Architecture and Sustainability
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A photograph of our studio at Riverside, taken shortly after we occupied it in 1990, shows only a handful of computers on the desks; today every single workstation has one. Computer screens have already replaced the traditional drawing board and some of the most fundamental aspects of our profession are changing as a result of this technology - in terms of working patterns, social relations, and our responses to environmental challenges. For example, many of the 'green' ideas that we explored in early projects are only now becoming a reality because of the new technologies at our disposal. This book is a survey of almost 40 years of work, a period of huge social and technological transformation. The rate of change is increasing rather than diminishing, and that can be seen reflected in the buildings and projects illustrated here.

However, it is also possible to trace consistent themes and concerns throughout our work.
Our buildings have always been driven by a belief that the quality of our surroundings directly influences the quality of our lives, whether in the workplace, at home or in the public spaces that make up our cities. This emphasis on the social dimension is an acknowledgement that architecture is generated by people's needs, both spiritual and material. Allied to this is a willingness to challenge accepted responses or solutions. Looking back I can see that our practice has been inspired by the polarities of *analysis* and *action.* This means trying to ask the right questions, allied with an insatiable curiosity about how things work – whether they are organisations or mechanical systems. And it means never taking anything for granted, always trying to probe deeper. This is due in part to a fascination with inquiry, with going back to first principles to identify whether there is an opportunity to invent, or re-invent, a solution.

The quest for quality embraces the physical performance of buildings - how well will they endure in a volatile world? Will they survive or become obsolete? Does the thinking behind their design anticipate needs that might not have been defined when they were created? Only time will tell, and so we design buildings that are flexible and able to accommodate change.

It is not only individual buildings but also urban design that affects our well being. A concern for the physical context has produced projects that are sensitive to the culture and climate of their place. We have applied these priorities to public infrastructure projects worldwide – in our airports, railway stations, metros, bridges, telecommunications towers, regional plans and city centres. For me the optimum design solution integrates social, technological, aesthetic, economic and environmental concerns.

The last two decades, in particular, have witnessed changes in public attitudes to ecology and energy consumption. In many of our projects we have anticipated these trends and have pioneered solutions using totally renewable energy sources, which limit the consumption of natural resources and offer dramatic reductions in pollution. Examples are not confined to buildings - working with industry we have created a new generation of wind turbines, cladding systems that harvest energy, even a solar-assisted electric vehicle.

While we frequently explore the newest technologies to find appropriate solutions, we frequently also seek inspiration from forgotten traditions: the use of natural ventilation, or finding ways to reflect natural light into an interior space, for example. There are often links between the ecology of a building, which is measurable, and the poetic dimensions of architecture, which are more difficult to quantify. For example, at Stansted, if sunlight dapples the floor at a particular time of day it is due to a conscious decision that sunlight should be an essential ingredient of the interiors. It has been thoroughly modelled and explored. It comes out of a passion for the quality of that space and for the humanity of the building.

Environmental issues affect architecture at every level. Buildings consume half the energy used in the developed world, while another quarter is used for transport. Architects cannot solve all the world's ecological problems, but we can design buildings to run at a fraction of current energy levels and we can influence transport patterns through urban planning. The location and function of a building; its flexibility and life-span; its orientation, its form and structure; its heating and ventilation systems, and the materials used, all impact upon the amount of energy used to build, run and maintain it, and to travel to and from it.

Sustainability is a word that has become fashionable in the last decade. However, sustainability is not a matter of fashion, but of survival. Sustainable architecture can be simply defined as doing the most with the least means. The Miesian maxim 'Less is more' is, in ecological terms, exactly the same as the proverbial injunction, 'Waste not, want not'. The United Nations recently warned, in its report *Global Environment Outlook 2000*, of a series of looming environmental crises sparked by increasing water shortages, global warming and pollution. It suggested that these trends can be halted, but only if the developed countries reverse their pattern of wasteful consumption of raw materials and energy, reducing levels by as much as 90 per cent.

Sustainable architecture is not concerned merely with the design of individual buildings. The planning study we undertook in the mid-1970s for Gomera, in the Canary Islands, pioneered the exploration of sustainable patterns of tourist development on the island. Our client, Fred Olsen, who ran cruises to the Canaries, shared our concern for environmental issues. We investigated the use of alternative energy sources - wind and solar power, and methane production from domestic waste - to reduce the island's reliance on imported oil and encourage self-sustaining development. It was a 'green' project long before the green agenda was seriously being discussed.

Similarly, sustainable architecture must address the context of our ever-expanding cities and their infrastructures. Unchecked urban sprawl is one of the chief problems facing the world today. As our cities grow horizontally rather than vertically, swallowing up more and more land, people are forced to travel greater distances between home and work. Between 1900 and 2000 the average distance travelled by an individual per day in Britain increased from 1.5 miles to 25 miles; and today 90 per cent of all shopping trips in Britain are made by car.

There is a direct correlation between urban density and energy consumption – smaller, denser cities promote walking and cycling rather than driving. For example, although Copenhagen and Detroit have populations of roughly equal size and similar climatic conditions, a person in Copenhagen consumes approximately 10 per cent of the energy consumed by his or her counterpart in Detroit. This can largely be accounted for by the greater reliance on cars in Detroit due to its population density of 39.2/km^2 compared to Copenhagen's 122.4/km^2.

High urban density leads to improved quality of life when housing, work and leisure facilities are all close by. High density — or high-rise — does not automatically mean overcrowding or economic hardship. Significantly, the world's two most densely populated regions, Monaco and Macao, are at opposite ends of the economic spectrum; and in London some of the most expensive areas are also the most densely populated. Mayfair, Kensington and Chelsea have population densities of 35,000 people per square kilometre: ten times higher than in some of the capital's poorest boroughs.

The Millennium Tower that we proposed in Tokyo takes a traditional horizontal city quarter - housing, shops, restaurants, cinemas, museums, sporting facilities, green spaces and public transport networks - and turns it on its side to create a super-tall building with a multiplicity of uses. It would be over 800 metres high with 170 storeys – twice the height of anything so far built – and would house a community of up to 60,000 people. This is 20,000 more than the population of Monaco and yet the building would occupy only 0.013 km^2 of land compared to Monaco's 1.95 km^2. It would be a virtually self-sufficient, fully self-sustaining community in the sky. This sounds like future fantasy. But we have, now, all the means at our disposal to create such buildings.

Many cities continue to spread their boundaries because nobody is prepared to make planning decisions at a political level. This is also true of infrastructure, such as transport networks and airports. Chek Lap Kok airport in Hong Kong is an example of how political will can produce a long-term solution to a problem, on an unprecedented scale, and achieve it quickly. In one tenth of the time that it has taken London's Heathrow airport to grow, Hong Kong has overtaken it by realising even more capacity in a single massive building. By 2040 Chek Lap Kok's planned passenger capacity, at 87 million passengers and 375,000 aircraft movements per annum, will be the equivalent of Heathrow and New York's JFK airports combined.

In Hong Kong, when the time came to select the site for a new airport there was no available land. The site itself had to be created. But far from being an obstacle to development, it became instead the catalyst for the largest construction project of modern times. In 1992, Chek Lap Kok was a compact mountainous island rising out of the sea off the South China coast. In an ambitious reclamation programme that involved moving 200 million cubic metres of rock, mud and sand, the island's 100-metre-high peak was reduced to a flat seven metres above sea level and expanded to four times its original size. At 6 kilometres long and 3.5 kilometres wide, it is as large as the Kowloon peninsula.

The almost universal model of an airport in the Western world is one of incremental, ad-hoc growth. Heathrow is still expected to expand on its original site by adding yet more terminal buildings. The end result is a non-finite architecture of individual structures, each in a continuous state of flux; the only limiting factors in this cycle being land and runway capacity. As a result, Heathrow is closer to the 'concrete jungle' of a 1960s' new town than to the planned development of Chek Lap Kok.

As architects we are rarely given the opportunity to influence the urban environment on the broadest scale through planning an entire city or neighbourhood, but we can improve the environment at a local level by insisting on the need for mixed-use developments. The 'clean' post-industrial nature of much work means that workplaces can be combined with housing and retail accommodation to create localised communities.

Our own studio in Battersea pioneered the reintroduction of mixed-use development in London. Although it has recently become fashionable to advocate the virtues of mixing uses such as living and working in one location, such compact communities, are in direct contrast to most of today's planning guidelines, which specify separate zones for residential, commercial or industrial use, or for leisure and culture. The consequent problems of this approach to urban planning – the social alienation, the need for extensive commuting with all its associated traffic and pollution, and the ecological impact of low-density sprawl – are only now beginning to be fully appreciated.

In the past, it was the blighting nature of heavy industry that was responsible for many of these zoning policies. Today, however, 'clean' industries, such as microelectronics, and new service-sector offices and studios are completely compatible with residential areas. In our work in Duisburg, in the former 'rust belt' of the Ruhr, we have demonstrated that inner cities can be revitalised by introducing these newer industries and locating them alongside housing and schools – even creating more green spaces in the process. Furthermore, we have shown that such buildings can be ecologically sensitive and strive towards sustainability. In the Microelectronic Park buildings we developed the technology to reclaim heat from extracted air and to convert hot water into cold – using an absorption cooling plant – to cool the building in summer.

Adaptability is one of the most important tools in sustainable architecture. Working patterns have become much more flexible over the last two decades. Many people now work from home on a laptop computer, connected to their colleagues via e-mail and fax. In response to technological developments, working patterns will no doubt continue to change. We cannot predict the precise nature of these developments, but we can build flexibility into the structure of buildings so that they can continue to be useful as circumstances alter. For example, the headquarters for Willis Faber & Dumas, completed in the mid-1970s, pioneered the use of raised floors throughout the office accommodation, at a time when such floors were used exclusively in computer rooms. Raised floors sit above the main structural slab, with a void in between for channelling electrical and telecommunications cabling. The flexibility inherent in this simple system has huge benefits in environmental terms. When Willis Faber undertook extensive computerisation in the 1980s it was able to do so with minimal disruption, and was the only large insurance company in Britain that was not forced to commission an entirely new building.

We are now installing raised floors for the first time in residential accommodation as part of a mixed-use project in Cologne, in Germany, which takes the mixed-use proposition to its logical conclusion. The project, on the Gerling Ring, not only combines apartments, offices, shops and restaurants within the same building, but provides a structure that allows individual units to be easily adapted from offices to apartments should the need arise in the future.

Germany's enlightened legislation on working conditions means that all office staff have a right to daylight and access to an openable window. This promotes the design of office buildings with relatively shallow floor plates, which means that, at a fundamental level, there need be little difference between the basic configuration of an apartment or an office building, except for the provision of bathrooms and kitchens. If, in 30 years time, there is no longer such a high demand for office space in Cologne, the offices can be converted to apartments in an efficient manner, avoiding the wasteful alternative of demolition.

Indeed, the constant cycle of demolition and rebuilding puts a huge strain on natural resources and energy usage; in terms of sustainability, demolition should be the option of last resort. In Britain alone demolition produces a staggering 70 million tonnes of waste materials annually. Construction of new buildings uses approximately 4 per cent of Britain's total energy consumption and generates 40 million tonnes of carbon dioxide each year. Up to 60 per cent of the energy and resources used in construction is spent on the shell and core of a building, so retention of a building's structure through conversion makes sound ecological sense.

Embodied energy is now one of the most important considerations in sustainable architecture. In simple terms, a building embodies the sum of the energy used to make all of its components plus the energy expended in its construction. The longer the building lasts, the greater the investment in its embodied energy will be. This tends to reinforce the argument for the use of high-quality materials that will have a long life. But it is here that the numerical equations for embodied energy become more difficult. For example, the refinement of aluminium requires such an enormous energy input that it has been dubbed an 'unsustainable' material. But high-quality aluminium can last for decades without maintenance. Lower grade materials, which may appear to be more sustainable, might need to be repaired or replaced in the same period, leading to a greater consumption of energy. In these terms, sustainability can be equated with durability, and the pleasure that people derive from things of quality; sustainability does not mean lack of comfort or amenity.

The shape and alignment of a building can also have a dramatic effect on energy usage. The form of the new headquarters building for the Greater London Authority (GLA) has been generated as a result of scientific analysis, aiming to reduce heat loss and gain through the building's skin, thus reducing its energy needs. Minimising the building's surface area results in maximum efficiency in energy terms. Its form is derived from a sphere, which has 25 per cent less surface area than a cube of the same volume. This pure form has been manipulated to achieve optimum performance; in particular to minimise the surface area exposed to direct sunlight. This strategy is backed up with a host of passive environmental-control systems. The building will be naturally ventilated for most of the year, with openable windows in all office spaces; heat generated by computers, lights and people can be recycled within the building, and cold groundwater can be pumped up through boreholes from the water-table to cool the building. The combination of these energy-saving systems means that for the majority of the time it will require no additional heating and will use only a quarter of the energy consumed by a typical high-specification office building.

A similar degree of geometric complexity is shared by another project – the London headquarters for Swiss Re - a 40-storey office building in the City of London. The profile of this tall tower can be likened to a cigar – a cylinder that widens as it rises from the ground and then tapers towards its apex. This form responds to the specific demands of the small site. The building appears less bulky than a conventional rectangular block of equivalent floor area; the slimming of the building's profile at its base reduces reflections, improves transparency and increases daylight penetration at ground level, while the tapering apex of the tower minimises the extent of reflected sky. The building's environmental strategy focuses on a series of sky gardens which are created by making six triangular incisions into the edges of each circular floor plate - in plan the floors resemble car wheel-hubs with radiating spokes. Each floor is rotated in relation to its neighbour so that the gardens spiral around the building's periphery. The gardens form part of the building's natural ventilation system and they will be filled with plants, which help to oxygenate the air.

Swiss Re builds upon the example we pioneered at the Commerzbank Headquarters in Frankfurt, which stemmed from a desire to reconcile work and nature within the compass of an office building. This, in turn recalls earlier projects: the design of Willis Faber, with its turfed roof garden, for example, was an early attempt at bringing the 'park' into the office; and at the Hongkong Bank we proposed 'gardens in the sky' which unfortunately failed to materialise. The Commerzbank also gave us the opportunity to design a building that is symbolically and functionally 'green' and responsive to its city-centre location: it is the world's first ecological high-rise tower. It is also currently the tallest tower in Europe - not that that is so significant. What is important is the way in which we developed a strategy that allowed us to place such a tall building in the city and to break down its scale. It rises from the centre of a large traditional city block. By rebuilding and preserving the smaller scale of the perimeter buildings we were able to restore the grain of the neighbourhood at street level. We were also able to enhance local amenities by providing a covered public arcade through the site, which provides a social focus, with cafés and spaces for exhibitions and other events.

Thirty years ago, when we were designing the Willis Faber building in another city centre location, a collaboration with Buckminster Fuller prompted the idea of enclosing the site in a free-form glass skin to create a building with its own microclimate. However, at the time we lacked the technological expertise to realise it the time available – its complex, double-curved geometry would have made it difficult to build. But today we have digital technologies that allow us to design and build structures such as the GLA and Swiss Re buildings in a fraction of the time it would have taken in the 1970s.

One such technique is parametric modelling, which was originally developed in the aerospace and automotive industries, for designing complex curved forms, and is now having a fundamental effect on the design of buildings. It is a three-dimensional computer modelling process that works like a conventional numerical spreadsheet. It allows any element of a design to be amended and automatically regenerates the model in much the same way that a spreadsheet recalculates numerical changes.

The same technology also allows curved surfaces to be rationalised into flat panels, which facilitates the economical production of cladding and glazing elements. This has enabled us to rationalise and demystify the structure and building components of highly complex geometric forms, allowing them to be built economically and efficiently. The Music Centre we are currently designing at Gateshead, on Tyneside, is a case in point.

The Music Centre is a key element in the cultural regeneration of the derelict riverside and will provide accommodation for the Regional Music School and three auditoria of varying sizes for performances of classical and popular music. Each auditorium is conceived as a separate enclosure linked by a concourse, in the form of a covered 'street', on the waterfront. The budget is relatively modest, and so we had to design a roof that would shelter the auditoria, the concourse and the music school in the most efficient way – closely hugging the buildings beneath.

In 'shrink-wrapping' the buildings a free-form shape was generated. However, it was clear that for the roof to be an economic reality, it would have to conform to geometric rules in order to rationalise the manufacture of individual components. We therefore made the form correspond to the arcs of nine circles. By altering the radii of the circles we were able to produce a roof form that was economical, and more easily understood, and to articulate its stainless-steel roof surface as a series of mass-producible panels.

However, such efficient forms do not necessarily require sophisticated modern materials. For example, on a project currently under development in St Moritz, in Switzerland, we are using parametric modelling to help design an apartment block, which, despite its novel shape, employs traditional timber building techniques. Timber construction is one of the most environmentally benign forms of building. Wood is an entirely renewable resource; furthermore it absorbs carbon dioxide during its growth cycle. The use of timber is especially sustainable if indigenous wood is used so that there is little or no energy expended in transportation. In Switzerland, building in timber makes perfect sense for a number of reasons. It is culturally sympathetic, reflecting local architectural traditions, and it contributes to the local ecology of harvesting older trees to facilitate forest regeneration.

Similarly, the new glass house at the National Botanic Garden of Wales draws lessons from the ecology of its site, in this case to heat and service the building in an environmentally friendly way. It is heated in part by a biomass boiler – a modern wood-chip combustion plant – which burns timber trimmings from the botanical gardens and prepared waste supplied by landfill contractors. This process emits negligible amounts of sulphur and nitrogen oxides compared to burning oil. Furthermore, the carbon dioxide emitted during the combustion process is broadly equivalent to the amount absorbed by the plants during their lifetime, creating a carbon dioxide cycle close to equilibrium. This environmental approach is continued throughout: rainwater from the roof of the glasshouse is channelled into storage tanks to supply ‘grey water’ for irrigation and flushing lavatories, while waste from the lavatories is treated in an on-site sewage-treatment plant using natural reed beds. Even the ash created by combustion can be used as a fertiliser. These are systems that work with, rather than against, nature and which have a minimal ecological impact.

Elsewhere, we have been working on other non-polluting forms of energy generation. The wind turbines we developed with the German company Enercon create clean renewable energy, each one producing enough power to supply 1,200 homes. The engineering of the turbine is both innovative and highly efficient. Unlike most turbines, it has no gearbox; the generator is driven directly by the rotor so that kinetic energy from the wind is converted directly into regulated electric current. Small wings at the tips of the rotor blades – like the ‘winglets’ on an aircraft wing - reduce aerodynamic noise and enhance the blades’ efficiency.

Such sustainable forms of energy generation can be augmented with integrated systems for heating and cooling buildings. The Reichstag in Berlin, for example, rather than burning fossil fuels, runs on renewable ‘biodiesel’ – refined vegetable oil made from rape or sunflower seeds. Together with the increased use of daylight and natural ventilation, this has led to a 94 per cent reduction in the building’s carbon-dioxide emissions. The building is also able to store and recycle surplus energy, using underground seasonal energy reservoirs.

The Reichstag now creates more energy than it consumes, allowing it to act as a local power station supplying heat to other buildings in the government quarter. Before the installation of new services the building consumed enough energy annually to heat 5000 modern homes; and raising the internal temperature by just one degree on a typical mid-winter’s day required a burst of energy sufficient to heat ten houses for a year. If a nineteenth-century building can be transformed from an energy-guzzler into a building so efficient that it is now a net provider of energy how much easier is it to design new buildings that make responsible use of precious resources?

Like the Reichstag, the British Museum is an historical building that has been reinvigorated by a contemporary architectural intervention. The Great Court is one of London's long-lost spaces; before its rediscovery the British Museum was like a city without a park. It is both a visitor hub at the heart of the Museum and a new cultural square for London, located on the pedestrian route from the British Library and London University, in the north, to Covent Garden in the south.

Originally an open garden, the courtyard was lost to the public when construction started on the round Reading Room and its associated book stacks, in 1852. The departure of the British Library created the opportunity to recapture this magnificent space and enhance the experience of the nearly six million people who visit the Museum each year. Covering an area of 6,100 square metres (equivalent to the turf at Wembley Stadium) the Great Court is the largest enclosed public space in Europe.

Sheltered beneath a unique triangulated glazed canopy, the Great Court is a major new civic and social space. With two cafés and a restaurant, it is possible to eat in the Great Court from early in the morning until late at night. Newspapers and magazines are on sale at the new bookshop. And for the first time in its history the magnificent round Reading Room is open to all. To complement the Great Court, the Museum’s forecourt has been freed from cars and restored to form a new public plaza. Together they represent a major new amenity for London and a new rendezvous for those who live or work in the neighbourhood.

The Great Court can also be understood in the context of the masterplan we have developed for the environmental improvement of Trafalgar Square, Parliament Square, Whitehall and environs in Central London. 'World Squares for All' aims to improve pedestrian access and enjoyment of the area for Londoners and the thousands of people who visit each year, whilst enhancing the settings of its many historical buildings and monuments. The first phase to be implemented focuses on Trafalgar Square. As part of a comprehensive programme of improvements, the northern side of the square is being closed to traffic and the National Gallery reconnected with the square to create a broad pedestrian plaza in front of the building.

Our proposals aim to redress the balance between people and vehicles, and to improve the quality of contemporary urban life. Any project of this kind is a balancing act, which must promote genuinely integrated solutions to cater for the many needs of our cities. This holds true for any historical environment attempting to sustain contemporary urban activities.

Our work in Nîmes showed us how the containment of traffic and provision of new amenities in a city centre can contribute to its economic and cultural revitalisation. The effect of the Carré d'Art and its related urban works in the Place de la Maison Carrée - has been to transform a whole urban quarter. The square is alive with people, a new outdoor café life has been born and there is a ripple effect extending well beyond the site. The Carré d'Art is a compelling demonstration of the way in which an individual project, linked to an enlightened political initiative, can regenerate the wider fabric of a city. A similar objective drives our project in Gateshead, which will help to establish Tyneside as a cultural destination in its own right.

Architecture is both an interior and exterior experience. The best architecture comes from a synthesis of all of the elements that separately comprise a building, from its relationship to the streetscape or skyline to the structure that holds it up; the services that allow it to work; the ecology of the building; the materials used; the character of the spaces; the use of light and shade; the symbolism of the form; and the way in which it signals its presence in the city or the countryside. I think that holds true whether you are creating a landmark or deferring to a historical setting. Successful, sustainable architecture addresses all these things and many more.

If sustainability is to be more than a fleeting fashion, architects in the future must ask themselves some very basic questions. For example, why do we still insist on using green-field sites when we could build on reclaimed land in our cities? Why do we demolish buildings that could easily be put to new uses? Why do we rely so heavily upon artificial lighting when we can design buildings that are filled with daylight? And why do we continue to rely upon wasteful air-conditioning systems in locations where we can simply open a window?