Sustainable Concrete Asset Disposal Optimisation

Mr Jared Fitzclarence

Dr Melinda Hodkiewicz
School of Mechanical Engineering

Associate Professor Benedict White
School of Agricultural and Resource Economics

Mr Guy Watson & Ms Esther Loh
Water Corporation

Abstract

The Water Corporation strives to conduct responsible business recognising that the 'best' path is not always the cheapest. Faced with numerous assets requiring disposal they are looking to achieve a balance between cost and sustainability in their operations. The burgeoning concrete recycling industry in Perth, Western Australia attempts to provide cost effective alternatives for concrete asset disposal. Simultaneously, changes within the waste disposal industry and recent government policies are powering a shift towards increased sustainability. In this paper the science of concrete recycling is introduced and the market for recycled by-products is shown. As policies change and costs rise, choosing a disposal method can be challenging. This paper outlines the limitations imposed by transportation on disposal operations and presents a model for identifying the optimal solution for a project. Preliminary results show that recycling is the only practical solution within the metro area and that transportation distances play a leading role in determining disposal method suitability. Work is ongoing to weight results for environmental performance, social benefits and corporate policy. These results will guide future disposal selection and work to increase the sustainability of many upcoming asset disposal projects around the state.

1. Introduction

Recent work undertaken within the Water Corporation has indentified a range of assets across their portfolio that require disposal. The Corporation recognises that asset disposal is a costly procedure that can pose significant environment impact. This project has been commissioned to identify strategies that will assist in upcoming disposal projects within the Corporation, by identifying more cost effective and sustainable disposal opportunities.

The Water Corporation produces a wide variety of waste material through disposal projects (See Table 1). Of these it was determined that the Corporation would realise the greatest benefit through a study into selecting appropriate concrete disposal techniques. This is due to a lack of topical sustainability guidelines and because findings relating to concrete, readily extrapolate to concrete piping and building rubble. It is estimated that the Water Corporation can produce 2500-3000 m^3 of concrete rubble annually for the next few years. Given current practice, this represents a substantial cost and a significant usage of available landfill space prompting an investigation into alternative practices.

In 2007 the "Waste Avoidance and Resource Recovery Act 2007" outlining the direction of the West Australian waste industry was unveiled (2007). One strategy is a target of 'Zero Waste' to landfills by the year 2020 (2007). In response the Water Corporation has recognised that it is becoming inappropriate to continue disposing concrete to landfill and is investigating alternatives.

Waste Stream	Current Disposal Practice
Soil & Earth	Treated on site and sent to landfill if contaminated beyond reuse.
Piping	Often retired and left in place underground. Depending on material it may be directed to metal recyclers or sent to landfill.
Operational Plant	Reused internally where possible, auctioned or recycled. Possible landfill if contaminated, highly variable.
E-Waste	Follows local laws regulating e-waste disposal.
Concrete	Directed to local landfill facilities.
Building Rubble	Directed to local landfill facilities.

Table 1 : Water Corporation Disposal Practices

1.1 Current State of the Art

The waste avoidance hierarchy implemented within Western Australia (WA), under the annex of the Department of Environment and Conservation (DEC), features a five-pronged strategy to limit the production and impact of waste within the state (DEC, 2007). The five strategies are to avoid, reduce, reuse, recycle and dispose; listed in decreasing sustainability. Of these only reuse, recycle and dispose are suitable for concrete assets.

Concrete is traditionally comprised of aggregate, water and cement, with structural supports where appropriate. When making new concrete structures, the aggregate, water & cement are mixed into a paste and then placed into a mould and around any supports. As the paste dries crystalline structures form and are locked in place by the aggregate giving the concrete strength. Aggregate size varies depending on the desired properties of the concrete and the mix will contain a range of sizes, varying from sand to large stones (CCAA, 2004).

Concrete has three constituents that can be recycled during disposal. Structural supports or 'rebar', typically made of iron or steel, are extracted by crushing and magnets are used to lift out the metal for sale. The small concrete 'rocks' generated by this process can be further crushed and screened producing Recycled Concrete Aggregate (RCA) which has a variety of uses (Yeo and Sharp, 1997). The remaining fine gravel or powder can be used as a landfill sealant fully reusing the original material. Current data shows that 79% of Construction and Demolition (C&D) waste generated in WA is sent to landfill, opposed to just 2% in Japan (Tam, 2009). One reason is that people don't realise the potential uses of recycled material. The Table 2 below shows some of the many proven markets for RCA worldwide:

Usage	Description & Uses
Bulk Fill	Highly stable fill used for block levelling etc.
Hardstands	Well draining, clean surface material e.g. depots, access roads
Drainage Material	Stormwater drainage, overflow areas
Concrete Backing Blocks	Large stationary concrete weight blocks, no reinforcement
Kerbing and Pavement	Equivalent or better strength result applications
Road Pavement	Equivalent or better results in base & sub-base use
Structural Concrete	Mixed with virgin aggregate to achieve equivalent results

Table 2 : RCA Usages (Tam, 2009, Sim, 2008b, Tam, 2008, Yeo and Sharp, 1997, Li, 2008, Li, 2009)

1.2 Market Conditions

A major factor in the slow growth of C&D recycling within WA was the availability of cheap local landfill facilities giving little incentive to invest in innovative recycling capabilities. Since the introduction of the 'Waste Avoidance and Resource Recovery Levy Regulations 2008' the industry has had clear guidelines detailing the extent of landfill cost increases. These extra costs are reaching a point where recycling is often less costly than using landfill and are triggering rapid growth in the recycling sector. The first C&D recycling facility began operating in Perth in 2005 and now there are six such facilities throughout the metro area (Sim, 2008a). At present no facilities exist outside the metro area but machinery can be taken to sites given sufficient incentive and plans are underway to develop a C&D recycling facility in the Albany area in the near future (Sim, 2008a).

The demand for recycled concrete material has been very small in WA. Due to the accessibility and low cost of virgin material, buyers for recycled material have been scarce. Studies showing material capabilities and lowered costs due to landfill price increases are opening up the market. Trials have been undertaken by main roads to determine the feasibility of using more recycled material. The exceptional performance of recycled materials led to paving specification changes in 2008 to encourage further use (Sim, 2008b).

1.3 Corporate Directions

The Water Corporation aims to show that a large company can operate responsibly, both in regards to environmental obligations and social impacts. It is recognised that disposal projects are typically given to project managers who have little time to investigate sustainable solutions for asset disposal. The Water Corporation wants tangible evidence to show the benefits of prioritising sustainability for use developing awareness and improving the management of future projects.

1.4 Project Objectives

The objectives of this project are: 1) Identify how the Water Corporation can benefit by changing disposal practices. 2) Understand how concrete can be disposed. 3) Identify negatives and benefits for each disposal option. 4) Create a model to aid in determining best practice. Once completed, the project will then compile results showing the impact of changing parameters and the most efficient practice for a given situation. The model will be used to explore disposal options within the Water Corporation. This will increase the awareness of sustainable disposal practices in concrete and other materials.

2. Process

Initial investigation identified what assets the Water Corporation disposed and what methods were used. Work was performed utilising the disposal timeline developed by Ken Walker and Wayne Davies to analyse upcoming disposal projects. To focus on significant data, projects with an expected disposal cost above $50,000 starting in the proceeding 18 months were targeted, determining the scope of upcoming projects. An estimate was then made for how much concrete is present in each case.

The waste industry in WA was analysed to determine potential local markets for recycled concrete aggregate (RCA) and other by-products of concrete recycling. The driving factors behind the industry were also examined, looking at past legislation and recent changes to applicable laws and levies.

Facilities for the processing of concrete waste were then identified and data was collected to provide the necessary variables for modelling. Once collated this was used to generate accurate variable approximations by liaising with companies in the industry.

Upon conclusion of the investigation into disposal options, drafting began on program modelling. It was decided to limit the program to achieve meaningful results and the decision was made that only landfill, stockpiling and crushing should be considered initially. This equates to just two disposal options in the metro area, namely landfill and recycling. It was decided that GAMS would be the ideal platform for writing the program due to its' free educational licensing, optimisation modelling specialisation, ability to rapidly compute long and complex equations and easily interpretable programming style. It was hoped to include full biasing support in the program, but the current edition has not yet achieved this. The results of the model have been used to create a series of results for presentation to the Water Corporation and further investigation.

3. Results and Discussion

Asset site plans, professional knowledge and firsthand experience have been used to estimate concrete asset volumes for the key assets subjected to site assessment surveys. Dimensions were collected from available plans and discussed with local site managers, who confirmed or modified specifications. Simple volume calculations were then engaged to determine the original concrete volume on each site. The next step is to calculate the volume of rubble generated when demolishing the asset, to reach figures applicable to further calculations. A conversion ratio of 1.6, as recommended by industry, has been used. The list of significant concrete volumes from these projects is shown in Table 3 below.

Asset Name	Region	Est. Cost	Est. Concrete	Est. Rubble
Mayor Rd No.1 Munster	Perth	$200,000	150 m^3	240 m^3
Mayor Rd No.2 Munster	Perth	$200,000	150 m^3	240 m^3
Wells St Reservoir	Mid West	$220,000	1200 m^3	1920 m^3
Tank Program	Agricultural	$450,000	250 m^3	400 m^3
Water Storage Complex Morawa	Mid West	$300,000	2000 m^3	3200 m^3
	Total	$1,270,000	3750 m^3	6000 m^3

Table 3 : Significant Upcoming Concrete Projects

The most significant equations from the model have been shown below to explain how the different processes interact to determine cost estimates. The variables used for modelling are listed in Table 4 and show current estimates of the respective parameters. Note that when conducting further modelling these variables must be re-evaluated for the given project. Figure 1 shows how cost increases with transportation distance with a project of fixed volume but varying distance from facilities. A secondary x-axis is included on the graph showing varying distance from the potential site to Perth, which drives the crushing cost but doesn't affect landfill and stockpiling. Note the distance to facilities counts for both landfill and stockpiling, although the distances may be different.

Equation Variables

Transportation Rate	$0.80/km rtn	Regional Stockpiling Rate	$10/$m^3$
Callout Rate	$16/km rtn	Regional Landfill Rate	$7/$m^3$
Metro Landfill Rate*	$17/$m^3$	Regional Crushing Rate	$7/$m^3$
Metro Recycling Rate*	$12/$m^3$	*includes all transportation	

Table 4 : Model Variables

Equation 1 : Sum of Volumes Constraint

$$Vol_{Total} = \sum_{i=StreamA}^{i=\text{Number of Streams}} Vol_{Stream(i)}$$

Equation 2 : Primary Disposal Stream Cost Equation

$$Cost_{Stream(i)} = Vol_{Stream(i)} \times \left[\overbrace{\left(Dist_{\text{To Facility(i)}} \times \underset{Transportation}{Rate_{\$/km/m^3}} \right)}^{\text{Transportation Cost}} + \overbrace{\underset{Disposal}{Rate_{\$/m^3}}}^{\text{Disposal Cost}} \right]$$

Equation 3 : Regional Crushing Cost Equation

$$Cost_{Stream(Crushing)} = \overbrace{\left(Dist_{Facility \rightarrow Perth} \times \underset{Callout}{Rate_{\$/km}} \right)}^{\text{Initial Cost}} + \overbrace{\left(Vol_{Stream(Crushing)} \times \underset{Crushing}{Rate_{\$/m^3}} \right)}^{\text{Crushing Cost}}$$

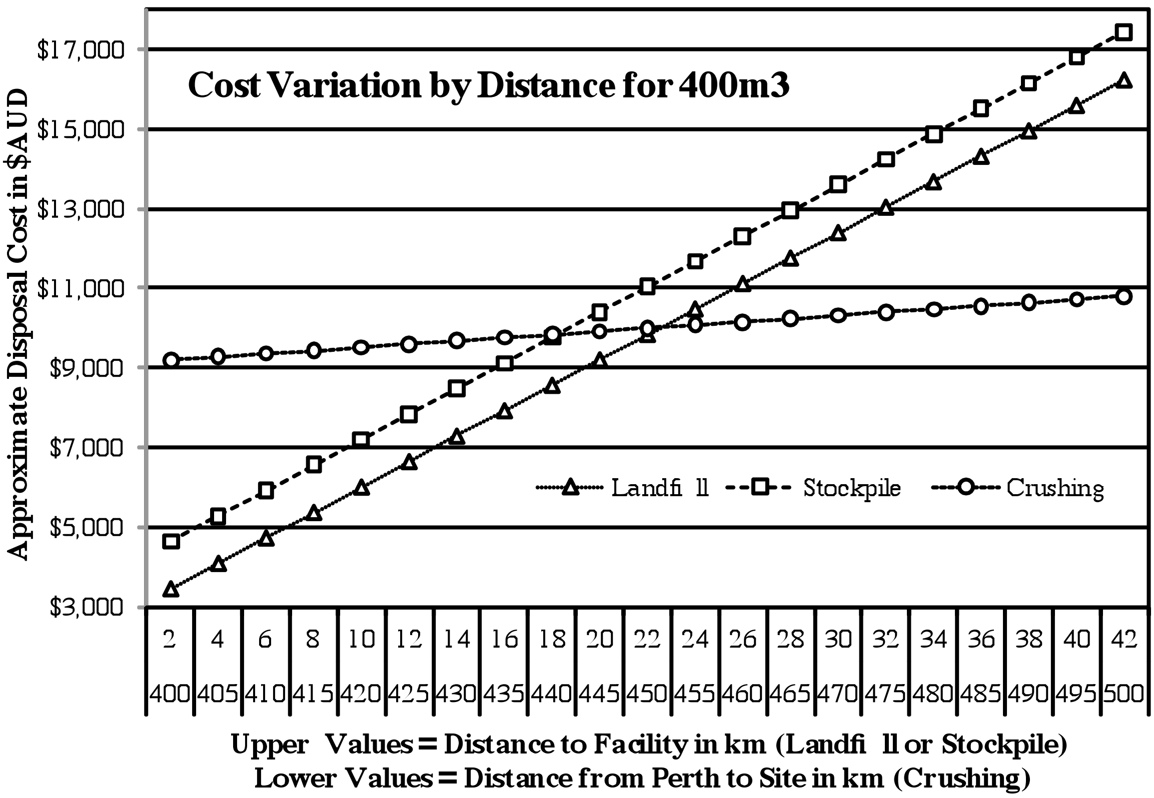

Figure 1 : Varying Disposal Cost by Method for a 400m^3 Concrete Asset

Using these values it is apparent that the most significant cost is transportation. In this way the high cost of transporting a crushing machine can quickly be overcome if the site is far removed from local facilities. This is particularly significant when differentiating between landfill and stockpiling. The results show that the cheapest option is essentially whichever is closest. Of particular interest are the costs for projects in the Metro area. Notably recycling will always be the cheaper option regardless of volume or location within the metro area. When this project was first begun this was not the case, but the quotes available now reflect the recent levy adjustments and expected directions. This demonstrates how government directives can rapidly change industry practices.

4. Conclusions and Future Work

The current model supports the view that transportation distances are the most significant factor in determining disposal methods. This is particularly important to shires and companies working to stockpile material for crushing. When strategically placed, these can quickly become cheaper than landfill. Alternatively, if landfill and stockpile distances are significant, high crusher callout fees can quickly be overcome for medium to large material volumes.

Unfortunately the most sustainable solution is not always the cheapest option. Future models aim to demonstrate the effects of result biasing to cater for corporate strategies and environmental policies. Theoretically this will present results that give priority to more sustainable practices, even though they may be more costly. This is in line with Water Corporation policy giving the results greater relevance.

Upon completion, these results and recommendations are to be shown to senior project managers within the Water Corporation. The aim is to start them thinking about how they can make their projects more sustainable. The Water Corporation has long held to corporate policies of environmental concern, this provides a tangible outlet for demonstrating commitment to these policies, both internally and to the general public.

5. Acknowledgements

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