CRC Construction Innovation

BUILDING OUR FUTURE

Final Report
Task 4: Waste Minimisation in Construction

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1. BACKGROUND

The Regenerating Construction Project for the CRC for Construction Innovation aims to assist in the delivery of demonstrably superior 'green' buildings. Components of the project address eco-efficient redesign, achieving a smaller ecological footprint, enhancing indoor environment and minimising waste in design and construction. The refurbishment of Council House 1 for Melbourne City Council provides an opportunity to develop and demonstrate tools that will be of use for commercial building refurbishment generally. It is hoped that the refurbishment will act as an exemplar project to demonstrate environmentally friendly possibilities for office building refurbishment.

The University of Western Sydney's role in the CRC CI research project relates specifically to the area of waste minimisation in construction. Best Practice Guidelines have been derived from widespread consultations with practitioners in the commercial refurbishment construction sector. Comments derived from these consultations have been included in this report wherever appropriate. In addition, drawing on a literature review of waste minimisation in construction, generic checklists have been developed which will be available for the use of the CH1 refurbishment project. These are included as *Priority Actions* under each sub section of this report. Where possible orders of priority have been identified, however, at this stage it is not possible to give quantifiable information as this is part of ongoing research.

Renovation and refurbishment of commercial buildings has traditionally been acknowledged as a high volume generator of waste material destined for landfill. In early 2005 the Melbourne CBD had a total stock of more than 3 million square metres of commercial space (www.prpaustralia.com.au). If major refurbishments are carried out at an average of twenty year intervals, there is considerable potential for large amounts of waste generation. Reuse and recycling strategies can help to minimise such waste generation.

Designing out waste, using long lasting materials and planning for deconstruction are all strategies that can assist in improving the efficient use of raw materials in construction. Along with accurate ordering of materials, good storage and site control practices, an emphasis on monitoring waste produced can contribute to the economic as well as the environmental performance of a construction project. In addition, consideration should be given to office fittings and fixtures which frequently have a relatively short service life when compared with other construction items. Specifying in accordance with the standard units, quantities or modules of different components can further reduce waste. Accurate condition assessment of the existing building components, coupled with a strategy of 'repair in place' when appropriate is likely to produce further savings. Each of these strategies needs to be addressed for a more sustainable solution and outcomes.

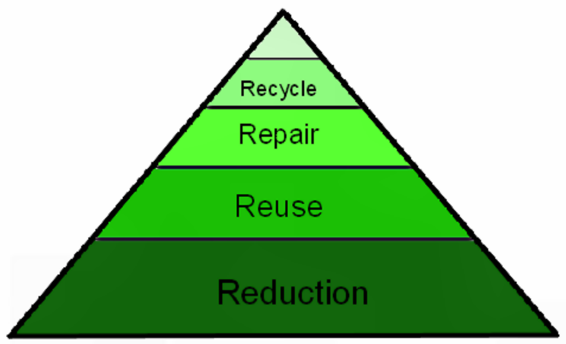
Bottom line savings of approximately 50% of the budgeted amount for waste removal have been achieved by Australian projects incorporating waste minimisation strategies from the WasteWise Construction Project and similar programs. Overseas examples such as the 'Zero Waste' program initiated by the California Integrated Waste Management Board have also achieved significant reductions.

Minimisation strategies can be categorised under the headings:

- Reduction
- Reuse
- Repair
- Recycling
- Disposal

As a general rule, this list goes from the most to least desirable option in environmental terms.

Hierarchy of Strategies for Refurbishment Projects



The top triangle represents the residual waste fraction for disposal

Despite current best efforts, a significant proportion of the theoretically recoverable resources in refurbishment projects still ends up in landfill. There remains, therefore, considerable scope for waste minimisation in construction to make a significant contribution to reducing greenhouse gas emissions and enhancing the sustainability of the built environment. It is acknowledged that waste minimisation is more than just quantifying and sorting of waste, it involves promoting favourable attitudes and encouraging ownership of the process at all levels of the construction process. During the implementation process in particular, written waste management plans have been widely shown to be both an incentive and a guide to waste management practice on a building site. Unfortunately however, it has been reported from several sectors of the industry that there is often no verification of these plans and little monitoring of the rates that are actually achieved. If overall industry performance is to be improved, then the question of responsibility for recycling and reuse rates has to be addressed. Industry will respond if it is required to raise rates, but it is unlikely to take the initiative while it remains unconvinced of the financial benefits. Successful implementation of waste reduction strategies at CH1 may give impetus to reconsidering priorities in commercial refurbishment generally. The publication of benchmark rates for reuse and recycling will make it easier to identify under-performance and to indicate those areas where regulators and environmental agencies should focus their attention.

2. STRATEGIES

Several broad options have been identified from practitioner focus groups as well as in the literature for construction waste management. These can be classified under the broad headings of reduction, reuse, repair, recovery, and disposal. With some exceptions these headings are generally in decreasing order of desirability. This report will seek to examine each option in detail and describe the potential use of each in a typical office building renovation.

2.1 Reduction

The primary strategy for effective waste minimisation in construction is the reduction of resources consumed by means of "modesty in design". This concept includes consideration of reducing space allowances, as well as reducing energy and materials consumed. Space allowance reductions need to be client-driven, however, materials and energy reductions can be significantly affected by the designer and the contractor. Industry practitioners clearly indicate that direction from the client was a major consideration in the priority given to waste management on a project. A client directive to achieve a high eco-rating for a project is likely to result in significant changes of practice on site which may replicated on future projects if benefits can be demonstrated. Exemplar projects such as CH1 can have spin-offs for the industry generally by demonstrating what is possible in the field of waste reduction and landfill diversion.

Source reduction involves being proactive in the waste generation process and seeking continual incremental improvements. In addition, 'long life loose fit' or 'design for diversified lifetimes' can successfully reduce overall material consumption in the long-term. Sustainability indicators are currently being developed to methodically categorise the existing building stock and therefore reduce the need for new construction. Systematic recording of the condition of commercial buildings, when linked with client requirements may be able to defer the need for major refurbishments for some time and therefore extend the useful life of many existing buildings.

Poor material control on site during the construction or renovation process has been identified as a significant source of waste. Better systems of materials ordering and quality control during construction can lead to considerable savings. Indeed, early work in the field found that the amount of waste generated in construction projects could vary greatly for otherwise comparable projects. It was found that substantial losses can be incurred through poor loading and storage practices, as well as through inappropriate packaging. Refurbishment practitioners report that there is likely to be a high packaging component in waste from the fit out phase of a project when time schedules are often tight and therefore sorting is minimised. This needs to be allowed for in project scheduling. Furthermore it was likely that any waste resulted from a combination of events rather than a single incident. These are issues for the construction manager to be aware of and to take control of, in order to reduce the occurrence of habitual waste generation.

Future developments in the field of materials handling and tracking are likely to involve the use of technologies such as Global Positioning Satellites (GPS) and Geographical Information Systems (GIS). This is already being tried in Hong Kong and shows considerable promise for minimising on site material waste. Both the design and the construction phases of a project can incorporate the waste minimising strategy of reduction in resources consumed. In both cases, careful planning and close analysis of the actual requirements of the project are keys to achieving successful reduction.

Priority actions on Reduction

- *Check that office space allocations are driven by occupant requirements rather than status or prestige.*
- *Aim for 'long life, loose fit' in facilities allocation. Choose longer lasting products and build to last.*
- *Designers should allow for optimal use of stock sizes of standard components and materials should be ordered in these quantities.*
- *Waste management specifications should be included in the construction documents, including tender guidelines and subcontracts.*
- *Set waste prevention goals at the outset of a project and target specific waste producing activities. Consider engaging a consultant to help with waste management.*
- *Form a waste management team on site and appoint a waste coordinator who will report waste figures to management regularly.*
- *Involve the site waste contractor in the process before construction commences and negotiate the options.*
- *Any hazardous material content in waste should be identified and flagged at the earliest possible stage.*
- *Prefabricated components should be used where possible.*
- *Avoid over-ordering 'just in case'. Re-evaluate estimating procedures if significant quantities of material are left over.*
- *Find suppliers who will take back any excess building materials for recycling or remanufacture*
- *Where possible suppliers should be required to deliver materials in returnable containers. . Suppliers should be required to minimise packaging of delivered materials.*
- *Tight materials control and material auditing should be required of all construction contractors.*
- *Unloading, all-weather storage and handling of materials should be controlled to avoid wastage due to onsite materials damage.*
- *Induction programs and onsite training in waste minimisation for all construction workers should be provided.*
- *Consider incentive programs for workers or subcontractors who make material savings, set targets.*
- *Consider any industry awards the project may be eligible for and determine any waste management criteria.*
- *Consider points to be gained in working towards any of the Green Building ratings (e.g. Green Star) by minimising waste during refurbishment.*
- *Integrate cost control, reporting and monitoring of waste minimisation initiatives throughout the project. Keep records of savings and compare from project to project.*
- *Organise the site to assist material handling including access and storage sites if possible.*
- *Site security systems need to be directed at preventing pilfering and vandalism.*
- *Confine and collect all litter within the site boundaries.*

2.2 Reuse

The reuse of building components in new construction is becoming an increasingly economically viable practice. Such reuse is greatly aided by forethought at the initial design stage to make future disassembly possible. Design for deconstruction makes possible many useful lifetimes for building components and so justifies the use of high quality materials in the initial fabrication. 'Design for disassembly' has the added benefit of being an aid to 'buildability' or efficient construction. Components such as partitions, ceiling panels, windows, doors, cupboards and light fittings are all readily reusable if they can be taken out of a building to be refurbished in a non-destructive manner. The establishment of secondary markets for such materials is already taking place and needs to be encouraged by local authorities, especially in large cities where the volumes and therefore the market opportunities are likely to be greatest.

It has been found that good communication with product manufacturers is crucial to effective design for deconstruction. Suppliers who make the effort to consider the end of life impact of their products should be encouraged by being given preference in project specifications. Controlling the environmental effects during disassembly must also be given a high priority as should ensuring that safety standards are maintained during disassembly. Ideas about systems of modular components have a long history in construction. Successful systems in which modular components are regularly reused are, however, not at all common. The need to be able to modify or customise components for a particular situation tends to work against large scale interoperability of building components. Buildings are significantly more complex artefacts than manufactured consumer products and thus they require a higher level of understanding to maintain their long-term value. Nevertheless, there is considerable potential to develop the 'disassembly and reuse' strand of waste minimisation in commercial building construction.

Priority actions on Reuse

- *Identify existing building components with significant 'residual life' and find suitable uses for them.*
- *Ensure fittings, fixtures and furniture are reused whenever possible.*
- *Schedule the necessary time for disassembly rather than destructive demolition.*
- *Order of demolition is often critical to the recycle potential of building components.*
- *All construction work should be designed to allow for future deconstruction at the end of its useful life.*
- *The use of modular and standardised components can aid future reuse.*
- *Consider setting up a webpage to publicise the sale of unwanted components with residual resale value. Some construction components, both new and used, currently find a market on e-bay. Alternatively, advertise items for resale in local newspapers.*
- *Some building components may be donated for reuse by community organisations. This may be a useful strategy for used work stations which make up a significant element in office refurbishments.*
- *Consider partnering with other projects for reuse of materials.*
- *Incorporate practices and contract specifications that encourage reuse and material salvage where possible.*

2.3 Repair

It is sometimes forgotten that making simple repairs as part of a refurbishment project can be the most environmentally friendly and cost effective option. Indeed repair may be the appropriate strategy for items as diverse as deterioration of finishes up to structural cracking in the building fabric. Considerable research is being done into the repair of concrete and steel structures with Fibre Reinforced Polymers (FRP). This practice has the potential to extend the useful life of structures that would otherwise be completely or partially demolished and results in considerable net energy savings.

Proper ongoing maintenance, using both condition-based and preventative assessments, is essential to the integrity of any built structure. A pre-refurbishment audit of the state of repair of all building elements has been found to aid in prioritising refurbishment work. Service life planning involves the prediction of the likely lifetime of a building and the design of its components to suit. The actual life of buildings is often considerably longer than their planned service life therefore more emphasis should be placed on the option of repair during a commercial building refurbishment.

Priority actions on Repair

- *Careful auditing of the condition of the existing building may make it possible to repair rather than remove components which are structurally sound but with deteriorating finishes.*
- *Structural strengthening should be given consideration for its potential to extend refurbishment possibilities.*
- *Preventative maintenance during a building's standard lifetime can significantly extend the useful life of many components.*
- *As–built drawings and specifications to be produced, checked and updated throughout the refurbishment project as an aid to ongoing maintenance.*
- *Investigate whether the refurbishment of furniture (including work stations) is more cost-effective than replacement.*

2.4 Recycling

It is important to distinguish between the reuse of building components and the recycling or recovery of building materials. Recycling involves a more extreme transformation and is consequently likely to be more energy intensive. A case study of the supply loops for structural steel sections makes this distinction clear. Steel structural sections can be reused as they are or steel scrap from buildings can be recycled as a component of new steel. Both are useful processes but the latter will involve the consumption of greater amounts of energy for the transformation. As a generalisation, metals are among the most easily and economically recycled of building materials. Industry practitioners report that it is now standard practice to sort and recycle all significant metal components in a refurbishment project.

Several studies have found that the energy used to remake materials from recycled materials was consistently lower than that needed to make new materials. The energy saving is of the order of 10%. It remains to be seen if similar quantifiable savings can be made recycling the material from commercial building refurbishments, though several authors have reported significant gains.

Separation of construction and demolition waste at source has been shown to be critical to the economics and practicality of recycling materials. An increased level of on site sorting of construction waste was used extensively for the construction of facilities for the Sydney Olympics. Five of Australia's largest construction companies were partners in phase1 of the WasteWise Construction Program which committed them to prevent waste generation, reduce waste, reuse waste, recycle waste and recover energy from waste prior to the disposal of any residual fraction. The program was able to achieve significant change in waste management behaviour on construction sites.

Constrained project scheduling has been shown to aid environmentally friendly dismantling of buildings to achieve high recycling quotas. The order in which demolition procedures are carried out, materials sorted, then finally collected and passed into the recycling loop is a critical managerial process. Such recycling loops can be either 'closed loop' resulting in the production of new amounts of the original product or 'open loop' resulting in the production of a different useful material. Specific recycling practices have been developed for particular building materials.

Concrete

Concrete waste from demolition can be pulverised and graded for recycling as aggregate in new concrete. Lightweight aggregate is produced from the fines portion of C&D waste in this manner. This practice has become increasingly commonplace in recent years and considerable research into the properties of the recycled product has been undertaken. The viability of recycled concrete aggregate seems to depend very much on the distances the product needs to be transported for recovery with the larger cities achieving robust rates of material recovery. In addition, concrete ground to a powder form can be used to replace some of the cement content of new concrete. Concrete waste which is unsuitable for the previous options can be used as fill in landscape regrading. As a general rule, transportation costs are likely to be a significant portion of the cost of recycling any bulk material.

Plasterboard

Recycling of plasterboard from refurbishments is currently the subject of disagreement with some practitioners being unaware of any recycling programs while others claim to recycle plasterboard at a rate of 80 or 90%. The industry in Victoria appears to be well in advance of the rest of the country in recycling plasterboard. Demolition and strip out contractors need to be up to date with developments in recycling of different materials which they may have previously considered only fit for landfill.

Metals

Metals, as previously mentioned, are relatively easy to recycle provided the disassembly problems are understood. Steel mills have traditionally included a scrap component in their steel production process. Raising the percentage recycled can produce positive results for both the steel manufacturers and the demolishers or refurbishers. This is a closed loop recycling process.

Bricks

Bricks laid in soft lime mortar have long been reused but it is only recently that brick waste has been tried as a component in the manufacture of new bricks. Introducing some degree of closed loop recycling for all suitable construction products is a necessary element of industry sustainability.

Glass

While some glass can and is used in a closed loop recycling process the viability of continual recycling of glass is affected by the introduction of impurities which are expensive to remove. The recycling of glass bottles and other containers is widely practiced but the 'cullet' or scrap produced from such glass has a different melt temperature from window glass so window glass has to be recycled through a separate open loop system. Waste window glass is used to manufacture the reflectors which are embedded in road surfaces along with lane-marking. The glass must be clear and uncontaminated by other kinds of glass. Another example of an open loop recycling system is the use of waste glass to form Foamed Waste Glass (FWG) which can be used as a lightweight aggregate in concrete or as a water-holding landfill material. FWG is an option for poor quality glass waste.

Recovery rates are clearly dependent on the combination of general project management issues and specific material recycling processes. The development of regulatory requirements for minimum recycled content in new building materials may be one way to ensure that recovery rates are lifted. By creating a viable market for recycled material feedstock incentive is created to sort and recycle more building waste.

Priority actions on Recycling

- *Where possible specify a recycled percentage in new materials used on a construction project.*
- *All clean hard waste (bricks, concrete, fill etc.) should be recycled either on or off site rather than sent to landfill.*
- *Metals are the easiest of materials to recycle in terms of energy efficiency, so priority should be given to separation of all possible metallic components during demolition and disassembly.*
- *All reinforcement and structural steel should be recycled.*
- *No tyres are to be sent to landfill.*
- *No topsoil to be sent to landfill.*
- *No petroleum products or associated containers should be sent to landfill. They should be required to go to appropriate recovery centres.*
- *Paints, stains and solvent remainders and their containers should be recycled by the relevant subcontractor rather than sent to landfill.*
- *All demolished material must be source separated into its component fragments.*
- *Provide clearly labelled colour-coded containers for recyclables on the site.*
- *All subcontractors should be required by means of the procurement system to sort their waste outputs.*
- *All manufacturers supplying material components for a construction project should have in place a strategy for "end of life" of their product.*
- *Minimise use of any materials with no current reuse/ recycling strategy.*
- *Any bulk fragment of construction (by volume) should be analysed for its recycle potential.*
- *Monthly reports should be done on total volume of waste removed from site, the percentage of waste recycled and any initiatives or savings achieved.*
- *If site space or access precludes onsite sorting, commit to an offsite facility with sorting and reporting mechanisms.*
- *Find out who recycles what in the vicinity of the project (most state offices of the MBA will have a recycling guide or list of recycling facilities).*

2.5 Disposal

Within the category of disposal there are sub areas which can include the composting of organic material and the use of wastes for energy generation. Theoretically all organic materials can be composted. In practice composting is often limited on building sites due to the time and space required for the practice. It is, nevertheless, an acceptable strategy for scrap timber and other organics from building waste when the timber is not in a condition that would allow it to be reused. This could be due to small section size or to deterioration from weathering, fungal decay or insect attack. It may be argued that composting of building waste could most usefully be done at specialist facilities rather than on site. Adequate sorting of compostable materials would, however, still need to happen on site.

Disposal of timber by burning to generate heat is a useful and practical application in cold climates where buildings often have boilers for heat generation. It is less readily useful elsewhere but may have some specialist applications.

The option of disposal of waste in landfill should be a last resort because of its environmental cost and its increasing monetary cost. In addition, the possible contamination of building wastes with heavy metals is a factor that should discourage reliance on landfill for construction waste disposal. The residual waste that is sent to landfill should be fully accounted for and sent to responsibly operated facilities where good records are kept.

Priority actions on Disposal

- *Investigate the possibility of using organic waste as compost.*
- *No green waste from the site should be sent to landfill. If necessary it can be sent to a waste contractor with composting facilities.*
- *Any timber sections in short lengths unsuitable for recycling should be considered for use as either woodchips or firewood.*
- *Any unrecoverable waste should be recorded by weight, volume and approximate composition before it is sent to landfill.*
- *No waste should leave the site without a destination recorded.*
- *Encourage feedback to the site manager of waste creation and disposal problems.*
- *Careful record keeping on 'waste arisings' during construction will help to identify areas of need and consequently aid future projects.*

3. BEST PAYBACK AREAS

Many of the priority actions mentioned above relate to environmental goals rather than to strictly commercial priorities. Nevertheless, a marketable commercial advantage is available to contractors achieving best practice. An analysis of the options in relation to waste management at the outset of the project (including during the Design Stage) is fundamental for project planners to allow for methodologies required for waste minimisation. This should include a comparison of costs of not recycling with recycling options. It is possible to identify some strategies that are likely to produce a positive return, some that will probably be cost neutral and some that may result in future benefits but involve an initial cost.

It is important to acknowledge the full cost of waste, both upstream and downstream of the project itself. In this regard it is helpful to engage as many stakeholders as possible in the refurbishment project. The building owner, for example, may see longer term financial benefits of designing for disassembly compared to structural changes. Similarly, commercial tenants may benefit from a modular design if, at the expiry of the lease, they are required to return the space as it was.

Target areas

- *Potential contractors should be informed that developing a waste minimisation strategy is a requirement to qualify for select tender lists.*
- *Mismanagement of materials on site, including unloading, stacking and storage is identified as a major source of waste. This can be reduced or eliminated by tighter materials handling rules and forward planning by the site manager.*
- *Target residual scrap caused by designing and detailing in non-standard quantities.*
- *Strongly encourage ordering of materials in supplier's preferred quantities.*
- *Bulk waste from concrete, brick and ceramic tile demolition should be targeted because it is heavy and represents a significant proportion by volume of waste currently sent to landfill.*
- *Sorted metal scrap has significant residual value. Aim at recycling as near as possible to 100% of metallic waste in refurbishments.*
- *As wet trades have been identified as disproportionately large generators of waste, they should receive careful attention from the site manager and close monitoring of the waste generated.*
- *Monitor the amount of mortar waste in bricklaying and implement careful management of that waste.*
- *Manage schedules to reduce waste of premixed concrete brought to site.*
- *Greatly reduce or eliminate packaging to building materials delivered to site as this feeds in to cost.*
- *Foster cooperation and collective responsibility for waste management by making it clear that top management supports waste minimisation goals.*
- *Promote your waste minimisation achievements.*

4. CONCLUSION

Waste minimisation strategies in office building refurbishment can make a significant contribution to the sustainability of the built environment as a whole. The refurbishment process is part of the loop of resource consumption. Refurbishments extend the useful life of a building thereby allowing continued use of the resources initially expended in its construction. If future life cycles are allowed for, by means of design for deconstruction and disassembly, then the savings generated by refurbishments can be ongoing. Something like the cyclic processes of systems in the natural world may eventually be achieved. This can certainly be aimed for as a worthwhile goal.

Proven strategies for waste minimisation include: reduction of resource consumption; reuse of components; recycling of materials; composting; and energy generation from organic wastes. Each of these has been demonstrated as an effective means of reducing construction waste. The imposition of waste minimisation strategies from the top down' however, may meet with entrenched resistance from those who see no reason for change and no benefit for themselves. Such a plan therefore should be supported by training and incentive programs which encompass the whole workforce. Safety and equity issues need to be given due consideration. It is generally regarded as helpful if all these matters are formalised in a written Waste Management Plan and the implementation process tends to be aided by clear definitions of the performance changes that are required. To ensure compliance with approved waste management plans some form of monitoring of waste performance needs to be introduced.

The question of how best to quantify waste minimisation in commercial construction remains unresolved for the time being. Baseline data is not yet available to any great extent although current research in this area is intended to produce some preliminary findings. Future research into ways of quantifying waste management options may well benefit from drawing on concepts developed by other disciplines. There is therefore considerable scope for further work into the ongoing development of 'Best Practice Guidelines' for the maintenance and refurbishment of commercial buildings.

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