Are Australian Building Eco-Assessment Tools Meeting Stakeholder Decision-Making Needs?

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ABSTRACT: The building industry seeks assessment and reduction of environmental, social and economic impacts in the built environment. There is a growing demand for decision-making support tools to facilitate this process. The building sector encompasses a broad range of professional activities including regulation, planning, design, manufacture and site development, and these span fundamentally different applications. Industry sector sustainable development relies on vast amounts of technically rich information, not yet streamlined, being shared between professions for varying applications at different stages and levels of the building life cycle. For consistent stakeholder decision-making, building eco-assessment tools (BEA) that address economic, social and environmental criteria as well as those used only for environmental assessment need to manage vast amounts of information necessary for credible assessment. Information and Communications Technology (ICT) platforms for sharing data provide a way forward in compiling and processing such complex information sets. Results of studies of twenty-eight tools showed that irrespective of the economic, social and environmental criteria they addressed most did not support:

- The majority of key stakeholders' criteria or provide sufficiently flexible applications;
- Stakeholder decision-making integrated over whole of building life considerations;
- Early intervention such as at policy development, investment and concept planning; and
- Functionality measures for pre/post occupancy and operational assessment

This paper discusses stakeholder needs in relation to building environmental and sustainability assessment tool applications. Stakeholders are shown mapped against potential tool deliverables, in order to highlight gaps between their needs and current tool attributes/applications in a strategic life cycle framework based on emergent theory. Possible ways to meet identified stakeholder needs are illustrated and discussed, considering ICT technology exploited in a new tool prototype, LCADesign, that has created a platform to facilitate information collection/connection and manipulation from divergent sources for flexible, variously formatted, outputs.

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1. BACKGROUND

According to Sarja (2002), ecologically sustainable development (ESD) and building design to reduce environmental, social and economic impacts involves coordinating stakeholder needs across an array of such criteria including functional, technical and ecological aspects. And Barton et al (2002) argue that addressing building sustainability issues requires building eco-assessment (BEA) tools that facilitate strategic life cycle decision-making. Cole et al (2000) also stress that BEA requires professionals to work through increasingly complex problems and Watson (2004) finds increasing demand for detailed design performance appraisal, for a uniform level of broad information and tools that use new methods.

Stakeholders use tools to benchmark, class, rank, assess, detail, badge, calculate and check environmental and sustainable, best and typical practice. While there is growing demand for their use, Seo (2002) and RMIT (2002) find that most stakeholders find BEA tools confusingly numerous, complicated and fairly unhelpful. This paper shows, the building sector encompasses a broad range of professional activities spanning fundamentally different applications. Increasingly, for sustainable development, the sector's stakeholders rely on vast amounts of technically rich information that is not yet streamlined, being shared between them at different stages and levels of building life cycle. Arguably the step change needed to overcome such challenges is to integrate and simplify tools and Watson et al

(2003) have depicted how Information and Communications Technology (ICT) can facilitate BEA with new systems to overcome some barriers in obtaining and verifying knowledge.

2. INTRODUCTION

The CRC for Construction Innovation (CRC CI) funded development of LCADesign, a tool for automated building environmental and economic life cycle costing (LCC). LCADesign is an acronym for Life Cycle Assessment (LCA) with Computer Aided Design (CAD). It is built on an ICT software platform, acting as a hub, to integrate outputs of 3D object-oriented CAD models, a national Life Cycle Inventory (LCI) database and recognised Life Cycle Impact Assessment (LCIA) environmental indicators. Integration is achieved via an express data manager to report comparative performance across building planning, design, quantity survey (QS) and checking applications.

Creating a hub and facilitating its use for various outputs would be much more difficult without such an ICT platform that also, as Jones et al (2001) outline, facilitates integration of applications essential to cover stakeholder needs. According to Construct IT (2000), and as shown in Table 1, level 3 ICT can facilitate linkage, compilation, integration and processing of information. Such ICT is useful for team sharing of data-rich 3D CAD file data integrated with that from LCA-LCC-QS-BoQ-databases in order to show outcomes in various BEA formats, such as used in LCADesign.

Table 1 ICT Change For ESD Design Project: Paper to Virtual Model (adapted from Construct IT 2000 IT Plan)

Breakdown	Level 0	Level 1	Level 2	Level 3	Level 4
Organisation	Hierarchical	Co-operative	Co-ordinated	Integrated	Intelligent
Process	Independent	Co-operative	Co-ordinated	Integrated	Virtual
Modeling	Collegiate	Co-operative	Co-ordinated	Concurrent	Interactive
Information	Serve 1-way	Service 2-way	Share 2-way	Share core data	Share data rich model
Technical	Paper	2D CAD	Simple 3D CAD	Object-oriented 3D CAD	Object-oriented 4D CAD
ICT platform /databases	Quantities Bill (BoQ)	BoQ, LCC & QS separate	LCC, LCI & QS separate	BoQ-QS-LCC-LCIA-CAD linked	ESD-LCIA-LCC-CAD-QS-BoQ-integrated

From the project outset, the authors determined that LCADesign had to feed both forward and backward from building phases of design to: definition, detailing, delivery and deconstruction as stakeholders need staged tools for:

- Defining service needs, goals and outcomes at project initiation;
- Designing with outcomes integrated over the project temporal life cycle;
- Detailing the supply chain with information considering whole of life cycle issues;
- Delivery of high quality construction as well as management in-use; and,
- Deconstruction considering recovery credits as opposed to demolition or waste.

To achieve this, a theoretical building sustainability assessment (BSA) framework, such as illustrated in Figure 1, was needed to provide reference points for, and inform connections to, databases, data managers and CAD models.

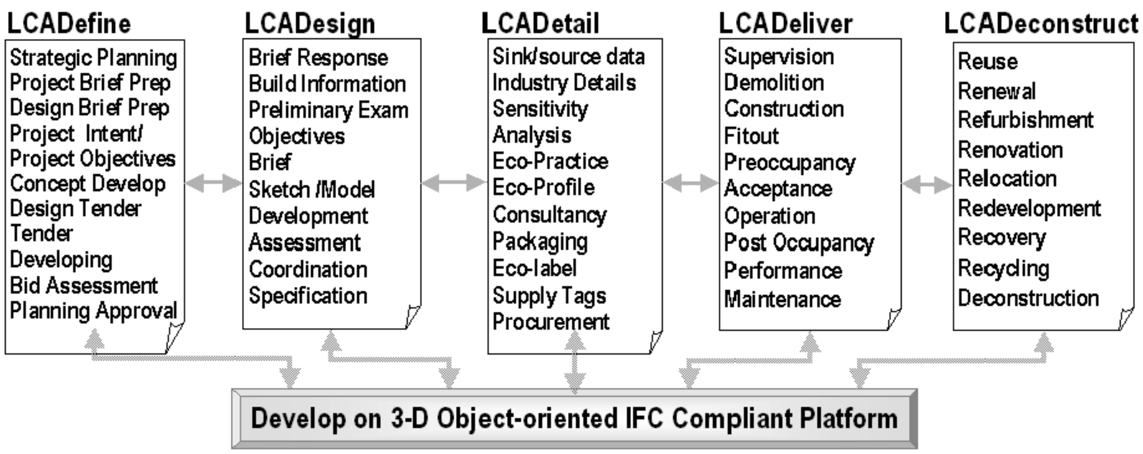

Figure 1. BSA Framework Skeleton, Modules and Basic Information Flow

Initially the framework evolved from efforts applied in:

- Characterising and resolving issues with tools meeting stakeholder decision-support needs;
- Identifying applications and formats of information required and useful at key process and decision points; and
- Establishing a platform for facilitated integration of applications at both overview and detail levels.

It became increasingly evident that, with such a framework informing an ICT communications manager, an automated 3D object-oriented CAD tool kit leveraging function off one platform offered a step change for streamlining BEA.

3. AIM AND SCOPE

The aim of this work was to explore and respond to the question: Are Australian building eco-assessment tools meeting stakeholders' needs? For this evaluation, tools listed in Table 2 were evaluated by considering technical and architectural reviews of:

- Basic tool and life cycle theory as well as typical features, attributes and functionality along with life cycle cover;
- Stakeholder-cover and need for tool applications and environmental, social and economic outcomes.
- A BSA framework of key tool applications for potential leverage off 3D CAD ICT platforms.

Table 2 Building Eco-Assessment Tools Studied

Overseas Tools	Reference	Australian Tools	Reference
Ecoprofile	NBI (2002)	Green Star	AGBC (2004)
BEAT	DBUR (2002)	Evergen	CSIRO (2002a)
GreenCalc	NIBE (2002)	AccuRate	CSIRO (2002b)
EQUER	EMCEP (2002)	NABERS	Environ. Aust (2002)
ECO-QUANTUM	IVAM (2002)	LISA	BHP (2002)
LEED	USNAGBC (2002)	NBGR	SEDA (2002)
BEES	NIST (2002)	BASIX	DIPNR (2002)
GBTool	NRC (2002)	LCAid	DPW&S (2002)
Green Globes	CEE&EEC (2004)	EPGB	DPW&S (2002)
ATHENA	TASMI (2002)	EcoSpecifier	RMIT (2004)
CASBEE	JSBC (2002).	First-Rate	SEAV (2002)
BREEAM	BRE (2002a)	GESOF	Qld Govt. (2002)
Material Environmental Profiles	BRE (2002b)	ESSAM	Barton (2002)
ENVEST 1	BRE (2002c)		
ENVEST 2	BRE (2003)		

4. METHOD

The work involved reviewing theory and practice papers considering:

- Tools and database reviews by Seo (2002), Foliente et al (2003) and Watson et al (2003);
- Architectural design and building industry supply chain reviews by Watson (2004) and Mitchell (2004);
- User applications over asset, design and building temporal and physical life cycles;
- Stakeholder needs and applications compared with tool applications and deliverables;
- Identification of gaps between user needs and tool attributes/applications and potential plug-in tools;
- Studies of newer tools and perspectives offered by ENVEST 2, GESOF, ESSAM, Green Star and NABERS;
- Prospective applications, tools and database leverage off object-oriented CAD ICT platforms.

5. BASIC BEA TOOL THEORY

Barton et al (2002) find that unless tools embody ESD requirements then, as most commonly occurs, they will exclude consideration of ESD in their application. Tools are intended to make a job easier or more efficient and to do this they should be practical and meet basic user needs. As Cole (2000) points out they must also be cost-effective and provide consistent outcomes. Watson (2004) proposes that they need to facilitate:

- Interaction with different professions, ideologies and paradigms throughout the project delivery process;
- Clear communication of assessment outcomes and provide decision-making support for tasks to be undertaken;
- Adoption of high-level principles in a life cycle framework with benchmarked impacts;
- Streamlining of information around theory to meet performance criteria and accommodate design support; and
- Restructuring as suites of various tool types to suit particular occupancy scenarios.

As Table 3 shows many stakeholders are involved in the building creation process and numerous BEA tool types and applications are in existence including guides, ratings, blueprints, manuals, badges, calculators, standards, rankings and checklists. Stakeholders require a variety of tools with appropriate applications both in the early stages and later phases of projects. Investment tools, for example, may be used to benchmark performance and communicate policy strategy, whereas in construction tools for scheduling and certification are more common.

Table 3 BEA Tools by Stakeholders, Application and Phase

Stakeholder	Profession	Communication	Documentation	Phase
Investor	Broker, Client	Policy, Benchmark	Feasibility Study, Strategy	Investment
Owner	Facility, Portfolio	Brief/Tender, Bid	Estimates, Classing, TQM	Acquisition
Developer	Urban, Builder	Bid, Estimate	Development Application.	Development
Planner	Portfolio, Asset	Guide, Benchmark	Guide, Benchmark	Planning
Provider	Logistics, Marketing	Market Analysis	Campaign Organisation	Initiation
Manager	Project, Site	Project Schedule	Project Planners	Construction
Supplier	Plant Control	Label, Profile	Templates, Labels, MDS	Procurement
Designer	Architect/Interior	Design, Model	Blueprints/Plans	Design
Surveyor	Quantity	Specification	Bills of Quantities	Procurement
Builder	Commercial	Plan, Certification	Plan, Fee Schedule	Delivery
Occupant	Asset Owner	Manual, Signage	Tenant, Checklists	Commission& Use

5.1. Life Cycle Thinking

Sarja (2002), Mitchell (2004) and Jones et al (2003) all stress that holistic life cycle structure is required for BEA and decision-making. Gilbert et al (2000), Barton et al (2002), Lovins (2004), Jones et al (2004) and Watson et al (2004) all show that, compared to the linear norm, life cycle thinking applied in decision-making drives more objective strategic planning to produce improved economic and environmental outcomes. Gilbert et al (2000), Lovins (2004) and Todd et al (2001) confirm that identifying successful intervention points in the process, before applying effort to integrate key environmental strategies, is critical. This is because, at each point in time pre-existing and subsequent operations need assessing, for example: in design for cleaner production, adaptive re-use, and disassembly.

Lovins (2004), Watson (2004) and Jones et al (2003) all stress that by the time designs have developed it is far too late to integrate most sustainability initiatives. Timing is critical because of issues such as prior allocation to master plan, infrastructure, orientation and budget limiting later opportunities. This means that if BEA tools are to apply from the earliest phase they must link to investment policy, benchmarks and rating applications. Watson (2004) also stresses that ecological design must be viewed:

- Professionally through a lifecycle perspective to understand the true situation;
- Holistically in context considering users/occupants and never in isolation; and,
- As cyclic concepts that need early consideration and budget allocation.

5.2. Redefining Applications By Life Cycle

While stakeholders need to know the environmental implications of upstream and downstream operations to make informed decisions Watson (2004) points out that stakeholders understanding of the building lifecycle varies significantly. Possibly this is because the term 'building lifecycle' loosely covers the 'planning and design development process' use and reuse from cradle-to-grave. However, it is asserted that, rather than management of asset, facility, design, construction and in use processes BEA tools have drawn on life cycle theory developed around a primary industry sector picture of mines, factories, consumer goods and transportation.

It is to be expected, then, that with such life cycle terminology poorly defined, key BEA elements and associations remain undifferentiated or obscured. Watson's (2004) new life cycle theory offers an advance in definition of terminology as he defines life cycle phases as being temporal or physical in nature. He differentiates the building's physical life cycle from actions over a temporal life cycle in design processes and asset planning that go to build it. His physical life cycle relates to material flows in forming objects and his temporal life cycle to sequencing of decisions as shown, for example, in Figure 2.

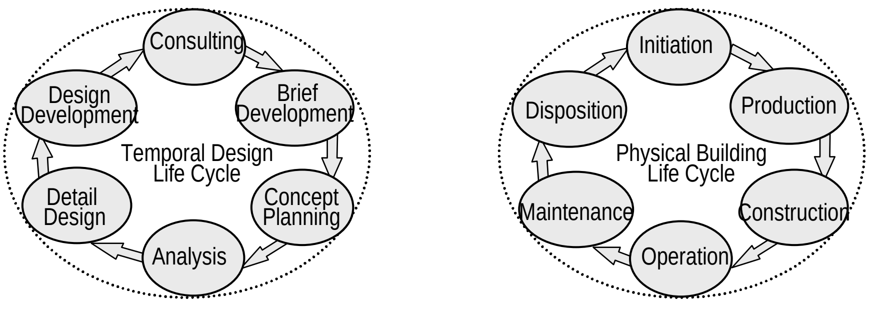

Figure 2 Diagrams of (a) Temporal Design Life Cycle Phases (b) Physical Building Life Cycle Phases

5.3. A Life Cycle Framework for Developing BEA Applications

A holistic life cycle frame of reference for considering stakeholders' BEA decision-making needs alongside appropriate tool applications was sought during LCADesign tool development. This was undertaken in order to facilitate stakeholders' consideration of up-and-down stream implications from earliest to latest project stages. A theoretical framework emerged that was grounded in consideration of built shell, interior and engineering function as ecological systems. In framework development Watson's (2004) assertion that tools must act to bridge service delivery needs, professional applications, management systems, design processes and occupant psychology was adopted as a guiding principle. Subsequently it was structured to align life cycle processes considering:

- Physical operations over the building life from material acquisition from, and disposition to, the earth.
- Temporal building processes over asset, design, project and building life cycles; and
- ICT support for professional project networking and information exchange.

As a conceptual map of the whole process of creating sustainable building the BSA framework was then used to re-evaluate strengths and weaknesses of the various tool types and criteria with a view to providing enhanced:

- Definition of objectives, tender and bid evaluation;
- Supply chain performance assessment for product procurement;
- Construction delivery applications post design to handover, post occupancy and maintenance;
- End-of-life recovery and reuse of material elements.

6. DISCUSSION AND RESULTS

As a consequence of knowledge assimilated from reviews of existing and new tool theory, results of tool gap analysis and comparative evaluation against the theoretical framework, key points were revealed where stakeholders' assessment needs had to be addressed. In the current climate of sustainability practice, the findings all pointed to a fundamental stakeholder requirement for clear communication from a common national platform. This requires the adoption of a common language linking disparate professions with fundamentally different application needs. Direction and communication, for example, is facilitated when tools clarify definitions, aims, objectives, policy, strategies and tactics and provide material for presentation and outcome reporting.

Seo (2004) found limitations including restricted scope, shallow focus, time-consuming application and specificity to country of origin that limits their usefulness in Australia. He found existing tools and frameworks were focused on physical metrics and that most lacked:

- Comprehensive support for stakeholder decision making;
- Integration of whole-of-life considerations from earliest investment planning;
- Consideration of policy development or pre/post occupancy assessment;
- Functionality measures for operational service delivery; and
- Flexible outputs for the broad range of potential users.

Watson (2004) found it desirable to provide designers with the means to appraise design performance against sustainability criteria and that tools typically did not address critical stakeholder requirements, such as:

- Stakeholder needs and relationships in the built environment;
- Different contexts in relation to the building industry; and,
- Local environmental and key social and economic criteria.

Table 4 shows reconfigured results from Seo (2002) and Foliente et al (2004) where, overall, 16% of tools covered four phases, 48% covered three, 24% applied to two and 12% one phase only. Most tools focus on one or two phases only, which may not be an issue if they reflect stakeholder position, scope of work or timeframe. Without a common language, however, the use of separate tools to achieve life cycle coverage can add confusion to already complex tasks. Design was the focus of most tools, few applied to brief development or concept planning and most ignored extant buildings, fitout and refurbishment. None had applications for investment or economic or social criteria.

Table 4 BEA Tool Life Cycle Cover (Results reconfigured from those of Seo (2002) and Folient et al (2004))

Tool	Plan	Design	Use	Dispose
CASBEE, GBTool, BREEAM, Green Star	√	√	√	√
Evergen, EPGB, BRE Profiles, BASIX, LCAid	√	√	√	
LEED, Ecoprofile, BEAT, Greencalc, EQUER, Envest, LISA		√	√	√
ATHENA and Green Globes, AccuRate		√	√	
BEES, Eco-Quantum, EcoSpecifier		√		√
NABERS, NBGR, Firstrate			√	

The review of newer tools found all covered the four given phases of new building projects except NABERS that applied to extant buildings in-use only. This is critical as renewal of extant buildings is most significant for ESD, because as Jones et al (2003) report large estate owners such as State governments can spend up to 10 times more annually on existing compared with new building stock. Apart from LCADesign, none of the newer tools directly assessed economic costs. The NABERS, GESOF and ESSAM tools, however, did consider community or social aspects. Also Watson et al (2004) show Envest 2 is just one tool in a larger kit outlined in BRE (2002a, b and c) that does address economic and social aspects. Because newer tools had increased life cycle coverage by phase as well as economic and community aspect they may be expected to better fill stakeholder needs than earlier ones.

Few tools provided sets of applications such as in the GESFOA and BRE tools (when used together as a set), which supported Watson's 2004 finding that there was significant need to provide users with:

- Document/ template briefs, specifications, contracts and bid/tender evaluations; and,
- Tools that can interact across framework, guideline and checklist applications.

Finally since they were not well served by existing tools, it is considered that, there is significant potential to provide managers, purchasers, operators and occupant applications with features for aligning ESD principles and policy as well as comparative performance assessment, against best building practice benchmarks.

7. TOOLS TO MEET STAKEHOLDERS NEEDS

The theoretical framework, as previously described, was used to predict tool components required to:

- Define building service needs, project goals and outcomes at investment or initiation phase;
- Design for integrated outcomes over the project temporal life cycle and to plug-in to existing tools;
- Detail information from the industry supply chain relevant to whole of life cycle issues;
- Deliver high quality project management, site-work, post occupancy as well as in-use assessment; and,
- Deconstruct considering design for disassembly recovery credits as opposed to demolition or waste.

In an LCADesign project proposal, BEA tool component applications, integrated together in modules, were all envisaged to have automatic take-off from 3D CAD Models. These all leverage function off the one ICT platform and together they comprise a practical toolbox, in which plug-ins and supplements in the right sequence and level of detail meet stakeholders' needs for comprehensive coverage and avoid current issues with ad hoc, linguistically confused, separate tools. Some examples of tool components of the five framework modules are listed in Table 5.

Table 5 BEA Example Tool Applications in Modules of the LCADevelop Framework

LCAD Modules	Some Examples	Application Requirements	Solutions/Plug-Ins
LCADefine	Brief Development	Compare With Best Practice Benchmarks	Rated Benchmarks
	Design Brief/Bid	Incorporating Economic & Environmental Costing	LCADesign Capacity
LCADesign	Brief Response	Audit/Assess Current Codes/Standards/Contracts	Codes, IAQ, Access
	Building Information	Compare All Levels Design Analysis Plug-In Tools	Orient, Space, Light
LCADetails	Procurement	Eco Specification & Industry Practice Details	Profile & Practices
	Eco Practice Notes	Sensitivity Analysis For Improvement Opportunity	Service Consultants
LCADeliver	Project Delivery	Eco Specification & Supply Affirmation Tags	Product Labels/Tags
	Pre/Post Occupancy	Project Guides, Benchmarks &Templates	Occupant Checklists
LCADeconstruct	Design for recovery	Credit Design For Disassembly & Re-Use Potential	Code To Credit Reuse
	Refurbish, Reuse	Refurbishment Recovery Eco Practice Notes	Guide & Checklist

The proposal addressed what was required to support and meet stakeholders' essential decision-making needs for Australian BEA tools considering provision of:

- Clear communication and alignment with ESD principles, policy and planning;
- Technical and linguistic coordination with other tools;
- Comparative assessment against best building performance benchmarks;
- Documentation/templates for briefs specification, contract and evaluation;
- Interactivity with supporting frameworks, guidelines and checklists; and
- Plug in tools to meet user needs for in-use assessment on ESD criteria.

The first framework module, LCADefine, has component tools to define investment and planning targets and setting of project objectives as they occur in concept development and initiation, in order to facilitate up-front acquisition of key information in the initial phases of a project, so as to better inform the planning process. Additionally the LCADesign Module ensures technical and linguistic coordination with other tools as well as linkage to parametric models.

The third, a module for selecting lower impact products, LCADetails assesses material profiles and supply-chain knowledge that according to Mitchell (2004) is currently under-informed compared to that in other countries with advanced procurement systems, albeit less so in ICT terms. An LCADeliver module contains applications for project decision-making to ensure that as-assessed and specified is delivered. Finally the LCADeconstruct module contains applications to give credit for design for disassembly and industry recovery initiatives for material reuse and recycling.

8. CONCLUSIONS

The paper has depicted stakeholders' BEA needs, a theory summary and an emergent BSA framework of integrated tools. It has revealed how tools fail to provide adequate support for stakeholder decision-making.

Many tools evaluated focused on physical rather than stakeholder required metrics such as functionality measures for operational service delivery. A primary need was for clear communication between disparate professions using a common BEA language. And currently, without a common language, the use of separate tools to achieve life cycle coverage generally adds confusion to already complex tasks.

Overseas-developed tools have limited relevance to Australian conditions and most have restricted scope, shallow focus, are time-consuming in application and ignore economic and social criteria.

The mapping of stakeholders' needs in a building life cycle framework against potential tool deliverables found no tools covered the entire building life cycle and also highlighted many current gaps in tool attributes and applications. The focus of most was design, few were applicable to brief development or concept planning, none had any investment applications and most ignored refurbishment and disposal phases.

Two newer tools addressed extant buildings, one in-use and one in fitout. In newer Australian tools there was also increasing coverage by phase and of economic and community aspects, so these better fill stakeholder needs than do earlier ones. In most tools there is also considerable potential to provide applications for managers, owners, purchasers, operators and occupants.

The theoretical BSA framework foreshadowed at least one step change with potential to create improved tools to meet stakeholders BEA needs. This is by exploitation of ICT platforms to facilitate collection and connection from divergent sources for flexible and varied outputs covering many building aspects, criteria, processes and life cycles. Key points that BEA tool developers need to address in future include provision of:

- Whole of life tools with true building environmental, along with additional social and economic cost, assessment;
- Better capacity to select appropriate goals and benchmarks over asset, design, project and building life cycles;
- Increased stakeholder and design support via integration of professionally and temporally aligned applications;
- Applications for early intervention such as at investment, policy development and planning stages;
- Functionality measures for pre/post occupancy and operational phases, and flexibly formatted applications;
- ICT technology to manage the vast amount of information necessary for credible assessment; and
- Full development of shared information platforms that facilitate consistent decision-making.

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