### Rising costs

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2008 saw the oil price peak at US\$ 147/bbl in July. This record high price substantially increased airline costs, but the price dropped to a low of US\$ 34/bbl in December 2008. Airports, particularly following 9/11 and the threat of liquid explosives first identified in London in August 2006, had to invest significantly in technology, infrastructure and staff to effect tighter security.

With current fuel and engine technology airlines are particularly exposed to oil prices. During the peak in 2008, fuel represented up to 40% of a typical airline's cost base. Recently, oil prices have risen again, though currently to less than the peak of 2008. Higher fuel prices coupled with slowing worldwide demand would further weaken airline finances, although some commentators would argue that if higher prices led to consolidation of airlines or more fuel-efficient aircraft, the medium-term gains might be worth most of the short-term difficulties.

Airports have invested significantly in security measures. These have required one-off investments in infrastructure (facilities to segregate passengers, additional security checks, protection of set-down roads, etc.) as well as increased operating costs for higher numbers of security staff. These additional costs, again combined with lower revenues from fewer passengers, are reducing or removing airport margins and limiting their ability to invest in

increased capacity. In the medium-term technological solutions are addressing many airport costs from security to baggage handling.

### System capacities

Whilst it could be argued that the airlines over-provide capacity, airports and airspace, particularly at the busy city centres, are under-provided. If unresolved, these capacity constraints will act as a brake on growth.

The world can perhaps be viewed in terms of two broad groupings: the economically developed world (that is Europe and North America), and the economically developing world as exemplified by India and China. The constraint to the developing world is the speed with which new infrastructure and indeed wholly new airports can be constructed. Currently 11 airports in the world handle over 50 million passengers per annum, only two of which, Beijing and Tokyo, are in the Asia-Pacific region. The Hong Kong Airport Authority forecasts that the region alone will have ten such airports by 2020, eight of which will be in China. None of these airports currently exists. It is also noted that one-half of the world's population lives within a five-hour flying time of Beijing.

The developing world also needs to address the sometimes chaotic situation at airports striving to cater for traffic for which the facility, operations and staff are not equipped. The arrival and departure processes can be confusing with a lack of adequate signs, inadequate transfer facilities, poor surface access, inefficient air traffic control systems, ill maintained equipment, and shortcomings in disaster and emergency planning.

The developed world's challenges can be summarised as achieving more with less: maximising the use of current capacity and building new capacity within tighter environmental and planning constraints. In 2008 the European Organisation for the Safety of Air Navigation (Eurocontrol) forecast that by 2030 the number of flights within Europe will be 1.8 times the number in 2007 and that, even with planned expansion, capacity across the region will be 11% lower than demand: some 2.3 million flights per year will not be accommodated and 60 airports across Europe would not meet their demand. These growth figures assume that national regulators increase controls to limit environmental impact. Uncontrolled growth would be up to 2.2 times current levels, with demand exceeding capacity by 25% in 2030.

This under-provision of capacity exists in spite of a 41% planned increase in system capacity by 2030 including 29 new runways across Europe. All these developments will face tougher planning restrictions at a local level, with the environmental impact of development more closely scrutinised than previously.



### China: a rapidly expanding domestic market

The current slowdown aside, China's aviation industry is undergoing major expansion and growth. On current projections China's domestic market will overtake Japan's to become the second largest market in the world behind the USA, potentially as early as 2010, growing to 950 million annual passengers by 2020. To serve this growth China plans to increase the number of airports from 192 (in 2005) to 244 by 2020, continuing its expansion at three new airports opened per year. This number of airports would mean that by 2020, 82% of the population, contributing 96% of the country's GDP, would live within 100 km of an airport, compared to 61% contributing 82% of GDP currently.



### Heathrow Terminal 5 - Beijing Terminal 3

Both terminals were opened in March 2008. Heathrow T5 (see photo) is the largest free-standing building in the UK: Beijing T3 is 17% larger than all Heathrow's five terminals combined and was, until Dubai opened its new terminal in October 2008, the largest airport terminal in the world. T5 opened 19 years after it was first proposed, 15 years after submission of its planning application following, at four years, the longest Public Inquiry in UK history. T3 was built in four years following an executive state decree and at, it is claimed, half the capital cost of T5.

The findings were also based upon the assumption that en route airspace capacity could be expanded to accommodate demand as necessary. The achievement of this assumption is based upon the European Commission's Single European Sky initiative that is seeking to reform the structure and management of Europe's currently inefficient airspace.

Airspace restrictions similarly apply in busy city areas across the world, for example New York where the US Federal Aviation Authority plans to have implemented the New York/New Jersey/Philadelphia Airspace Redesign project by 2012, covering five states and 21 airports. The four largest airports in the region currently handle 8,000 flights per day and are among airports in the USA with the most delays.

## Environmental impact

Although debated, globally, aviation represents only 2% of man-made carbon emissions. However, whilst other sources of emissions are reducing, aviation's contribution is forecast to increase to 3% by 2050. In developed countries, aviation's contribution to the national total is significantly greater than 2%.

Within the context of airport development it is likely that increasingly, particularly in the developed world, the environment will be seen as a capacity constraint in the same way that runway or terminal capacity limits growth.

Airport infrastructure can arguably be developed to be carbon neutral, at least through the use of carbon off-setting. Across the world airports are developing strategies to reduce their environmental impact and are preparing environmental master plans to supplement their technical and operational plans. The concept of a 'green' airport is starting to take hold. The airports making up the Airport Council International (ACI) Europe agreed in 2008 the Airport Carbon Accreditation scheme committing the airports to the aim of carbon neutrality from ground operations.

The impact of rising energy costs has also made energy efficiency and sourcing renewable energy a priority. The solar power facility at Fresno Yosemite International Airport is the largest solar power system in the USA and will meet a forecast 40% of the routine power requirement of the airport for lighting, air conditioning, control, and tower communications.

By contrast, however, aircraft activity remains a significant contributor to carbon emissions. Current and reasonably foreseeable technologies are not alone believed sufficient to reduce emissions, although aircraft and engine manufacturers and fuel suppliers are developing alternative technologies. In June 2009, IATA pledged to stop the growth in aviation's emissions by 2020 and have cut emissions by 50% by 2050. Within Europe, airlines will be included in the European Emissions Trading Scheme from 2012, while debate is ongoing regarding the appropriate level of free permits and how international flights are included.

Although in the very early stages of development, promising steps have been taken by aircraft manufacturers in the use of fuel cell



technologies (hydrogen cells). Hydrogen fuel cells have been tested successfully on small aircraft such as unmanned aerial vehicles and, more recently, piloted aircraft. Typically fuel cells convert chemical energy into electrical energy without combustion with only water as a by-product, making it a zero-emission technology. The technology is a long way from the stage when a commercial aircraft could be totally powered by fuel cells. However, in the medium-term, at least a part of the electrical requirement for lighting, in-flight entertainment, heating, and communications could be met through an auxiliary power unit running on fuel cells thus reducing total emissions.

### Europe: The Single European Sky



European airspace is already fragmented and increasingly congested. Individual states are providing independent national air traffic control that forces aircraft to fly inefficient routes, increasing operating costs and environmental impact. The Single European Sky initiative seeks to overcome the lack of cohesive decision-making across national borders and replace the current system with a single, unified structure to improve safety, efficiency and capacity, reduce delays and reduce emissions. These objectives are to be achieved by a more effective airspace structure with an integrated management architecture based upon new and more efficient technology.



### Narita International Airport Eco-Airport Master Plan

In 2002, the Narita International Airport, Tokyo, developed an Eco-Airport Master Plan setting targets to reduce greenhouse gas emissions and air pollutants as well as for waste recycling and other reduction targets. The airport made seven 'Eco-Airport' Commitments to reduce its impact to the lowest reasonable levels. To meet the targets a number of initiatives were introduced including the development of noise mitigation measures, the use of energy efficient light emitting diodes for taxiway lights, the promotion and use of ground power units over auxiliary power units, the re-use of old pavement materials, the installation of solar panels on the terminal building and the introduction of a cogeneration system, a thermal storage system and a rainwater treatment plant amongst others. Today, these measures are becoming commonplace, but in their day the initiatives were forward thinking.

## Changing aviation market

Traditionally, and still the case in many countries, aviation was the preserve of state-owned, 'flag carrying' airlines. In 1971, Southwest Airlines in the USA developed the low-cost model that nearly 40 years later has been adopted by first Ryanair, subsequently easyJet and others in Europe, and more recently in the Asia-Pacific region. For the more traditional airlines the rise of the low-cost airline has changed the face of aviation. The price competition on short-haul routes and the consequent reduction in their passenger numbers has weakened their business models. A number of carriers have restructured as 'hybrid' carriers with a low-cost short-haul arm feeding their traditional long-haul markets. Some low-cost airlines are now considering extending their network into these long-haul markets. It is not clear, however, whether the low-cost model can be extended into long haul; it has been tried by a few but, so far, they have failed.



The low-cost airlines have also forced a redefinition of airport facilities. Traditional large gateway airports are ill-suited to the rapid turn-around times fundamental to the low-cost model, and require investment in infrastructure that the low-cost airlines perceive as adding unnecessarily to their cost base. In response, a number of regional airports are being developed specifically to meet the needs of low-cost airlines, and low-cost terminals have been built at otherwise traditional airports. Recent notable examples include the Air Asia terminal in Kuala Lumpur, Jet Blue's facility at New York JFK and Frankfurt Hahn for Ryanair.

## Maritime transport

This section on maritime transport covers the three global segments of the industry, namely container traffic, liquid bulk and dry bulk. There are of course other segments such as cruise ships, ferries and general cargo, but by definition these tend to be regional rather than global.

At present the maritime transport world is still reeling from the effects of the global economic downturn. The effects on world trade have been profound and will continue to be so for some time to come. Shipowners have laid up thousands of vessels whilst ports around the world are experiencing hard times. The container and bulk cargo sectors have been particularly badly affected.

### Container and liquid bulk markets

In recent years the world of freight transportation has seen a significant modal shift towards containerisation for finished products and goods. International container terminals have experienced double digit growth year-on-year with the largest terminals in Asia-Pacific region moving in excess of 20 million containers per annum. The ever-larger vessel sizes and requirements for larger and faster cranes has challenged the engineering community to develop new terminals to accommodate these colossal vessels, each of which can carry more than 12,000 containers.

For the dry bulk materials market, there has been a major boom in ship building to accommodate an increased coal and iron ore trade, largely from Brazil and Australia to China. This, in turn, has precipitated expansion of the existing terminals in the export countries and the construction of new terminals in China.

In the liquid bulk trade, the crude oil and petroleum shipping market is reasonably mature in terms of overall tonnage of products shipped. Ship building therefore has been mostly driven by regulations regarding the phase-out of single-hull tankers and their replacement with double-hull tankers. However, there has been an unprecedented expansion of the liquified natural gas (LNG) business, resulting both in large numbers of new carriers being built and carriers effectively doubling in size over the past three years.

### Terminals to be upgraded

The emphasis had been very much on keeping pace with the ever-increasing demands of the carriers and the exponential increase in volume. To address the forecast volume increases for containers, dry bulk and LNG the shipping industry reviewed vessel capacity and invested heavily in new-build orders, moving the bottleneck from the ships to the terminals. The infrastructure providers responded admirably with a significant number of new terminals brought online in the past decade, many funded by operators, investment banks and private equity shareholders.

With the downturn of the global economies at the end of 2008 and the associated significant slowdown in international trade the industry is reporting an overall drop in container terminal throughput of between 10% and 25%, depending on the specific location. Many of the major new proposed developments have been suspended pending internal review, and many others have had their budgets reduced or withdrawn by the investors. The industry is refocusing on the assets in hand and looking for efficiencies within its operations. The use of automation continues to grow in popularity, with many more

schemes looking at upgrading and conversion to rail-mounted automated stacking in the container yards.

## Dry bulk shipping to stabilise

The dry bulk industry has also suffered from the global economic downturn. 2008 was a year of records for the industry, going from the highest daily charter rates in history in July to some of the lowest by the end of the year. The Baltic Dry Index, an index of sea transport charter rates for bulk carriers which is believed to provide a good picture of global demand for bulk commodities, also had a record year in 2008 going from well above 11,000 points midyear to below the 700 point level in December.

A slow return to a more normal dry bulk market is expected. However, the current volatility does not provide clear visibility as to when the current turmoil will end. On the demand side, any positive developments for the dry bulk industry will depend on China's appetite for infrastructure development. Both the Chinese and Indian economies are expected to remain the key drivers and consumers of dry bulk commodities. Inventories are at lower levels today than a few months ago, the scrapping of older ships is accelerating, and the shortage of financing has led to a number of new-build cancellations. These trends are likely to contribute to slowly restoring a more balanced supply and demand equation for shipping.

## Future developments

On the supply side, infrastructure development also came to a halt in 2008. However, the slow return of key economic fundamentals and the extraordinary financial performance achieved by the global mining giants over the past few years has led to a surplus of cash being spent on acquisitions and new exploration. There is renewed interest in new facilities in Latin America and eastern Africa. Now that demand is likely to slowly increase over the next few years, operators are taking the opportunity to start planning new facilities in these regions. The current low charter rates are creating a window of opportunity to link cost cutting on the mining side with more efficient production and export terminals. Increased competitiveness from Brazilian, Chilean, Colombian, and eastern African fields is likely. Efficient production and exportation could very well become a key element for the medium term as shipping rates stabilise to more traditional levels.

For the LNG business, there is still a relatively high level of activity in the construction of both export terminals (and the liquefaction units to produce the LNG) and import terminals. This is driven by the considerations that LNG is a desirable fuel source for electrical power plants owing to its clean emissions, higher public acceptance (as compared to nuclear), pricing advantage relative to fuel oil fired plants, and



greater security of fuel supply (as compared to gas supplied from Russia via pipelines to eastern and western European countries).

The challenges going forward are a little less clear than they were perceived only a few months ago, as the world is a much less certain place. In the words of one British explorer, "Gentlemen, we are stepping off the map." The industry anticipates greater levels of due diligence and business planning prior to the commitment of project funding. The caution which will characterise project investment will provide additional time to seek answers to the difficult questions, and greater rigour can be expected in the evaluation of new capital investment ventures.

It is interesting to note that in South America, economies which have taken it upon themselves to stand on their own two feet owing to lack of support from the banking world appear to be faring more favourably and may provide a fertile ground for investment opportunities and renewed interest by the money markets.

During this period of contemplation and reflection by the maritime sector, the importance of preparing or updating port master plans will be particularly valuable. The UK's Department for Transport guidance on port master plans notes particularly the need for stakeholder engagement and the value that can be attained by early dialogue – a dialogue that is facilitated by consulting engineers.

How world trade will react to the much anticipated Panama Canal Expansion remains to be seen. What is undoubtedly true is that the world is witnessing a shift in trade patterns, with an inevitable diversion of cargo from the Atlantic to the Pacific coastlines of the Americas.

There are clearly still some difficult times ahead but there are no shortages of projects, only a shortage of funding. Time will tell how quickly money begins to flow once more and the industry returns to the volumes seen in early-2008.

## The engineer's response

### Rail

The engineering community has played a significant role in the continuing development of rail, both high-speed lines and metros, together with the innovations currently being considered which will help maintain rail as an increasingly important, and safe, mode of transport.

### Roads

Roads represent a major investment for most countries, with engineers called upon to ensure that skills and knowledge are transferred to regions where they are required. The availability of skilled professionals and a knowledge of design codes is a fundamental consideration when constructing and maintaining roads in developing countries. A proactive approach to road safety through appropriate governance is a priority everywhere, and engineers will continue to contribute in this vital area. The industry and its partners are also beginning to address climate change and its impact on road networks. Finally, engineered systems to facilitate improved management are now becoming essential for optimising road use.

### Air

In the developed world, airport expansion is increasingly

contentious, with tighter environmental constraints forcing ever greener development proposals. For the developing world, the construction industry's capacity to deliver the demanded additional capacity is perhaps the most significant constraint to growth. For both aspects, the engineering community lies at the heart of both the direction air transport should take and the techniques for delivering the long-term solutions.

### Maritime

The engineering community continues to develop new and innovative solutions in the maritime sector. Close working relationships with shipping lines and terminal operators promotes the common goal of efficiency and sustainability. More rigour and a greater level of due diligence and business planning prior to the commitment of project funding can be expected.

The engineering community also has a major opportunity to contribute to structuring projects in the dry and liquid bulk sectors. This is because projects are complex, involving a variety of elements from the production centre to the export terminal. A lack of structure has led to poor risk management and continues to create delays and shortfalls in most regions.

# Buildings and the Built Environment



Buildings and the built environment have long been symbols of prosperity and growth. A large proportion of private equity is tied up in buildings, although in many parts of the world much of that equity is held by only a few. The quality of buildings and particularly of dwellings clearly differentiates between haves and have-nots, developed and less developed, favoured and less favoured. Ownership models vary considerably and this too has consequences relating to quality, location, energy efficiency, and implications for the environment.

Buildings are responsible for on average 30% of total energy use and associated greenhouse gas emissions in society, both in developed and developing countries. The energy is mainly consumed during the use stage of buildings for heating, cooling, ventilation,

lighting, appliances, and vertical transport. Only a smaller percentage, normally 10-20%, of the energy consumed is used for materials manufacturing, construction and eventual demolition.

The potential for a drastic reduction of the energy consumption in buildings is significant. With proven and commercially available technologies, the energy consumption in both new and old buildings can be reduced by 30-50% without significantly increasing the investment costs of either new construction or renovation projects. The Intergovernmental Panel on Climate Change (IPCC) stated in its fourth assessment report that the building and agriculture sectors have the largest potential for significantly reducing greenhouse gas emissions.

## The current situation

### The role of technology

Engineering expertise has helped provide the material quality of life that developed communities enjoy. In combination with cheap and readily available but primarily non-renewable energy it has enabled humans to populate areas where the natural environment would otherwise not be conducive to dense occupation. An estimated 30% of the world's energy usage now goes towards acclimatising buildings (air, light and heat) and vertical transportation.

Improvements in structural engineering knowledge and related areas leading to stronger, lighter materials, sophisticated computer modelling and analysis, greater predictability of natural hazards, and improvements in construction systems and techniques have led to safer, taller and grander structures. Similar developments in mechanical and building services engineering have resulted in improvements in vertical transportation and internal climate control to match the structural innovations.

In the less-developed world, particularly away from major centres, poverty is often coupled with

a lack of technical knowledge (and the lack of technology transfer) resulting in the ongoing propagation of substandard building stock. This is particularly apparent in relation to the technology available for minimising the effects of natural hazards such as earthquakes. For example, in the developed world seismically prone areas benefit from considerable improvements in engineering knowledge relating to seismic design and codification. In poorer areas, new building (and re-building following earthquakes) continues to be carried out with little or no consideration or knowledge of seismic resistance, with the result that disasters of the past are inevitably to be repeated once more.

### Urbanisation

An incredible rate of rural to urban shift has occurred over the last 100 years, with the world's urban dwellers making up 13% of the total in 1900, 30% in 1950, 50% in 2008 and a predicted 60% by 2030. This has created both considerable material growth and considerable poverty. A consequence of this urban growth has been 'urban spread' or 'suburbanisation': the conversion of productive rural land into low density

housing with a reduction of rural productivity and increased demands on urban transport and other infrastructure. Uncontrolled and unplanned expansion, particularly in the less-developed world, has resulted in social problems, inadequate infrastructure and the destruction of many, if not the majority, of natural habitats and heritage sites.

Many would say that inadequate housing is at the root of many, perhaps even most, of the social, economic and health problems that plague third-world communities. Attempts at urban intensification have had mixed results with some very good and some very poor examples, with success being measured primarily on a sociological scale. Attempts to create high density, low cost, public housing without due consideration of social impacts have typically been unsuccessful. Poor examples include high rise housing estates constructed in the 1960's and 1970's without adequate open space, and without access to employment, recreation and social services. Better examples include some of the compact Asian cities that are confined by natural boundaries.

## Planning

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Globalisation in the industrial and manufacturing sectors and improvements in productivity and technology have left many cities with underutilised industrial areas or in some cases wastelands. Lack of good engineering advice and

effective planning and environmental controls has led to haphazard, unsustainable and at times unsafe growth, particularly in less-developed cultures. Buildings are poorly sited and/or have inadequate resistance to natural hazards. The consequences of this can all too often be seen when natural disasters occur (for instance, earthquakes or flooding) and what should be survivable events not unsurprisingly become large-scale humanitarian disasters.

## Climate change and sustainability

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The potential effects of climate change on buildings are generally not well understood. Wind loadings are expected to change dramatically in some latitudes, as are ambient temperatures. Rising sea and groundwater levels in coastal areas will result in some dramatic consequences over the next 100-200 years. There is a growing awareness of sustainability and energy efficiency issues as related to buildings and the built environment, particularly in the developed world. However, effective actions to date are really only scratching the surface of true sustainability. In the developing world, where the gap between energy supply and demand is increasing rapidly, the lessons and new technologies relating to sustainability and energy efficiency are not being applied owing to the lack of regulation, investment and technology transfer.

## Future developments

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### Sustainability in buildings

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The concepts of 'zero carbon' and 'zero waste' are being adopted for buildings in many parts of the world. These are good starting points, although the boundaries need to be pushed effectively towards carbon extraction/banking. The construction materials sector is developing arguments to demonstrate the sustainability and energy efficiency of its products, yet there is little objective advice as to the true, relative comparisons between competing products.

The design life of buildings and structures is typically too short when considered against sustainability objectives. In particular, locking up for long periods materials that either contain carbon or have consumed much energy in their production is clearly desirable.

With current energy costs, energy efficiency is typically not a primary economic driver for commercial construction. Until life-cycle energy efficiency becomes effectively mandatory, short-term economic return will be the main factor used by decision makers. Along with appropriate legislation, new funding models are needed

to fund projects that have long duration ecological payback periods. For instance, pension funds that invest over the long term are seen as a potential match in this regard since they have the ability to capitalise on long-term payback periods.

### Urban renewal and adaptive re-use

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Urban renewal and intensification (or brown-field redevelopment) need to be led by central and local government. They require strategic planning to coordinate location, transport, access to employment, and environmental renewal. Mixed-use developments incorporating all the components of 'live, work, play, shop' have been demonstrated to be particularly energy efficient, by spreading peak demand and reducing the need for transport systems.

Adaptive re-use of existing structures is a desirable outcome from a sustainability viewpoint, and yet construction economics will often suggest that new-build is more cost-effective. The modern engineer has the skills to refurbish, re-strengthen, re-insulate, re-service, re-clad and even re-locate building structures.

Planning for future re-use should be a core requirement for building design. If not as whole structures then as component parts. In other words, recycle, retain, re-use, recondition, and reduce waste.

## Planning and legislation

The desire for a long building life has to be balanced with an acknowledgement of changing demands, improving and more stringent building standards, and potential climate change effects.

In the developed world, increased knowledge about all aspects of building design and performance, in subjects as diverse as seismic response, sensitivity to wind and other loadings, material durability and toxicity and, importantly, energy efficiency, are leading to more stringent building performance regulations. In a cultural environment that applauds asset growth this helps to satisfy a mature society's demand for increased quality, value, safety, and



sustainability.

In the less-developed world, demands are more basic with accommodation and shelter being the primary driver and sustainability being less of an imperative. However, design can play a vital role here too in applying, for example, simple seismic and/or hurricane wind design principles to basic structures. This can markedly reduce the effects of natural disasters and the dependency of those who frequently have lost both their homes and the ability to feed themselves. The transfer of cost-effective technologies in fields as diverse as sanitation, seismic resistance and sustainability is vitally important for the world's economy.

## Necessary actions

### Legislation

Regional, central and local governments need to work closely with engineers, planners and other design professionals to respond strategically to population growth and develop policies that lead to true sustainability and to environmental recovery.

In the current recession there is a real risk that these issues will be set aside in the interests of economic expediency.

Sustainability, climate change and the use of dwindling non-renewable resources are effectively inter-generation issues and cannot be left to market forces alone.

### Building solutions

Urgently needed are innovative building solutions that meet the required social and planning objectives whilst being energy efficient, sustainable, of high value in terms of quality and efficiency, and remain cost effective.

### Concepts on which to concentrate

There are several concepts which the construction and built environment sector should focus upon if buildings are to meet the needs of future generations:

- Project Sustainability Management
- Urban regeneration
- Adaptive re-use of buildings

- Multi-use development
- Higher population densities; compact communities
- Design for long-life and re-adaptable buildings/structures
- Energy efficiency, both in building materials and energy use over the life of the building
- Long-term social and planning goals
- Improving the resilience of structures in developing countries
- Transferring sustainability and energy efficiency technologies to the developing world
- Respect for heritage and cultural values
- Effective legislative and financial incentives, globally (real incentives for whole-life energy efficiency and sustainability)
- Codification of energy/sustainability principles.

### The engineer's response

Engineers will need to work more closely with regional, central and local governments and other design professionals to develop strategic responses to population growth and policies for true sustainability and environmental recovery.

Engineers will also need to continue creating innovative building solutions that meet social and planning objectives while being energy efficient, sustainable, of high value, and cost effective.

Engineers, along with legislators, should provide the necessary leadership to society to not only improve the lives of the have-nots but also to maintain the standards of living of the developed world.

Finally, it is essential that engineers find better and faster ways to engage in an ongoing and effective transfer of knowledge and technology from the developed to the less-developed world.



# Disaster Risk Mitigation and Adaptation

Over the period 2000-2008, 2,000 million people were affected by natural disasters, with losses of 770,000 dead and costs of US\$835 billion. Most disasters (approximately 90%) were related to extreme weather events. Of particular concern was the fact that the number of disasters has been increasing over recent decades (see Fig. 19), with evidence mounting that climate change is an important trigger via, for example, more intense hurricanes, higher rainfall intensities and heat waves.

Whether climatic extremes ultimately lead to disasters such as flooding, landslides, severe drought, and forest fires strongly depends on the vulnerability and resilience of human societies and natural ecosystems. Factors that play an additional role in the severity of any impacts include unplanned settlements, environmental degradation, urbanisation, industrialisation, and the increased human population in hazard-prone locations.

The impact of natural hazards may be aggravated by factors linked to human activity (for example, intensive socio-economic investment and inadequate technical standards for construction in risk-prone areas). Conversely, technological risks can be

aggravated by natural conditions, with technological impacts adding to natural impacts (power failures are linked to the outbreak of fires; chemical pollution is linked to flooding), illustrating that the vulnerability to natural disasters is often the result of multiple risks.

The impact of disasters on the population varies depending on the type of disaster. In the European Union, disasters caused by extreme temperatures have led to over 75,000 casualties since 2000, representing 95% of all deaths caused by disasters. 76% of these deaths occurred in France, Italy and Spain. Flooding, which killed 524 people in 2000-2008, was more widespread and had high economic impacts. Vulnerability to floods appeared to be particularly high in Romania (38% of the deaths) followed by Italy (15%) and Bulgaria (15%).

With the emergence of climate change and the increase in extreme weather-related events new challenges lie ahead for societies and design professionals. Systems are required that increase resilience to natural hazards, and at the same time are in line with sustainability requirements. New concepts and new paradigms are required which not only incorporate new technologies and innovations, but also

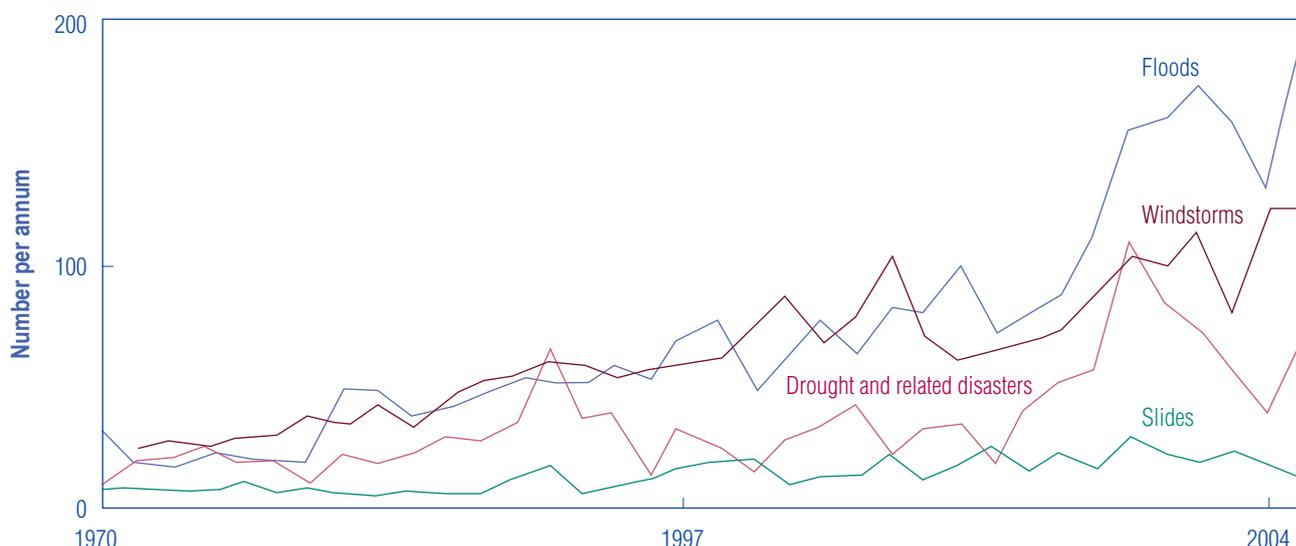


Fig. 19 - Trends in the number of hydro-meteorological disasters. Source: International Strategy for Disaster Reduction, 2009.

consider the governance aspects in the development, implementation and management of disaster mitigating systems. Sustainability and adaptive and mitigative approaches to climate change are therefore important steering elements.



## Paradigm shifts and innovative solutions

### Decentralised wastewater treatment and sanitation

As indicated in the section *Water and Waste Management*, conventional centralised systems for wastewater treatment require huge financial investments, and have relatively high maintenance and operation costs. These costs are a barrier for developing countries to build and operate centralised sanitation systems. Industrialised countries also face huge problems in the maintenance and operation of their sewerage systems and treatment plants. In Latin America, less than 20% of the wastewater collected is actually treated, whilst in the European Union, of 540 major cities, only 79 have advanced tertiary sewage treatment, 223 have secondary treatment, 72 have incomplete primary treatment, and 168 cities in total have either no, or an unknown form of, treatment of their wastewater.

Today's systems of centralised wastewater treatment without resource recovery need a transition to decentralised concepts based on source separation, resource recovery and re-use. Decentralised systems also have the advantage that they help reduce the vulnerability to natural disasters.

Public property often includes critical facilities that should be designed to be uncompromised during a flood or hurricane. Water supply and wastewater facilities that provide for public health and safety are examples of such critical facilities.

For flooded areas, sewage treatment is often the last thing back online, because plants are at the lowest point of the city and thus under the deepest water. One of the post-Katrina concerns during flooding in New Orleans in 2005 was gastrointestinal illnesses from direct contact with floodwaters. New Orleans's two wastewater treatment plants were damaged: the larger facility, which served 1.2 million customers, was flooded; the smaller facility, located on the west bank of the Mississippi River, experienced extensive wind damage.

In general, conventional systems comprising centralised wastewater treatment are relatively more vulnerable to disasters than decentralised units. In decentralised systems the diversity of treatment units, ease of repair, and other factors may make them more resilient than centralised ones, but technology choices and local conditions will inevitably affect comparative resilience.

However, decentralised wastewater systems are not a panacea for all issues. Proper siting, maintenance, management, and regulatory oversight is necessary to ensure their reliability – just as it is for centralised systems.

### Flood protection

In flood protection, the trend is moving from 'safe fail' systems (targetting almost 100% protection) to 'fail safe' systems (if flooding occurs damage will be minimal) and from building against nature to building with nature. This trend can be seen in the management of delta areas as well as in river basin management.

### Delta areas

In delta areas, demographic and economic development leads to growth in the number of people and economic activities to be served and protected. At the same time, the vulnerability of deltas is increasing because of rising sea levels, subsiding soft soils, and increasing pressure on space and the environment. In conventional terms there are basically two options to respond to the increase in vulnerability: adapt land and water use or adapt the infrastructure.

In The Netherlands, the focus has always been on prevention of flooding through flood defences. Nowadays, flood risk management aims to minimise the probability of flooding and/or the impact of flooding (both casualties and damage). The UK also has regulations for spatial development and flood risk: the Planning Policy Statement 25 (or 'PPS 25'). The aim of PPS 25 is to ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas of highest risk. PPS 25 effectively defines the type of land use which is compatible with particular flooding probabilities.

A great deal of infrastructure in deltas has been there for decades, even centuries. Rehabilitation of this infrastructure opens up many new opportunities to enhance its functionality. Examples include the transition of conventional embankments into 'super levees' in Japan and the reconstruction of the Closure Dam of Lake IJssel in The Netherlands, with the incorporation of innovative concepts, including nature development and energy generation.

It is well known that storm and flood protection is provided by delta ecosystems that include mangroves, coral reefs, dune systems, and salt marshes, but also include coastal forests, sea grass beds, intertidal flats, and lagoons, depending on the delta considered. The paradigm shift for flood protection is ecological engineering to restore these ecosystems in, for example, mangrove restoration projects. Other, more recent, approaches for the protection of coastal zones against erosion include the application of soft engineering measures such as beaches and foreshore sand nourishment. For instance, a new approach of 'supernourishment' is currently being studied in The Netherlands.

## River basins

For centuries rivers have been used and adapted to economic needs, resulting in the normalisation and canalisation of river stretches. However, groynes and the narrowing of flood plains has hindered the rapid discharge of water and ice, increasing the risk of flooding. Over the past few decades the adverse consequences of these river engineering measures have become apparent, especially with climate change resulting in higher peak discharges.

In The Netherlands the old practice of raising and strengthening embankments along rivers has been replaced with a new approach that gives more room for high waters. This so-called 'room for rivers' policy contains a wide range of measures, such as the lowering of flood plains, the creation of side channels,



the lowering of groynes, river dredging and the realignment of dykes. Conventional dyke strengthening has become an option of last resort, to be used only if other interventions prove not to be technically or financially feasible.

## Climate friendly urban infrastructure

In urban infrastructure and buildings, multi-functional approaches are required. The section *Buildings and the Built Environment* stressed what can be achieved to create sustainable and energy efficient buildings. Meanwhile cities are moving towards constructing sustainable buildings that are not only climate friendly (i.e., energy efficient) but also climate proof (i.e., disaster resilient).

Many cities have undertaken initiatives to reduce greenhouse gas emissions. Some have initiatives aimed at sustainable buildings, with cities such as Hamburg even having a special award system – the HafenCity Ecolabel.

## Interaction with civil society

It is not only technological solutions that can improve resilience to natural disasters. An important element – perhaps the most important – is steering the management of vulnerable areas, including deltas and cities in disaster-prone regions. There are usually many conflicting interests in these areas of economic and ecological importance, and the challenge is to find the so-called 'win-win-win' solutions.

## Co-operation between levels of government

Prevention is an integral part of the disaster management cycle. The impacts of disasters may be reduced by measures aimed at preventing the disasters, enhancing preparedness and response, and ensuring effective recovery/reconstruction. Potential measures in these areas require a range of instruments which may fall within the competence of different authorities and involve a diversity of private and public actors. Hence there is a need to have a platform for structured communication and negotiation between all parties involved in the development of these vulnerable areas. The founding of the Delta Council in the south-western

delta of The Netherlands is an example of such a system for multi-level governance.

## Adaptive approaches and dealing with uncertainty

Climate change is introducing many uncertainties into the management and planning of effective measures to protect vulnerable areas. Various adaptive approaches are being developed for delta areas and vulnerable cities. An example is the Thames Estuary 2100 project in the UK. It incorporates decision-making on required changes to the existing flood management system, taking into account uncertainties in the predictions of the rise of the sea level.

## The development of new mitigation tools

The inclusion of risk reduction criteria in environmental regulatory frameworks represents another innovative approach to disaster mitigation. For example, in the application of Environmental Impact Assessment (EIA) in disaster risk reduction three

essential actions have been identified for the environmental assessment process:

- the collation of data on natural hazard-related risks as a fundamental first step in a broader project scoping;
- in areas of risk of natural hazards, a systematic analysis of natural hazards and related vulnerability; and
- a full assessment for certain types of projects in high-risk areas.

In addition to EIA's, a number of instruments are commonly used for country-level environmental analyses. Most notable is Strategic Environmental Analysis (SEA), a methodology for developing inputs to specific policies or plans. It has been applied in at least 14 countries in Asia, Latin America, Africa, and Central Europe.

## Public - private sector co-operation

Co-operation between government and the private sector in the development of infrastructure is a well-known approach, possibly driven by the lack of public financing and the limited capabilities and capacities of the public sector. With new concepts and innovative solutions needing to be implemented, new elements need to be considered. In particular, the risk sharing that comes with innovative projects must be handled by existing or new forms of contracts between government and the private sector for the supply of works and services.



## The involvement of stakeholders

Finally, the involvement of stakeholders is essential, not only in developing sustainable and disaster resilient solutions but also in the maintenance of new types of systems as they are developed. New financial instruments including new forms of insurance, for instance, flood insurance with a variable premium depending on risk reduction measures taken, may motivate stakeholders to undertake preventive risk reduction to decrease the damage arising as a result of storms and floods.

## The engineer's response

With the potential for disasters increasing dramatically, engineers are expected to highlight the potential events, assist in the development of mitigation initiatives, and ensure appropriate design and construction. Measures adopted will have to explore shifts in paradigms to find innovative solutions that allow man to work with nature rather than against it. But technological solutions alone will be insufficient. Engineers will need to interact closely with society at large to gain support for essential mitigation strategies, playing a major leadership role in establishing conditions for true sustainability.



# Trusted Advisers

As the custodians of existing infrastructure and the developers of future infrastructure, consulting engineers recognise a responsibility to innovate and to improve the products of their efforts. The industry understands the importance of instituting a dialogue with the rest of society. If consulting engineers are to ensure that improvements are made promptly and effectively, they must speak out about the things that are considered to be mistakes, and be equally vocal about those things that are considered as advances in best practice.

## Sustainable development

So far, the consulting engineering industry has been relatively content in its role of serving its clients, meeting their needs and wants to the best of its ability. In the area of sustainability, its focus has been on projects, applying technologies and methods that deliver better and more sustainable performance in a way that is cost effective. For the most part, engineering firms left the matter of needs and wants up to the client.

However, in the case of sustainable development, there are highly compelling reasons for the consulting engineering industry to take more of a leadership role, not necessarily in determining client needs, but in drafting the technology roadmap for achieving conditions of sustainability. Creating such a

## Ethics and integrity

The World Bank estimated in 2008 that approximately US\$ 1 trillion is paid each year in bribes, and the most consistent picture that has emerged in recent years has been the gradual withdrawal of many reputable international firms from certain parts of the world because it is impossible to function in these regions without being involved in bribery. If the consulting engineering industry is busy, this is an effective approach – but local firms cannot leave.

Many organisations have developed tools to help reduce corruption. Perhaps the most significant step was taken by the OECD. Its recommendation of 1994, in which industrialised nations pledged to reduce the supply side of bribery worldwide, was a catalyst for other initiatives and became the seedbed for the 1997

FIDIC, the International Federation of Consulting Engineers, is uniquely placed to help consulting engineers and society address the issues facing the world as a whole. It uses its worldwide network to bring best practice in one geographical area to the attention of everyone, and seeks to ensure that projects are carried out in a manner that ensures professionalism and high standards for sustainability, integrity and quality.

roadmap will frame the problems and issues of non-sustainable economic development and give the necessary context to the projected consequences and need for action.

The engineering industry not only has an obligation to serve its clients to the best of its ability, but it also has an obligation to serve the public by identifying poorly conceived policies and programmes. Having experience in many sectors of the economy, the industry works from an important vantage point where it can identify both the cross-sector opportunities and the potential mistakes societies should avoid.

OECD convention on bribery which criminalised bribery carried out anywhere in the world by citizens of the signatory countries.

In 1996, The World Bank redefined its policy on corruption, and began to take a much more proactive stance in procurement guidelines for everyday practice. Shortly afterwards, the International Monetary Fund, the World Trade Organization, and the multilateral development banks (MDB's) began focusing on ways to reduce corruption. Currently, all the MDB's have departments to detect corrupt activities and to punish companies and individuals who violate guidelines. More recently, efforts have focused on identifying the symptoms of project malfeasance in order to allow such activities to be intercepted at an

early enough stage to enable corrective actions to take place during project execution. This increased emphasis on early identification is a positive step, and regular dialogue with the MDB's continues to promote an increased focus on the prevention of corruption.

In 2004, the World Economic Forum published its *Principles for Countering Bribery* and, recently, other engineering organisations have become involved. There are now numerous resources for the formulation of anti-corruption measures and for certification, compliance monitoring and training.

Meanwhile, organisations such as Transparency International publish country ratings which identify the business community's perception of the worst offenders. There is also an index to expose the degree to which companies are likely to engage in bribery when doing business abroad. These indices are useful in defining countries in which corruption is a serious risk to consulting engineering firms.

With all of this activity, it is reasonable to ask whether the incidence of corruption around the world has decreased. Unfortunately, there seems to be no evidence of a reduction.

The business relationship that consulting engineering firms strive to create with their clients is that of trusted adviser, a relationship that cannot thrive unless the firm acts with integrity towards all of its stakeholders, whether internal or external to the business. This is such a key component of success that integrity, along with quality and sustainability, are the values upon which FIDIC is based.

In 1996, FIDIC issued a policy statement as a first step in exploring ways to protect the consulting industry from corruption. It concluded that corruption was wrong because it undermines the values of society,



breeds cynicism, and demeans the individuals involved. It involves more than stealing funds; it amounts to stealing trust. A formal effort to identify specific courses of action that could lead to reduced corruption in consulting engineering began in 1998. It was soon apparent that although most firms were "doing their best" to define and implement anti-corruption policies, many lacked consistency in the day-to-day implementation of such policies and failed to obtain systematic feedback to improve their integrity management process.

These considerations led to FIDIC's development of a practical tool, namely a comprehensive Business Integrity Management System (BIMS) for consulting engineering firms which was published in 2001. In recognition of the multi-sided nature of corruption, in 2007 a parallel Government Procurement Integrity Management System (GPIMS) was developed for public sector organisations that procured consulting services.

Whilst there is evidence showing that a formal and systematic approach for managing integrity works better than sporadic efforts developed by individual companies, integrity management has been slow to achieve success in the consulting engineering industry. FIDIC will therefore continue to push for the implementation of integrity management as an industry benchmark. Combatting corruption also requires a concerted effort by everyone involved in projects – clients, contractors, government procurement groups, and funding agencies alike – to help prevent, and not just punish, corrupt practices.

## Quality

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FIDIC's definition of quality encapsulates the key attributes of professional services including skill, experience, innovation, integrity, sustainability, and best business practice.

The keystone to ensuring quality and best value from an infrastructure project is the procurement of the consulting engineer who is best able to provide the solution to meet the client's requirements over the lifespan of the project. The engineer should be selected by an open and transparent process which focuses upon the engineer's ability to meet the project needs and who, with the client, actively seeks to add value by applying the principles of environmentally sustainable design together with the benefits of innovation, local knowledge and cost-effective practices to ensure the best quality outcome.

In striving to meet these objectives, FIDIC develops international best practice tools and guidelines, not just for its members, but also for their clients. An informed client is more likely to understand and appreciate the value of investing in quality advice. A strong component therefore of FIDIC activities are educational programmes for its members, as well as for the market place. Ongoing training and capacity building will also ensure that quality is maintained and enhanced, and that the industry is better able to continue providing the quality services which society will continue to demand.



**International Federation of Consulting Engineers  
(FIDIC)**

World Trade Center II

PO Box 311

1215 Geneva 15, Switzerland

Telephone: +41 22 799 49 00

Fax: +41 22 799 49 01

E-mail: [fidic@fidic.org](mailto:fidic@fidic.org)

WWW: <http://www.fidic.org>

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