State of the World Report 2012

Sustainable Infrastructure

FIDIC
Fédération Internationale des Ingénieurs-Conseils
International Federation of Consulting Engineers
Internationale Vereinigung Beratender Ingenieure
Federación Internacional de Ingenieros Consultores

KENCA

State of the World Report 2012 Sustainable Infrastructure

The **FIDIC State of the World Report 2012** was commissioned by the FIDIC Executive Committee, comprising: Geoff French, URS, UK (President); Pablo Bueno, Typsa, Spain (Vice President); Andreas Gobiet, Gobiet & Partners, Austria; Jae-Wan Lee, Sekwang Engineering Consultants, Korea; Akihiko Hirotani, Oriental Consultants, Japan; Bisher Jardaneh, Arabtech Jardaneh Group, Jordan; Chris Newcomb, McElhanney Consulting Services, Canada; Alain Bentéjac, COTEBA, France; Kaj Möller, SWECO, Sweden.

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KENCA represents the business interests of the consultancy and engineering industry in Korea. It is the leading business association in its field, representing Korean consulting firms operating in various engineering disciplines.

KENCA has been working closely with government, major clients, the media and other stakeholders, to promote the contribution that engineers and consultants make to the development of Korea's infrastructure, and fully supports the need for developing sustainable infrastructure. KENCA is proud to host the FIDIC 2012 World Conference in Seoul, where this report is being launched.

FIDIC is the 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 90 countries from all parts of the globe and encompassing most consulting engineers in private practice.

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 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 the FIDIC World Consulting Engineering Conference and an extensive programme of seminars, conferences, capacity building workshops and training courses.

FIDIC's contracts and agreements are recognised internationally as the industry standard for infrastructure, civil engineering and construction. They have been adopted by the mutilateral 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 for the built and natural environment.

- Procurement
- Consultant selection
- Risk management
- Scope of services
- Quality management
- Quality of construction
- Business integrity
- Environmental management
- Project sustainability
- Insurance
- Capacity building
- Transfer of technology
- Professional liability
- Information technology
- Project management

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Executive Summary

Maintaining and improving our Quality of Life today offers many new challenges and opportunities. This report sets out to make sense of sustainable development in the context of key infrastructure. It describes how decisions might be made towards a sustainable future in our societal fabric, of roads, railways, ports and airports, in water and wastewater, and in power generation. In other words, in all that underpins society worldwide.

In 2009, the International Federation of Consulting Engineers (FIDIC), released the 'State of the World: FIDIC Infrastructure Report 2009', to raise awareness of the increasingly complex challenges being faced by the infrastructure sector today. These include economic crises, global urbanisation, non-renewable resource depletion, water scarcity, climate change, waste management and increasingly complex disasters, which threaten the resilience of critical infrastructure and services globally. A key message resonating through the report was the leading role that the consulting engineering industry has to play in tackling these challenges. The Report offered constructive examples as to how that can be achieved.

In parallel, through the publication of their Project Sustainability Management Guidelines (PSM) in 2004 FIDIC began the process of making a significant contribution internationally to the global arena of emerging sustainability guidelines and tools for the infrastructure sector. Such tools use internationally recognised sustainability indicators, calculation methodologies and green technologies to guide project teams reliably towards sustainable project design and execution. The 2004 PSM framework proposed a set of core project sustainability issues traceable to the overall sustainability indicators endorsed by the world's governments as the basis for Agenda 21, an internationally agreed global action plan by the UN for sustainable development. By relating these issues to engineering projects, PSM enables project owners and consulting engineers to set project objectives and associated indicators, and pursue the full range of opportunities for improving sustainability performance. PSM II is currently under development to further enhance the guidance it provides for projects to be executed more sustainably.

Following on from these developments, this State of the World 2012 Report 'Sustainable Infrastructure' presents FIDIC's belief that these challenges can only be addressed by having a clear view of sustainability in infrastructure development.

Sustainable development is derived from the Brundtland definition and embraces respect for environmental concerns, social fairness, and future generations whilst acknowledging the realities of economic drivers.

Infrastructure needs to deliver its service over its lifetime, efficiently and reliably, and it needs to be adaptable and resilient to change and shock. This implies assets with a long useful life, with minimum reliance on non-renewable resources, with maximum benefit to society and the environment and which contribute to, rather than endanger, economic prosperity in the long term. At its core, sustainable development is a way to express society's demand for all aspects of decisions to be taken into account, not to allow narrow interests to avoid consideration of the full implications of decisions. It is a modern expression of the ambition to act responsibly, fairly, effectively, efficiently, sensitively, and with a view to the long term.

The approach of sustainable development offers a systematic perspective which is crucial for embracing complexity, balancing tradeoffs and managing competing priorities that are in the nature of modern infrastructure projects. Sustainability is not responsible for this complexity or trade-offs, rather it brings them together so that informed decisions can be made early.

Sustainability ensures that risks to infrastructure assets and services are predicted early and mitigated against. Furthermore, its systematic perspective enables consideration of risks occurring when systems individually considered are suddenly put together.

Rather than being one of many competing objectives, sustainable infrastructure is an underlying philosophy which should guide decision-making throughout projects for meeting the wider objectives of durability and performance.

This Report focuses on the nature of decisions made by project teams, their impacts and some of the dimensions of sustainability that influence decision-makers, including Risk, Resilience and Opportunity. Identifying the barriers to the uptake of sustainability, the report presents a global review of the key Sustainability Tools under deployment in the infrastructure sector today, including Rating & Certification Tools, Decision-Support Tools, Calculators and Guidelines, which utilise motivators of risk minimisation, resilience, opportunity, competition, security and prosperity to guide project teams towards sustainable infrastructure assets and services.

Why decision-making?

This Report seeks to aid decision-making as a way of facilitating sustainable infrastructure. It highlights the importance of participatory, transparent decision-making which involves affected stakeholders, as a prerequisite to ensuring buy-in to decisions and minimising disruptions as projects proceed. It requires that consulting engineers are better equipped with the skills to facilitate sustainable projects and that they are involved as early in the project development path as possible.

To this end, the report presents a new approach. This is the Hierarchy of Sustainability Decisions that project teams are faced with during the life-cycle of a project. The hierarchy is composed of 6 categories of decisions (Conceptual, Inherent, Strategic, Tactical, Operational and End-of-Life) which are distinct in terms of when during the project cycle they are made, their power to influence project sustainability and the detail of information that guides them.

Conceptual Decisions: These are typically made during the Project Initiation stage where decisions at a high level are made, and there are minimum constraints on the project and maximum opportunity for sustainability thinking to be incorporated in all aspects of the planned development. Furthermore, questions on whether the project is justifiable from a sustainability point of view can be raised.

Inherent Decisions: These are typically made during the Design Brief and Feasibility stage by which point the nature of the project to be carried out (in terms of services) and the stakeholders this will involve have already been outlined, but major decisions such as the detailed site selection for example, may not yet have been made. There are now more constraints on the project, but within these, there is still potential to look at the bigger picture of how the development can repair, restore and upgrade the communities and local economy it is influencing.

Strategic Decisions: These are typically made during the Design Outline and Design Option Formulation stages

of the project, leading up to what is commonly known as Optioneering - a multi-criteria decision-making process where the most suitable design option is selected for further development. Decisions at this stage are based on more detailed information regarding feasibility, innovation, synergies, boundaries and quality. The project is split into discrete components (water, energy, waste etc.) and a strategy for the execution of each is developed.

Tactical Decisions: These are typically made during the Detailed Design and Construction stages of the project and decisions are concerned with the detailed development and execution of each project component, guided by decisions taken during previous stages. Decisions made at this stage and their realisation is highly dependent on the skills of designers, contractors and operators.

Operational Decisions: These are concerned first with ensuring that operational sustainability is considered throughout project development, and that a sound Operational and Management plan is in place to realise them once the project is delivered and operation begins.

End-of-life Decisions: As with operational sustainability, these are concerned with ensuring that end of life considerations for the project are considered right from the start of its planning, prioritising the minimisation of waste through assets that are adaptable to upgrades, flexible to the integration with new systems, flexible to a change of use at the end of its useful life, dismantling into individual components which can be re-used, sold on or recycled.

Key Messages

- The nature of sustainability decisions during a project changes significantly, each stage offering a different visibility of tradeoffs, risks and opportunities, thus being valuable in its own way. Conceptual and Inherent decisions during the early stages of the project, suffer from lack of detailed information, but benefit from an overall view of the project and a lack of constraints on project definition. It also enables the setting of Overarching Sustainability Principles that will guide all subsequent stages of the project. Another way of expressing this is to say that decisions made at each stage of the hierarchy are progressively determining the range of opportunities that are available to subsequent stages. The chance for greatest impact both positive and negative is at the earliest stage, when often the functionality of the project or scheme tends to dominate discussion and sustainability is insufficiently considered.

- Along the hierarchy, early decisions form the assumptions and constraints for subsequent decisions. This is the case for any project, whether there is concern for sustainability or not. What the FIDIC Hierarchy highlights is that unless sustainability is prioritised from the outset, decision-makers are already very limited at later stages in making choices that will have a profound effect on the sustainability of the project. If the project encounters bottlenecks such as community opposition, more costly operations or environmental violations, it becomes increasingly, and ultimately prohibitively, expensive to alter the course of the project.
- Moving from Conceptual to Tactical concerns, i.e. as the project develops, decisions are naturally governed more by what is economically and technically feasible rather than what is desirable due to the nature of the work that project stages involve. Therefore, if sustainability is not embedded into early conceptual, strategic thinking, then technical and economic parameters end up dominating the nature of the final product.
- A Whole-Life sustainability approach is important from the project onset, which includes considerations of minimisation of embodied resources, sustainable material procurement, construction, operation and decommissioning.

Decisions along the Sustainability Decision-making Hierarchy are made by different actors who come on board as the project progresses. There is a challenge in ensuring that the sustainability vision behind earlier decisions is carried forward through iterations from one decision-maker to another, as ownership of responsibility and risk changes hands.

Sustainability - Risk, Resilience and Opportunity

This Report focuses on three dimensions of sustainability which influence decision makers of infrastructure projects and the extent to which they are willing to take sustainability concerns on board. These are the dimensions of Risk, Resilience and Opportunity. There are of course other important motivators which include contribution to society and the environment or setting a global example for innovation and progress. However, given that the progress of mainstreaming sustainability thinking into projects is so varied across the globe, the dimensions discussed in the report are those which help make a Business Case for sustainability.

Risk

The report defines Project Risk and Service Risk as the risks felt by stakeholders depending on their legal or professional responsibility during the Project Phase or the Service Phase of a project.

During the Project Phase, crucial decisions are made by decision-makers who are not involved in the long-term operation of the resulting assets. These decisions are governed by the desire to reduce perceived Project Risk by reducing capital expenditure, potentially shying away from novel technologies, materials or design methods, and by delivering the final product as quickly as possible and according to specifications. Taking sustainability on board then, can itself be considered an added risk as well as an opportunity.

Sources of Service Risks during the employment of infrastructure assets include:

- Climatic and extreme weather uncertainties: the increasing interconnectedness of critical infrastructure in urban centres poses a risk of increasing vulnerability to the real threat of increasingly frequent and compound natural disasters.
- Political and economic uncertainties: Sustainability thinking can advise on efficient use of resources, maximisation of local energy generation and use of local resources and services for reducing operational expenditure and increasing resource security.
- Resource scarcity and material criticality: Sustainability can provide the framework to consider increases in efficiency, reuse and recycling to minimise reliance on crucial resources of water, fuel, chemical agents and rare-earth metals.
- Human, material and system performance: Sustainability calls for material selection which encourages adaptability, disassembly, reuse, reduction of waste, recycling and safety. Its systemic perspective also helps view infrastructure systems as Complex Adaptive Systems where the behaviour of a system is different to the sum of the behaviour of its components, and may therefore hide other risks.

Key Messages

- This Report identifies that the main barrier to sustainable infrastructure is the perceived increase in risk (Project Risk) that taking sustainability on board during project development involves. This leads to sustainability being considered at a minimum (compliance level) during these stages, which actually leads to a compromise in the long term sustainability and resilience of assets i.e. increases the Service Risk felt by owners and operators.
- As early decisions constrain the project, such decisions have influence and repercussions throughout its lifetime.
- Major infrastructure projects have for many years employed Risk Assessment to aid decision-making. By adopting the language of risk for sustainability, it may be possible to engage decision-makers in infrastructure projects with the aspirations of sustainability.
- For these reasons, a large proportion of the State of the World 2012 report is dedicated to the introduction of Sustainability Tools, whose purpose is to guide practitioners towards sustainable projects and reduce the perceived Project Risk of taking sustainability on board. These do not provide a solution to sustainable infrastructure, but they do offer valuable support towards achieving it.

Resilience

The importance of protecting critical infrastructure from threats lies not only in its critical role of sustaining societies and economies, but also in its role of helping communities and economies to rebuild themselves following any shock. For this reason, ensuring that critical infrastructure is resilient to the risks outlined above is becoming more and more central to the sustainability agenda as these risks are becoming increasingly complex.

Sustainability thinking from the project onset is crucial in making clear the connections of the intended project with the local and wider society, economy, environment, and other businesses, and understanding where these connections can cause serious vulnerabilities putting the entire system at risk. Sensitivity to the interests of society, economy and the environment implies that sustainability approaches attempt to nurture these connections and ensure they are elastic, adaptable and resilient.

Opportunity

Sustainability can offer project teams opportunities both at the Project Phase and during the Service Phase of projects. During the Project Phase, designing with sustainability in mind can enable teams to exploit various financial incentives as a reward for the incorporation of green technologies, for achieving water or energy consumption targets or for the acquisition of certification by a relevant Rating & Certification scheme for example. Although it is a hurdle for project teams to develop the skills for sustainable design and construction, once this experience is acquired it offers its developers a competitive advantage over other contractors or engineering consultants. As a result, several consulting engineering firms are now offering Sustainability Services and accompanying Sustainability Tools as part of their normal service portfolio.

During the Service Phase, sustainability thinking during project development offers the obvious benefits of: increased efficiencies hence reduced cost and increased resource security; increased synergies for more competitive and income generating business; reduced disruptions due to the presence of healthier surrounding communities and economies; benefits from employment of innovative technologies and systems; increased resilience to environmental, social, economic and political threats.

Sustainability Tools

FIDIC recognises the importance of sustainability guidelines and tools, like PSM, in reducing the risk perceived by project teams of adopting sustainability during project development. This Report offers a global review of the tools currently available on the market. These have been grouped into the four categories of: Rating & Certification Tools, Decision Support Tools, Calculators and Guidelines, which differ mainly in their origin and intended use.

Rating & Certification (R&C) Tools: These are typically produced by governmental or reputable non-governmental institutions offering schemes against which projects can be assessed and rated for their performance against sustainability. Critical quality characteristics for these tools include: guidelines offered to applying projects; intensity of evidence collection required; timing and risk management; credibility & recognition offered to awarded projects; performance levels available and methods of performance scoring; options for tailoring the assessment process through materiality, weighting, minimum standards; quality of sustainability criteria employed.

Decision Support (DS) Tools: These are typically produced by engineering consultancies or engineering and construction firms that wish to ensure the sustainability of their own projects and to offer sustainability services to their clients. Their Critical quality characteristics include: the quality of the Sustainability Criteria Set employed in terms of visualisation & usability, relevance, traceability to international standards; ability to provide relevant and adequate sustainability input during critical decision-making points in the project development process; quality of guidance, materiality and baseline assessment at initial stages in the project; quality of input to the design process; ability to capture the sustainability performance of design options and facilitate multi-stakeholder, multi-criteria decision-making; ability to ensure sustainable construction, operation and decommission.

Calculators: Calculators are of value in informing the assessment stage of the above two types of tools by providing quantitative and qualitative information in the form that is required. Their Critical quality characteristics include: guidelines for use, suitability, improvement of results; quality of in-built library; suitability of functions; quality of methodologies employed; data intensity; assumptions; comprehensiveness; calculation boundaries; speed; simplification.

Guidelines: These form the backbone of all other tools as they provide expert advice on what constitutes economic, environmental, social and institutional sustainability for each sector of infrastructure. Their Critical quality characteristics may include: geographical and sectoral relevance; quality of indicator sets; validity and traceability of information.

Key Messages

- DS tools are generally superior to R&C tools in capturing the complexity of incorporating sustainability into projects. R&C tools risk mechanistically following a checklist, without appreciating the value of what they are doing. The lack of focus on participatory decision-making with R&C tools, a principle itself of sustainability, risks R&C applicants not being able to gain cooperation from other stakeholders, on which project progress depends.
- R&C tools may be preferred to DS tools in attracting projects and rewarding them for their efforts. DS tools are not typically linked to any financial incentives or government recognition, do not offer certification at the end of the process, nor visibility of project successes which could be used to justify to external stakeholders the reasons for the chosen design.
- There is potential in the future for collaboration between DS tool firms and R&C bodies.
- R&C tools offer certification and hence are very focussed on ensuring that the claimed sustainability performance of a project is representative of the actual performance.
- DS tools are generally very focused on the Design Option appraisal phase of projects. Their contribution is much lower at the stages of guiding design and generation of these options. Their contribution is also much lower at stages following detailed design, partly because DS developer firms are not necessarily involved in the construction, operation or decommission of projects.
- Tailoring the assessment process of R&C and DS tools to the project at hand is a very important function. With DS tools there is generally significant freedom to do this. For R&C tools this is a challenge because there is a trade-off between tailoring the assessment and ensuring comparability between awarded projects of a similar type. Tools should be as targeted as possible to the type of projects they are assessing.
- Calculators can be particularly useful when developed for intended use with specific R&C or SD tools, as they provide data that can directly inform the decision-making processes.
- There is a risk that stand-alone calculators, particularly ones recommended for compliance to regulatory requirements, are treated as design tools in order to maximise the chances of compliance. This can severely undermine other important dimensions of quality design including sustainability, aesthetics, comfort, usability and even constructability.

Chapter1

What is Sustainability?

There is no shortage of definitions of sustainable development, starting famously from the 1987 definition in the Brundtland Report 'Our Common Future' as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN 1987).

Several models of sustainable development have been developed, including the 5 Capitals Model by Forum for the Future (defined as "natural, social, human, manufactured and financial capital"), the Triple Bottom Line (defined as "society, environment and economy" or "people, planet, profit") and the four-systems conditions of the Natural Step Framework. All these systems point to development which would only be truly sustainable, and hence universally beneficial in the long term, if it balances social, environmental, economic interests and technological capabilities justly, as expressed in their local context. Despite widespread and consistent efforts towards delivering meaningful change, progress in engineering and infrastructure has been slower than might have been expected. The essential difficulty lies in the details of how these aspects are measured, balanced and valued, and then how decisions are made.

The aim of this report is to explore the critical dimensions of sustainable development and the tools that can enable infrastructure developers, owners and managers to work towards projects which ensure asset performance and resilience in a context wider than just business profitability.

Why focus on decision-making?

Utility firms and property owners/managers provide critical services of water, power, transport, and waste management, to society, investing in large scale infrastructural assets of significant value and operational cost. At the interface between the service provider and final user, there is naturally a focus on service and quality. At the same time, there are wider issues of society's enduring wellbeing, and infrastructure has to be delivered in a context of respect for environment, social fairness, and a long-term future. These sometimes competing needs have to be considered together. This balancing of unlike aspects is the essence of sustainable development. The process of achieving agreed outcomes depends crucially on sound decision-making techniques.

Infrastructure needs to deliver services over its lifetime efficiently, reliably, and be adaptable and resilient to shocks. This implies assets with a long useful life, with minimum reliance on non-renewable resources, which minimise impact to society and the environment and which benefit, rather than endanger, economic prosperity in the long term. Sustainable infrastructure then, rather than being one of many competing objectives, becomes an underlying philosophy which guides decision-making towards meeting corporate objectives of durability and performance. Furthermore, it offers a systemic perspective which is crucial for embracing complexity, balancing tradeoffs and managing competing priorities that are in the nature of modern infrastructure projects.

This State of the World 2012 Report highlights decision-making as a way to facilitate sustainable infrastructure. Decision-making is addressed at the different stages of the infrastructure project cycle, from inception through development to implementation and decommissioning.

The emergence of a project is often a tortuous process which can take many years. Any project is set against the context of a political and economic background, which can be dynamic, and usually results from policies of a national government, which can then be translated into local ambitions, action plans, and development programmes. The considerations of wider implications of such programmes and projects are becomingly increasingly expressed as aspects of sustainability. The language and conventions of sustainability, up to now, have not expressly acknowledged different layers for different stages, as a project takes form. But the features of sustainability of a project differ for different stages of development of a scheme.

Sustainability Decision-making hierarchy

In order to better understand sustainability decision-making during infrastructure lifetime, six distinct levels of decision-making are identified. These are Conceptual, Inherent, Strategic, Tactical, Operational and End-of Life decisions, as shown in Figure 1.1.

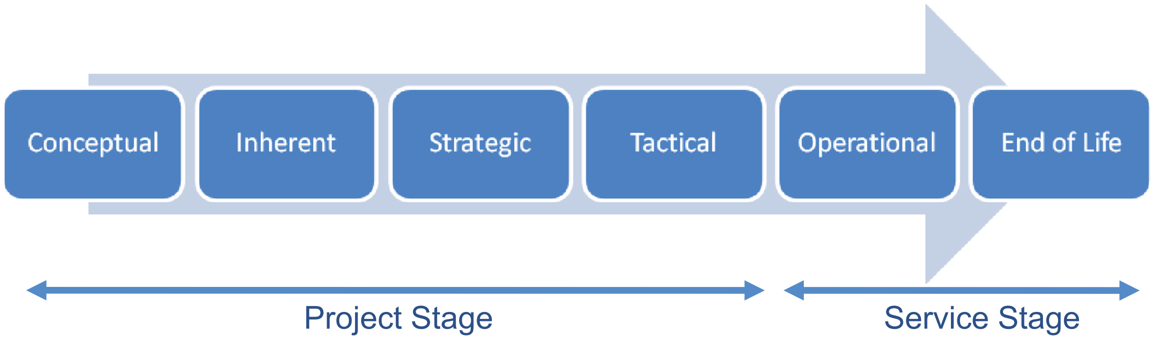

Figure 1.1 Sustainability decision-making hierarchy

Figure 1.1 also demonstrates the weight of sustainability decisions at the Project Stage rather than the Service Stage of projects.

It is a hierarchy, because as the project moves from high level strategic thinking to specifics, decisions made 'consciously' or 'sub-consciously' at each level, form the assumptions of subsequent levels. For example, Inherent decisions made on site selection at initial stages of the project, form assumptions during Strategic and Tactical levels on designing site layout, whether the initial decisions were made from a sustainability perspective or not. In terms of sustainability, each decision made in the early phases of development has a strong and largely irreversible influence on subsequent phases. Taking a sustainability perspective from the outset, which encourages consideration of all interests, risks and opportunities, reduces the chances of having to respond to pressures for change later on. Equally, the opportunity for major sustainability gains is more prevalent at the earliest stages of project formulation. This was highlighted by the 'State of the World FIDIC Infrastructure Report 2009' and raises the challenge of the early involvement of consulting engineers in projects, engineers with the breadth of skills required to make systematic, multi-disciplinary decisions.

Figure 1.2 shows the decision-making in relation to sustainability involved at different stages in the project cycle. The figure highlights the importance of whole-life sustainability considerations, including operational and end-of life considerations, right from the project initiation stage. It also indicates typical entry points for different actors showing the challenge of carrying decisions and assumptions through the cycle as responsibility changes hands.

The nature of sustainability decisions during a project changes significantly, each stage offering a different visibility of tradeoffs, risks and opportunities, thus being valuable in its own way. Conceptual and inherent decisions suffer from lack of detailed information, but benefit from a birds-eye view and a lack of constraints on project definition. They also enable the setting of overarching, sustainability principles that guide all subsequent stages of the project. Strategic and Tactical decisions are far more constrained, but contain the wealth of information to design principles into infrastructure in a technologically and financially feasible way. The chance for greatest impact, both positive and negative, is greatest at the earliest stage, when often the functionality of the project dominates discussion and sustainability is insufficiently considered. The following paragraphs explain this novel characterisation of sequential approaches to sustainability as a project evolves and matures.

Conceptual Sustainability Decisions

Conceptual sustainability decisions come at the project initiation stage, where there is minimum constraint on the project. During this stage there is maximum opportunity for embracing the widest range of issues and benefits and achieving what FIDIC's Project Sustainability Management guidelines define as Restorative Sustainability. That is sustainability that goes beyond minimising damage and tries to restore and improve society and the environment.

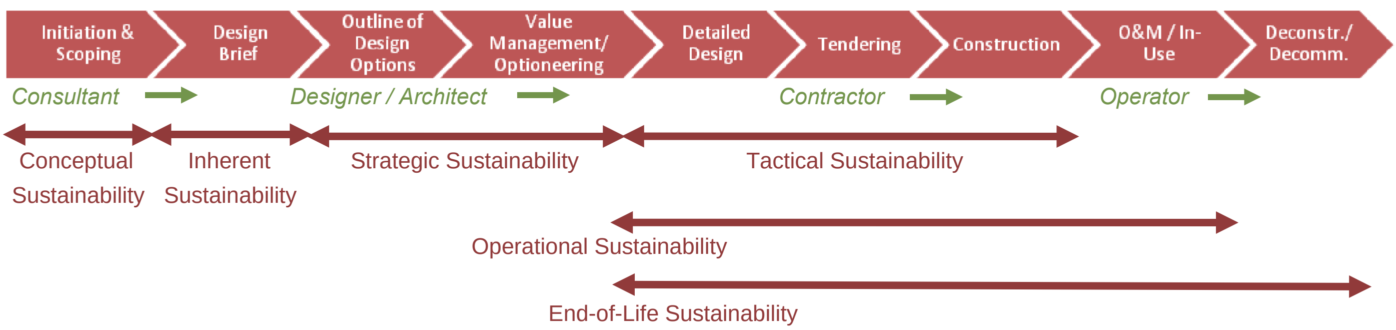

Figure 1.2 Sustainability decision-making potential along project cycle

There is therefore potential for:

- Sustainability thinking to be incorporated in all aspects of the planned development
- Selection of development site locations
- Identifying benefits and adverse impacts for communities and environments
- Identifying current and future vulnerabilities and building in resilience
- Deciding whether it would be more sustainable in the long term not to proceed with the development

This last point on whether or not to proceed with a project is often not made (or allowed as an option to be considered) by the consulting engineer, whose appointment is based on the assumption that the project will proceed. The Conceptual Phase applies most pertinently to large scale projects such as entire city developments, major water or wastewater schemes on a city scale, new transport systems, or nuclear, wind, or hydroelectric power proposals.

Inherent Sustainability Decisions

Inherent sustainability decisions are typically made at the Design Brief stage of the project by which point the nature of the project to be carried out (in terms of services) and the stakeholders this will involve have already been outlined, but major decisions such as the site for the development may not yet have been selected.

Inherent sustainability decisions, like conceptual ones, are still based more on the desired outcomes. There are now more constraints on the project due to the decisions made at the Conceptual Stage. There is still potential to look at the bigger picture issues such as:

- What site is feasible and desirable to develop, in terms of ease of access, environmental impacts, cost and opportunities to maximise on the investment?
- Where should the development best be placed to benefit society by providing needed services? Which communities could benefit the most from these, and who is disadvantaged?
- What is the range of services that it could offer, and the positive and negative impacts of these?

Strategic Sustainability Decisions

Decision-making becomes strategic as design teams consider different strategies with associated indicators and targets that will ensure the satisfactory fulfilment of sustainability objectives identified at the conceptual stage of the project. Decisions at this stage are based on more detailed information regarding feasibility, quality, innovation, synergies, and boundaries. The project is split into physical components and a strategy for the execution of each is developed. This includes financing models, procurement method, responsibilities, design options, necessary expertise, costing and engineering feasibility.

A project which begins to consider sustainability only at this stage in the project cycle, risks being limited in its potential as there are already limitations on the project due to decisions made during previous phases. There is of course some overlap between stages dependent on the style of development of each project.

The detail that characterises strategic sustainability allows for the outline design of different options informed by specialised studies and water, carbon and energy calculations for each option, leading up to the evaluation of options, and to the choice of a final design. Decision-support tools (Chapter 3), are particularly important during this phase, in helping decision-making through information management, multi-criteria analysis and identification of the most sustainable option. Although application for the necessary permissions may be carried out at an earlier point, the project now has a selected design and results of specialised studies.

Tactical Sustainability Decisions

Once the project is defined, decisions are concerned with the realisation of strategic objectives for each project component through detailed design, technology and material selection and preparation of Tender Documents. Tactical sustainability decisions are concerned with how this can be done most sustainably to minimise impact. This includes:

- Design for constructability, operability and de-constructability including minimisation of embodied and operational carbon, water and energy (Life cycle analysis)
- Technical design which incorporates passive design, waste minimisation, non-renewable resource minimisation, ethical & sustainable material procurement, renewable resource maximisation (and generation), design for re-use or recycling

Tactical sustainability decisions are limited by decisions made earlier in the process, but have the responsibility of implementing sustainability objectives in the design details. Decisions made at this stage and their realisation are determined by the skills of consulting engineers, designers, contractors and operators.

Operational Sustainability Decisions

These are concerned firstly with ensuring that operational sustainability considerations are considered throughout the planning and construction project phases, and a sound Operational and Management plan is in place to realise them.

Behaviour of operators, managers or occupiers at the operational/in-use stage of the project can severely compromise the intended sustainability performance of the development at the design and construction stage. A comprehensive management system for Maintenance and Operations which extends the useful life of components, ensures timely monitoring, repair and replacement can ensure optimum system operation throughout asset lifetime.

End-of-Life Sustainability Decisions

Similarly to operational sustainability, it is important that decisions made throughout the project cycle, and particularly during project planning, are made with sustainability at end-of-life in mind, prioritising the minimisation of waste. This includes decisions which promote infrastructure that is:

- Adaptable to upgrades
- Flexible to integration with new systems
- Flexible to change of use at end of useful life
- Can be dismantled into individual components which can be re-used, sold on or recycled

Case Study I:

Olympic Park - London 2012

The Conceptual, Inherent and Strategic Sustainability Decision-making for the main site of the London 2012 Olympic and Paralympic Games with whole-life considerations in mind from the outset

Conceptual Sustainability

In the earliest stages of deciding whether or not to make a bid for the Games in 2012, decisions at a conceptual level were made which had implications for sustainability that were then effectively locked into the project. The decision that London would be the bidding city, the decision that the main Olympic Park would be located in an area which would respond positively to the requirements of the International Olympic Committee to provide a lasting legacy for the event, and the decision to seek for sustainability as a guiding principle of the bid were all conceptual and pivotal in the future decisions.

Inherent Sustainability

In the development of the London Bid for the 2012 Olympic and Paralympic Games, the Bid Team were able to build on the conceptual sustainability principles and the reasons for the choice of the Olympic Park site included the regeneration of a poor and run-down part of London, using the Games as a catalyst, the clean-up of a seriously contaminated area following industrial abandonment, and excellent transport connections already in place and capable of upgrading. Of course the selection of this location came at a cost. The major overhead power lines would have to be taken underground, the decontamination would entail significant cost, and there were businesses on the site which would be displaced, as well as communities which would be disrupted.

Strategic Sustainability

The headline theme for the games, 'Towards a one planet 2012', expressed an overarching vision of minimising the use of resources throughout the preparation (planning & construction), staging (operation) and legacy (end-of-life and beyond) of the Games. To this end, 12 objectives were decided on, with subsequent decision-making focusing on how these objectives could be realised in preparation, during and after the Games. These included: Minimisation of carbon emissions, efficient water use, reuse and recycling; protection and enhancement of biodiversity and ecology; transport and mobility which prioritises cycling, walking and use of public transport; waste reduction through efficient use, reuse and recycling of materials; supporting communities with new, safe, mixed-use public space, housing and appropriate facilities to the demographics; identification, sourcing and use of environmentally and socially responsible materials; a highly accessible Olympic Park and venues; optimisation of positive and minimisation of adverse impacts on land, water, noise and air quality; creation of employment and business opportunities locally, regionally and nationally; providing for healthy lifestyle opportunities during the design and construction of the Park and venues; to involve, communicate and consult effectively with stakeholders and the diverse communities surrounding the Olympic Park and venues.

Tactical Sustainability

The guidance set by the prior stages enabled the design teams to deliver a wide range of sustainability gains through detailed decisions such as almost complete recovery of construction and demolition waste, high levels of materials transport to site by rail and barge, design of permanent facilities with Olympic additions which are demountable, sustainable urban drainage systems, enhanced ecology and water quality, prudent selection of materials for construction, training and employment opportunities for local people, and transparent and efficient management procedures.

Case Study II:

Swedish SymbioCity Approach for Cafoeidian Eco-City in Tangshan, China


© Sweco - Tangshan Bay Eco-City

Strategic Sustainability

The Cafoeidian Eco-City project, to be completed in 2020, is a joint collaboration between the People's Republic of China and the Swedish Ministry of Environment and Sustainable Urban Development in Sweden. The planned eco-city development in Tangshan is part of a larger development of a new international deep water harbour and a large industrial area incorporating equipment manufacturing, chemical industries, steel industries and modern logistics. Swedish Consulting firm SWECO was appointed when the development site had already been identified, to work on several tasks including the development of sustainability guidelines and conceptual physical planning for the first phase of the Eco-city.

To carry this out, SWECO utilised their in-house Decision-Support tool (see Chapter 3) which is based on a sustainable masterplanning framework called the SymbioCity Approach. Characteristics of this approach include encouragement of holistic, interdisciplinary and iterative planning, identification and utilisation of synergies and efficiencies between sub-systems (transport, energy, water systems), and systemic consideration of environmental, economic and social benefits in the development of new cities.

Strategies identified through the SymbioCity Approach were based on 9 major planning themes for development of a: Liveable, Innovative, Accessible, Green & Blue, Climate-neutral, Resource Efficient, Flexible and Beautiful city. The strategy for each theme is accompanied by planning and monitoring indicators with associated targets, including achieving 95% energy supply from renewable sources and dedicating 35% of the city area to public spaces including green spaces and market places. Characteristics of the development include: urban nodes around the city which act as centres for innovation, science, trade or spectator sports; road and transport infrastructure which encourages walking, cycling and public transport; a citywide framework of green (parks, greens, recreation areas) and blue (canals, ponds and rivers) features; energy efficient buildings, local renewable power production from wind turbines and waste incineration with potential for inclusion of tidal and solar systems; integrated handling of energy, waste and water for utilisation of synergies including the use of biogas from waste to power vehicles; grid development pattern which is flexible to rapid or slow expansion, with strong urban integration for better quality of life, liveability, social security, inclusion and health.

Chapter2

Sustainability - Risk, Resilience and Opportunity

In order to identify the opportunities and threats affecting infrastructure projects, sustainability should be a major early stage consideration. The benefits of this approach include balancing risks, improving resilience and capturing opportunities that might otherwise be missed. Most importantly, this approach can reduce the barriers to more sustainable projects.

Risk

In the 2009 publication of the ISO 31000 Risk Management standard, risk is defined as the 'effect of uncertainty on objectives'. Risk accompanies strategic decisions made about an uncertain future. Sustainability thinking is holistic and participatory and, by including different perspectives and areas of expertise, enables early identification and mitigation of risks arising from infrastructure's complexity and its interdependence with other systems.

During the infrastructure project cycle different stakeholders have legal and professional responsibilities for the project, and their perception of risk is governed by those responsibilities. More importantly, during the project phase, crucial sustainability choices are often made by decision-makers who are not involved in the long-term operation of the resulting assets. To explore this further, a differentiation is made between Project Risk and Service Risk.

Project Risk

Project risk refers to the risks felt by different participants involved during the Project Phase of an infrastructure asset's life-time - i.e. clients, funders, consulting engineers, architects and contractors. Taking sustainability on board to ultimately benefit the operation of infrastructure can increase the short-term risk felt by these participants. This can be a barrier to the uptake of sustainable project design.

Service Risk

Service risk refers to risks felt by participants during the Service Phase of an asset's lifetime, namely asset owners and operators, and facilities and maintenance managers. Such risk is spread over a longer proportion of the asset's lifetime and includes the real threat of vulnerability to economic or environmental shocks, social change, escalating costs due to resource scarcity and asset degradation.

The short term risks of adopting sustainability at the Project Phase can discourage uptake, and potentially increase long term service risk.

Sustainability & Project Risk

The question is therefore, what is the scale of risk felt by different participants at the Project Phase that governs their decisions, and how can this be mitigated to encourage the inclusion of sustainability? Sustainability can increase perceived project risk in the following ways:

- Designer skills: Lack of appropriate skills for sustainability can lead to a design that does not meet client requirements or is not practicable to construct. This can make tendering uncompetitive with fewer contractors willing to take on the job, and at a higher price for those that are.
- Contractor skills: Lack of contractor staff skills for sustainable design can lead to a final product that does not meet quality specifications and does not have the desired performance. The client can perceive this as a waste of investment. This can also discourage contractors from bidding in the first place
- Technology credibility: Increased risk posed to clients, associated with adopting a novel technology the performance of which may not be fully understood, and which may be surpassed by higher performing versions later
- Multidisciplinary & multi-stakeholder: The multidisciplinary nature of sustainability requires the engagement of many experts. This makes the process more complex, involving more stakeholders, more specialists, and more information
- Complexity: Decisions need to be made balancing many trade-offs, multiple priorities (compared to the conventional cost-time-quality), and large

amounts of information

- Sustainability limits: There is no perceived limit to sustainability. How much sustainability is sufficient? Is zero negative impact a realistic target to strive for?

What responsibilities and risks different participants carry depends, at least partly, on the procurement method selected. Different contracts can favour or discourage uptake of sustainability considerations.

Single stage, two-stage and design-build procurement are commonly used procurement methods. All involve the invitation of tenders by firms who typically compete on the basis of price and quality. Two-stage procurement is distinct in that there is an early tendering and contractor appointment before the design has been finalised, with the selected contractor contributing to the design process. Design-build involves the appointment of a single entity including both the designer and the contractor. This ensures their joint responsibility throughout the project.

Green Procurement or Sustainable Procurement is an emerging term used to describe the consideration of environmental, social and economic parameters in addition to the conventional ones of cost, time and quality, for selecting suppliers and service providers (contractors, designers, consulting engineers). These considerations become embedded in tendering and specification documentation and require that suppliers are able to report on the sustainability impact of the materials and products they offer (e.g. embodied waste, carbon, water involved in their production, and their consumption during operation). It also requires that bidding designers and contractors can collaborate with such suppliers and have the expertise to deliver the final product at the required sustainability standard. Prequalification of consultants, suppliers or contractors to recognise those able to deliver sustainable services and products can help to compensate for the risk associated with the designer and contractor skills identified above. Such a competitive advantage can encourage other firms to develop their skills and services to ensure they can also meet the prequalification requirements.

Sustainability & Service Risk

According to the World Economic Forum 2010 Global Risk Report, the world is characterised by more system risks than ever before due to increasing interconnectedness, underinvestment in much-needed infrastructure, biodiversity loss, cyber vulnerability and creeping risk due to "tipping points" being reached. In their report, the WEF express elegantly through graphical representations the interdependence and severity of different global risks, which can be adapted to articulate the dimensions of sustainability. One of the benefits of linking the language of risk to the aspirations of sustainability is that risk necessarily requires an understanding of the interrelationship of many factors, and sustainability equally depends on such complexity.

Furthermore, major infrastructure projects have for many years handled project design and delivery using, among other tools, Risk Assessment, to aid decision-making. By adopting similar language for sustainability, it may be possible to engage decision-makers in infrastructure projects more effectively.

Sustainability thinking very quickly highlights trade-offs. For example a tidal power project can, from one sustainability perspective, offer the opportunity for huge increases in renewable energy use. From a different sustainability perspective, it can result in widespread environmental loss and change. Sustainability is not responsible for these trade-offs, rather it brings them to the surface so that informed decisions can be made. Furthermore, sustainability thinking enables the systematic thinking needed to avoid the risk of what happens when things considered individually are suddenly put together.

Risks to infrastructure assets, utilities and services that can be predicted and mitigated by being examined through the lens of sustainability, are elaborated on below.

1.Natural Hazards

There has been an increase of natural disasters over the last three decades. This is demonstrated in Figure 2.1, although it may be argued that early data in particular suffers from a lack of information and reporting of incidents. It is also true that increasing urbanisation, and increasing population pressures mean that natural hazards, such as earthquakes, tsunamis, droughts, floods, hurricanes and cyclones will have progressively more adverse consequences.

This implies that interdependent infrastructure will have to operate under increasing pressure from its external environment from multiple directions. The nature of connectivity between systems will determine the way that impact is felt. For example, in 2003, a power outage in northern Ohio caused the largest blackout in the history of North America which affected, amongst others, water supply (loss of pressure due to pumping failure), power supply (hydro, coal and oil fired plants had to be employed to replace nuclear), telecommunications and transportation (airports and rail stations shut down due to lack of electricity) for 50 million people. Estimates for the total cost of the blackout, which lasted around 4 days, range between $4 - 10 billion.

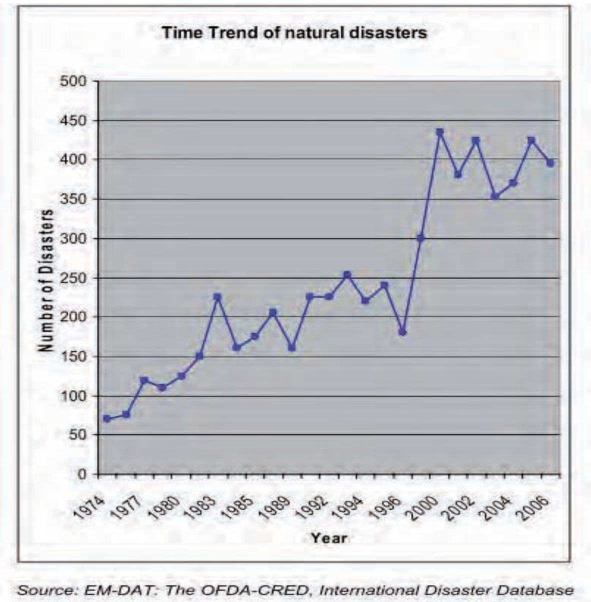

Figure 2.1 Increasingly frequent and complex natural disasters (1974-2006)

2.Political and economic uncertainties

Infrastructure projects involve high capital costs and years of operational costs throughout an asset's lifetime. They require stable financial environments and constant revenue streams to ensure healthy businesses. The Global Financial Crisis that started in 2008 is an example of economic instability that has had far-reaching implications on businesses, employment, the housing market and infrastructure finance.

Sustainable infrastructure can help to reduce exposure to these uncertainties by advising on sustainable sourcing to reduce tensions, increased efficiencies to reduce cost and consumption and use of local sourcing, local generation and use of renewables to increase security. Unsustainable infrastructure can lock communities and businesses in to diminishing and expensive resources, vulnerable infrastructure configurations and outdated standards.

3. Resource scarcity

Water, one of our most abundant resources, is already critically scarce for a quarter of the world's population. The heavy reliance of global economies and industries on non-renewable sources has been raising the concerns of increased carbon footprint, resource depletion and resource security. However, switching to a green economy is also a challenge. While the current infrastructure may be unable to deliver a low-carbon future, there is a danger that switching to green technologies on a large scale will increase resource stresses on an entirely different set of non-renewable materials.

As one example of resource scarcity, the US Department of Energy outlines 14 materials that will become critical, in terms of importance and uncertainty in supply, with the growth of a green economy (Figure 2.2). Cobalt in particular, vital for use in lithium ion batteries of electric vehicles, is making a comeback after lack of supply in the 1970s forced its replacement with other metals. Its newly found applications in military aerospace engineering and green technologies (with a single electric vehicle expected to require 9.4kg of Cobalt) are over and above its current demand in cell phone, tablet and laptop technologies that also use lithium ion batteries. Currently 99% of Cobalt production originates from African mines, and is predominantly processed and sold by Chinese firms.

According to the US Critical Materials Strategy, the following materials will reach criticality in the short and medium term:

- Lithium, Cobalt, Manganese, Nickel, Neodymium, Praseodymium, Cerium and Lanthanum used in electric vehicle batteries
- Neodymium, Praseodymium, and Dysprosium with Samarium and Cobalt as potential substitutes, magnets used in electric vehicles and wind turbines
- Lanthanum, Cerium, Europium, Terbium and Yttrium used in phosphors for energy efficient lighting
- Indium, Gallium and Tellurium used in thin films for solar cells

Figure 2.2 shows the criticality of these materials in the short and medium-term.

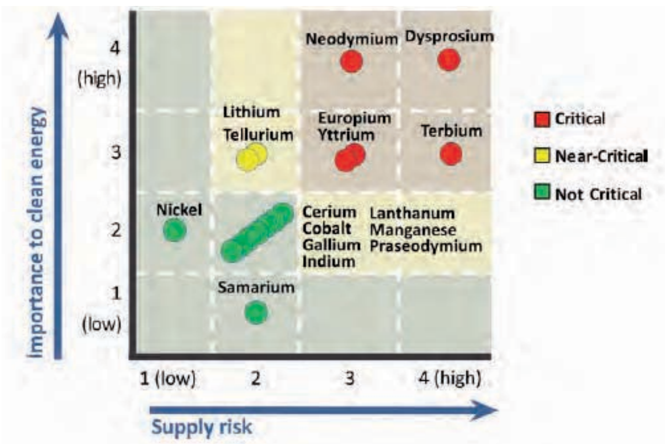

Figure 2.2 Medium-term criticality of green technology raw materials

4. Human performance

An inevitable source of risk for infrastructure is uncertainty associated with human performance during the operation of critical assets. A dramatic example of this is the Bhopal Gas tragedy in India. This has been labelled one of the world's worst chemical industrial accidents. On the 3rd December in 1984, toxic gas (methyl isocyanate (MIC)) leaked from the Union Carbide India Limited pesticide factory in the Indian city of Bhopal. The leak was caused by water entering one of the MIC storage tanks, which triggered a reaction and caused a tremendous increase in temperature and pressure in the tank. The MIC plant was not designed to handle runaway reactions and so the toxic gases were automatically released into the atmosphere.

The gas spread through the shanty towns of Bhopal, resulting in the death of 3,000 people during the first weeks and leaving 100,000 persons with permanent injuries. It is believed that the accident was caused by compromised safety standards at the factory for the purpose of cost-cutting. Although human error cannot be eliminated, the combination of safety and sustainability practices ensures that the adverse impacts of errors or negligence to a wide spectrum of stakeholders are fully understood and mitigated against, from the project onset.

5. System performance

Conventional engineering design is focussed on extensive testing of individual components to determine expected performance and resilience. However, there is less consideration of the emergent behaviour of components once they are combined and interacting. The increasing interconnectedness between services implies that damage at any point in the system can have knock-on effects through that and other systems. A further aspect of vulnerability for critical infrastructure is the long life span of its assets, which can lead to components being added on over time, without adequate consideration of system behaviour and systematic risk management. This stems from the fundamental problem which sustainability tries to tackle, which is the lack of holistic consideration of infrastructure systems in their entirety and not merely of the component parts individually.

Sustainability thinking demands the input of consultants and other experts, and early stakeholder involvement to bring to light possible adverse effects of infrastructure development. It requires the selection of development routes with the least all-round risk, and hence maximum buy-in, and its systematic perspective allows identification and reinforcement of critical interdependency connections within infrastructure, or between infrastructure and the society it serves. Finally, sustainability rises to the challenge of assigning a value to the cost of social and environmental impact, thus enabling a balanced cost and benefit analysis of options during project initiation and raising the question, "Is it a better option not to carry out this project?"

Sustainability can most easily be embraced when an organisation is able to take into account all the consequences of its decisions. If all aspects are the responsibility of a single organisation, including the long term implications, then the decisions made will be holistic, rounded and more sustainable.

Resilience

The Institute of Resilient Infrastructure (IRI) of Leeds University in the UK, defines resilience as the 'ability of a system to withstand disruption and continue to function and develop', adding further that 'resilient infrastructure is low carbon infrastructure'.

"Failure in one asset or infrastructure can cascade to disruption or failure in others, and the combined effect could prompt far-reaching consequences affecting government, the economy, public health and safety, national security and public confidence."

National Strategy for Physical Protection of Critical Infrastructures and Key Asset, US (2003)

Infrastructural vulnerability describes critical assets' exposure and susceptibility to threat, with risk describing the severity of its consequences. The pursuit of infrastructure resilience then involves reduced probabilities of failure, reduction of negative consequences when failure does occur, and reduction in recovery time, through an increase in the system's ability to persist, adapt and transform.

Infrastructure as a Complex Adaptive System

To better understand the behaviour of infrastructure, it should be modelled as a Complex Adaptive System (CAS). This is an attempt to explain that the behaviour of a system is more than merely an addition of the behaviour of its individual components. Such systems occur widely in nature, and have several important characteristics of resilience (shown in Figure 2.3), from which infrastructure systems could also benefit. These characteristics are also inherently encouraged by the incorporation of sustainability into project design and operations.

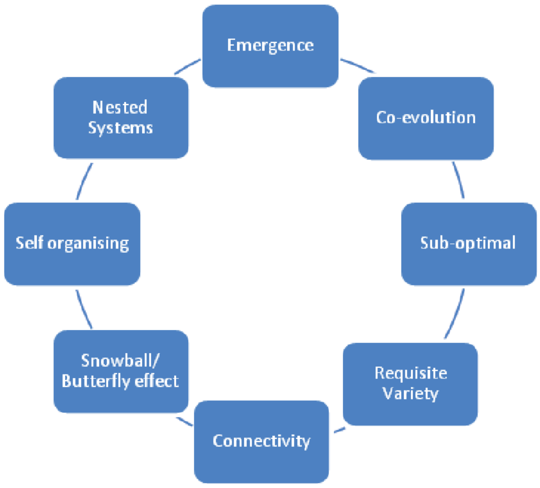

Figure 2.3 Resilience characteristics of Complex Adaptative Systems (CAS)

A sustainability perspective is holistic, and recognises the connectivity between infrastructure services and within the systems of society and the economy. By prioritising these connections, sustainability encourages, through the participation and early involvement of experts, their criticality to be identified and that they are nurtured to be flexible and strong. The advancement of infrastructure to the detriment of society or the environment, would in turn negatively impact infrastructure in the longer term. Sustainability embraces and offers frameworks for participatory, multi-stakeholder, multi-criteria decision-making, that do not shy away from complexity. This offers a wide-ranging view of the project which enables identification of emergent behaviour and risks, and which embraces diversity and variety of opinions, skills and interests. It can be a feature of Complex Adaptive Systems to encourage self-organising of system components such that they can react and adapt to maintain viability.

A CAS system tries to be sub-optimal, i.e. not striving for optimisation in its services. Rather it need only be slightly better than its competitors, spending remaining energy on robustness and effectiveness rather than efficiency. This is again in line with sustainability which tries to move projects away from the narrowly focussed ambitions of quality, time and cost, which can potentially be optimised to the detriment of other important parameters such as robustness and societal, environmental and economic enhancement.

Opportunity

During the Project Phase, sustainable design can enable teams to exploit various financial incentives as a reward for the incorporation of green technologies, for achieving resource consumption targets or for acquiring certification by a relevant Rating & Certification scheme. Sustainability Tools that are aligned with government policies allow for endorsement of such schemes, making it increasingly beneficial for projects to strive for sustainability targets.

Although it is a hurdle for engineering consultants, designers and contractors to develop skills for sustainable design and execution, once this experience is acquired it offers a competitive advantage over other contractors or engineering consultants. Several consulting engineering firms and design and build companies are already broadening their service portfolio to include sustainability services. This has largely been the motivator for the development of Decision Support tools, which are discussed in Chapter 3.

During the Service Phase, sustainability enables operators to capitalise on earlier sustainability decisions through:

- increased technical efficiencies;
- reduced operational and maintenance costs;
- resource security through local energy generation, local resource utilisation, and reduced consumption;
- identification of synergies for greater efficiencies, buy-in and ultimately a profitable business;
- reduced disruption due to the presence of healthier communities and economies which in turn have a positive impact on infrastructure systems;
- utilisation of innovative technologies and systems offering a competitive advantage;
- increased resilience to environmental, social, economic and political shocks

The extent to which a client adopts these approaches can be an indicator of their commitment to sustainability.

Chapter3
Sustainability Tools

Overview

The aim of this section is to investigate the nature of sustainability tools currently available on the market. These are not a solution to sustainable infrastructure projects, but offer valuable support. Such tools aim to reduce the risk of incorporating sustainability at the Project Phase, for the benefit of long-term sustainability, asset risk reduction, and to maximise exploitation of opportunities. This Report has grouped sustainability tools into the four categories shown in Figure 3.1 below, depending on their origin and intended use.

Figure 3.1 Sustainability tool categories

Decision-Support (DS) Tools

These are typically produced by engineering consultancies and occasionally by academia. What differentiates DS tools, is that they use sustainability guidelines and methodologies to provide expert consulting support to decision-making all along the project cycle. The most popular feature of a DS tool is an assessment framework which uses Multi-criteria Analysis Methods to assess the sustainability performance of different design options during the Appraisal of Design Options stage. However such tools are equally valuable in guiding the project Design Stage according to sustainability principles.

The incentive for developing a DS tool is to develop in-house expertise in project sustainability, to offer sustainability consulting services to clients and even to help clients' projects prepare for rating and certification (R&C). The Decision-Support tools investigated as part of this study are listed in Table 3.1.

Tool	Developer	Sector	Country of origin
HalSTAR	Halcrow	All infrastructure	UK
SPeAR	ARUP	All infrastructure	UK
ASPIRE	ARUP & Engineers Against Poverty	All infrastructure	UK
INDUS	Mott MacDonald	All infrastructure	UK
Tandem Empreinte	Egis	All infrastructure	France
Sustainable Water Engineering Opportunity Tool	Mott MacDonald	Water & Wastewater Sector	UK
SWARD Guidelines (Sustainable Water industry Asset Resource Decisions)	Richard Ashley (University of Bradford), David Blackwood (University of Abertay Dundee), David Butler (Imperial College), Paul Jowitt (Heriot-Watt University)	Water & Wastewater Sector	UK
Safety & Sustainable Development (S&SD) Valuation Framework	AngloAmerican	Mining Sector	International
SPRIng	University of Manchester in collaboration with City and Southampton Universities	Nuclear Energy Sector	UK
MAESTRO – Arrival Departure Manager	Egis Avia and French Civil Aviation DSNA	Transport (Aviation) Sector	France
Symbio City Approach	SWECO	Urban Planning	Sweden
Sustainability Matrices	Max Fordham	Buildings	UK

Table 3.1 Decision Support tools investigated

Rating and Certification (R&C) Tools

These are typically produced by reputable governmental or non-governmental institutions, sometimes in collaboration with academia. They are intended to assess, rate and award a planned or existing development, depending on its performance against relevant sustainability criteria.

The incentive for applying for R&C is to gain recognition for the sustainability performance of a development and gain competitive advantage in the market. The incentive for a certifying body is to set nationally or internationally recognised voluntary sustainability standards for their sector. The Rating & Certification tools investigated as part of this study are listed in Table 3.2.

Calculators

Calculators are important in informing DS and R&C tools by providing quantitative and qualitative values in the form that they are required. Calculators are developed both by the private and public sector either as isolated tools or to accompany another sustainability tool (e.g. the Building Energy Intensity Tool (BEIT) calculator accompanying the Green Building Index (GBI) R&C tool in Malaysia). Calculators are intended to provide values for a variety of quantities such as carbon emissions, energy use or water consumption for a specific design option. They are of particular importance to R&C tools, as these place more emphasis on collection of quantitative evidence for sustainability assessment.

The incentive for using Calculators is to report on values required by regulation, certifying bodies or clients. The incentive for developing a Calculator is to standardise methodologies for the speedy, expert calculation of quantities of importance. Appendix I provides a non-exhaustive list of some of the Calculators currently on the market.

Guidelines

Guideline documents typically inform other sustainability tools on sustainability quality, standards, indicators or methodologies. They can also inform on relevant regulations and sector specific sustainability technologies and strategies. These can be general and directed at a wide audience, including members of the public for awareness-raising. More usefully, they can be targeted at specific sectors or geographies and present key opportunities, risks and coping strategies. Appendix II provides a listing of some useful Guideline documents which are freely available online.

Tool	Certifying body	Sector	Country of origin
CEEQUAL	Institution of Civil Engineers (ICE)	All Infrastructure	UK
ENVISION	Institute of Sustainable Infrastructure (ISI) & Harvard University	All Infrastructure	US
IS	Australian Green Infrastructure Council (AGIC)	All Infrastructure	Australia
GreenLITES	New York State Department of Transport	Transport	US (New York)
Greenroads	University of Washington & CH2MHILL	Transport	US
STARS	Portland Bureau of Transport	Transport	US (Portland)
INVEST	US Department of Transport Federal Highway Administration	Transport	US
BREEAM	Building Research Establishment (BRE)	Buildings	UK
LEED	US Green Building Council	Buildings	US
CalGREEN	California Building Standards Commission	Buildings	US (California)
CASBEE	Japan Sustainable Building Consortium	Buildings	Japan
Estidama	Abu Dhabi Urban Planning Council	Buildings	Abu Dhabi
BERDE	Philippines Green Building Council	Buildings	Philippines
GreenMark	Building and Construction Authority of Singapore	Buildings	Singapore
GBI	Association of Consulting Engineers Malaysia & Malaysian Institute of Architects	Buildings	Malaysia
Green Star	Green Building Council of Australia	Buildings	Australia
BEAM	Hong Kong Green Building Council	Buildings	Hong Kong
Sustainable Community Rating	Government of Victoria (Australia)	Buildings	Australia
Green Star SA Rating Tools	Green Building Council South Africa	Buildings	South Africa

Table 3.2 Rating and certification tools investigated

Decision-Support Tools

Decision-Support (DS) tools are predominantly developed by consultancies and hence are typically used to support consultancy services rather than to act as standalone tools. This is one reason why they are not usually made fully commercially available - consulting services are considered indispensable for their correct use.

DS tools are also called Process tools, because they outline a process which maps onto the conventional project cycle and uses various tools (such as calculators of multi-criteria analysis methods) to support more sustainable decision-making.

DS tools are developed to assist engineering consultants who are advising client projects. For this reason they are flexible enough to be tailored to a range of projects. This can include advising a specific project phase (such as site selection), advising an entire project, or advising organisational practices and corporate social responsibility.

Overall, this Report distinguishes DS tools for their participatory nature, their injection of sustainability consultant expertise into client projects, for their management of complex sustainability decision-making and for their innovative sustainability models. A core feature of DS tools is a set of sustainability criteria and indicators, called a Sustainability Criteria Set (SCS), which serves different functions along the project cycle. It is an intellectually intensive feature and so is not usually made publicly available in all detail. An SCS enables three basic activities: visualisation, assessment and guidance. In the following sections advice is provided on how DS tools can offer decision support to each stage in the project cycle.

Table 3.3 summarises recommendations on how DS tools can contribute to each stage in the project cycle

Project Phase	Contribution of Decision Support Tools
Scoping & Objectives	*Conceptual Sustainability decisions (incl. considerations of Operational & End-of-Life)* • Advice on sustainability related opportunities & risks to be incorporated into overall project objectives and goals • Baseline assessment
Design Brief & Feasibility	*Inherent Sustainability decisions (incl. Operational & End-of-Life)* • Sustainability priorities incorporated into project definition • Sustainability considerations ensure whole-life integration of risk, value and opportunity in feasibility studies • Sustainability priorities are translated into weightings to be used during performance assessment of design in subsequent stages
Design Outline & Option Formulation	*Strategic Sustainability decisions (incl. Operational & End-of-Life)* • Checklist of important features for sustainability performance • Guidance and criteria for designers on sustainable design • Innovative technologies and methods to improve sustainability performance
Appraisal of Design Options	*Strategic Sustainability decisions (incl. Operational & End-of-Life)* • Involvement of experts in advising on specialised studies and detailed weightings for performance assessment Assessment of each design option against sustainability criteria • Calculators to provide useful values needed for the assessment Participatory assessment which brings stakeholders, experts and planning authorities together to decide on final weightings, materiality and performance of each option • Comprehensive performance mapping of each option enables selection of best performing option Sensitivity analysis inspires confidence in results
Detailed Design of preferred option	*Tactical Sustainability decisions (incl. Operational & End-of-Life)* • Performance snapshot of preferred option used for improvement • Detailed guidelines on sustainable design and novel technologies • Guidance for incorporating whole-life considerations including constructability, operability and de-constructability
Tendering Action	• Guidance for ensuring contractor selection based not only on cost and time but also ability to produce desired sustainability outcome
Construction	*Tactical Sustainability decisions (incl. Operational & End-of-Life)* • Guidance on realising design intent • Assessment of end product against performance criteria to enable comparison with intended sustainability performance at design stage
Operation/In Use	*Operational Sustainability decisions* • Assessment of product in operation to enable comparison with intended sustainability performance at design stage • Guidelines on operational procedures for whole-life sustainability
Deconstruction /Decommission	*End-of-life Sustainability decisions* • Guidelines on good deconstruction/decommission procedures (re-use, recycle, disposal) for whole-life sustainability

Table 3.3 Contribution of Decision Support tools

1. Scoping & Objectives

During project initiation, the client and engineering consultants explore the vision behind the desired development and how this can be realised in a given regulatory and commercial environment. Overarching project objectives are formalised and alignment with organisational and national strategies are explored for identifying regulatory requirements and incentives. It involves the preparation of financial and technical feasibility studies to advise on areas of high risk, uncertainty and constraints to development. It also involves the preparation of a project management structure, scheduling, identification of external expertise required and selection of a suitable procurement method.

The size, complexity and key drivers for a project will determine the need for sustainability decision support. DS tools assist with processing large amounts of data and supporting decisions in the face of complex project impacts, risks, interests and tradeoffs.

The larger and more disruptive the planned development, the more crucial this support becomes. It can be perceived that conducting such projects sustainably will add to their complexity, but sustainable thinking from the outset enables early identification of tradeoffs, risks and opportunities that would exist regardless and would cause delays later.

For this reason, the following actions identify the recommended ways that DS tools can be utilised for: guiding uptake of sustainability principles, informing the baseline assessment and determining the materiality of impacts.

Guidance

During Conceptual or Inherent decision-making, sustainability DS services can offer valuable support in:

- Early exploration of affected groups (Stakeholder Analysis) and likely negative impacts. This enables identification of ways for project development to minimise impact and disruption
- Formalisation of pro-sustainability strategic goals and objectives with associated targets. This helps other stakeholders buy in to the project vision later on. It becomes a common language for designers and ensures that the developer commits to their sustainability priorities throughout the project
- Selection of pro-sustainability Key Performance Indicators (KPIs) for evaluating against later
- Social and Environmental Impact Assessments alongside financial or technical feasibility studies
- Systemic perspective from the outset which embraces interdependence between infrastructure systems and with society and the economy. This maximises the chances of identification of unforeseen risks and vulnerabilities that may cause delays or even failure later on. This helps formulate overarching strategies that guide scheduling, assigning of responsibilities, specialist studies, design of options and procurement considerations so as to mitigate these risks
- Early identification of trade-offs and support of decision-making in light of these
- Collaborative project planning which encourages buy-in and explores win-win avenues through dialogue with local or national government, interest groups or possible beneficiaries
- Emphasis on the local context and early awareness of local needs, peculiarities and regulations that may influence project development

Baseline Assessment

Early feasibility analysis includes an assessment of the baseline state prior to the planned development. It is critical that a holistic sustainability assessment of the stresses and interests of a region is made to determine if and how the project should proceed. DS tools can guide considerations of the following:

- What local or national critical service gaps exist that could be met by the project?
- What would be the direct and indirect benefits (e.g. employment, local economic regeneration) of providing such services, and how could the development maximise these? What are the possible negative effects of the project on social vulnerabilities?
- What are the local or national strategies and regulations that could accelerate progress or cause delays? What necessary specialist studies or licenses do these point to?
- Will any strain on local resources be exacerbated by the project?
- What local competing or supporting services (e.g. transport services) are available?

- What local environmental vulnerabilities could be exacerbated by the project and in turn cause further complications and delays?

- What would be an optimum site for the development in order to maximise the use of existing services, contribute towards local regeneration and minimise adverse impacts on affected communities and the environment? Design teams should always consider whether it is better for the project not to take place at all, or to change radically from the initial scope or location.

Materiality

As the project vision is formalised and a baseline assessment conducted, some potential sustainability impacts will emerge as priorities over others. It is advised that the Sustainability Criteria Set of a DS tool is used at this stage as a comprehensive list of potentially important criteria to consider (e.g. air or water quality). This is then subjected to a materiality test – i.e. testing whether, and by how much, each criterion is 'material' or 'relevant' to the project. The most flexible or rigorous DS tools offer the following options for tailoring the SCS to the project:

- Materiality Test: determining which criteria and indicators are of relevance to the project and eliminating the rest. A thorough materiality test should take into account project strategy, risks, concerns of different stakeholders, current and future challenges and opportunities, themes highlighted by regulation and certifying bodies and sustainability impacts identified by experts.

- Assigning overarching Weightings: Weightings assigned to sustainability criteria reflect the criteria's relative importance to the project, and are important during design option appraisal in subsequent stages. Overarching weightings are typically assigned by the client at this early stage, with sustainability consultant support. However, these are likely to be biased to the client's priorities. It is advised that assigned weightings are refined later on in the project with input from experts and potentially affected stakeholders. Weightings are optional and some DS tools avoid them considering that they add to the subjectivity of an already quite subjective process.

- DS tools also offer the flexibility for their assessment to be tailored to the criteria of an R&C tool that the project team wishes to apply for. This Report supports such an approach because it takes advantage of the in-depth consulting support of DS tools and the rigorous evidence-gathering and certification reward of R&C tools, thus maximising both motivation and sustainability quality.

DS services ensure that identification of priorities at this early stage is not biased to the interests of the client, but is truly representative of the likely impacts of the project. Using the same Sustainability Criteria set for setting overall project objectives, for conducting the baseline assessment and for assessing design options, offers a common platform for dialogue and sound decision-making.

2.Outline Design & Option Formulation

The Outline Design stage of the project engages the team in more Strategic Decision-making in terms of translating the overall objectives into specific strategies for the planned infrastructure, leading to the development of design options. Once these options are assessed and an option selected, the process of obtaining the necessary regulatory permissions is initiated.

Chapter 2 discussed areas of perceived Project Risk which can act as barriers to sustainability uptake. Large infrastructure projects involve multiple components and services, and this makes it harder for design teams to ensure sound knowledge of sustainable design for each system in isolation and in combination. DS tools have the capacity to support design teams in minimising these barriers and increasing their chances of acquiring planning permission. Their focus on collaboration and retaining decisions from one project phase to the next can empower designers to maximise their creativity and expertise to meet the project brief.

However, from the DS tools investigated, the majority focus more on design option appraisal. There is less focus on guiding sustainable design in the first place, which would maximise the quality of design options from their conception.

It is important that aside from posing the right questions during the assessment, DS tools offer guidelines as to how those questions can be addressed. The small number of tools that have standardised their sustainable design guidelines have found it offers a common language and is great for training young designers in sustainable design. It is also important for projects with no design option appraisal activity, where a single design is outlined and then developed further according to priorities and technical and financial feasibility.

R&C tools would be a good point of reference for DS tools wishing to strengthen their sustainable design guidelines. Some of them contain extensive guidance on this, as part of evidence gathering to inform the assessment process.

Option generation is an iterative process which increases in detail, complexity, stakeholder and expert involvement as it progresses. Iteration serves to utilise resources efficiently and build consensus around options. However, it is important to ensure that ideas and decisions are captured and not lost through the process. It is a process of creative divergence where designers initially come up with a large set of options, and strategic convergence as these are subsequently tested and refined against technical and financial feasibility and regulatory compliance.

3.Appraisal of Design Options

It is recommended that appraisal of design options is conducted through a Value Management workshop (also known as an Optioneering Workshop). This workshop tries to reveal the values and priorities of different stakeholders and thus build consensus and buy-in around the selected design option. This is encouraged because it becomes a collaborative, highly participatory process where engineering consultants, designers, clients, experts, planners and community representatives meet to evaluate each design option and agree on the preferred one.

This is a critical phase where DS tools need to be employed. This is because although project costs do not increase dramatically until construction begins, by the time detailed designs are produced for tendering, the project is already locked into a specific route of development. Should problems arise, such as opposition by local communities or environmental authorities, it becomes difficult and costly to choose a different avenue of development.

It is advised that such conflicts of interest and negative impacts are explored early, to minimise the cost of their mitigation. However, earlier stages of project development suffer from insufficiency of information on which to make decisions confidently, because studies have not yet been conducted nor design configurations produced. Therefore the timing of such a workshop is important. It must maximise the information available to decision-makers, maximise the flexibility in feasible routes that the project can take, but minimise the cost of selecting one route over another. If this is done in a participatory way, through the holistic lens of sustainability it can ultimately minimise the potential for disruption and associated costs later on in the project.

Stakeholders attending the workshop must be well informed about the project for meaningful design option assessment to be made. Therefore, it is recommended that prior to the workshop:

- Results from environmental and social impact analyses are made available to participants
- Design options are reduced to a manageable number of technically and financially feasible options. These are circulated to participants so that questions can be answered during the workshop
- Independent experts are consulted and detailed weightings assigned to sustainability criteria that will form part of the assessment process. These are circulated to participants so that objections or questions can be discussed during the workshop. Weightings need to marry stakeholder priorities, expert opinion and project viability.
- Calculations of critical values for each design option have been conducted and values made available to participants (e.g. lifecycle carbon, water consumption, capital or operational cost)

The confidence of a decision-maker is linked to the reliability and accuracy of the data on which decisions are made. Therefore, it is recommended that data provided is as accurate as the decisions they inform need them to be. They should refer to the same geographical area and period of time and, if collected from external sources, should if possible come from official survey departments.

Option Appraisal Workshop: Multi-criteria Decision-making

Aside from answering participants' questions, the purpose of the workshop is to evaluate each design option. With DS tools this can be done using the assessment framework containing the SCS, which is typically in software form. A strength of DS tools is in facilitating multi-criteria multi-stakeholder decision-making by processing large amounts of data, capturing the opinions and decisions of stakeholders and presenting them in a way which enables the selection of a single option. The assessment is a subjective process that depends on the opinions of the individuals conducting it. This is why doing so in a participatory way is important in increasing the credibility of the final decision.

Checklist

In its simplest form, option assessment is conducted by going through the list of indicators for each option, and taking into account data from calculations, studies and designs, deciding whether the option fulfils the requirements for that indicator or not. It should be cautioned that this approach relies mainly on dialogue, with the assessment framework as a prompt which captures the justification for the final option. There is a danger that it can neglect evidence and in-depth consideration of each criterion and so requires strong consultant expertise.

Mapping & Visualisation

Software based appraisal is useful in clearly presenting the SCS on varying levels of detail (from theme to indicator level) throughout the workshop while capturing decisions made, and presenting results. DS tool developers who are not advocates of sustainability performance scoring as they feel this encourages point-hunting, utilise instead the software's visualisation capability. A traffic-light colour system (red to green) is often used to present the agreed score of each option against each indicator into a colour representing performance. The advantage of this is that it enables the presentation of performance of a single design option against all sustainability criteria in one diagram. It becomes possible then for participants to determine at a glance the sustainability strengths and weaknesses of a given option. The visualisation characteristics of the assessment framework are important because they can reveal, or conceal, results which could affect decisions being reached.

Multi-criteria Analysis Methods (MCAM)

A variety of Multi-criteria Analysis methods have been developed to address the challenge of making decisions when multiple options (alternatives) and criteria (attributes) exist in a given problem. These broadly fall into two families :

Multi-Attribute-Based Utility Theory (MAUT) methods

These include the Simple Multi-attribute Rating Technique (SMART), Analytical Hierarchy Process (AHP) and the method of Generalised Means. It is recommended that AHP is used, as it is a method that can easily be understood by diverse audiences and applied quickly in a design option appraisal workshop.

During AHP, decision-makers conduct comparisons of pairs of options against a single criterion and assign a value of relative performance for each pair. The tabulated results are used to produce a performance ranking of options against each criterion, which is then combined across all criteria. Taking any assigned weightings into consideration, a ranking of design options is produced according to their overall sustainability performance. AHP can also be used for combining opinions on weightings for the different criteria of the assessment framework.

Outranking Methods

These involve the comparison of pairs of options where the extent to which one option performs equally or better than another on the majority of criteria (called the concordance condition), is established, as long as its worst performance on the remaining criteria is acceptable. This analysis is conducted for all pairs, providing an overall rank of options in terms of their sustainability performance.

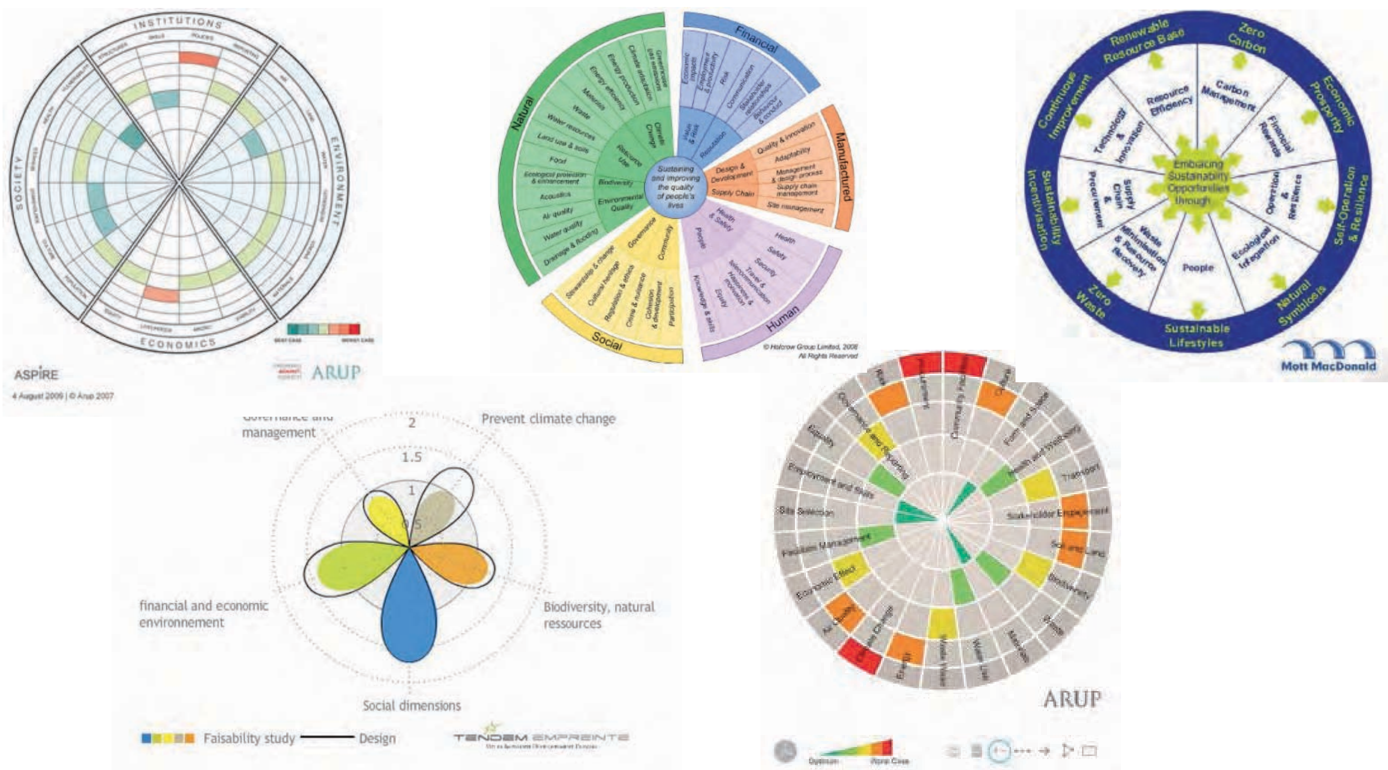

Figure 3.2 Sustainability Criteria Sets presented in a way as to facilitate multi-criteria decision-making

Sensitivity Analysis

The role of an assessment framework is to inform decision-makers with robust data rather than to make the decision-making a mechanistic, automated process. It is important that decision-makers have confidence in the overall ranking of options provided by the assessment tool. It is recommended that a Sensitivity Analysis is conducted on the results. The purpose of this Sensitivity Analysis is to give an indication of which criterion or combination of criteria the final ranking is mostly influenced by. This signals to stakeholders that the score or the weighting assigned for each option against these critical criteria may need to be looked at more closely. It is possible, that revising these or slightly modifying design options may significantly change the overall option ranking.

The more sophisticated assessment tools developed in industry incorporate a sensitivity analysis capability within the functions of the tool. During a sensitivity analysis, a variable, for example the weighting assigned to criteria, is changed (divided equally, changed to extremes) to observe how the ranking of options is affected. This enables the identification of the rank sensitivity to a variable. The disadvantage of this method is that only one variable can be varied at a time. An alternative method which enables simultaneous variation of more than one variable is a Monte-Carlo Simulation.

Finally, the ultimate decision for which option to go ahead with, needs to be based on the human judgement of the ultimate decision-makers in the project. The decision-maker's final decision is also largely affected by their attitude to risk. An option whose success relies on external factors, such as public participation, or which is entirely novel and has little to draw from existing expertise, will be less attractive. This is where ongoing support from sustainability DS services is important, to ensure that risk is minimised.

4.Detailed Design

Once consensus has been reached on the preferred design option, the project team proceed with the preparation of technical designs and specifications. Detailed costing, a procurement plan and technical packages for tendering are also developed and detailed regulatory applications can be made.

The option appraisal workshop will have provided valuable information which the design team can now take on board in producing detailed designs, including:

- A sustainability performance snapshot of the selected design option
- Recommendations on how that sustainability performance can be further improved

- Advice on how the design can best meet planning regulation, constructability and operability
- Advice on reduction of CAPEX and OPEX
- Further investigation needed to satisfy stakeholders (e.g. Carbon Management Plan)

The recommendation for DS tools to better guide the Outline Design stage also applies for the Detailed Design stage. These guidelines must now consider the holistic design for the project life-cycle including sustainability, functionality, cost, reduced CAPEX and OPEX, material procurement, constructability and operability. Where risk is unavoidable, design should be based on worst case scenarios.

Furthermore it is encouraged that a Construction Plan and Operational Plan are developed, incorporating information on expected sustainability performance and a monitoring and evaluation schedule. This is important to ensure that the performance intended at the design stage is realised during construction and maintained during operation.

5.Construction, Operation, Deconstruction

Ultimately, consultants will hand over the project to contractors and so DS tools do not focus substantially on the construction, operation and deconstruction phases of the project. Nonetheless, it is important to carry design intent through to subsequent project stages. For this reason, life-cycle thinking is very important from the earliest stage of a project. It is also advocated that the SCS is used to provide a sustainability performance snapshot of construction or operation and be compared with that at the design stage.

Although using the same SCS as at the design stage for assessing construction and operation enables comparison, for meaningful assessment the indicators would need to change significantly. For the tools investigated, the questions posed to the decision-maker to guide scoring are planning-orientated and are not suitable for exploring the same criteria at construction or operational stages.

Rating & Certification Tools

Introduction

Figure 3.3 below shows a typical Rating & Certification (R&C) scheme structure and introduces terminology used further in this report. An R&C Scheme contains different tools, each offering a slightly different sustainability performance assessment to suit a different typology or project phase. Assessments described by each tool typically differ in terms of their Sustainability Criteria Set, flexibility for scoping out (eliminating) criteria and in pre-assigned weightings.

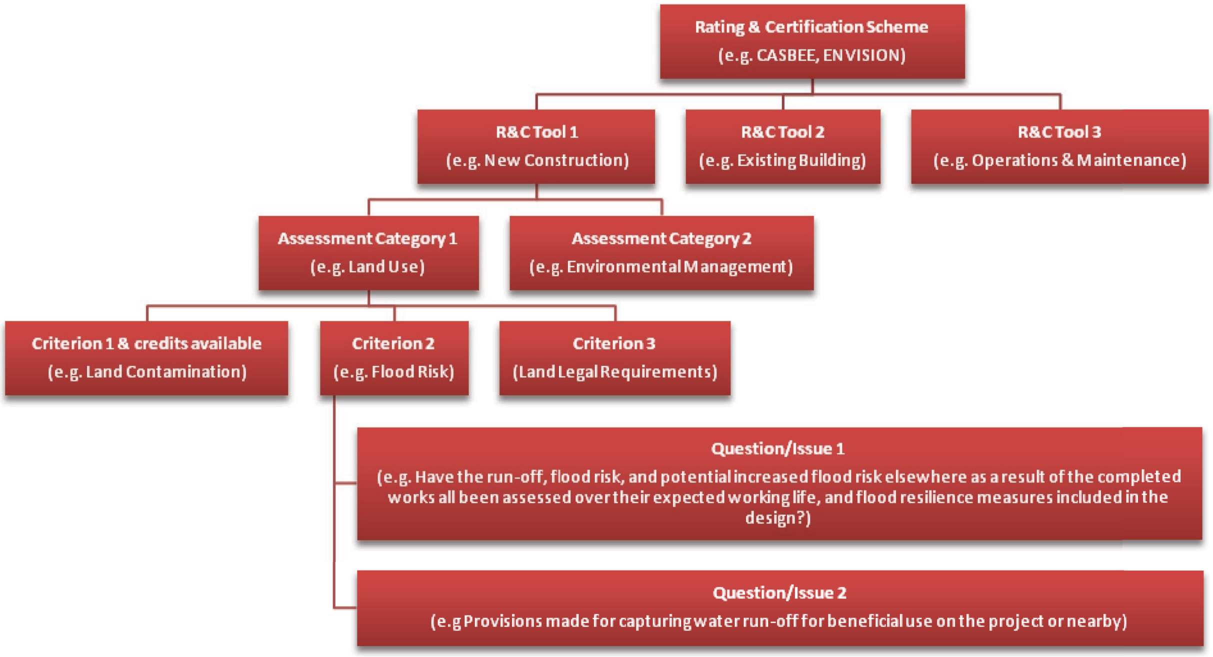

Figure 3.3 R&C scheme component breakdown

Each tool contains a series of categories each dedicated to a specific sustainability theme. Categories will contain a series of criteria which relate to specific issues within that theme that need to be considered. Schemes that offer scoring assign a maximum number of available credits (or points) for each criterion. It is considered useful that each criterion is further sub-divided into specific questions to be addressed, indicating what proportion of the total credits available can result from each question.

Figure 3.4 shows the typical process for obtaining sustainability certification for an infrastructure project. Depending on the scheme, the Applicant can be separately an architect, a design team, a Design and Build firm, a contractor, a client, or a team of the above.

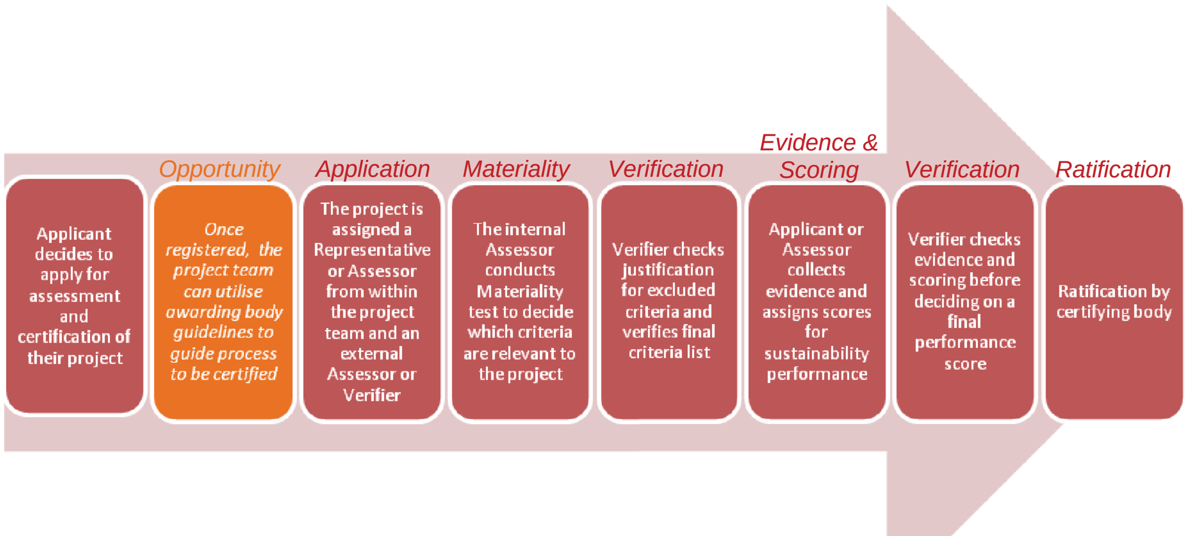

Figure 3.4 Process of obtaining rating and certification

Benefits of seeking sustainability certification for an infrastructure project include:

- Recognition by one's firm, sector and the general public of their commitment to executing a project with social, environmental and economic vulnerabilities and opportunities in mind
- Credibility: third party assessment and validation of this commitment
- Guidance: in sustainable planning, design, construction or operation & maintenance
- Qualifying for different government incentives, attracting business, higher sales or rentals
- Greater marketing exposure

Typical award types include: Outline Planning Award; Design Award; Whole Project/ As Built Award; Operations & Maintenance/ In-Use Award; Interim Award. The latter is an interim award that usually does not stand on its own. It can be an Interim Design Award in a Whole Project Award between design and construction, or an Interim Planning Award between the outline planning and detailed planning phases.

R&C tools which target not a single structure (such as a building) but a collection of structures with interlinking services, such as in the development of a new city or area regeneration, focus primarily on assessing the Outline and Detailed Planning phases of the project, rather than the Construction stages (e.g. BREEAM Communities or Pearl Communities)

Figure 3.5 Summary of R&C Tool quality characteristics discussed in this section

1.Timing

Project teams should be aware that the most time-consuming part of the rating process is the collection of evidence to prove sustainability performance. Behind the collection of evidence however, is also a project planning, design, construction or operation executed to certain sustainability standards. And so the following is recommended.

When to start

It is encouraged that the team registers with an R&C scheme as early in the project as possible. If a Whole Project/As-Built award is sought, the team should still register early, but the assessment and evidence collection will follow through to post-construction completion. More importantly, starting the rating process early also enables the project team to incorporate R&C tool sustainability guidelines, strategies and technologies into the project design.

When to collect evidence

Rather than waiting until a project phase is completed, evidence should be collected throughout the project as information becomes available.

When to carry out assessment

Particularly if the team is expected to conduct their own assessment of the project, it is encouraged that assessment and assigning of credits for each criterion takes place during project development and as evidence is collected. This enables real-time improvement of the project to improve score.

2.Risk Management

The risk of not obtaining a good score despite the investment can deter a project team from applying. The following methods are recommended to certifying bodies for maximising support and reducing risk to projects:

Iteration

- Offering multiple rounds of assessment review between which a project team has the opportunity to provide further proof or clarify uncertainties to the review committee
- Offering the opportunity for an informal assessment before formal submission
- Allowing appeals against final score and re-submission

Support

- A certifying body representative (Assessor or Verifier) is appointed to support the project team
- Advice and verification provided on the criteria scoping out and weighting process
- Training offered for team members to become qualified assessors for the project
- Software platform: Use of online software tools for better information management, for communication between the team and awarding body and ease of correction and iteration. It also allows easier incorporation of Calculators into the process
- Supporting documents: including technical manuals, case studies, reporting formats etc.

Cost

- A tool which is cost conscious, seeks evidence which is feasible to collect in terms of time, effort and cost and is proportional to the importance of the sustainability criterion in question
- A tool which does not undermine the financial and risk implications of sustainable design
- The process should be rigorous to ensure quality, but easily comprehensible in terms of steps, milestones, reporting, effort/cost, evidence requirements and ultimate benefits of assessment.

3.Guidance to Applicants

In comparison to DS tools which can have a high sustainability consultant involvement in project development and assessment, implementers of R&C Tools are much more hands-off. In most cases, project teams are required to apply R&C tool sustainability criteria to project design on their own, collect evidence of conducting this satisfactorily, conduct self-assessment and assign credits according to the performance they feel their project has achieved. This is then submitted to an external assessment panel to review and provide an appropriate award. Therefore, project teams applying for certification have to rely heavily on guidance from software and manuals that accompany R&C tools.

The hands-off nature of R&C tools in comparison to DS tools is another reason why rigorous collection of evidence, justification of tailoring options by the project team and adequate guidelines by the certifying body are so important. An R&C tool that is weak in any one of these three areas risks significantly compromising the quality of the assessment.

Below is a list of recommended information that should accompany each criterion in the sustainability assessment, in order to guide the project team satisfactorily. R&C tools investigated provide a variety of these, but very few provide all. Guidance must answer 4 basic questions:

1. What needs to be taken into consideration for my project to be sustainable?
2. How do I go about considering each criterion, step by step?
3. What evidence do I need to collect to prove that each criterion has been considered satisfactorily?
4. What is the significance of each criterion in the overall assessment and how are credits awarded for each question within it?

With this in mind, the kind of information that should accompany each criterion includes:

- Goal: a one-liner on what this sustainability criterion is trying to ensure
- Total number of credits available for that criterion
- Goal breakdown: A breakdown of sustainability questions/issues that need to be addressed to ensure the criterion is satisfied
- Evidence Schedule: what evidence is needed, in what form (incl. units), and at which phase of the project should it be collected
- Credit breakdown: Total credits available for that criterion divided among the sustainability questions/issues to be addressed
- If the R&C tool does not award credits for each criterion but rather presents increasing levels of sustainability performance, guidelines are needed on what will satisfy each level
- Responsibility: At what project phase the criterion needs to be considered, and hence whose responsibility it is to ensure it is fulfilled
- National or international regulations or standards that the criterion is aligned with
- Strategies & Technologies: which can be used in the project to satisfy sustainability issues
- Calculations & Methodologies: used to produce data required as evidence for certification

- Useful Calculators, whether these have been developed specifically for the R&C tool or not
- Criteria dependency: other criteria in the assessment that the criterion in question is related to, particularly ones which need to be fulfilled before this one is tackled
- Differentiating between structure typologies in terms of evidence required, useful strategies and technologies, calculations and methodologies, and points available
- Minimum standards that need to be achieved (if relevant)
- Whether the criterion is mandatory or voluntary
- Whether and under what circumstances the criterion can be eliminated
- Sustainability benefits of complying with this criterion (particularly if voluntary)
- Current benchmarking performance for this criterion
- Case studies where the criterion has been implemented successfully
- Potential difficulties in applying a criterion to the project
- Glossary, useful resources or references

Evidence Requirements

Collection and development of evidence may involve many things including preparing design documents, presenting calculation results or providing plans for management, execution and monitoring. It can thus require significant time, effort and cost to produce. For this reason R&C tools should minimise evidence requested, while ensuring sustainability performance and evidence of it.

One way of minimising effort is to request evidence which can be extracted from existing project processes and documents (e.g. Tender or Planning Permission documents, Engineering Feasibility Studies, Cost Appraisal, Specialist Studies) or be inexpensive to produce from them. More generally, the assessment must request actions and evidence that are within the power of project teams to perform and supply. It needs also to allow for iteration of evidence gathering, verifying, refining, elaborating on or resubmitting. Finally, as already discussed, when evidence is collected has a big impact on the team's ability to collect it in sufficient detail, and the cost and effort involved.

Final Output

The final output of the R&C process is a certificate from a reputable organisation which showcases to the sector, interested parties and the public, a development that has achieved a certain standard of sustainability. It also provides valuable information to the project team as to the sustainability performance of their development. This can best be achieved by providing:

- A certificate specific to the project scale, type and phase being certified
- A final score and an interpretation of the sustainability performance it represents
- A score breakdown showing credits awarded compared to credits available
- A narrative of strengths and weaknesses and improvement recommendations
- Guidance for subsequent project stages to carry through the sustainability intentions of the certified phase

4.Credibility & Recognition

The nature of R&C tools requires them to be linked to a credible, reputable organisation within the target sector. This is encouraged for the following reasons.

- Government Incentives: Government can provide financial and other incentives to reward developments that achieve high ratings (e.g. GreenMark, Singapore) or to reduce capital investment required for sustainability enhancement through tax exemption on added cost (e.g. GBI, Malaysia)
- Scoping for future regulation: Assessment can become a mandatory regulatory requirement, particularly when the certifying body is a regulating or planning permission granting authority (e.g. Estidama, Abu Dhabi). R&C is usually voluntary and seeks performance over and above regulation. However it has the important potential, as regulation becomes more ambitious, for components from its sustainability assessment to be absorbed into national standards and regulation.
- Alignment to regulation: Proximity to government implies that sustainability criteria can stem from regulatory requirements, helping projects meet and exceed these. Thus R&C tools can and should be designed to accelerate fulfilment of policies (e.g. Code for Sustainable Homes and the Green Deal). They do not however, usually replace existing standards.

Not all R&C tools offer Certification. Some only go as far as to verify the project (e.g. Envision). This can be to avoid the complexity of becoming a certifying body, or because it is felt that providing a certificate of a level of achieved performance undermines the complexity and dynamic nature of sustainability.

Credibility is also ensured by assessors being trained by the awarding body, and by having the assessment results reviewed by an independent team of experts from either within the awarding body, or an approved external one.

5.Assessment

This section focuses on the assessment aspect of the R&C process, particularly on sustainability criteria, how scoring is set up for receiving credits and the levels selected to indicate sustainability performance.

Scoring

The score available for each criterion in the assessment should be designed by assuming a certain performance minimum, usually at the point of regulatory requirement, and a performance maximum according to existing benchmarking performance. Negative scoring can be used to indicate lack of regulatory compliance. There are typically three scoring options:

I.Criteria are not allocated credits

The assessment is effectively a yes/no checklist and can undermine the complexity and cost behind meeting different criteria. However it is useful when criteria are all mandatory (as in the case of a Standard), or with schemes that develop a set of tools of differing complexity, a checklist being the least complex (e.g. Envision).

II.Each criterion has a number of credits, indicating its share in the overall score

Credits earned for each criterion are added to calculate the category score, weightings (if they exist) are then applied to each category, category credits are summed up including any bonus points earned for innovation, and the final score is used to decide the award level to be granted. Ideally, there should be a breakdown of credits available within a criterion in terms of any or all of the following:

- Sustainability questions that need to be addressed (e.g. if A is achieved, gain 1 credit. If B is also achieved, 2 credits)
- According to different percentages of achieved quantity (e.g. one credit for 30% of material obtained from recycled sources. Two credits for 50%)
- Total number of points available for a criterion is subdivided according to the progress achieved along a process (e.g. planning, execution, monitoring)

III.No credits, instead, criterion performance is divided into fixed sustainability levels

A minority of tools fix sustainability performance levels, such as Adequate, Very Good, Enhanced, Conserving, Restorative, which are used both for the final score and for each criterion individually. The applicant is guided on what will ensure each level is achieved for each criterion. The risk is that it can be unclear to the applicant what activities will lead to each level of performance, and by how much.

Performance levels

Once the final score is calculated, it needs to be compared to different performance levels which translate to a level of sustainability obtained. Performance levels can be expressed in 4 ways:

- An overall percentage such as: 40% or 60% overall performance achieved
- An increasing numeral such as: 1-5 Pearls (Estidama) or Code 1-6 (Code for Sustainable Homes)
- Descriptive sustainability levels: Improved, Superior, Conserving, Restorative (Envision)
- Generic performance levels: Poor, Good, Very Good, Superior (CASBEE)

This is important as it forms part of the certificate, and marketing material that is later shared publicly. The performance level needs to be easily comprehensible, particularly regarding where it lies on the scale of poor to excellent. In one case for example, it is not intuitive that the performance level Scheme Plus is superior to Scheme Gold.

6.Tailoring

Tailoring is one of the key functions of an R&C tool and refers to its ability to tailor the sustainability assessment to the type of project being reviewed. This is not easy because in contrast to DS tools where performance comparison is usually made between design options within the same project, with R&C tools the comparison is between projects. A good R&C tool is one which strikes a balance between standardisation to enable comparison, and flexibility for meaningful project assessment. Table 3.4 describes the main parameters that differentiate projects and how R&C schemes respond to these.

Several mechanisms are recommended for tailoring. These include:

- Materiality: the ability to exclude from the assessment criteria which are considered Not Applicable, without compromising the final score. Reliable justification should be required to ensure that omission is made on the grounds that they are irrelevant, rather than that they are difficult to obtain evidence for. These should be revisited later on to ensure they are still irrelevant
- Voluntary Criteria/Tradable Credits: the ability to not address criteria and still obtain certification, compromising however, the final score
- Mandatory Criteria: certification will not be awarded unless these are satisfied
- Weightings: the ability to assign weights to different criteria or categories of criteria to reflect their importance in the overall score
- Minimum Standards: within voluntary criteria there can be minimum standards to fulfil, linked to minimum legal requirements, even if no further progress is sought

7.Innovation

It is recommended that R&C tools offer credit for innovation. This can serve three purposes:

- To acknowledge and reward innovative strategies, technologies or methodologies
- To acknowledge and reward performance beyond best practice, i.e. exceeding maximum standards defined by the R&C tool's assessment
- To acknowledge sustainability expertise and design measures not covered by the tool

These should be carefully reviewed formally by the certifying body to ensure the effectiveness of new technologies/ strategies or of additional sustainability criteria.

None of the schemes investigated has developed tools for the Deconstruction or Decommissioning project phases, although life-cycle considerations at the design stage are strongly encouraged. Instead, primary focus is on the Design or the entire project until Construction-completion. However, an increasing number of schemes are recognising the importance of assessing the performance of structures in-use or during operation and maintenance and are developing tools for this. Greater effort should be made to develop R&C tools for assessing operational and particularly end-of-life activities.

Tailoring Parameters	R&C Scheme setup
Target industry: buildings, transport, water, energy, waste, communications etc.	Unless the scheme targets all infrastructure types, it is industry-specific
Project type: new construction; upgrade, renovation or refurbishment; conversion; expansion	Different tools are developed under the same scheme (e.g. BREEAM Communities, BREEAM New Construction)
Project geography: projects in different geographies with different regulations and social, environmental and economic vulnerabilities	
Project scale: Different levels of assessment to reflect project scale and complexity; requiring more effort, evidence and time from projects which have a potentially higher overall impact. Projects can range from small, single structures; to large complex structures such as a railway; transmission or distribution networks such as for water or electricity; or city developments with multiple services	Tailoring is made within the tool OR different tools are developed within the same scheme
Structure typology: E.g. buildings sector: residential, offices, retail, campuses, healthcare, prisons or education. Transport: highways, roadways, bridges, railways, bus and cycleways	
Contract type: differing in procurement and management, such as Project contracts, or Term contracts involving multiple works orders	Tailoring is usually made within a tool, but development of different tools exists with some schemes
Project phase: Planning, Design, Post-Construction, Operation/ In-use, Deconstruction, Decommissioning phases. Actors can strive for sustainability within their own realm of influence	
Target sector: A public, commercial or private development	Tailoring is made within the tool

Table 3.4 Tailoring parameters in R&C schemes

Tools that are useful for all types of infrastructure can have some significant shortcomings. They have a larger capability to exclude some criteria which are also more generic and there may be less opportunity for useful guidance in terms of methodologies, strategies etc. It is strongly recommended that R&C tools should be as specific to sub-sectors, structural typologies and geographies as is possible.

Dominance of the Buildings Sector

The Buildings Sector is far more advanced than others (Transport, Water, Energy, Communications) in the development and deployment of R&C tools. This is due to several factors, including:

- Competition: The buildings sector is diverse and competitive while the transaction market between a utility and a customer is a natural monopoly with operators being assigned specific geographical regions to serve. This competition in the buildings sector stimulates market actors to strive to demonstrate the higher value of their development.
- Decentralisation & shorter life-span of assets: The buildings sector is more decentralised than utilities and its assets have a shorter life-span and higher turnover than utility infrastructure assets, and are thus able to respond to demand and incentives more quickly
- Regulation: The rapid development of the urban environment, particularly in response to housing needs due to migration in emerging economies, and its share in global emissions has stimulated the development of more stringent laws regarding emissions, energy consumption, water consumption and sustainable design
- Motivation: In the buildings sector, sustainable design impacts customers (tenants or owners) directly by affecting working or living conditions and comfort. In combination with increasing awareness, this has led to greater demand for environmentally and socially responsible developments by the public or companies who wish to be associated with a property which reflects their corporate ethos. In contrast, the demand for sustainable infrastructure for utilities comes predominantly from the latter's desire to reduce risk and resource depletion and to comply with regulations, rather than due to the customers themselves.

R&C & DS Tool Comparison

This report ultimately aims to advise organisations who wish to develop their own tools, or those who are looking to decide which tool on the market is most suited to their needs. An important distinction needs to be made particularly between R&C tools and DS tools, in terms of their strengths and weaknesses which stem from their intended use. Because the ultimate aim of an R&C tool is to provide certification it has the following advantages over a DS tool:

- Evidence hungry: More focus is placed on providing documentation as evidence to justify the ultimate score. This encourages project teams to investigate more rigorously the sustainability performance of different project components, thus inspiring confidence in project design and developing skills in sustainable project development.
- Credibility: Unbiased, third party assessment (or verification of self-assessment) of projects, and certification by a reputable institution can give confidence to the general public and affected stakeholders that the sustainability performance of the development is that which is being claimed. A certificate also offers the project visibility and can potentially attract further investment, higher paying tenants or attract further business for those involved in its development.
- Government Support: Such tools are developed by bodies with close links to government, hence closely aligned with regulation, and can take the form of nationally recognised voluntary standards. This increases their chances of being promoted and supported by government (via incentives), and of such voluntary standards being absorbed into regulation and made mandatory in the future.

Despite the above, an R&C tool can suffer from the following characteristics:

- Point Hunting: The project team and assessor (especially if from within the team), will generally try to maximise the project score for the minimum cost. This can lead to the so-called point-hunting phenomenon where the project team's attention is diverted from trying to develop a truly sustainable project, to trying to gain as many points as possible from criteria requiring minimum effort, thus targeting the 'low-hanging fruit'. And this is where the different characteristics of R&C tools, discussed in this Report, can encourage or discourage such behaviour. DS tools do not usually aim to produce an aggregate project sustainability score and thus suffer less from this phenomenon, focusing attention instead on improving the sustainability performance of areas of critical impact.

- Guiding Design: The drive for achieving a high score can also imply that sustainability checklists offered by such tools might be used to guide the design stage of the project to ensure that the design gains maximum points. While this may sound a good idea, many such tools are not developed with the intention of guiding design and thus do not offer detailed guidelines towards this. In the case where the assessment is just a checklist, this can severely compromise the quality of the design in terms of parameters such as functionality, aesthetics and constructability.

DS tools become more useful in :

- Involvement & support: Because the development of a sustainable project is top of the agenda, the client works closely with their consultants to ensure that the project truly maximises sustainability performance from start to finish. The increased support by sustainability consultants implies that the sustainability assessment can be much more tailored to the needs, nature and vision of the project from the outset, and puts them in an ideal position not only to assess design options, but also to train and guide design engineers in truly sustainable design.
- Inclusivity: Another strength of DS tools is that they embrace stakeholder involvement in the assessment and decision-making process, thus increasing transparency, inclusivity and chances of buy-in from project stakeholders. They also tend to encourage the involvement of experts in identifying areas where the project may have a significant negative impact and prioritising these in the assessment.
- Consulting for Certification: Finally, several DS tools are designed to be compatible with popular R&C tools, such that their clients can benefit both from continuous support and ultimate certification.

In conclusion, the recognition and confidence attached to pursuing an R&C tool assessment can make it stronger in motivating project teams towards pursuing sustainable infrastructure. On the other hand, the step-by-step ongoing support and participatory nature of DS tools can make them stronger in facilitating truly sustainable infrastructure in the long term.

Calculators

Developers of Rating & Certification and Decision-Support tools are increasingly recognising the need to develop calculators which build on existing methodologies to provide data which is compatible with their own assessment frameworks. These calculators are needed in order to provide a user-friendly platform for rapid, sometimes simplified, calculations of data.

In their simplest form, calculators are spreadsheets with inbuilt data libraries which use data submitted by the user to calculate needed values. In their most complex form, they are simulators which combine design modelling with calculations to simulate different design or process scenarios, enable comparison and output important values.

Quality Features

These are features and characteristics which are recommended for assessing the quality and suitability of a calculator.

1.Guidance for Users

This refers to guiding information accompanying the calculator, either within it or within accompanying documents (such as a User Guide). This should include information on:

- How to use the calculator incl. use of the data libraries, insert inputs, display results etc.
- Data which needs to be inserted by the user, in what units, what separate calculations need to be performed to obtain these and where required information can be found (e.g. the water flowrate of kitchen appliances for calculating water consumption)
- Assumptions and conditions behind pre-set calculations in the tool for correct results
- Calculator suitability for infrastructure types and compatibility with other tools or standards
- Once calculation results are obtained, guidance on how these can be improved
- Mandatory or suggested upper, lower, optimum performance targets set by regulations or certification tools for comparison with output values

2.Database Library

These are inbuilt datasets within tools which include information needed for calculations. They are very important not only in ensuring calculation accuracy, but in speeding up the calculation process. For parameters where the user might not have sufficient data, the calculators often use recommended values from these data sets. It is recommended that these libraries include:

- Values or models for different standard industry materials and components (e.g. embodied carbon and costing of construction materials)
- Values for standard techniques (e.g. construction techniques or concrete formulations)
- Stored common design configurations with their calculation results
- Partial results for common project types or geographical locations (e.g. pre-calculated results for proximity of mass transport links to the project site for commonly occurring postcodes)

Data for parameters typically come in the following forms:

- Built-in values within tool libraries (which can usually be altered by the user)
- Suggested values (which can be used by the user if no data exists)
- User-defined values (typically relating to the specific project)

3.Function

Recommended uses for sustainability calculators include:

- Comparison of specific parameters, such as the carbon footprint, of two options. This can be comparing the performance of an existing structure with a proposed retrofit, or a baseline case (do nothing case or normative case) with a proposed development
- Improvement of performance of a design against a specific parameter. Care should be taken not to undermine other important parameters for design quality, just because they are not considered in the calculator or required by regulation
- Combined modelling function with data calculation (such as thermal performance) for optimisation of design and component configurations
- Providing data needed for sustainability appraisal of baseline, proposed design options, construction, operation or decommission

4.Methodology

Some calculators, particularly ones embedded into other Sustainability tools, apply simple methodologies. It is important that the benefits of cost and speed that come with simplicity do not compromise the validity of the calculation. More complex calculators usually employ recognised methodologies in economic, social and environmental assessment, and some of these are presented below. Depending on the nature of the results, input can include for example: product specifications, design details, bills of quantities, planned operation and maintenance schedules. Some common methodologies embedded in calculators or used to inform assessment tools include:

Economic:

- Economic Cost-benefit analysis (CBA)
- Social Cost-benefit analysis
- Cost-effectiveness Analysis (CEA)

Environmental:

- Life Cycle Assessment (LCA)
- Material Input per Unit of Service (MIPS)
- Environmental Risk Assessment (ERA)
- Material Flow Accounting (MFA)
- Cumulative Energy Requirements Analysis (CERA)
- Environmental Input-Output Analysis (Env. IOA)
- Analytical Tools for Eco-design
- Life Cycle Costing (LCC)
- Total Cost Accounting (TCA)
- Environmental Impact Assessment (EIA)
- Environmental and Social Impact Assessment (ESIA)
- Risk Assessment
- Strategic Impact Assessment (SIA)

5.Results Report

Standalone calculators (as opposed to ones embedded in assessment frameworks) typically enable the production of a report meaningfully highlighting calculation results. Features of a report can include: graphical representations of design option results for comparison, reporting to standards required by ISO or regulation, annual expenditures, summaries, distribution or cumulative profiles, bill of quantities required, project specifications etc.

6.Characteristics

Important characteristics of calculator quality and usefulness include:

- Data transparency and flexibility: the ability for the user to view and add to or alter values in the inbuilt database
- Data intensity: time and expertise required to collect and process data required for calculations. This affects speed, feasibility and accuracy of results. Recommended values are important in cases where data does not exist, particularly in the case of low-income country projects
- Assumptions and suitability: clear communication of assumptions and conditions under which the calculation is valid, to avoid erroneous results
- Boundaries: clear communication and useful setting of calculation boundaries, for the project (e.g. a whole-life, embodied, construction or operational calculation)
- Form of inputs and outputs: is the calculator compatible with the available form of inputs (e.g. data from suppliers) and are outputs provided in the form required by assessment tools, standards or regulations (e.g. tCO_2eq)?
- Comprehensiveness: the extent to which relevant factors are considered and incorporated appropriately into the calculations
- Simplification: Simplification of calculation is needed to reduce costs of data collection, increase speed of use, increase ease of use by potentially non-expert users. However it must be balanced with accuracy of prediction and realistic modelling of real-life scenarios
- Suitability: Calculators typically advise performance on a small number of parameters hence should not be advertised as being able to advise on overall sustainable design or sustainable project execution, particularly if not accompanied by detailed design guidelines to help improve performance. Because regulation can rely on the values of such calculators, it can be tempting for designers to modify design parameters with the main purpose of reaching the target values required by regulation. However this can compromise the planned development in terms of other important quality parameters
- Speed: Given that a calculation in a given project may be calculated several hundreds of times, speed becomes significant. It is recommended that calculators are developed to standardise calculations and offer speedy results. Speed can further be increased through:
  - Having a library of results for commonly occurring conditions, design configurations or geographical locations
  - Integration with design modelling and visualisation of the structure being modelled
  - Having an existing library of data which can be altered if needed, otherwise provides necessary or recommended figures if the user has none better
  - A complexity of calculation which reflects the criticality of the value and the decisions it informs

Appendix I provides a comprehensive, though by no means exhaustive, list of commercial Calculators currently on the market.

Guidelines

Numerous sustainability guidelines have been created to drive industry towards more sustainable projects, and here just a few are mentioned. These form the backbone of R&C, DS Tools and Calculators because they provide expert advice on what constitutes economic, environmental, social and institutional sustainability for each sector of infrastructure. Some of these go further to include indicator sets and targets which can be adopted for use in assessment frameworks.

Indicator Sets

It is recommended that useful, relevant indicator sets should be :

- as sector and geography specific as possible
- clear in terms of what data they require and in what units
- reasonably feasible (in terms of time, cost and expertise) to acquire data for
- auditable
- straightforward to understand
- as universal as possible and independent from the particular conditions of the project
- quantifiable so as to provide objective measurement, avoiding personal or subjective appraisal
- in a form useful for international standards and certification

Appendix II identifies some of the guidelines for advising on infrastructure sustainability

Chapter 4
FIDIC's Role

This Report has been produced by FIDIC in recognition of the need for the consulting engineering industry to take more of a leadership role in sustainable development. Engineers have an obligation to serve their clients, but they also have an obligation to serve the public by identifying incomplete or insufficient policies and programmes.

In 2009 FIDIC issued its first State of the World Report to raise awareness of the increasingly complex challenges being faced by the infrastructure sector. A key message of that Report was the leading role that the consulting engineering industry has to play in tackling these challenges.

In parallel, through the publication of the Project Sustainability Management Guidelines (PSM) in 2004 FIDIC began the process of making a significant contribution internationally to emerging sustainability guidelines and tools for the infrastructure sector. PSM II is currently under development to further enhance the guidance it provides for projects to be executed more sustainably.

This Report outlines current best practice and procedures as they exist at the time of writing. There is no doubt that they will continue to evolve and FIDIC will produce future updates of this Report as part of its core commitment to sustainability.

Of course sustainability is only one of the three basic principles of FIDIC, the other two being Ethics & Integrity, and Quality. There is evidence that a formal and systematic approach for managing integrity works better than sporadic efforts developed by individual companies. FIDIC continues to push for the implementation of integrity management as an industry benchmark. Combating corruption also requires a concerted effort by everyone involved in projects - clients, contractors, consultants, government procurement groups and funding agencies alike - to help prevent, and not just punish, corrupt practices.

FIDIC advocates that the keystone to ensuring quality and best value from an infrastructure project is the procurement of the professional consultant who is best able to provide the solution to meet the client's requirements over the lifespan of the project. The procurement should be by an open and transparent process which focuses on the ability of the professional consultant to meet the needs of the project, and of all the stakeholders.

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

Appendix I. Sustainability Calculators

Developers (country)	Calculator (D=deployed, UD=under development)	Type	Sector (Tool to be used with)
ISI & Harvard University (US)	Economic Assessment Tool (UD)	Unknown	All infrastructure (ENVISION)
AGIC (Australia)	Materials Calculator (UD)	Unknown	Buildings (IS)
	Change in Ecological Value Calculator (UD)	Compares the ecological value of the site chosen for development before and after development.	Buildings (IS)
BRE (UK)	Water Efficiency Calc. (D)	Option between a basic (for simple homes) or a detailed (for complex homes) calculator which calculates potable water consumption of a dwelling.	Buildings (Code for Sustainable Homes (CfSH))
GBCA (Australia)	Mass Transport Calc. (D)	Assesses the extent to which a building can be accessed using commuting mass transport, based on population density, mass transport type, average interval between services during peak periods, and proximity of transport stops to development.	Buildings (Green Star)
	Potable Water calc. (D)	Calculates potable water consumption of the building taking into account appliances and greywater, rainwater or blackwater recycling.	Buildings (Green Star)
	Change in Ecology calc. (D)	Compares the ecological value of the site chosen for development before and after development.	Buildings (Green Star)
	Sewerage Calculator (D)	Water consumption due to sewerage system, taking into account water consumption and sewerage reduction due to recycling.	Buildings (Green Star)
JSBC (Japan)	Life cycle Carbon Calculator (D)	Calculates CO_2 emissions over building life-cycle	Buildings (CASBEE)
ACEM & PAM (Malaysia)	Building Energy Intensity Tool (BEIT) (D)	Calculates energy consumption of a building based on structure characteristics, heat gain from building walls, glazing and roof, lighting requirements, plug load requirements, air conditioning requirements and other miscellaneous loads. Enables calculation comparison between existing and improved design	Buildings (GBI)
PHILGBC (Philippines)	Credit Weighting Tool (D)	environmental impacts and the relative importance impact to determine the weighting for each criterion	Buildings (BERDE)
Mott MacDonald (UK)	LifeCYCLE (D)	Auditable lifecycle costing and whole-life carbon footprinting for buildings (adaptable to other sectors). UK but adaptable to other countries. Produces info to ISO and best practice standards on: capital cost, lifecycle cost,	All infrastructure (INDUS; Sustainable Water

Developers	Calculator	Type	Sector
		embodied & operational CO_2, resource requirements, waste reports, building life span, spec optimisation based on whole life performance, material transportation impact. Database of construction materials and elements and their embodied carbon and cost. Reports produced which can accompany design options for option appraisal and design optimisation.	Engineering Opportunity Tool)
	CapIT (D)	Construction capital cost and CO_2 calculator for building and civil engineering projects. Optimises specs based on cost and embodied CO_2	All infrastructure (INDUS; Sustainable Water Engineering Opportunity Tool)
	Carbon Pilot (D)	Estimates cost of incorporating different carbon footprint reducing measures (passive or active, particularly renewables) in early building design, taking into consideration orientation, lighting, cooling and heating etc. by combining cost, energy and carbon data. Uses NCM default values for base building.	Buildings (INDUS; Sustainable Water Engineering Opportunity Tool)
USGBC (US)	Water Efficient Landscaping Calc. (D)	Calculates reduction in potable water use for irrigation in landscaping due to plant species factors, irrigation efficiency, use of captured rainwater or recycled greywater or use of water treated by a public agency specifically for non-potable uses. Compares design to baseline case	Buildings (LEED)
Egis & World Bank	ROADEO (Road Emissions Optimisation) (D)	Enables calculation of road work items based on general characteristics, outputting bill of quantities at the feasibility study stage. Based on this and general project characteristics, CO_{2e} emissions are calculated. For new alignment, widening and rehabilitation of roads.	Transport (Tandem Empreinte)
Egis	OPTRA Eco-comparator (D)	Calculator and Simulator which determines roadwork impact on traffic, emissions, noise and mobility around the works, by calculating extent of congestion, time wasted, increased fuel consumption and increased emissions. Advises design of diversion measures so as to minimise impact. Offers optimum time window for road works to minimise disruption. Real-time use offers transit time information to users and optimal traffic management plan operation. Post-roadworks impact evaluation through simulation and use of traffic counts observed.	Transport (Tandem Empreinte)
	Ground Movement Strategic Planning (D)	Enables evaluation of different infrastructure design and operation scenarios in terms of capacity and carbon emission reduction. Supports decisions such as terminal geometry, parking stand usage, addition of taxiway, addition of rapid exits. Utilises in-built aircraft and engine databases, emission figures, descriptions of routings between parking positions and runways, apron allocation rules and traffic characteristics.	Transport-Aviation (Tandem Empreinte)

Developers	Calculator	Type	Sector
Egis Avia and French Civil Aviation DSNA	OPAS – Air Traffic Control Simulator (D)	Sends pseudo-ATC instructions to aircraft in simulation, adjusting speed, altitude, direction and ensure separation. Simulator generates trajectories close to radar tracks observed in real life, allowing for comparison of aircraft emissions and noise in different airspace configurations, and also on the ground evaluating different routings, for example rapid exit taxiway, aircraft parking scenarios etc.	Transport-Aviation (Tandem Empreinte)
Egis Avia	PHOTOVOLTAIC – Glare and Safety Assessment (D)	Informs on risk of glare for pilots and tower controllers due to photovoltaic modules installed in the vicinity of the airports. Determines potential angles of reflection between solar panels and aircraft paths approaching the runway, between solar panels and tower control, estimates solar power during such times and reflection in the direction of the observer. Advises on new geometry for solar farms to avoid glare in critical directions.	Transport-Aviation (Tandem Empreinte)
Environment Agency (UK)	Carbon Calculator (D)	Calculator for direct and indirect carbon emissions during construction, calculated on the basis of construction materials, transport distance, and mode of transport. Also calculates emissions due to personnel travel during construction, where one or both the distance and mode of transport is known. Provides information for optimising mode of transport and journey patterns to reduce emissions.	Construction
@one Alliance (UK)	Anglian Water Carbon Modeller (D)	Enables in one tool, the modelling of different design configurations for planned waterworks which uses in-built library of components and materials to output the carbon footprint of each design configuration.	Water
Royal BAM Group (Netherlands)	Project Carbon Calculator (PCC) (D)	Uses a list of emissions factors to calculate carbon footprint during construction of buildings or public utilities infrastructure through consideration of construction materials, construction site equipment, personnel, waste, transportation and energy consumption on site.	Construction
Department for Communities and Local Government (DCLG) (UK)	National Calculation Methodology (NCM): Simplified Building Energy Model (D)	Based on the UK National Calculation Methodology for calculating annual energy use for a proposed building in comparison to a baseline for compliance with the UK Buildings regulations, SBEM calculates monthly energy use and carbon emissions given building geometry, construction, use and HVAC and lighting equipment. Focus on non-domestic buildings. Used to produce Energy Performance Certificates (EPCs)	Buildings
	Standard Assessment Procedure (SAP) (D)	Calculation methodology and associated calculators for determining energy performance of domestic buildings. Used to produce Energy Performance Certificates (EPCs)	Buildings
International Road Federation (IRF) (International)	Calculator for Harmonised Assessment and Normalisation of Greenhouse gas Emissions for Roads (CHANGER) (D)	Estimates total CO_2 equivalent during road construction projects. Suitable for 188 countries. In-built database of construction techniques and materials. Its pre-construction model considers clearing, piling, cut export and fill import transport to and from the road site. Its pavement module considers on-site electricity and fuel consumption, pavement construction materials, materials transport, and construction machines. Maintenance module under development.	Transport [Construction]

Developers	Calculator	Type	Sector
Road Maritime Services New South Wales; New Zealand Transport Authority; Transport and Infrastructure South Australia; Department of Infrastructure, Energy and Resources Tasmania; Main Roads Western Australia; VicRoads, Victoria	Carbon Gauge (D)	Calculates whole-life greenhouse gas emissions associated with road projects. Specifically, the tool focuses on the construction, maintenance and operation (street lights and traffic lights) project phases. Based on the Greenhouse Gas Assessment Workbook for Road Projects.	Transport
Asian Development Bank	Transport Emissions Evaluation Models for Projects (TEEMP) (D)	Developed to support ADB member countries as part of the Sustainable Transport Initiative. To be used in the planning stage but also post project evaluation, particularly in countries where access to data is limited. 15 different tools for CO_2 emissions calculations compared to a baseline case, including bike-sharing, bikeway, Bus Rapid Transit (BRT), combination measures, expressway, metro, road, railway, rural highway etc.	Transport
AggRegain	CO^2 Emissions Estimator Tool (D)	Calculates $C0_2$ output resulting from four types of construction applications: bitumen bound, concrete, hydraulic bound, unbound, and outputs an estimate of CO_2 savings from selecting specific sustainable construction techniques.	Construction [Aggregates]
VINCI Construction & Eurovia	CO^2 CRETE. IMPACT (D)	Calculation of carbon emissions relating to the formulation and installation processes of concrete, utilising concrete constituents, formulations, production techniques, transportation and installation conditions and the geographical properties of the worksite.	Construction [Concrete]
	GAIA.BE (D)	Lifecycle analysis of environmental impacts of road and water treatment projects from material extraction to project delivery, including raw materials, production, laying and transport.	Road and Waterworks Construction
	CONCERNED (D)	Calculates the carbon footprint of projects including construction, operation, maintenance and use thus supporting development of low-carbon solutions.	All infrastructure
	GESTIM (D)	Calculates the carbon footprint on major construction projects from material manufacture through to project delivery.	Construction
	EQUER (D)	Building life cycle simulation tool which considers fabrication of materials, construction, building use, renovation and demolition. It enables energy calculations and can also model impacts due to occupant activity. Facilitates comparison between design alternatives during Design Option Appraisal.	Buildings
	ACV QUARTIER (D)	Same functions as EQUER but enables analysis of an entire district rather than a single building, based on: primary energy consumption; greenhouse gas emissions, water consumption, waste production; exhaustion of natural resources and impact on human health.	Urban Environment
UNEP SBCI	Common Carbon Metric	Methodology for calculating energy use and carbon footprint in buildings	Buildings

Appendix II. Useful Sustainability Guidelines

Tool	Type	Developer	Sector	Country
International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)	Guidelines	International Atomic Energy Agency	Nuclear Sector, International	International
Project Sustainability Management (I&II)	Guidelines & Indicator Set	International Federation of Consulting Engineers (FIDIC)	All Infrastructure, International	International
Inventory of Carbon and Energy (ICE)	Embodied energy and carbon coefficients (MJ/kg or kgCO_2/kg) for over 1700 building materials	Hammond G, Jones C (2008), Department of Mechanical Engineering, University of Bath, UK	Materials, International	International
Hutchins UK Building Blackbook: the Cost and Carbon Guide	Price and CO_2 emissions database for all activities of work (small to major) during construction	Hutchins 2011, Franklin + Andrews – Mott MacDonald	Construction, UK	UK
Cement Sustainability Initiative (CSD), 2005	Environmental and social impact assessment (ESIA) Guidelines	World Business Council for Sustainable Development	Cement, International	International
ISO 14000 Environmental Management	Family of standards	International Organisation for Standardization (ISO)	Non-specific, International	International
ISO 31000 Risk Management	Family of standards	International Organisation for Standardization (ISO)	Non-specific, International	International
ISO Environmental declaration of building products (ISO 21930-2007); Framework for methods of assessment of the environmental performance of construction works (ISO 21931-1:2010); Sustainability Indicators (ISO/TS 21929-1:2006)	Family of standards	International Organisation for Standardization (ISO)	Construction, International	International
Guidelines for Sustainable Procurement	Guidelines (Under Development)	CIRIA: Construction Industry Research and Information Association	Construction, UK	UK
High Performance Building Guidelines (1999)	Guidelines	City of New York Department of Design and Construction	Built Environment, US	US
Sustainable Urban Site Design Manual (2008)		City of New York Department of Design and Construction	Built Environment, US	US
Sustainable Aviation Resource Guide	Guidelines	Sustainable Aviation Guidance Alliance (SAGA)	Transport (Aviation), US	US
Equator Principles	Financial industry benchmark for assessing and managing social and environmental risk in project financing	Equator Principles (EPs)	Non-specific, International	International
Performance Standards on Social & Environmental Sustainability	Standards	International Finance Corporation (IFC), World Bank	Non-specific, International	International
Environmental, Health and Safety General Guidelines (EHS) & Industry Specific	Guidelines	International Finance Corporation (IFC), World Bank	Non-specific, International	International
Sustainability Reporting Guidelines, and Power; Aviation; Mining & Metals; Construction & Real Estate; Oil & Gas sector supplements	Guidelines	Global Reporting Initiative	General and sector specific, International	International
Agenda 21 for Sustainable Construction in Developing Countries (2002)	Guidelines	CIB & UNEP-IETC	Construction, International (Low-income Countries)	International (Developing Countries)
World Development Indicators	Indicators	World Bank	Non-specific	International

Tool	Type	Developer	Sector	Country
Industry as a Partner for Sustainable Development: on Automotive; Construction; Consulting Engineering; Oil & Gas; Waste Management; Road Transport; Water Management; Electricity; Aviation; Railways; ICT	Guidelines	United Nations Environment Programme (UNEP) & other partners	Sector-specific, International	International
Industry as a Partner for Sustainable Development: on Iron & Steel; Aluminium; Coal; Chemicals	Guidelines	UNEP & other partners	Material-specific, International	International
Issue Briefs, Facts and Trends on Coal; Carbon Capture & Storage; Hydro; Hydrogen; Nuclear; Natural Gas; Transmission & Distribution	Facts, trends and issue briefs	World Business Council for Sustainable Development (WBCSD)	Energy Sector, International	International
Sustainability Framework	Guidelines	WaterAid	Water Sector, International (Low-income Countries)	International – (Developing Countries)
Access for the poor and excluded: Tariffs and subsidies for urban water supply	Guidelines	WaterAid	Water Sector, International (Low-income Countries)	International – (Developing Countries)
Guidance Notes on Services for the Urban Poor: A Practical Guide for Improving Water Supply and Sanitation Services	Guidelines	WaterAid	Water Sector, International (Low-income Countries)	International – (Developing Countries)
Design Manual for Roads and Bridges (DMRB)	Guidelines	Highways Agency	Transport, UK	UK
CESMM3 Carbon and Price Book 2011	Embodied carbon and cost data for all civil engineering works	Institution of Civil Engineers	All Infrastructure, UK	UK
Fact Sheet 18 [P1 and P2] Embodied CO2 of Cement	Embodied carbon data	British Cement Association	Cement, UK	UK
DEFRA - Guidelines to DEFRA's Greenhouse Gas Conversion Factors for Company Reporting (2009)	UK government greenhouse gas emission factors for calculating emissions from activities such as energy use, water consumption, waste disposal, recycling, transport activities etc.	Department for Environment, Food and Rural Affairs (DEFRA)	All infrastructure, UK	UK
Greenhouse Gas Assessment Workbook for Road Projects	Guidelines for greenhouse gas emission assessment	Transport Authorities Greenhouse Group	Transport, Australia & New Zealand	Australia & New Zealand
UWP Sustainability Guidelines	Overarching guidance for introducing sustainability into projects. (Under Development)	UWP Consulting Ltd.	All infrastructure, Sub-Saharan Africa	Sub-Saharan Africa
Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects	Guidelines	Asian Development Bank	Transport, International	International
Sustainable Transport Initiative: Operational Plan	ADB Operational Plan	Asian Development Bank	Transport	International

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Additional sources include all the documentation on the Sustainability Tools presented in this report, that are freely available on the web.

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