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Introduction

*Miles Keeping*¹, *David Shiers*², *Ann-Marie Aguilar*³ and *Michael Beavan*³

¹ Hillbreak Ltd., Buckinghamshire, HP18 9TH, UK

² School of the Built Environment, Oxford Brookes University, Oxford, OX3 0BP, UK

³ Arup Associates, London, W1T 4BQ, UK

The term ‘Total Architecture’ implies that all relevant design decisions have been considered together and have been integrated into a whole by a well organised team empowered to fix priorities. This is an ideal which can never - or only very rarely - be fully realised in practice, but which is well worth striving for, for artistic wholeness or excellence depends on it, and for our own sake we need the stimulation produced by excellence.

Ove Arup, 1970, http://publications.arup.com/publications/o/ove_arups_key_speech.

Achieving excellence in design and construction is, arguably, an even greater challenge today than when Ove Arup first began practice as an engineer and architect in the 1920s.

Now, as then, each project design and construction team must tackle what is a unique combination of variables, particular to an individual building or piece of infrastructure. Site-specific technical and aesthetic considerations, the functional needs of the eventual users, financial and contractual constraints, macro-economic conditions, Building Codes and legal requirements (all of which are subject to constant change), mean that every new project is, in effect, a *prototype*.

But as awareness has grown of the potentially devastating effects of contamination, atmospheric emissions and the finite nature of many natural resources, now, at this point in the 21st century, designers and project managers must also help to achieve the international community’s wider goals of reducing negative environmental impacts arising from human activity. The increasing interconnectedness of societal systems around the world means the design and management of buildings and infrastructure must respond not only to local and national ecological issues but also to global environmental concerns.

It could be said that the principles of sustainability have long been at the heart of the best architecture and engineering projects. Even before the term ‘green’ was applied to buildings, many designers tried hard to strike a responsible balance between the natural and the built environments and to meet the needs of the present, whilst leaving a

positive legacy for future generations. However, today there is an expectation that *all* property professionals put sustainability at the heart of their projects and indeed, there is legislation in many parts of the world to ensure that this is the case. But how is the environmental impact of property to be minimised whilst at the same time ensuring that buildings also meet the high aesthetic, practical and financial expectations of stakeholders?

In order that Built Environment students and practitioners can better understand how to meet today's sustainability objectives, this book sets out to explain some of the techniques used by leading architects and engineers.

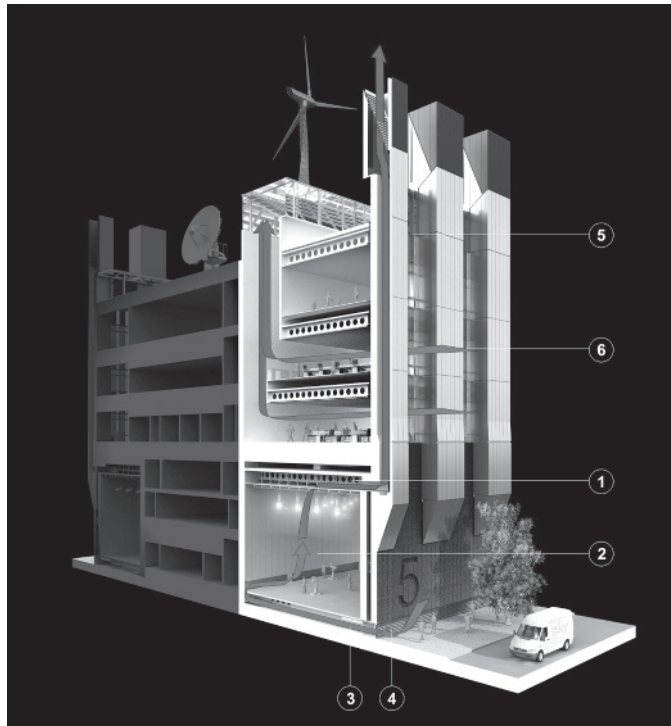
Sustainable or 'green' building can be defined as 'design and construction which seeks to minimise negative environmental impacts in an integrated and holistic way over the whole life-cycle of the project'. Green projects will commonly have the following features:

- Maximised opportunities to re-use existing buildings, structures and materials through recycling, refurbishment, conversion, adaptation and extension.
- Utilised and/or enhanced existing public transport networks to reduce dependency on fossil-fuel-powered vehicles as part of a carefully planned transport strategy.
- Minimal negative site impact through sensitivity to site ecology, flora and fauna.
- Minimal consumption of energy from non-renewable sources both during construction and post-occupancy through the use of energy-efficient lighting, heating, 'natural' ventilation and cooling systems and by careful orientation and façade treatments.
- The use of materials which have the lowest possible environmental impact and which have been responsibly sourced as part of a carefully planned maintenance, repair, reuse and replacement strategy.
- Responsible water management both in use, through 'grey water' capture and in disposal, through Sustainable Urban Drainage Systems (SUDS).
- Carefully planned waste management strategies during both construction and after occupation.
- Minimal use of harmful chemicals in the construction and post-occupancy management of the project through careful specification of construction material preservation treatments, cleaning fluids, paints and solvents as well as substances which may harm human health, wildlife and insects.
- High standards of air quality and natural lighting to ensure healthy indoor environments for living and working.
- Respectful, transparent and inclusive engagement with local community and stakeholder groups and a positive contribution to the public realm.

Environmental Assessment

Low environmental impact projects would also normally have an independently certified 'green badge' which measures and verifies good practice. Licensed assessors evaluate energy efficiency, levels of carbon emissions, transport impacts, the use of low impact materials etc. against a set of metrics derived from Life Cycle Assessment (LCA) data by leading environmental researchers, architects and engineers within organisations such as the Building Research Establishment (BRE) and the US Green Building

1. Waste heat from the studio lights rises through the studio ventilation chimneys
2. As waste heat rises, a small negative pressure is set up in the studios
3. This pressure drop overcomes the resistance of the sound attenuators, drawing in fresh cool air from the exterior
4. Exterior intake grilles
5. When external conditions are in appropriate for natural ventilation, mechanical ventilation and cooling of the studio spaces can be implemented using the same chimneys.
6. Office natural ventilation chimney follows similar principles



Principles of 'Natural Ventilation' as illustrated at the Sky TV studio, London, UK. Source: Image courtesy of Arup Associates; <http://www.arupassociates.com/en/case-studies/sky-studios/>.

Council (USGBC). Assessment programmes including *BREEAM* (the Building Research Establishment Environmental Assessment Method), *LEED* (Leadership in Energy Efficient Design) in United States and *Green Star* in Australia are now widely used with some 538,200 BREEAM certified developments globally and almost 2,230,600 buildings registered for assessment since its launch in United Kingdom in 1990 (BRE, 2016).

Commonly used green design and assessment tools:

- BREEAM: <http://www.breeam.com/>
- LEED: <http://www.usgbc.org/leed>
- Green Star: <http://www.gbca.org.au/green-star/green-star-overview>
- Passivhaus: <http://www.passivhaus.org.uk/>
- The Home Quality Mark: <http://www.homequalitymark.com/>
- SKA: <http://www.rics.org/uk/knowledge/ska-rating-/>
- The Green Guide to Specification: http://www.brebookshop.com/documents/sample_pages_br501.pdf & <https://www.bre.co.uk/greenguide/podpage.jsp?id=2126>

Other sources of guidance for practitioners and clients include:

- Blue Angel Ecolabelling: <http://www.ecolabelindex.com/ecolabel/blue-angel>
- Managing Agents Sustainability Toolkit: <http://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/bbp-managing-agents-sustainability-toolkit.pdf>

The use of environmental scoring systems has become a popular way of marketing the ‘green credentials’ of the buildings and master plans of property owners, occupiers and other stakeholders. Such badging is seen increasingly as an indicator of, and is synonymous with, high-quality design and a progressive, responsible approach to social and environmental concerns.

Users of these tools should be aware that although their methodology strives to be objective and robust, as with any scoring system, marking criteria, parameters, performance standards, the reliability of the underpinning data used and the level of importance attributed to particular issues are subject to debate. For example, when scoring the ‘greenness’ of a building project, is *resource use* (say, of water) more or less important than *waste management* issues?

No environmental design tool will be without its critics, but as long as methodologies are transparent, the ways of measuring green performance will remain useful and, at the very least, will encourage designers, engineers and constructors to move in the right direction.

Typical BREEAM Categories against which the environmental performance of a project are assessed:

<i>Management</i>	<i>Health and Wellbeing</i>
Project brief and design	Visual comfort
Life cycle cost and service life planning	Indoor air quality
Responsible construction practices	Safe containment in laboratories
Commissioning and handover	Thermal comfort
Aftercare	Acoustic performance
	Safety and security
<i>Energy</i>	<i>Transport</i>
Reduction of energy use and carbon emissions	Public transport accessibility
Energy monitoring	Proximity to amenities
External lighting	Cyclist facilities
Low carbon design	Maximum car parking capacity
Energy-efficient cold storage	Travel plan
Energy-efficient transportation systems	
Energy-efficient laboratory systems	
Energy-efficient equipment	
Drying space	
<i>Water</i>	<i>Materials</i>
	Life cycle impacts
Water consumption	Hard landscaping and boundary protection
Water monitoring	Responsible sourcing of materials
Water-leak detection	Insulation
Water-efficient equipment	Designing for durability and resilience
	Material efficiency

Waste	Land use and ecology
Construction waste management	Site selection
Recycled aggregates	Ecological value of site and protection of ecological features
Operational waste	Minimising impact on existing site ecology
Speculative floor and ceiling finishes	Enhancing site ecology
Adaptation to climate change	Long-term impact on biodiversity
Functional adaptability	
Pollution	
Impact of refrigerants	
NO _x emissions	
Surface water run-off	
Reduction of night-time light pollution	
Reduction of noise pollution	

Source: BRE Global, BREEAM UK New Construction non-domestic buildings technical manual 2014
Reference: SD5076 – Issue: 4.0

EPCs and DEC

From 2005 onwards, the requirement for an Energy Performance Certificate (EPC) indicating the energy efficiency of the fabric and the building services of most individual commercial and residential properties was rolled out in United Kingdom. Following the introduction of EPCs, certificates showing the energy use and efficiency of the *operational* performance of many types of commercial property also became a requirement in the form of a Display Energy Certificate (DEC) (Figure 1.1).

Taking the form of an ‘ecolabel’ similar to that found on white goods, these ratings are a legal requirement for most buildings and part of a 2002 EU Directive programme to reduce energy use in buildings (EU Directive 2002/91/EC; <http://www.energysavingtrust.org.uk/home-energy-efficiency/energy-performance-certificates>; <https://www.gov.uk/buy-sell-your-home/energy-performance-certificates>).

As with any designed system, actual performance in its operation is not always that which the designers had anticipated. In the case of buildings, we very often see a significant performance gap between design intent and operations. This is because of the innocent misunderstanding that designers have of how the building will be operated once it is occupied. In other words, design tools and metrics inadequately account for building occupiers’ behaviour.

When new buildings are commissioned, regulations dictate that they need to be certified as having achieved a certain level of energy efficiency. In United Kingdom, for example, EPCs are mandatorily required for the construction, sale and letting of buildings and are meant to demonstrate the building’s energy performance. But the problem with EPCs is that they assess only the theoretical performance of the building and its design intent, but do not measure the energy actually consumed in the building once it is occupied. Consequently, buildings which appear to be energy efficient very often are not.

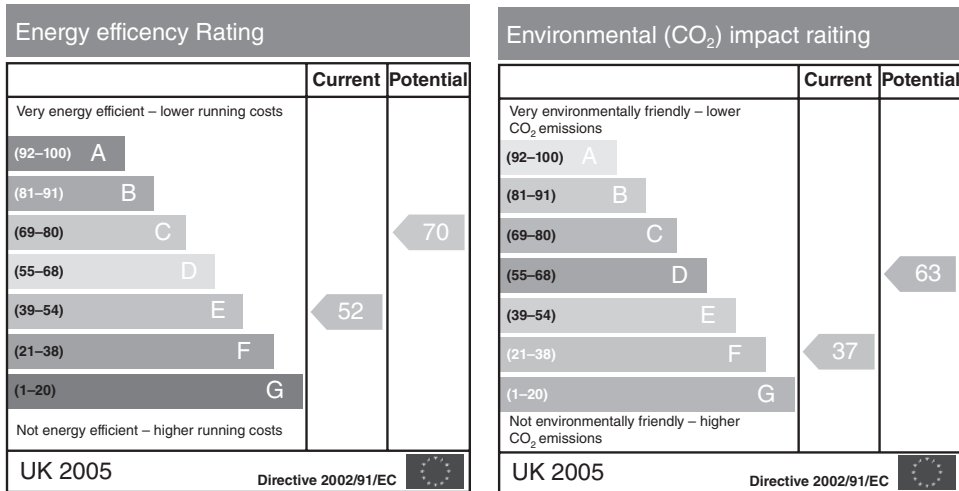


Figure 1.1 Typical Energy Certificates. *Source:* https://en.wikipedia.org/wiki/Energy_Performance_Certificate used under CC BY SA-3.0 https://en.wikipedia.org/wiki/Wikipedia:Text_of_Creative_Commons_Attribution-ShareAlike_3.0_Unported_License

Evidence of this performance gap has been provided by the Better Buildings Partnership and JLL (JLL, 2012) which found that because there is such a variation in occupiers' energy demands (which can depend upon factors such as energy loadings of fitted-out space, intensity of energy use and occupiers' operating hours), pre-occupation building energy assessments have no correlation to actual energy consumption. In this study of over 100 commercial buildings in London, it was discovered that buildings with the lowest energy asset rating (G) performed better in terms of energy intensity than buildings with the best energy asset rating (A). Equally, a building with a high-energy asset rating (B) performed worse than most buildings with lower energy asset ratings (C to G) (http://www.jll.co.uk/united-kingdom/en-gb/Research/JLL_BBP_tale_of_two_buildings.pdf).

The problem is designers are driven by the use of design tools and metrics which do not account for occupier behaviours. Until such time as designers are required and able more accurately to determine the realistic performance of a building with occupiers in it, we shall not be able to design buildings with suitable levels of energy efficiency and will therefore continue to produce poorly performing buildings (some of which might even win awards for their energy-efficient design!) and lock-in carbon inefficiency for future generations to deal with.

If designers are to improve their practice in this area, they will need to invest more time and thought in undertaking suitable post-occupancy evaluations (POE) and analysing the results so as to inform future design decision-making.

Materials and Components

The life-cycle impacts of construction materials are measured in a design tool known as the *Green Guide to Specification*. In *Green Guide*, the environmental performance of

materials is rated using an A+ to E scale so that specifiers can see at a glance which material or component option (Element Type) provides the lowest negative environmental impact (http://www.brebookshop.com/documents/sample_pages_br501.pdf).

Life Cycle Assessment (LCA)

LCA is a method of evaluating the environmental impacts of construction materials and components over their full life cycle, from the 'cradle to the grave'. This means taking into account all the impacts associated with the production and use of the material from the first time there is a human intervention (normally the extraction and transport of the raw materials) until the last (the fate of the materials in the waste stream).

Undertaking LCA is a detailed and complex process involving many measures of the environmental impacts associated with the manufacture, transport, maintenance, repair, replacement and disposal of materials over a building's lifetime (normally taken as 60 years).

LCA involves calculating an extensive range of impacts including:

- The mass in tonnes of all the materials used in manufacture (including packaging)
- Production and transport energy (measured in terms of mega joules of fossil fuel depletion and kg of climate changing CO₂)
- Emissions from manufacturing, energy use, transport and disposal (e.g. CO₂, methane, nitrogen oxides and sulphur dioxide)
- Water extraction (measured in m³)
- Ozone depletion (measured relative to the equivalent amount of ozone-depleting CFCs)
- Human toxicity (using the EU toxicity model *USES-LCA* which describes the effects of toxic substances on the environment using a common reference unit related to the substance dichlorobenzene – a toxin and acknowledged carcinogen, see <https://en.wikipedia.org/wiki/1,4-Dichlorobenzene>)
- Waste disposal (in terms of tonnes of solid waste produced)

These data are normally obtained via environmental databases (sometimes held by national governments), trade associations and the manufacturers themselves.

See: Ecoinvent, <http://www.ecoinvent.org/database/database.html>

Environmental Legislation

In many jurisdictions of the world, the regulation of the environmental performance of buildings has developed most quickly since the 1980s. In those early days of performance regulation, the focus was usually upon the health and safety of building occupiers and builders. As our understanding of sustainability risks has developed, we now better appreciate how buildings are responsible for significant amounts of resource depletion, contributing to climate change and leading to other environmental degradation and so regulation has encompassed these issues.

At a supranational level, the European Union (EU) has taken significant steps in developing our understanding of the impact which buildings have on our environmental

capacity. Given the highly developed nature of EU member states, it is not surprising that its building sector is one of its most resource-consuming economic sectors. The EU suggests that over their whole life cycle (i.e. from the extraction of materials, through the manufacturing of construction products and the construction process itself, to building use and maintenance) buildings in the EU account for approximately:

- 1/2 of extracted materials
- 1/2 of energy consumption
- 1/3 of water consumption
- 1/3 of waste generated

These issues form the basis of environmental regulation of buildings in most jurisdictions because national and municipal governments and other policy-forming bodies are cognisant that they will need to deal with resource efficiency across buildings' life cycles, particularly relating to energy, water and waste, and that such regulation will only increase in importance (<http://ec.europa.eu/environment/eussd/buildings.htm>).

During the design and construction phases of building procurement, design professionals will need to consider each aspect of locally applicable regulation in the following areas:

- Operational performance
 - Targets and standards for reducing energy and water use and waste generation (e.g. Minimum Energy Efficiency Standards)
 - Building regulations relating to thermal and water efficiency (e.g. Part L of the Building Regulations)
 - Taxes applicable to the occupation and ownership of buildings (e.g. Climate Change Levy)
 - Requirements to monitor and improve building performance (e.g. Energy Savings Opportunity Scheme)
 - Incentives to improve building performance (e.g. Feed-In Tariffs)
- Building Assessment
 - Providing evidence of attainment of a specific level of green building assessment (e.g. BREEAM or LEED), for example, to secure planning permission
 - Certification of certain aspects of building performance (e.g. an EPC)
- Waste
 - Duty of care regulations relating to the transportation, storage and recycling of waste, especially waste classed as 'hazardous' (e.g. Waste Transfer Notices)
- Materials
 - Requirements to declare the environmental characteristics of individual products (e.g. Environmental Product Declarations)
 - Requirements to demonstrate the responsible sourcing of materials (e.g. certification against Programme for the Endorsement of Forest Certification (PEFC) or the Forest Stewardship Council (FSC) criteria).

Since the end of the 20th century, the focus of much regulation has understandably been on seeking to tackle climate change and the security of energy supplies, both through adaptation and mitigation. There is no doubt that regulation in the area of climate change mitigation will increase in terms of the demands placed upon building

owners and developers and thus their professional advisers. In this regard, designers of buildings must ensure that they are able to forecast likely regulatory change relating to operational carbon emissions as well as embodied carbon within buildings. A key aspect of this will relate to how building designs and refurbishment plans avoid locking-in carbon inefficiency by specifying carbon-inefficient materials and systems which do not enable a flexible approach to reuse and recycling.

Corporate Social Responsibility – CSR/ESG

As regulators have increasingly turned their attention to sustainability-related matters and climate change in particular, we have witnessed many building owners and developers becoming more attuned to the need to demonstrate an approach to good corporate citizenship which goes beyond regulatory compliance. Corporate Social Responsibility (CSR) grew out of philanthropic motivations of business people and in the latter part of the 20th century as business and social interests became more closely aligned; we saw stakeholder expectations for a more strategic approach. In the 21st century, many real estate owners and developers have formalised their approach to CSR and integrated it more firmly within their day-to-day operations as Environmental, Social and Governance (ESG) activities.

Building designers need to understand their clients' ESG motivations which will have significant implications for the work they do in designing and delivering new buildings and overseeing the refurbishment of the existing building stock. We can divide these motivations or drivers into three categories:

- *Internal drivers* Many organisations acknowledge that if they can demonstrate meaningful attendance to ESG issues, they will thereby demonstrate an appropriate approach to risk management in their operations and delivery of their product – buildings. This has obvious appeal to their shareholders and other stakeholders, such as lenders, joint venture partners and insurers, and arises because their buildings should be characterised by being less costly, less likely to be in breach of regulations, have greater market appeal and suffer reduced obsolescence rates.

Another motivation for businesses to promote ESG factors within their organisations relates to human resources factors, in the belief that having recognisably good ESG policies and procedures will be attractive in the recruitment and retention of employees, particularly millennials.

- *Market drivers* Owners and developers of commercial properties clearly appreciate that in order to maximise returns they need to provide buildings which will appeal greatly to target occupiers and purchasers. We have witnessed very significant growth in demand for buildings which demonstrate high levels of environmental performance and in themselves enable occupiers to display their own preferences for strong corporate ESG performance.
- *Regulatory drivers* As discussed earlier, regulatory change relating to building design and performance has grown significantly in recent years and is likely to do so further as resources become scarcer and climate change worsens. The importance of this as a historic driver of improved ESG performance by building owners and developers should be obvious. What is less clear, perhaps, is how the evolving regulatory context

will lead to changes in the ESG-related demands of building designers' clients – it is likely that an even greater focus on carbon efficiency as well as transparency in environmental assessments and reporting will exercise the minds of building designers in future.

Those real estate organisations which can ably demonstrate that they have a high-quality approach to ESG issues internally, tend to be those which set the bar when it comes to the quality of their products and the standards which their project partners, including building designers, have to meet in order to help their clients produce market-leading buildings. Examples in this regard are provided in British Land's Sustainability Brief and Hermes Investment Management's Responsible Property Investment Report 2015 (<http://www.britishland.com/sustainability/governance-and-policies/policies>; <https://www.hermes-investment.com/wp-content/uploads/2015/10/Hermes-Real-Estate-Responsibility-in-practice.pdf>).

To suggest that all building owners and developers have sufficiently strong approaches to ESG would be a woeful underestimate of the current situation, however. So, whilst designers need to understand their clients' motivations in this regard, they will also need to ensure that they provide sufficient leadership in this area in order that their clients' interests and sustainability are both best served. In this respect, they should first be sure that their own approaches to ESG are fit for purpose but in trying to help their clients improve ESG approaches, they might be well advised to examine the approaches of some market-leading building owners and developers such as those discussed herein.

'Green Value'

Understanding how to produce buildings with lower environmental impact is necessary and of course vital to the work of today's and future design teams. The science relating to buildings' effects upon the Earth's systems and thus the need for lower impact and more environmentally efficient buildings is well documented. We are increasingly seeing efforts to reduce the environmental impact of buildings being scientifically based on the need, for example, to meet specific carbon emission targets which should contribute to a sustainable future.

It is essential to also recognise that many buildings are financial assets – they represent investments to owners who, particularly in the non-domestic property world, often do not occupy the buildings themselves. Rather, the buildings are assets which produce income and are tradable commodities. In this context, it is important to understand the motivations of such owners and particularly to appreciate how financial markets have responded to the changing need for green buildings.

Real estate developers and owners seek to maximise the value of their assets and understand that value is influenced by a variety of factors. These factors have traditionally included location, quality of design and construction, obsolescence rates, lease terms, operating expenses, liquidity and the quality of tenants. Appreciating how to balance the relative merits of these when determining the value of a building has long been part of the art of valuation.

But as sustainability-related issues have increasingly become important because of regulatory change and thus a greater number of green buildings have come to the

market, valuers have had to understand how these traditional market factors can be seen differently and that new factors must also be taken into consideration. Furthermore, they need to appreciate how greener buildings have increased in demand amongst particular groups of investors and developers, as well as occupiers, namely those who are interested in top quality or 'prime' buildings.

Figure 1.2 usefully summarises determinants of value of green buildings as they relate to the different stakeholders.

There have been a number of studies which purport to demonstrate that, in essence, the greener the building, the higher the value and it can be tempting to accept this as a modern maxim. Of course, the truth is rather more nuanced than this and, indeed, some studies, although few, have even tried to demonstrate that the opposite can be

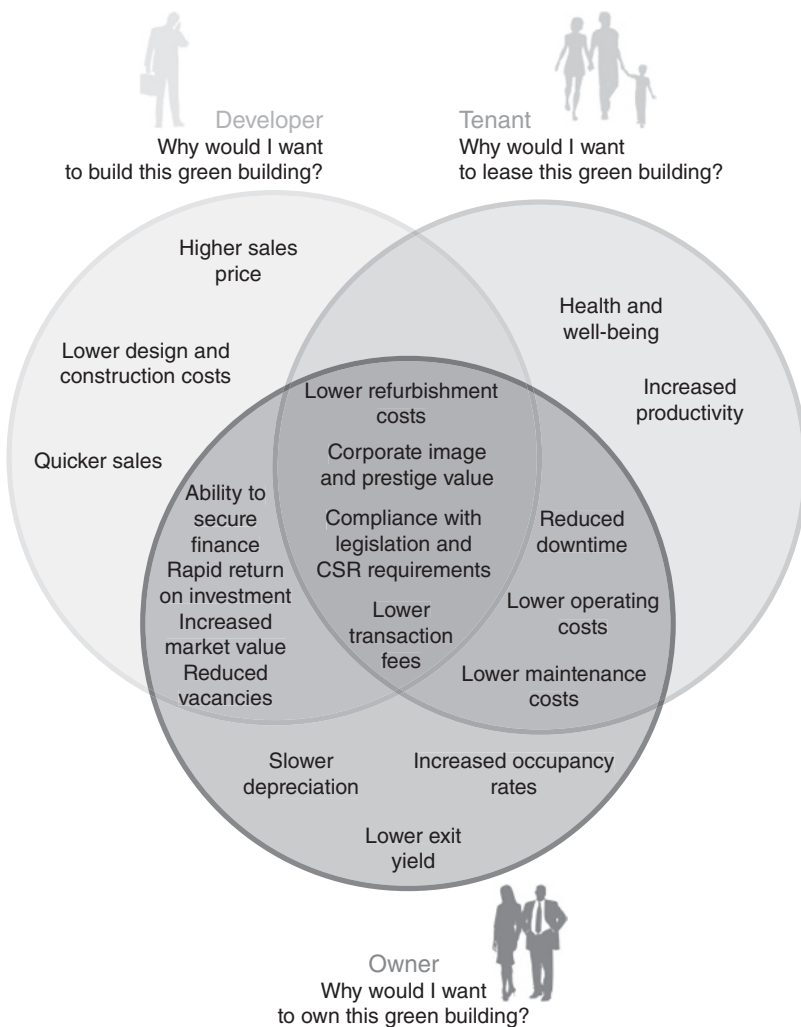


Figure 1.2 WGBC (2013) The Business Case for Green Buildings. Source: http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf

the case. But working through the evidence, both empirical and anecdotal, tells us quite a compelling story that buildings which are more valuable than their otherwise comparable peers tend to be greener buildings. In other words, better quality and certainly ‘prime’ buildings are nearly always green buildings. This is very valuable knowledge for landlords and developers who commission new buildings and refurbishments and are eager for their buildings to be let out or sold more quickly and have slower rates of obsolescence, quicker rates of rental growth and higher occupancy rates.

Study of the green value phenomenon began in the early 2000s. The following provide a useful analysis of the key issues:

- Eichholtz, P., Kok, N., Quigley, J.M. (2010) “Sustainability and the dynamics of green building: New evidence of the financial performance of green office buildings in the USA”. Research Report. RICS Research.
- Fuerst, F. & McAllister, P. (2011) “The impact of energy performance certificates on the rental and capital values of commercial property assets”. *Energy Policy*. Vol 39 No 10, pp.6608–6614.
- Newell, G., McFarlane, J. & Kok, N. (2011) “Building Better Returns. A Study of the Financial Performance of Green Office Buildings in Australia.” University of Western Sydney; Australia and University of Maastricht, Netherlands.
- Pivo, G. & Fischer, J. D. (2010) “Income, value and returns in socially responsible office properties”. *Journal of Real Estate Research*. Vol 32 No 3, pp. 243–270.
- Sayce, S., Sundberg, A. & Clements, B. (2010) “Is Sustainability Reflected in Commercial Property Prices: an analysis of the evidence base”. Kingston University; London.
- World Green Building Council (2013) “Business Case for Green Buildings: A Review of the Costs and Benefits for Developers, Investors and Occupants”. WGBC. (http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf accessed 02-09-2016).

The Design Process

This book makes extensive use of case study examples provided by a number of leading designers including Arup Associates. By studying the work of influential and innovative architectural and engineering firms and the forward-thinking clients and construction companies with whom they work, it is hoped that students and practitioners can better understand how today’s built environment challenges can be met.

From the founding of the firm, Arup have strived to be as socially and environmentally responsible as possible in all their actions (they have been actively engaged with humanitarian and charitable causes for almost 70 years) whilst at the same time often leading the way in the innovative architectural and engineering solutions which they have devised.

The firm was founded in London in 1946, as Ove N. Arup Consulting Engineers; a practice where professionals of diverse disciplines could work together to produce projects of greater quality than was achievable by their working in isolation. In 1963, Ove Arup, together with the architect Philip Dowson, formed Arup Associates; a unique,

multi-disciplinary design studio which combined all disciplines in a single team with a common method and philosophy.

Arup's *Unified Design Principles*:

- Unified design delivers a holistic architecture driven by a sustainable agenda.
- Designs must achieve whole life sustainability which reaches beyond obvious notions of 'energy saving' to maintain culture and tradition through a re-prioritisation of the importance of human experience, the senses and memory.
- Whole life sustainability places people first. It enhances the cultural value systems found within different locations rather than creating modernist models that expect people, cities and places around the world to behave in identical ways.
- Design must evolve from the user's perspective at a human scale both for the individual and the community.
- Unified design is a radical, pan-disciplinary, collaborative approach that focuses on people-oriented design from the outset, through the unified vision of architects, engineers, artists, sculptors, social scientists and others. The design process should maximise the potential of collective creativity.
- Design solutions are generated from fundamental research and experiential goals.
- Optimum solutions are found through exploratory parallel studies.
- There are no standardised solutions for any site, context or use.
- There is no pre-determined visual style; each project finds its own unique expression.
- Each project aims to discover rich and subtle environments which respond to all the senses.

(Arup Associates, 2008)

Whilst each construction project may be, in effect, unique, the underlying principles of the design process vary little. The same fundamental steps are followed for any project whether it is large-scale infrastructure or small-scale product design: *analysis, conceptualisation, synthesis, verification (testing), resource planning and execution*.

In simple terms, the requirements of the brief are established and the main constraints and challenges of the project identified (*analysis*); technical and logistical solutions are developed addressing the problems to be solved (*conceptualisation*) which embody the values and philosophy of the project team and stakeholders (*synthesis*); prototypes, models or other representations are created in order to test the solution and to refine the design (*verification*); the materials and resources needed to deliver the design are organised and the project is built and handed over (*resource planning and execution*).

It is important to remember, however, that the handing over and occupancy of a project are not the end point in any design process. One of the key principles of the sustainable agenda is to assess 'whole-life' impacts, performance and costs. *Life Cycle Assessment* or *Life Cycle Analysis* (LCA) and *Quality Assurance* protocols now ensure that the performance of all buildings and products should be monitored throughout their entire life cycle and must be continually reviewed and improved.

For many architects and engineers, the design process is not linear. Rather, it is often thought of as being circular because problems are rarely either solved or indeed fully

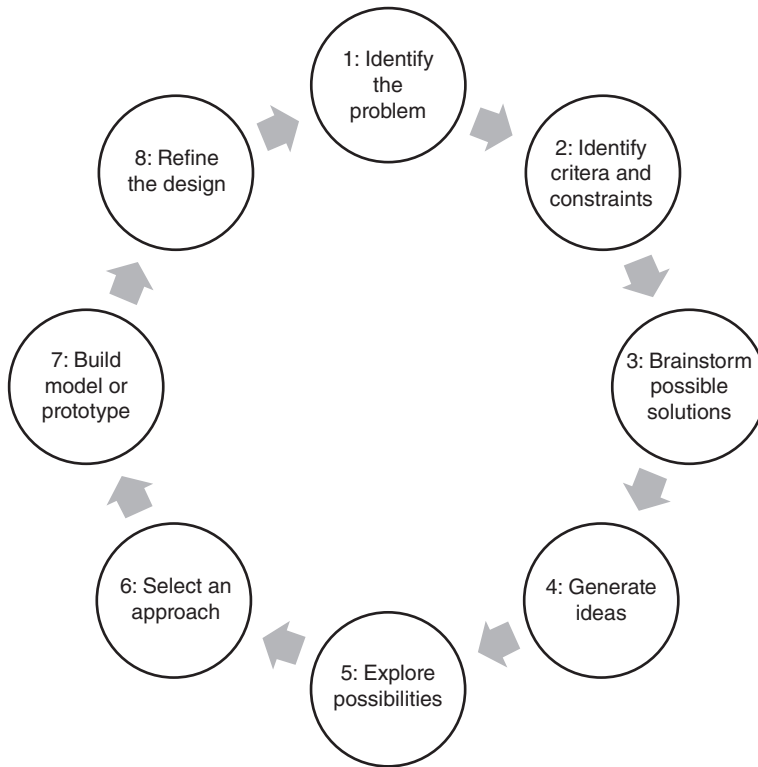


Figure 1.3 The Basic NASA Engineering Design Process. *Source:* NASA, https://www.nasa.gov/pdf/630754main_NASAsBESTActivityGuide6-8.pdf

understood first time, but require several rounds of analysis and problem solving during the development of a project.

An explanation of a classic Design Process can be seen in these ‘work stage steps’, first developed by NASA to solve design problems in the space programme (Figure 1.3):

- 1) Identify the Problem e.g. how do we design the...which will...?
- 2) Identify Criteria and Constraints i.e. specify design requirements (criteria) and list the limits on the design due to available resources and the environment (constraints).
- 3) Brainstorm Possible Solutions - sketch, model, describe and explain ideas as the team discusses ways to solve the problem. Graphics and descriptors should be quick and brief.
- 4) Generate Ideas – develop two or three ideas more thoroughly by creating more detailed descriptors e.g. 3-D drawings or models which are accurate and where parts and measurements are clearly labelled.
- 5) Explore Possibilities – the developed ideas should be shared and discussed among the team. Pros and cons of each idea are recorded on or next to the descriptors and drawings.
- 6) Select an approach work in teams to decide which of the proposals best solves the problem and write a statement to explain why the team chose that solution. This should contain reference to the criteria and constraints set out at Stage 2.

- 7) Build a Model or Prototype - construct a scale or full-size model based on the drawings.
- 8) Refine and Improve the Design - examine and evaluate the prototype against the criteria and constraints at Stage 2. Enlist or present to others to review the solution and help to identify the changes which need to be made (Figure 1.3).

(NASA, 2016) <https://www.youtube.com/watch?v=c0wh4GxoL28&list=PLiuUQ9asub3TqAiPRqhOjudMTPeMzwPtL&index=6>

However, it is perhaps more helpful to visualise the design process as an upward *spiral*, where the idea, building or product is in an ongoing state of evolution and improvement in response to identifying and then solving technical, aesthetic, financial and procurement-related problems at an ever-more detailed level.

The idea of a constantly improving 'Quality Spiral' was developed by an Engineer, Joseph Juran, in the 1950s. His experience as a practitioner had enabled him to see how a more systematic, yet dynamic approach to design might make consistent, repeatable and reliable outcomes more likely rather than using more intuitive approaches to problem-solving and those where solutions would often become fixed at an early stage (<https://www.youtube.com/watch?v=OEN48Vz7KRA>; <https://www.youtube.com/watch?v=umkh4pUnAhg>; <https://www.google.co.uk/?ion=1&espv=2#q=joseph%20juran%20quality%20spiral>).



Problem solving in building is an inter-disciplinary, collaborative process. *Source:* Image courtesy of Arup Associates.

Every Arup project is a response to a specific client and particular site and viewed as a new opportunity with no pre-defined style. Instead, always working from the inside out, through multiple parallel studies, the practice seeks to find an optimum solution which responds to the external environment but which is never driven by image alone. Every project results from a level of client collaboration and research and there are no standard solutions.

Arup have developed tools to help their designers identify and analyse the key requirements of clients and building occupiers. By using surveys, workshops, interviews and

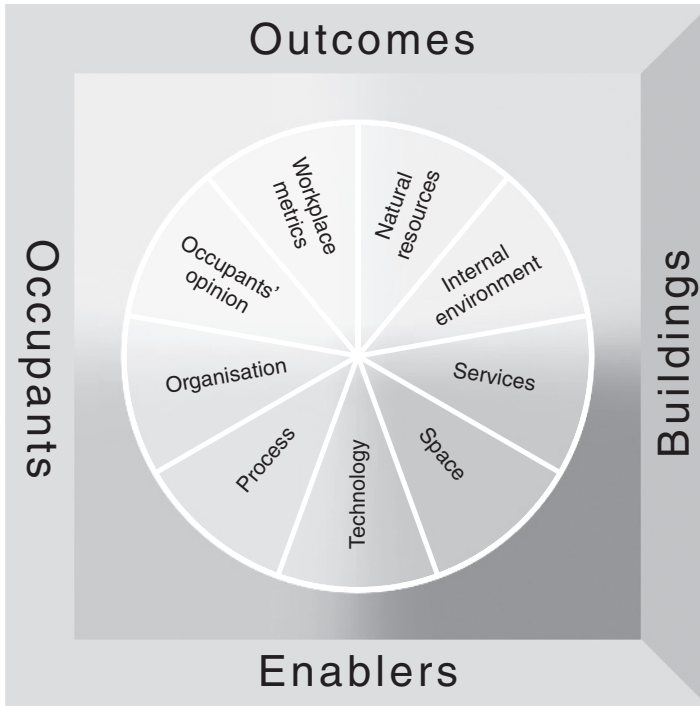


Figure 1.4 The Integrated Workplace Performance Tool. Source: http://publications.arup.com/publications/t/the_arup_journal/2010/the_arup_journal_2010_issue_1

other data analysis tools, the needs and priorities of the building users, their productivity issues and relationships with social and physical environments can be identified and addressed in the design of buildings.

For example, the *Integrated Workplace Performance Tool* (IWP) was developed by Arup in 2004 specifically to consider client workplace and productivity issues (Figure 1.4).

The nine sectors shown here can affect the performance of the building and are split into 'soft' aspects (left side), physical aspects (right side), those which can be assessed (outcomes) and those which can be both assessed and changed (enablers).

IWP is used as a structuring tool to gather a clear understanding of the client requirements and to develop guidelines for the design of effective and flexible facilities that support the productivity and well-being of their occupants, while also reflecting the organisation's culture. The IWP methodology is valuable not only in structuring the data collection process and analysing the information gathered, but also in communicating ideas within the final document issued to the organisation's teams.

The tool was derived from Professor David Canter's work to support architects in developing design briefs for various types of project. It is conducted by asking a small sample of people across an organisation, in a structured way, to indicate their understanding and experience of the various departments and sections that make up the whole organisation (exploring the atmosphere and style of those departments and sections in ways that relate to the social and physical arrangements that enable them to be effective). This process reveals the adjacencies and relationships within the organisation and

indicates the significance of the spatial relationships that characterise the organisation at various levels of detail.

The first phase is to develop a design framework for the workplace and to give the brief a development context and focus. The second phase captures and analyses the responses of the occupiers before, in the third phase, Arup Associates (partnered with Arup's organisational behaviour consulting team) develop the final brief.

The IWP framework allows the workplace to be considered as individual aspects in context or in a holistic manner. Such evaluations provide deeper analysis and understanding of the psychological and social representations individuals hold regarding their environment, and enable this to be translated into recommendations for that environment's design. An iterative workshop is normally carried out to develop the design and layout of the environment from the users' perspective, normally a half-day focus group workshop held with a small, yet representative sample of users meeting with representatives of Arup Associates.

See Case Examples at:

Ibid. http://publications.arup.com/publications/t/the_arup_journal/2010/the_arup_journal_2010_issue_1

The *Socio-Technical Systems* (STS) approach illustrated below was developed by Professor Chris Clegg in 2008 in association with Arup Associates for use in schools and offices projects (Figure 1.5). This tool utilises workshops and focus groups in order to develop the design and layout from the client's perspective, based on six characteristics of the built environment.

The STS model uses a structured approach to elicit the users' personal views, needs, and perspectives on six fundamental characteristics of the built environment (people, processes, technology, vision and goals, culture and the building itself), to effectively and reliably inform the design. Workshops provide a means of piloting the approach and also serve to highlight where additional focus may be required for ensuring that all important and relevant information continues to be drawn out and considered in the design.

These exercises are intended to deliver general schematic representations of the overall psychophysical structure of the organisation, as perceived by individual respondents and various sub-groups of respondents. These schematic representations appear similar to the 'bubble diagrams' that feed directly into many architectural briefs, but unlike those hypothetical frameworks for selecting building form and environmental characteristics, these were derived directly from those who have day-to-day experience of the organisation. As tools to support the design process, these diagrams prove valuable to the design team and to the client in understanding perceptions of the business and its functionality, and consequently, the spatial relationships within the architecture that directly respond to these business and functional needs.

It is important that clients feel positive about this type of collaboration as sensitivities and dynamics between directors and executives, front line and support staff from different parts of an organisation can be challenging. Using an inclusive, but strictly academic approach, Arup have learned that the designer's mediating role in social and organisational mapping exercises between these different worlds is critical (Figure 1.5).

In 2011, Arup introduced the Sustainable Project Appraisal Routine programme (SPeAR); a tool which appraises projects based on key themes such as transport, biodiversity, culture, employment and skills (Figure 1.6).

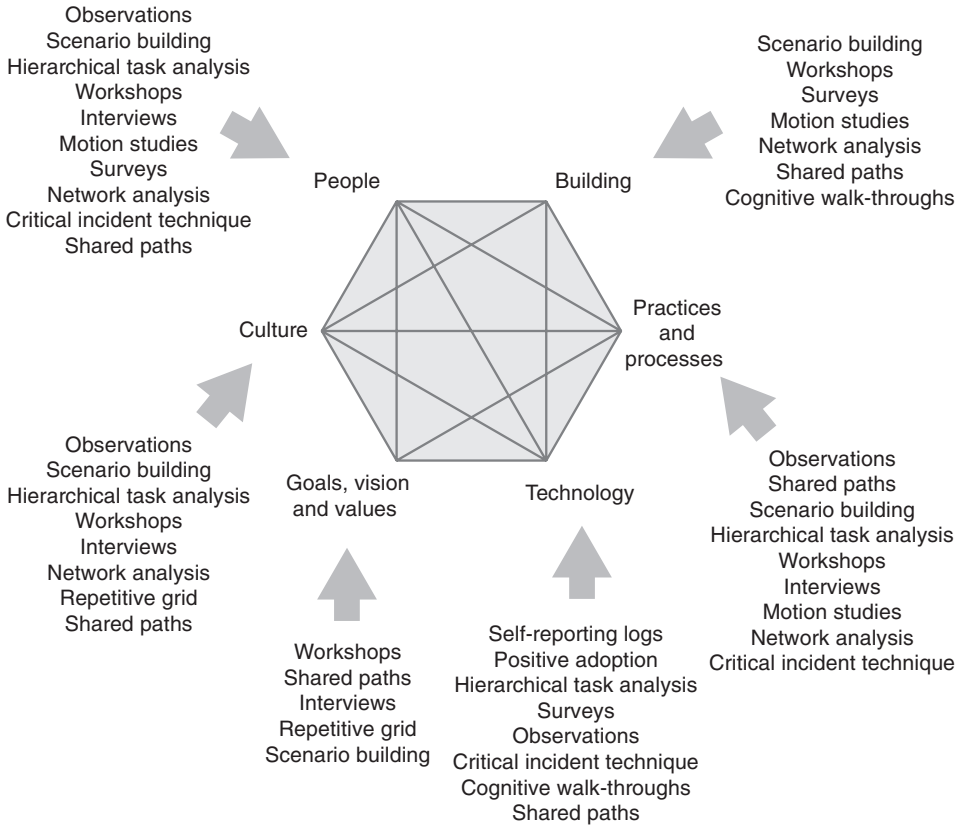
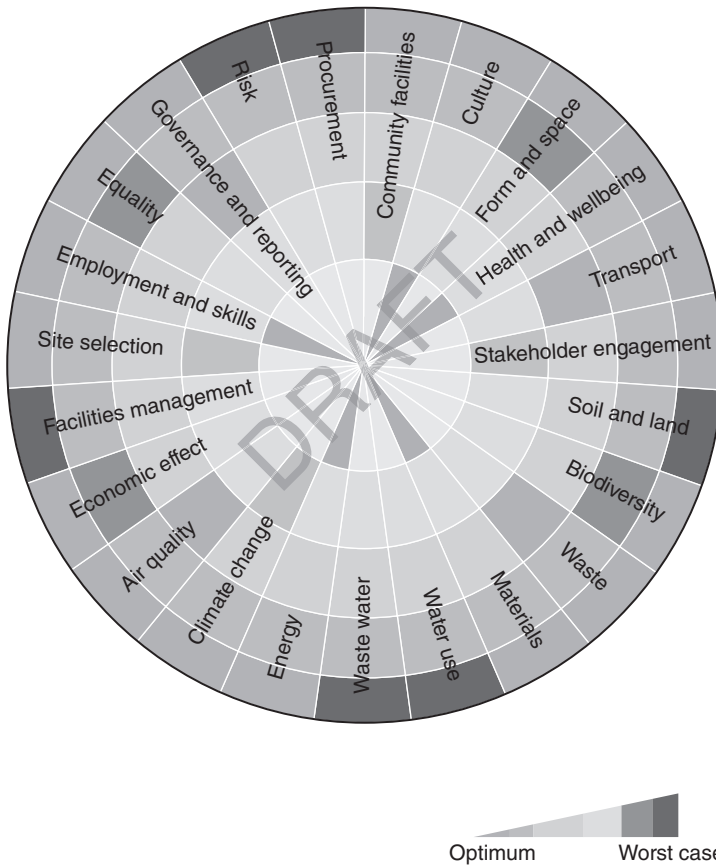


Figure 1.5 The Socio-Technical Systems (STS) design tool; developed by Prof. Chris Clegg and Arup in 2008. STS and the other tools used by Arup, identify the most relevant design decisions so that they can inform the overall solution. *Source:* Ibid. http://publications.arup.com/publications/t/the_arup_journal/2010/the_arup_journal_2010_issue_1. Also see: <https://www.google.co.uk/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=Arup+integrated+workplace+performance+tool>

Results are presented graphically on the SPeAR[®] diagram – a traffic light system indicates performance in each area. The software also generates a tabulated summary of the input data so the process is robust and auditable (<http://www.arup.com/Projects/SPeAR.aspx>; <http://www.arupassociates.com/en/exploration/unified-design-research-unit-people-centred-design/>).

The tool covers all kinds of projects including design and delivery of new infrastructure, master plans and individual buildings. It helps to monitor and evaluate project performance and support informed decision-making throughout a project. Early on it might be used to carry out a baseline appraisal, gap analysis or identify key performance indicators. During the design stage it can be used to compare and assess the pros and cons of various design options, identify key risk areas, guide decision-making and stakeholder participation, and assess the implications of design changes. It can also be used to undertake evaluation upon project completion, and during operation, which can inform organisational learning and approaches to future projects (Figure 1.6).

SPeAR[®]

ARUP

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Figure 1.6 The Arup SPeAR tool. See demonstration at: <http://www.oasis-software.com/spearapp/app/flash.html>

All of the tools described above show the workplace as a system of inter-related elements and provides a comprehensive framework of factors to be considered when designing a new building. It is the integration of the solutions arrived at for each of the problems identified which can lead to a unified design or, in the words of Ove Arup, *Total Architecture*.

The Arup projects described in this book are evidence of both a dedication to quality and to *Total Architecture* whereby all relevant disciplines and design decisions are integrated into a unified whole. This approach has evolved over time from the firm's initial focus on structural design in projects such as the Sydney Opera House, through to the work of Arup engineer Peter Rice on the Centre Pompidou in Paris and the recent engineering and architectural works at the Beijing and London Olympics.

The holistic and inclusive approach of the Arup practice today can be attributed in part to its unconventional ownership structure. It is managed 'in trust' on behalf of its entire staff who are in effect, partners in a collective enterprise, dedicated to the pursuit of Ove Arup's stated goal of excellence.

Cost and programme considerations are critical factors in the development of Total Architecture. Rarely seen as an obstacle to achieving original and innovative design by Arup, construction cost targets have played an important part in the design process and have helped to create integrated, sustainable solutions which meet the needs of clients, users and the community. Buildings and infrastructure which are delivered over-budget or late are often the result of less than rigorous analysis, design or procurement planning. They may also have been wasteful in their construction and are therefore less sustainable.

The skill of an Architect and the excellence of an architectural solution are measured by the ratio between what is obtained, and what is expended.

Ove Arup, Speech to the Architectural Association of Ireland, 1954

Source: <http://elastemgzn.com/mysteries-of-the-mall/>

Also see:

Arup Associates; *Making Green Pay*, http://publications.arup.com/publications/a/a2_magazine/a2_magazine_issue_2

In the 21st century, what is *expended* can be taken to include not only financial cost but also the natural resources and human commitment invested in projects and the negative impacts on habitats and ecosystems. What is *obtained* from a building must also be measured in more than monetary value; there must be net-gain socially, environmentally and architecturally.

In this context, however, it is of vital importance that we recognise the need to deliver buildings which are consistent with an environmentally sustainable future and specifically those which help to mitigate climate change. As per the discussion in Chapter 4, scientific consensus on climate change has been achieved and the buildings sector needs to play a leading role in reducing global temperature rises.

Many countries have set targets for carbon emissions reduction (e.g. the UK Climate Change Act 2008 has set United Kingdom a legally binding target of an 80% CO₂ emissions reduction by 2050) and will need to regulate and encourage their citizens, businesses and other organisations to play their part in meeting such commitments. In December 2015, 196 countries signed the Paris Agreement at the United Nations Climate Change Conference, COP 21. The Agreement sets a goal of limiting global warming to less than 2°C compared to pre-industrial levels and to attempt to limit the temperature increase to 1.5°C. In order to achieve the 1.5°C goal, global emissions will have to achieve a rate of zero before 2050. These estimates of necessary emission levels are based on scientific estimates and these need to translate into decision-making at the national and sub-national levels, including within the decisions and actions that businesses make.

Historically, whilst recognising the significant role that buildings play in contributing to climate change, building owners and developers have set somewhat arbitrary targets for energy and emission reductions. Very often these targets have been based on

estimates of reductions which can be made most easily (the 'low-hanging fruit' analogy) rather than on a systematic approach to helping to meet scientifically agreed targets such as the 1.5°C goal suggested by COP 21. This needs to change if a sustainable future is to be achieved and building designers will have to understand the role that science-based targets will play as the basis for setting long-term goals for greenhouse gas emission reductions. Science-based targets have been defined as:

Targets adopted by companies to reduce GHG [greenhouse gas] emissions are considered 'science-based' if they are in line with the level of decarbonisation required to keep global temperature increase below 2°C compared to pre-industrial temperatures, as described in the Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). [Applies to the 4th or 5th AR of IPCC as well as modeling of the IEA.] <http://sciencebasedtargets.org/>

Land Securities has developed science-based targets which, it considers, will bring emission intensity from its properties – including its tenants – into line with an 80% reduction by 2050 (http://www.landsecurities.com/websitefiles/Sustainability_Report_Online_2016.pdf).

In the absence of anything like the sort of regulation needed to meet objectives such as that of COP 21 and in the context of a growing population and economic growth, it will be increasingly important for all to consider how best such targets can be met through voluntary action before potentially harsh corrective regulation needs to be implemented. It will certainly be in businesses' best interests to undertake early action and perhaps in the buildings sector particularly, given its significant contribution to carbon emissions and the longevity of its product.

Also see:

http://www.arup.com/homepage_cities_climate_change

http://publications.arup.com/publications/c/cities_alive

http://publications.arup.com/publications/a/a2_magazine/a2_magazine_issue_16

www.arup.com/~media/Publications/Files/Publications/A/Arup_in_cities_v3.ashx

Whilst this book stresses the importance of a unified approach to design, the text is divided into six principal chapters; each addressing an important aspect of sustainable architecture and engineering:

- Master Planning
- Transport
- Energy
- The Building Envelope
- Environmental Services
- Materials

Each section may be read on its own or as part of a narrative which attempts to provide an overview of the sustainable design process.

Throughout the text, photographs, architectural and engineering drawings and diagrams, case examples as well as other data and information are often provided via web links. Whilst the main text sets out to explain the principles of property-related

sustainability, it is intended that this book should also act as a portal to other sources where detailed information and further links can be accessed.

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