SUSTAINABILITY MEASURES FOR DECISION SUPPORT

A NATIONAL BUILDING PRODUCTS INVENTORY

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ABSTRACT

Australia has no nationally accepted building products life cycle inventory (LCI) database for use in building Ecologically Sustainable Development (ESD) assessment (BEA) tools. More information about the sustainability of the supply chain is limited by industry's lack of real capacity to deliver objective information on process and product environmental impact. Recognition of these deficits emerged during compilation of a National LCI database to inform LCADesign, a prototype 3 dimensional object oriented computer aided design (3-D CAD) commercial building design tool. Development of this Australian LCI represents 24 staff years of effort here since 1995. Further development of LCADesign extensions is proposed as being essential to support key applications demanded from a more holistic theoretical framework calling for modules of new building and construction industry tools. A proposed tool, conceptually called LCADetails, is to serve the building product industries own needs as well as that of commercial building design amongst other industries' prospective needs. In this paper, a proposition is examined that the existing national LCI database should be further expanded to serve Australian building product industries' needs as well as to provide details for its client-base from a web based portal containing a module of practical supply and procurement applications. Along with improved supply chain assessment services, this proposed portal is envisaged to facilitate industry environmental life cycle improvement assessment and support decision-making to provide accredited data for operational reporting capabilities, load-based reasoning as well as BEA applications. This paper provides an overview of developments to date, including a novel 3-D CAD information and communications technology (ICT) platform for more holistic integration of existing tools for true cost assessment. Further conceptualisation of future prospects, based on a new holistic life cycle assessment framework LCADevelop, considering stakeholder relationships and their need for a range of complementary tools leveraging automated function off such ICT platforms to inform dimensionally defined operations for such as automotive, civil, transport and industrial applications are also explored.

Keywords: Building Eco Assessment, 3-D object oriented CAD, Information and Communications Technology

BACKGROUND

Throughout their life, building products have a significant impact on the environment and are a 'fundamental source of environmental challenge.'[1] Furthermore, the concern about product impacts brought to the creation of a more sustainable built environment is considerable, especially in the context of Ecologically Sustainable Development

(ESD). Building ESD assessment (BEA) tools therefore need to facilitate stakeholders' effort to conceptualise, create and deliver more balanced economic, social and environmental outcomes.

The Australian response to the Brundtland Report [2.] and Agenda 21 [3.] has been to publish a National Strategy for Ecologically Sustainable Development (NSESD) [4.]. Within this document ESD is defined as development that 'uses, conserves and enhances the community's resources so that ecological processes on which life depends are maintained and the total quality of life, now and in the future, can be maintained' [4.].

In Australia, the building product industry is a significant resource user, yet, has limited understanding or capability to redress detrimental environmental impacts or provide verifiable information along the supply chain to building specifiers [5]. Here it is particularly, small and medium enterprise (SME) manufacturers that are at most significant disadvantage in product and process environmental management, as they have minimal understanding of environmental impacts related to their product's extraction, impacts along the supply chain and fate at end of life [5]. Typically, SME's also have insufficient knowledge of as well as strong reluctance to provide any specifier's due diligence sustainability requirements to relate and disseminate sound information as there are perceived and real disadvantages rather than an accepted duty of and obligation for disclosure [5].

While those in the food industry are required by law to provide nutritional and health safety information along with their packaged products no such demand is made of building products that are undeniably reliant on depleting scarce natural resources and generating pollution that impacts on community health in both human and natural ecosystems [5]. There are, however, many international examples of building product LCI databases including Athena's and BRE's databases and product eco-profiling systems [6]. In Australia, however, despite great initiatives, such as ecospecifier and that for organic fabrics and paint, there is no nationally accepted comparable eco-profiling system to provide such information to inform supply or procurement [7].

INTRODUCTION

Australia has no nationally accepted building products LCI database for use in BEA tools [5]. Green supply chain information is limited by industry's real capacity to deliver objective process and product impact information [5]. Recognition of these deficits emerged from longer-term research [12] work and compilation of a National LCI database to inform, LCADesign, a prototype 3-D CAD commercial building design tool. Development [6] of the LCI represents 24 staff years effort since 1995 [8].

As part of the LCADesign project supported by the Cooperative Research Centre for Construction Innovation (CRC CI) [9] an inventory database for significant building products has proceeded through second stage development. LCADesign is a prototype commercial BEA system with automated 3-D CAD take-off capabilities using new Industry Foundation Class data transfer protocols [5]. Its function is managed by an Express Data Manager and exploits an LCI database as depicted in Figure 1.

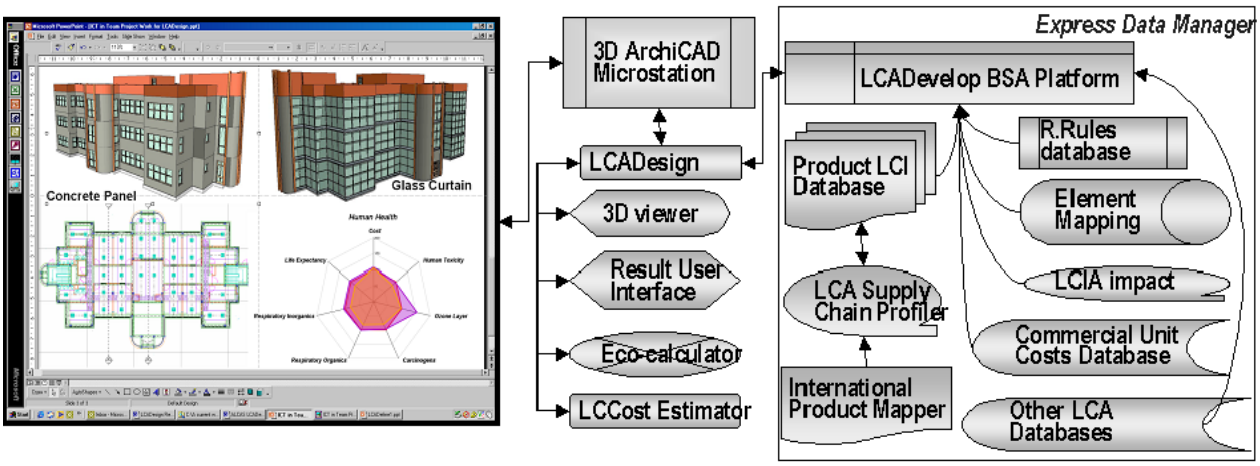

Figure 1. Schematic of LCADesign ICT data flows

To enable industry environmental assessments, LCADesign is automated to take off in real time from 3-D CAD models. It provides a range of reports of environmental measures on which to base environmental impact assessment using accepted international and new domestic performance indicators [5]. From proposed design models, practitioners can identify hot spots, drill down on components as well as compare them with operational estimates and CASE studies

[5]. Delivery of industry databases linkable to CAD to generate aggregated and component specific environmental reports presented significant challenges previously outlined in earlier papers [6].

OBJECTIVE

This paper aims to:

- Examine implications ensuing from work in structuring the LCI database supporting LCADesign;
- Reflect upon the derivation of a new holistic theoretical framework [10] as depicted in Figure 2. ;
- Describe LCADevelop, a toolkit concept emerging from this framework with a procurement tool LCADetails;
- Further conceptualise demands for a national LCI in LCADetails as one component of LCADevelop [11] and,
- Consider the proposed development direction and future possibilities for application of LCADetails.

The intent is to examine the propositions that there is need and demand for and now the means to provide a nationally accredited building products eco-procurement portal to facilitate 'greening' of the industry supply chain. The examinations draw upon prior reviews considering:

- BEA Tools life cycle coverage [7];
- A new sustainable BEA framework leveraging function off 3-D CAD IFC compliant files [5];
- Modelling operations in a national industry sector LCI [6] including LCI Procurement Applications [12];
- Characterising LCI results and data quality principles by bulk, shaped and item product class [11] and
- Potential for exploiting the LCI database for LCADetails.

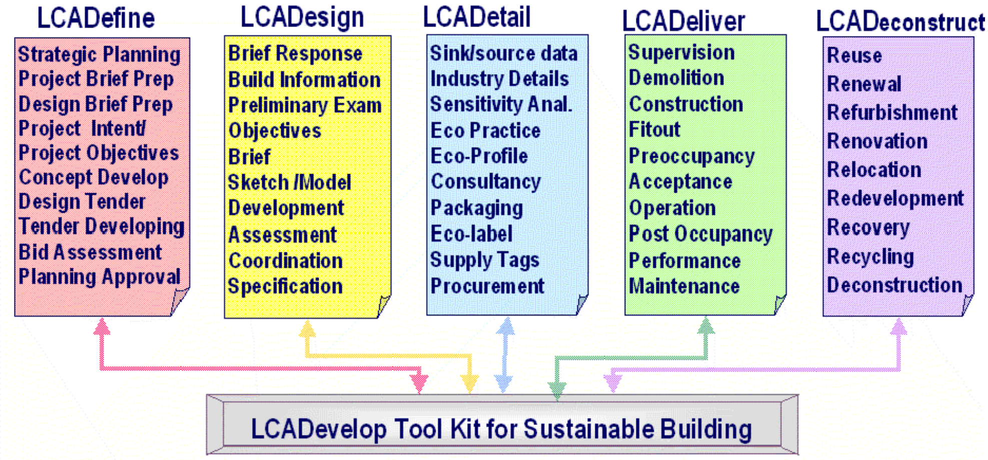

Figure 2. LCADevelop Sustainable BEA Framework Skeleton of Modules including LCADetails

METHODOLOGY

This paper provides an overview of developments to date, including a novel information and communications technology (ICT) platform, and integration for automated take off from 3-D CAD product models. The LCADetails proposal emerged from characterisation and analysis of BEA tools with respect to stakeholders and users' requirements, in applications across asset, project, design, building, and product lifecycles [7]. Work reported in this paper is also based upon the theoretical sustainable BEA framework described in recent papers [10]. Earlier work found that existing tools and frameworks have a predominately scientific focus and metrics that lack provision of practical:

- Support for stakeholder decision making, policy development and assessment of policy implementation;
- Integration of whole of built asset life considerations from earliest investment/planning to fate at disposition;
- Consideration of policy development as well as pre/post-occupancy assessment and;
- Functionality measures for operational service delivery, churn, spatial and maintenance considerations [13, 14].

In this paper LCA is applied as 'a technique for assessing the environmental aspects and potential impacts associated with a product'. [15]. The LCADesign LCI database was developed using methodology defined by International Standards for Environmental Management Systems (EMS) [15]. The standards set out the methods for understanding and reducing environmental burdens and impacts associated with life cycle operations including upstream air, soil and water resource depletion issues, and downstream emissions to air, soil and water issues [16,17]. Inventory is subsequently used in Life Cycle Impact Assessment to reveal local, national and global environmental impacts of such burdens as well as comparative performance assessment against criteria set in various improvement initiatives [16,17].

BEA TOOLS LIFE CYCLE COVER

Results of a recent study of BEA tools, as illustrated in Table 1, indicated that most tools focussed on design and few on procurement [7] where they can affect the supply chain and collectively have very long term effects [12].

Type Vs Phase	Tools Types Used	Project Definition	Concept Design	Detail Design	Supply & Procure	Construct	Fitout	Occupy& Maintain	Renew Dispose
Investor Developer Council	Benchmark Policy Guide Rating Goal Strategy Tactics Plan Model Estimators Standard Reference								
Provider Designer Supplier	Benchmark CoP Tactics Plan Calculator Standard Checklist Specification EMS Certification								
Manager Designer Builder	Tactics Plan Calculator Standard Checklist Specification EMP Certification								
Owner Tenant Operator	CoP Manual Plan Report Standard Certification Badge								

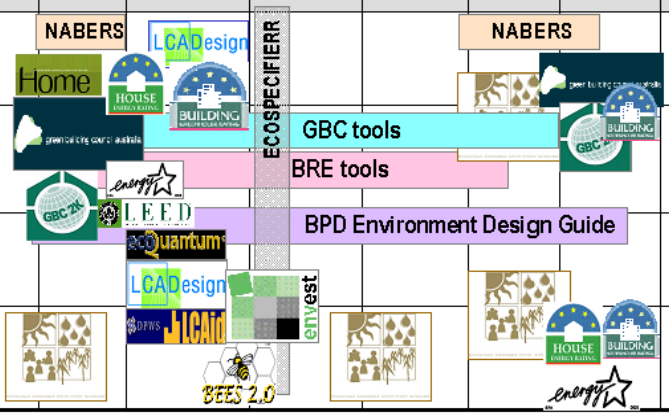

Table 1. Temporal Clustering of BEA Tools across the Temporal Life Cycle

Few of the BEA tools studied by the authors [[7], Seo [16,] and Foliente et al [17], covered procurement phase in-depth assessment. It is asserted that since LCA-based BEA tools most often apply their scope of assessment, cradle to gate rather than cradle to grave, industries, particularly providing bulk products, that have conducted LCA studies of their products and operations are technically well positioned to provide good information to the supply chain and their own stakeholders and customers. But many are hesitant to do and no good faith or legislated obligation applies [12].

It is asserted that procurement and design detailing, for example, should consider cleaner production and recyclability. In procurement Sarja [18], Lovins et al [19], Watson [20], Cole et al [21] and Barton et al [22, 23, 24] all stress that it is critical for stakeholders to identify points of successful intervention in the process before applying effort to integrate key strategies. This is because whole of life environmental strategies apply in each phase and at each point in time pre-existing and subsequent operations need assessing in acquisition, manufacture, supply, procurement and design detailing. In procurement stakeholders, for example, need instruments to budget, inform, tender, bid, select and estimate work. Applications in project procurement may rate, rank, benchmark, specify and schedule sustainable, superior and average building products and systems [7]. For this reason, a framework was sought to apply life cycle thinking for procurement considering all requirements throughout the building life cycle rather than only the product life cycle, that is quite different, as shown in Figure 3 [7].

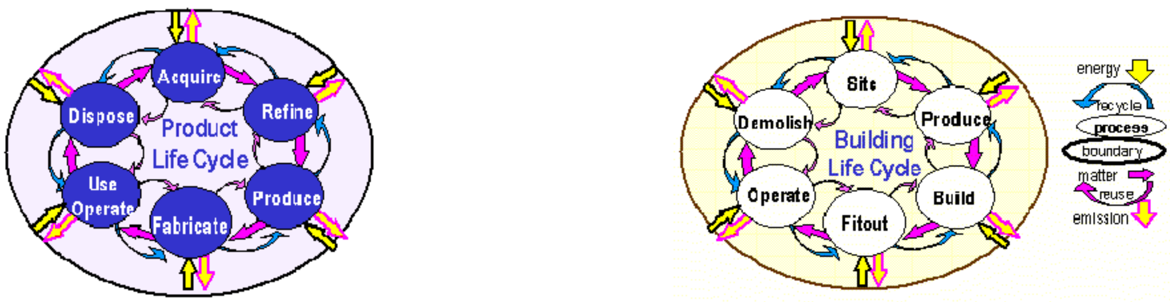

Figure 3. Flow Charts of Product and Building Physical Life Cycle Phases (adapted from Watson [20])

A THEORETICAL BEA FRAMEWORK

As previously noted, further extensions of LCADesign were perceived to be required to populate the more holistic theoretical framework Figure 2. depicts. The need to understand sustainable BEA in a holistic light, from planning, land development, design, construction, procurement, maintenance, use and disposal, covering interactions between buildings, services, infrastructure, occupants and particularly the natural environment [1 to 24] has been accepted and this drove production of a new theoretical framework [10]. The intent of the framework is to support decision-making through better definition and communication and to facilitate generation of strategies and assessment of response throughout the asset life cycle.

LCADevelop the BEA framework depicted in Figure 2. , as a skeleton of temporally aligned modules of tools includes: LCADefine for project definition, LCADepict for parametric modelling, LCADesign, LCADetails for procurement and supply, LCADeliver for project delivery and LCADeconstruct to credit reuse at end of life, are all 3-D CAD-based applications staged along temporal decision-making flows [20]. Currently, practitioners require support to:

- Define service needs, goals and outcomes at project initiation for accommodation over whole of asset life;
- Design with tools integrated to avoid existing overlaps/confusion over the project life cycle;
- Detail the supply chain for performance improvement and procurement, considering life cycle impacts;
- Deliver quality throughout project site development and construction to handover/operation and occupancy;
- Deconstruct to credit design for resource recovery and reuse rather than demolition and waste, at the end of life [7].

The subject of this paper is the LCADetails module considering learnings from the theoretical framework to support efforts across the building products industry supply chain particularly of SME's [12]. The framework evolved from work in LCADesign to understand the timing of and implications for decision-making required to meet stakeholders' BEA needs. The framework was based on analysis, aggregation and synthesis of leading BEA theories and tools. It encompasses both temporal and physical life periodicities while providing a frame of reference for vertical and horizontal integration of essential BEA applications [10]. It is asserted that this has the capacity to enhance support for building design and construction professionals' efforts in creation of more sustainable building initiatives because it revealed characteristic BEA application typologies at key process points to advance sustainability solutions [10].

PROPOSED LCI PROCUREMENT APPLICATIONS

New BEA tools, based on the LCADetails concept, are proposed to serve building product industries own needs as well as those of commercial building designers. The proposition is to exploit, in a web based module, the existing national LCI database to serve the Australian building products industries own needs as well as details BEA needs. This is to facilitate improved supply chain assessment, industry impact improvement, decision-making and operational reporting capabilities via provision of acceptable data for load-based reasoning as well as BEA activities [12].

LCADetails is intended to address supply chain issues and provide product information for manufacturers in-house as well as professionals in the public domain. A dual approach is considered essential to facilitate provision of an accurate and detailed picture of the product supply chain while aiding the products industry collect LCA information on a commercial-in-confidence basis for industry interests while meeting the somewhat different needs and interests of design and construction BEA professionals. Furthermore it is intended to build industry understand about inventory information and how it may apply to improve the environmental performance of their own products and processes. LCADetails is considered an appropriate and more practical platform to inform dimensionally defined products and performance essential in aeronautical, automotive, civil, transport and industrial applications rather than assessment lacking consideration of any 3-D assessment as currently occurs. Applications in large scale 4-D project case studies reveal the potential of this approach adopted in Boeing design and maintenance, Disney World's Death Mountain and in Stanford University's 4-D visualisation initiatives for hospital construction, airports [28] and locally in creative industries [29]

This paper proposes an industry owned and managed web-based portal to modules is a practical way to obtain industry input to any LCI database that is essential to determine building product eco-profiles. The focus in LCADesign is to automate user-estimation of product environmental impact from that detailed in 3-D CAD models. LCADetails focuses, however, focuses on intra-industry data collation for improvement planning and guidance on product selection as a precursor to provision of professional level, selected and public access data across the construction industry, as a whole as, is essential as BRE found consensus development on such sensitive information to be critical [12].

In this fashion the very heavy commitment required to maintain an LCI database is also dispersible across all interested parties. The quality of existing databases is also enhanced for an industry that has demonstrated keenness in seeking credible data to improve their own environment bottom line as well as to provide information to underwrite choice in building products on the basis of environmental impacts. Conceptually, LCADetails is considered most useful for the industry sectors that supply building and construction, as it is an intelligent means to provide:

- Continuously updated information for in-house industry environmental assessment and reporting;
- Support to in-house BEA early market implementation assessment as well as product improvement [12]
- A prototype procurement system for ongoing development of profiling industry and its products towards.
    - Web based procurement/labelling systems for product profiles needing industry data inputs and
    - Direct input of credible data from manufacturers, fabricators and importers on an annual basis.

This module conceptually provides for a portal to address supply chain issues and product information to building professionals and manufacturers. It is to enhance ICT and ESD capacity via accurate detailed pictures of the supply chain intra-industry as well as inter-industry to design and construction professionals, while aiding industry collection of life cycle information. It is especially applicable to assist SME's understand how to improve their own ESD.

LCADESIGN LCI SCOPE OF WORK APPLICABLE TO LCADETAILS

Currently conducted in a cradle to construction system boundary, all key industry practitioners have agreed that for commercial development the scope of LCADesign assessments must become "cradle to grave" as depicted in Figure 2. . Over a given design life, LCADesign practitioners need to account for flows of resource and energy inputs and outputs to air, land and water in design, construction, fitout, operations, maintenance, refurbishment, recycling. The LCADesign LCI includes Australian and overseas flows involved in acquisition, processing, transporting, fabricating, finishing, use, disposal and reuse of metal, masonry, timber, glazing, ceramic, plastic, fitting, composite and coated product considering:

- Mining, crushing and chemical use in extraction of raw material;
- Acquisition of cultivated, collected or harvested agricultural material;
- Fuel production to supply power and process energy and material transport;
- Manufacture and use of chemicals in the processing of raw material,
- Process energy, fuel and transportation of raw, intermediate and ancillary materials,
- Matter and energy transformations and consumption in processing such as lubricants, tyres, energy.
- Product packaging, maintenance, renewal, recycling and disposition.

A this time it does, however, exclude burdens from:

- Incidental activities and travel of employees engaged on-site in production facilities,
- Capital facilities and equipment, product packaging, maintenance, recycling, and
- Noise and dehydration as well as maintenance and fate post-demolition considering re-use and rework.

The Australian industry LCI data was developed to represent typical industry practice with currently common technology with coverage applicable to the Australian building and construction sector. Environmental performance is evaluated across sectors, by technology type and license conditions. Industry product flows typically cascade from primary to secondary to final processing and then in-service operations as depicted, for example, in **Figure 3** where a diverse range of material flows of bulk product is essential just to make concrete.

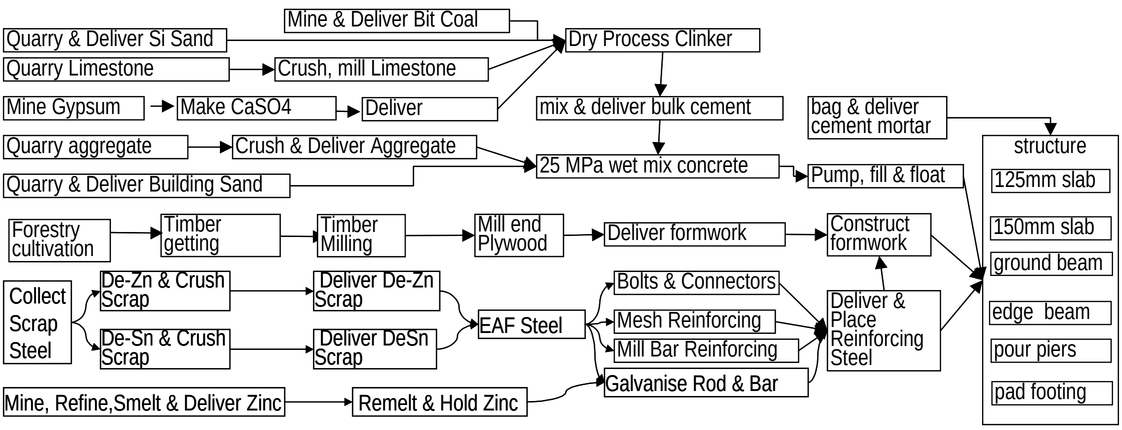

Figure 3 Summary Flow Chart Of Unit Operations In Concrete Production And Delivery

Environmental performance is evaluated by a company's geographical coverage, technology, fuel source and fleet type and by imposed license conditions. Typical industry practice is tracked and delivery based on closest proximity. Technology pictures are constructed from building product knowledge acquired from the public domain, commercial-in-confidence and professional sources as well as personal experience and via industry sources to support consistent LCI results considering all significant variables that can be affected by supply, procurement design and BEA.

MODELLING OPERATIONS IN LCADESIGN NATIONAL LCI

Database creation involved LCI compilation on top of an existing global LCI model database to facilitate delivery of Australian national LCI datasets in the global context essential for building and construction applications by adoption of the Boustead Company Limited (BCL) Model 4 [30]. Maps of national operations were developed to profile core operations including transport considering raw product, scale and type of operation and ratios of local, state and imported weighted averages by flows of base product mass and feedstock.

Typically, product mass flows were based initially on IBIS market activity reports for particular product, confirmed with reference to company annual and industry sector reports, product marketing campaigns, company websites and by reference to previous Australian LCA literature. Compilation of pictures of market shares over the entire supply chain begins with descriptors of parent company, locations, logistics and technology involved in operations including period of commitment to improved environmental performance, standards and management systems including the:

- State-of the art of all process technology for each operation under study,
- Reductions in process raw product, energy and water consumption,
- Reductions in process emissions, effluents and solid waste, as well as
- Transport and distribution systems exploited and any increased efficiency therein.

Domestic product LCI was facilitated by building on the first stage commercial-in-confidence datasets developed by the Department of Public Works and Services now (Department of Commerce) representing >20 years of staff effort from 1995 to 1999. Collaboration was also established on national datasets, particularly for energy generation, developed by RMIT using the Simapro Model. An extensive domestic and global inventory database was then developed covering raw products, fuel, feedstock, energy, water, transport, intermediate and secondary processes as well as bulk and fabricated products and smaller items whose contribution to BEA of human health impact can be significant. Challenges in providing transparency and even data quality distribution to stakeholders were described elsewhere in [6]. The greatest challenge was to capture representative data for imported small items used in building and construction applications.

CHARACTERISING LCI RESULTS BY PRODUCT CLASS

The CRC CI national LCI results reveal that the main products classes in the Australian commercial building supply chain are sourced from infrastructure & natural resources, followed by bulk product, fabricated shapes and a vast range of specific items such as, for example, outlined in Table and described in the following.

Table 2. Classes of product types in the CRC CI database

Infrastructure	Bulk	Shapes	Items
Fuel, Feedstock, Power, Water, Transport, Minerals, Forestry, Agriculture.	Concrete, Cement, Sand; Lime, Plaster, Stone, Clay, Masonry, Metal, Glass. Structural Steel, Aluminium, Grain, Timber.	Masonry, Metals, Cables, Composites, Ceramics, Porcelain, Polymers, Fittings, Furnishings.	Paper, Fibres & Fabrics, Paints, Pigments, Sealants, Intermediates, Glues, Packaging

Bulk Product Lines

Bulk product lines, characterised by high bulk, very low imports, with price based predominantly on mass, volume and flow rates and differentiated by strength in-compression include cement, glass, aggregates and structural steel. There are typically <4 main suppliers with large-scale integrated near-continuous operations close to raw material supply, usually under multinational vertically integrated ownership reliant on advanced technology. For merchandising they exploit horizontally integrated structures and long-term contracts/associations with developers, and distributors. Transport to regional markets is most often via company-owned marine or rail bulk-carrier fleets and delivery to site via road fleet. Most such plants operate under accredited quality and environmental management systems and increasingly stringent local and State government licence conditions as to emissions and waste.

Table 3 Bulk Product lines

Base Material	Product Lines
Concrete	Cement, Mortar, Crushed, Aggregate, Sand; Lime and Plaster
Steels	Reinforcing and Structural
Timber	Structural, Formwork and Laminated Beams
Glass	Float, Flat and Coated
Clay, Masonry	tiles, bricks, blocks, shapes and pavers

By virtue of being the largest product mass this product class forms the highest embodied energy flows to new and in existing commercial buildings. It comprises the major building share of resource and biodiversity depletion impacts. Products in this class are the most representative with high data quality sourced from few players, with fewer variables, few unknowns and stable product differentiation. Data compilation is further supported by the clear data patterns and points existing in the comparatively well-documented, highly-integrated, large-scale operations and ascertained by referring to performance data used in the comparatively long term, high-visibility campaigns dominating this market.

Shaped Product Lines

Shaped product lines are characterised chiefly by high surface area and tensile strength, low but increasing imports with price typically based on area or length and differentiated by finish and durability. Typically, individual product substrates vary little but surface finish does greatly in line with service requirements from <20 main suppliers of shaped products including pipes, cables, cladding, fabrics, panels and coatings. Many such companies are locally owned, running regional operations with moderate but increasing levels of overseas ownership. These companies typically rely on established intermediate-scale plant with some advanced technology and market share is maintained by developing strong customer service relationships with trade outlets.

Table 4 Shaped Product lines

Base Material	Product Lines
Board	Plasterboard, Particleboard; Ply; Timber Panelling, Composite Laminates
Panel & Strip	Steel, Aluminium, Copper, Polymer: PE, PP, PVC, PU & PA* & Composites
Sheeting	Paper, Aluminium; Iron, Copper and Cr/Al/Zn/Si/Polymer Coated Steels
Coatings	Paint, Sealants, Finishes, Pigments, Lime-putty, Plaster, Render
Forms	Pipe, Wire and Extrusions: Iron, Aluminium, Copper, Steel and Plaster
Cables	Copper, Aluminium, Glass, Polymer and Stainless Steel composites
Fabric	Wool/Cotton/Hemp/PE/PP/PVC/PU//PA Composites/Carpet/Underlay/Linoleum
Wool /Foil	Insulation Batt/Blanket: Mineral/Sheep/Polymer/Aluminium/Glass/Resin/Paper

*PE: polyester, PP: polypropylene, PVC: polyvinylchloride, PU: polyurethane, PA: polyacrylate

Companies rely more often on shorter-term contracts for raw product supply and exploit national industry affiliations to protect wider interests. Plant operations are typically less energy but more water intensive than bulk product per unit mass with reliance on more physicochemical quality control in product finishing usually under semi continuous shift operations. Located close to regional markets, delivery to consumers is mostly by regional road and rail carriers under short-term contract. Most plants employ in-house quality and environmental management systems and operate under government (local and State) licence conditions for noise and dust emissions, chemical and solvent storage as well as water consumption and release of toxic emissions to air and water.

Shape products comprise the largest surface area coverage and consequently major share of human health-related impacts of new and existing commercial buildings mainly from chemical finishing, cleaning and maintaining interior surfaces that surround occupants. With more players, variables, unknowns and product differentiation, LCI for this class, presents greater challenges for quality data compilation than bulk products. While shape production employs smaller-scale operations over a wider technology range many share a common material base and supply chain from which a substantial portion of environmental burdens derive comparable with that of the bulk product class. Most additional concern for data variability is related to shaping and surface finishing operations involving heating, compression, quenching with most variation directly related to well-known physical parameters such as melting point and reduction force. Altogether such operations are considerably less resource/energy intensive than that of bulk operations per unit mass. Typical surface finishing, however, involve chemical processing and significant emissions to air land and water that impact on human health.

Itemised Product Lines

Itemised product lines as shown, for example, in Table 5 form a class with highly diverse fabrications/finishes and high import levels mostly transported in containers via commercial marine shipping. Typically producers exploit small-scale advanced-processing plant to make and/or package for example glues, composites, connections and fittings. Price is per unit or gross item number and differentiated by size and performance or style and horizontally integrated trade-outlets increasingly use their purchasing power, importing and short-term contracts with local suppliers to control unit prices and dominate regional markets. Supply is also strongly influenced by overseas design trends and technology change. Numerous companies operate plants located close to regional centres with delivery by on-road trucking contractors.

Table 5 Itemised Product lines

Type	Product Lines
Composites	Glues/Fillers/Putties/Adhesives/Chemicals/Solder/Jointing Tapes;
Connections	Nuts, Bolt, Nails, Screws, Rods, Tubes, Hinges, Flats and Angles
Small Shapes	Timber, Ceramic, Metal, Glass and HD & LDPE, PVC, PS Polymers
Finished Items	Timber, Polymer, Ceramic, Metal, Porcelain and Glass;
Fittings	Polymer, Metal Timber, Glass And Ceramic Components;
Fabrications	Timber, Paper, Metal, Polymer, Ceramic, Glass and Laminations.

While this class of product forms the smallest commercial building product mass flow, with the highest churn rate it comprises the major commercial building fabric share of impacts related to solid waste to landfill and subsequent emissions to water and air. Potential for such impact reduction by item recyclability/adaptability is considerable. Items present overwhelmingly numerous variables, unknowns and extensive product differentiation and sampling is used to develop LCI. The supply chain involves a wide technology range and details that are not well documented. But, as for shapes, it is advantageous for data quality that many items also share a common base product and supply chain from which a substantial portion of environmental burdens ensue. However it remains disadvantageous that most items suffer similar data quality issues as those related to shape finishing operations as well as issues related to their importation and unknowns concerning country of production.

GENERAL DATA QUALITY PRINCIPLES

Challenges in providing transparency and comparably even data quality distribution on which to base assessment of building environmental impacts were outlined previously [6] including considerations demanded for a national LCI with extensive operations and imported products, adaptability for the future, a demanding integrated data exchange, as well as ensuring transparency and broad stakeholder acceptance. A simple standard, however, was developed to describe the LCI data quality that exploits qualitative data indicators based on a pedigree matrix pattern as shown in Table 6 .

These approaches were adopted to describe confidence levels particularly where lack of data contributed the large uncertainly related to, for example, imported items such as hinges, nails, bolts and screws of various base material. For reasons already defined, LCI data quality is typically higher for bulk products, than shapes than items. For LCADesign applications only, the comparable data quality within each class offsets the different data quality between classes where, for commercial building shell and fitout most significant substitutions are made from the same product class.

Table 6 Data Quality Pedigree Matrix (adapted from Pedersen Weidema et al 1996)

Correlation	1	2	3	4	5
Reliability	Verified	Expert	Sectoral	Qualified	Estimated
Completeness	100% sites	>50% sites	>25% sites	One, few sites	Other
Duration	Representative 3yr	Representative 2yr	Representative 1yr	Annual	Other
Temporal	Post 2001	Post 1997	Post 1993	Post 1990	Pre 1990
Geographic	Area under study	Ave .includes study	Sample of area	Similar area	Other
Technology	Actual	Comparable	Typical	Conventional	Characterised
Sample size	>99% continuous	>20%	>10%	]3%	Undefined

Verified=audited company report, Expert=industry representative, Sectoral=Industry sector report, Qualified=regional data & theory, Estimated =assumed ex national or overseas source.

EXPLOITING THE LCI DATABASE FOR LCADETAILS

Industry could adopt the existing LCI database to provide support for procurement but in addition via further development of a prototype LCADetails for procurement is proposed to provide an automated product profiler and to facilitate development of:

- An industry-wide validated database providing information on ESD;
- Industry sector footprint and supply chain profiles for product environmental assessment;
- A portal for sourcing supply chain data for a new building 3-D CAD product models assessment service;
- Facilitating green procurement, BEA and LCA by Government Departments and
- Linking CAD based product LCI/industry profiles of processes such as eco-labelling.
- Facilitated sourcing of industry input into LCI databases and development of industry based product profiles.

A wider industry customer and professional organisational need was identified as that industry requires BEA tools to :

- Support collation of up to date and credible industry based LCI information;
- Collate an industry controlled comprehensive database of Australian manufacturing supply chain eco-profiles, and
- Become potentially the first Australian national source for authoritative industry environmental LCA.

Some LCADetails applications and plug in tools, for example, are shown in Table 7 .

Tools	**Attributes**	**Applications**
Eco-Footprint Report	Sink/source data on state of domestics sources/sinks	Links to SOE/Resources
Supply Chain Data	Industry Details of best /typical/poor practice	Eco-profiles/practices
Ecopractice notes	Sensitivity Analysis for improved practice opportunity	Service Consultants

Ecolabels , Ecoprofiles	Eco-Profile reports of industry sectors performance	Eco-practice notes
Sensitivity Analysis	Provide LCA report cards for eco-marketing/labeling	LCA packaging/practice
Greener Packaging	Supply Tags to confirm procurement /avoid substitution	Tagging avoid substitution
Greener Procurement	Green Supply , Marketing and Eco specification	Ecoprofile & labeling

Table 7 LCADetails Tools, Attributes and Applications

The existing CRC CI national LCI database may be more readily enhanced by:

- Involving industry to provide inputs via a web-based system to obtain information on products;
- Profiling and labelling information presented through industry sector approaches to product performance checklists;
- Detailing product supply chain integrity and developing activity cards to ensure delivery is as specified;
- Creating a system of LCI/LCIA and LCA sector eco- footprint reports with load based reasoning.

A web-based module is considered the key to obtaining wide industry input to any LCI database for product eco-profiling. The focus in LCADetails is on producers, designers and buyers ease of automated environmental impact assessment from that detailed in 3-D CAD models of product lines. All are LCA and CAD based tool modules depicted in a schematic in Figure 4 of the ICT flow in a new LCADevelop tool kit including LCADetails.

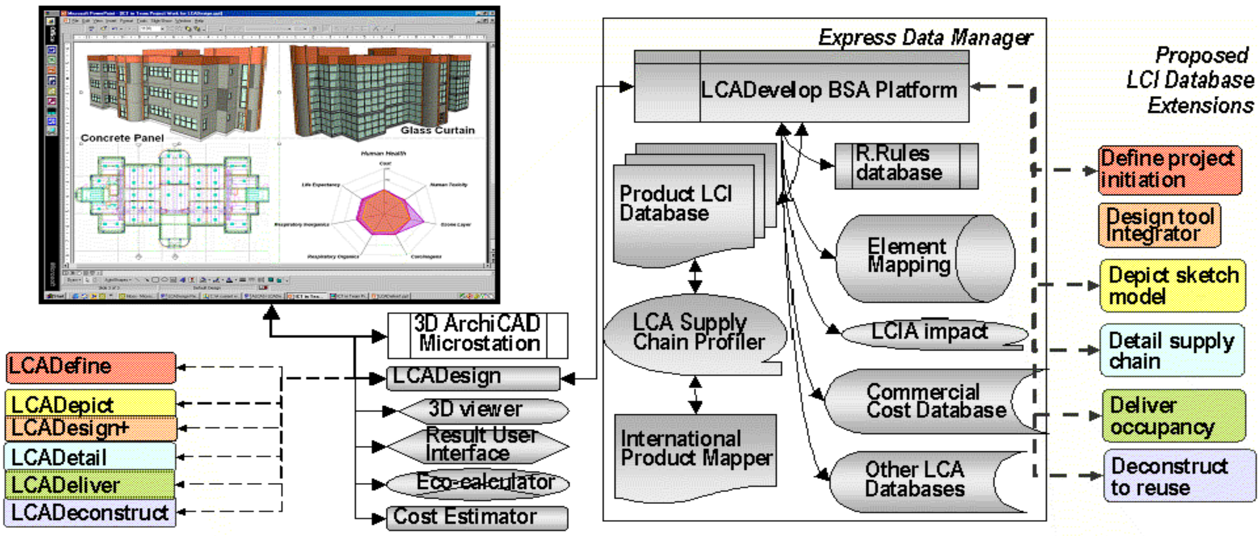

Figure 4. Schematic of LCADevelop Tool Kit Modules and ICT Flow including for LCADetails

LCADetails focuses on using building product knowledge acquired from industry suppliers for improvement planning and procurement guidance on product selection to the construction industry as a whole. The quality of the existing database can be enhanced in house for industry product development to facilitate their seeking of credible data further up and downstream of their own operations to improve their environment bottom line as well as to those who need credible data for assessing choice in building products on the basis of environmental impacts. It is considered most useful for the industry sectors that supply building and construction as it will provide for enhanced:

- Continuously updated information for industry environmental assessment, and
- Support to in-house building environmental assessments and product improvements
- Eco-profiling, specification and eco-labelling requiring high quality data
- Full cradle to cradle assessment

The market opportunity is potentially widespread, in particular for:

- Performance Assessment of supply chain
- One stop shop for product 3-D CAD based object oriented LCA assessment
- Enhanced initiation of objectives, tenders, bid evaluation for more sustainable products
- Development of Australia's only industry developed national tool to assess impacts of construction products
- Applications for delivery processes from design to end of life

In any commercial venture any national LCI database could also be enhanced by:

- Creating standards for industry sector product profiling, labelling information and performance checklists
- Detailing product supply chain integrity and developing activity cards to ensure delivery as specified;
- Creating a system of LCI/LCIA and LCSA sector footprint reports with load based reasoning.

CONCLUSIONS

Arising from work to develop a prototype 3-D CAD design tool for LCA of commercial buildings, new theoretical concepts of BEA tools were depicted integrated across a novel information and communications technology (ICT) platform to support stakeholder whole of life decision making on considerations from investment to post-occupancy. The concept of a prototype procurement system for profiling industry/products was depicted as a web based supply chain labelling system for product profiles obtaining industry input. For this a direct input of credible data from manufacturers, fabricators and importers was considered essential.

A product profiler system for improving, updating and utilizing the LCI database for industry sector footprint and supply chain profiles for environmental assessment of products LCADetail for procurement, for example, provides a commercial opportunity for returns based on:

- An industry-wide validated database providing information on ESD
- Providing a new building 3-D CAD product models assessment service
- An independent consultancy to industry seeking environment bottom line improvements
- Facilitating green procurement, BEA and LCA by Government, Industry and Community.
- Linking CAD based product LCI/industry profiles of processes such as eco-labelling and greenhouse gas rating systems that seek such database development.

The paper discussed examples of industry stakeholder requirements at procurement and showed attributes, and applications considering ESD criteria and environmental performance benchmarks for a proposed tool, LCADetails described to facilitate sustainability initiatives. For BEA tools to influence procurement they require specific LCA and LCI applications considering the importance of supply chain features. This is because a national industry accepted and LCI database is essential for accreditation of supply chain information for procurement was shown to affect stakeholder selections considering the entire product life cycle.

The paper also reviewed modular components of a comprehensive tool kit for stakeholders and schematics depicting LCA-LCC linked systems inclusive of other BEA Australian tools. As proposed this is an integrated tool kit, based on a new BEA framework informing a communications manager, leveraging function off an ICT platform and automated to take off from 3-D CAD models. It is staged to initially define project outcomes; design for outcomes integrated over the life cycle; detail the supply chain as well as deliver construction best practice and credit recovery in deconstruction.

REFERENCES:

1. Martin, P. and Verbid National Products Accounting Strategy: A path to competitive advantage for Australian Industry. Profit Foundation Pty Ltd, 1998
2. The World Commission on Environment and Development, (1987) Report from The Brundtland Commission: Our Common Future. Oxford, Oxford University Press,
3. United Nations Agenda 21: Programme of Action for Sustainable Development, (1992) Rio Declaration, United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, June
4. Department of Environment Sports and Territories, (1992) National Strategy for Ecologically Sustainable Development. Council of Australian Governments.
5. Tucker, S.N., Ambrose, M.D., Johnston, D.R., Newton, P.W., Seo, S. and Jones, D.G. (2003) LCADesign: An integrated approach to automatic eco-efficiency assessment of commercial buildings. CIB W078 New Zealand.
6. Jones D.G., Johnston D.R. and Tucker S.N., (2003) LCI for Australian building products in Proc. Intl. C.I.B. Conf. Smart and Sustainable Built Environment (SASBE2003), Brisbane Australia.
7. Phillipa Watson, Penelope Mitchell, and Delwyn Jones, (2004) Environmental assessment for commercial buildings: stakeholder requirements and tool characteristics: Report 2001-006-b-01 part 2, Research Program B Sustainable Built Assets, CRC for Construction Innovation.
8. Watson, P., Jones, D. and Mitchell, P. (2004) Temporal and Physical Life Cycles, Fourth Australian Life Cycle Assessment Conference, 23 - 25 Feb 2005, Sydney
9. Cooperative Research Centre for Construction Innovation, Brisbane, Australia http://www.construction-innovation.info/projects.php?project=4
10. Watson, P., Jones, D. and Mitchell, P., (2004) A Building Sustainability Assessment Framework; International CRC CI Conference Clients Driving Innovation, The Gold Coast, Queensland, Australia.
11. Delwyn Jones, Penelope Mitchell and Phillipa Watson (2004) LCI Database for Australian Commercial Building Material: Report 2001-006-B-15, Research Program B Sustainable Built Assets, CRC for Construction Innovation.
12. Mitchell. P (2004) Life Cycle Thinking (LCT) Implementation: A New Approach For ‘Greening’ Industry And Providing Supply Chain Information, University of Queensland Doctoral Thesis, (submitted July 2004)
13. Seo, S., (2002), International Review Of Environmental Assessment Tools And Databases, CRC for Construction Innovation, Report Number 2001-006-B-02, Brisbane, Australia.
14. Foliente, G., Seo, S. and Tucker, S. (2004) A Guide to Environmental Design etc, CSIRO MIT, Australia.
15. AS/NZ ISO 14001:1996 Australian/New Zealand Standard® Environmental management systems-Specification

with Guidance for use (1996), Standards Australia, Homebush, Australia :

- AS/NZ ISO 14004:1996 General guidelines on principals, systems and supporting techniques.
- AS/NZ ISO 14010:1996 Guidelines for environmental auditing-General principals.
- AS/NZ ISO 14011:1996 Guidelines for environmental auditing-Audit Procedures- Auditing of EMS.
- AS/NZ ISO 14012:1996 Guidelines for environmental auditing - Qualification criteria for auditors.
- AS/NZ ISO 14031:1999 TM Environmental management - Environmental performance evaluation-Guidelines.
- AS/NZ ISO 14040:1998 Environmental management-Life cycle assessment-Principals and framework.
- AS/NZ ISO 14041:1999 EMS-Life cycle assessment-Goal and scope definition and inventory analysis.
- AS/NZ ISO 14042: 2000LCA-LCIA.
- AS/NZ ISO 14043: 2000 LCA-Life Cycle Interpretation.
- ISO 2001, "ISO/TS 14048 LCA – Data documentation format", ISO/TC 207/SC 5/WG 2/TG N 20, SIS

16. Wood, G and Jones DG. 1996. Life Cycle Analysis-How It Works And Practical Applications, ESD In Architecture And Building Conference, Sydney, Australia.
17. Wood, G and Jones DG. 1996. Using Life Cycle Analysis-To Understand Environmental Impacts, RMIT Design For The Environment Conference, Sydney, Australia.
18. Sarja A. (2002), Integrated Life Cycle Design of Structures Spon Press, London.
19. Lovins, A., (2004) Green Development, Rocky Mountain Institute, USA.
20. Watson, S. (2004), Improving the implementation of environmental strategies in the design of buildings, University of Queensland Doctoral Thesis, Queensland.
21. Cole, R. J., Lindsey, G. and Todd, J. A. (2000) Assessing Life Cycle: Shifting from Green to Sustainable Design, Proc, Sustainable Buildings 2000, The Netherlands.
22. Barton R.T., Jones D.G. & Gilbert D., J., (2002) Facilities Management, Strategic Asset Management Incorporating Ecologically Sustainable Development, Henry Stewart Publications Alden Press, Oxford, UK 2002.
23. Barton R., Jones D. & Gilbert D., Project Management: Initiating Sustainable Projects, (2000): Shaping the Sustainable Millennium, Selected CIB SABE Conference papers, QUT Press, Brisbane, Australia.
24. Barton R., Jones D. & Andersen H. (1999) Proc Intl. Conf HKIVM, Incorporating Values of ESD into Project Definitions Using Soft Value Management, Hong Kong.
25. Queensland Government (2000), Guideline for Ecologically Sustainable Office Fitout, (GESOF), http://www.build.qld.gov.au/aps/ApsDocs/ESDMasterDocument.pdf in Aug 2004, Australia.
26. Jones D.G., Messenger G. and Lyon Reid K. (2004), Sustainability a William McCormack Place, CRCCI: International Conference: Clients Driving Innovation', Gold Coast, Queensland, Australia.
27. Jones, D. G., Lyon Reid, K., and Gilbert, D., (2003), Sustainability Assessment Considering Asset And Building Life Cycles, in Shaping the Sustainable Millennium, Selected CIB SASBE papers, QUT Press, Australia.
28. Fisher, M., Keynote: Visualisation and Information on Recent Stanford University Projects, QUT CRCCI: International Conference: Clients Driving Innovation', Gold Coast, Queensland, Australia.
29. Betts. M., Keynote: Visualisation and Information in QUT Projects. CRCCI: International Conference: Clients Driving Innovation', Gold Coast, Queensland, Australia.
30. Boustead, I. (1995) The Boustead Model for LCI Calculations, Vol 1 Data Sheet 1-60, Dec.