Life Cycle Costing in Radioactive Waste Packaging: Reducing Costs Whilst Accelerating Clean-Up – 16131

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ABSTRACT

In recognition of the high up-front costs and potentially long timescales to implement the more traditional methods of encapsulating wastes, in the UK alternative approaches to help accelerate hazard reduction and reduce such costs are being deployed. When considering such the cost of alternative approaches to waste packaging strategies, it is important that the complete waste life cycle is taken into account.

This paper will demonstrate that when evaluating waste packaging options, whilst individual elements (e.g. container costs) within an overall waste management programme may appear to offer a cost benefit by comparison with alternatives, the programme as a whole may not necessarily be the most cost effective solution when life cycle costs are taken into account, or when other technical issues are considered. To illustrate this point this paper will present a view of the application of LCC, utilising a number of waste packaging scenarios, to promote discussion and consideration of the benefits of undertaking a holistic assessment of the investment decision as part of an overall waste management strategy.

BACKGROUND

The original strategy for managing intermediate level waste (ILW) in the UK was developed in the 1980s by the UK Nuclear Industry Radioactive Waste Executive (NIREX), which is now Radioactive Waste Management Limited (RWM), a wholly owned subsidiary of the Nuclear Decommissioning Authority (NDA). The strategy involved retrieving ILW and sorting and encapsulating it in cement based grout within thin-walled stainless steel containers. The containers would then be transferred to a large purpose-built shielded ILW store on site, where they would be stored until transported to the planned final deep geological disposal facility once available.

Such a strategy requires remote handling facilities for processing and encapsulating the wastes together with shielded stores and shielded transport containers for transport. To implement such a strategy requires lengthy programmes for the design, construction and commissioning of such facilities and in gaining necessary regulatory approvals. This may be preceded by a period of research and development as compatible encapsulants and waste packaging designs (containers) are sought.

In recent years, waste management organisations responsible for managing the clean-up of legacy facilities within the UK have sought innovative solutions which could potentially both accelerate clean-up and hazard reduction on sites, and offer a lower cost. In assessing packaging options for transport, storage and disposal of ILW, cost is not the only factor. Other attributes have to be considered such as safety, technical performance (with practicability and feasibility), social and ethical and security. However, cost clearly plays an important part in deciding a strategy for packaging ILW.

Many of the recent innovative packaging solutions in the UK have focused around a new family of packaging designs known as robust shielded containers (RSCs). These are self-shielded containers manufactured from materials such as ductile cast iron or fabricated steel; when manufactured in ductile cast iron they are often referred to as Ductile Cast Iron Containers (DCICs). When referring to RSCs this paper is primarily referring to DCICs.

To meet the performance requirements for disposal traditional thin-walled containers and self-shielded concrete containers require the waste contents to be encapsulated in cement based grout (dependent on waste material and compatibility with cement). However RSCs meet the necessary performance criteria with minimal reliance on the wasteform. As a consequence RSCs remove the requirement to build, operate and decommission complex and expensive encapsulation plant as this is no longer integral to waste packaging operations.

Furthermore, thin-walled unshielded packages require highly engineered facilities and shielded stores for interim storage, all with remote handling capabilities. RSCs, and to a certain extent self shielded concrete containers, also remove the need for these complex facilities.

By comparison with the traditional processes for waste packaging that use thin-walled containers, or indeed in comparison with self-shielded concrete containers, RSCs appear to be less cost effective based upon container costs. However, by considering the full life cycle cost of the build, operation and decommissioning of all aspects of the alternative waste management container strategies, a different picture emerges.

Where the waste owner has yet to commit to a waste management strategy and has incurred little or no expenditure on plant and equipment, this paper argues that RSCs offer waste owners the lowest cost solution.

However, where the substantial costs for plant and equipment have already been incurred and the facilities to encapsulate waste in thin walled containers and then store the packages exist, it may be that thin-walled containers are the better option in terms of lowest future costs.

Finally, there are some technical considerations around the suitability of containers to house certain wastes, depending upon the chemical, physical and radiological form of the waste. These factors also influence life cycle cost and are considered in this paper.

LIFE CYCLE COSTING

A thorough Life Cycle Cost assessment is a process that can help strategic planning and decision making for packaging radioactive wastes. These decision making processes are often guided by legislative requirements which look to ensure that risks from nuclear operations are As Low As Reasonably Practicable (ALARP) and that environmental impact, from say a waste management strategy, offers the Best Practicable Environmental Option (BPEO); these balance the benefits (reduced risk, most environmental benefit and least damage) of acceptable cost against the benefit offered. The principles of balancing cost and risk reduction in waste management were embodied within Radioactive Waste Management Policy, Final Conclusions, Command Paper 2919 published in 1995 [1].

What is the relevance of Life Cycle Cost to packaging of radioactive wastes?

Instead of considering only the initial purchase cost of items, organisations should look to quantify the costs of acquisitions, operation and disposal – the life cycle cost - of the complete waste packaging process. That approach may drive very different decisions on the most cost effective solution for packaging wastes.

> "There is considerable evidence to suggest that many organisations, in both the private and public sectors, make acquisitions of capital items simply on the basis of initial purchase cost. With the notable exception of military applications, very few assets seem to be appraised on the basis of their total lifetime costs. Two decades ago it was claimed that, very few firms appear to undertake life cycle costing studies at the acquisition stage of a physical asset's life, nor do they collect all costs over their life cycles, and apart from isolated examples, the evidence suggests this situation has not radically changed."
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> "The Life Cycle Cost of a physical asset begins when its acquisition is first considered, and ends when it is finally taken out of service for disposal or redeployment (when a new LCC begins). LCC seeks to optimise the cost of acquiring, owning and operating physical assets over their useful lives by attempting to identify and quantify all the significant costs involved in that life, using the present value technique. LCC is concerned with quantifying different options so as to ensure the adoption of the optimum asset configuration. It enables total LCC, and the trade-off between cost elements during the asset life phases, to be studied to ensure optimum selection."
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> *Source - International Journal of Project Management, Vol. 15, No. 6, pp. 335-344, 1997, Elsevier Science Ltd and IPMA, Life cycle costing--theory, information acquisition and application David G. Woodward*

Within any programme, the best opportunities to achieve an optimised solution at the lowest cost occur during the early concept development and design phase of a project. At this time, significant changes can be made for the least cost. At later stages of the project many costs have become "locked in" and are not easily changed. To achieve the maximum benefit available during this early stage of the project it is important to explore all processes and cost elements included within the life cycle.

"As over 70% of the total life cycle cost of a product is committed at the early design stage, designers are in a position to substantially reduce the life cycle cost of the products they design, by giving due consideration to life cycle cost implications of their design decisions"

Source - Product life cycle analysis: state of the art review, International Journal of Production Research, Y Asiedu and P Gu, Volume 36, Issue 4, pp 883-908, 1998

This paper demonstrates that when evaluating waste packaging options, whilst individual elements (e.g. container costs) within an overall waste management programme may appear to offer a cost benefit by comparison with alternatives, the programme as a whole may not necessarily be the most cost effective solution when life cycle costs are taken into account and when other benefits offered by alternative strategies are considered.

PACKAGING OPTIONS FOR INTERMEDIATE LEVEL WASTE IN THE UK

In the UK, and indeed globally, decommissioning activities of redundant plant and legacy waste facilities are being pursued to reduce the hazard from the wastes that exist within. These operations are producing significant volumes of Intermediate Level Waste (ILW). In the UK 2013 Radioactive Waste Inventory [2] it is estimated that about 200,000 ILW packages (existing waste packages and future arisings) would be produced from decommissioning, managing legacy wastes and future operations. These ILW packages comprise three broad categories: unshielded ILW containers [3] (e.g. 500 litre drum and 3 cubic metre boxes/drum as shown in Figure 1), shielded ILW containers [3] (e.g. 2m and 4m ILW boxes and 6 cubic metre concrete box as shown in Figure 2), and robust self-shielded containers (DCICs) [4] as shown in Figure 3 (e.g. Croft Minibox and 3m3 Safstore).

Figure 1. Unshielded Waste Packages (500 litre drum and 3 cubic metre box)

Figure 2. Shielded Waste Packages (6 cubic metre concrete, 4m & 2m ILW box)

Figure 3. Robust Self-shielded Containers (Croft MINIBOX AND Croft 3m3 Safstore)[1]

To meet disposability requirements in the UK, waste packages must prevent or minimise the release of activity from the waste package in impact or fire accidents [5]. Traditionally containment performance is achieved by a combination of the waste container and waste form; with immobilisation of the waste by encapsulation. In the case of ILW, encapsulation is primarily in a cement matrix contained within a thin-walled waste container. Such containers either have no concrete shielding to form an 'unshielded waste package' or additional concrete shielding within the container to form a 'shielded waste package' (see Figure 1 and Figure 2). Traditionally, shielded waste packages have also tended to be transport packages for low dispersible materials (Low Specific Activity Materials – LSA – and Surface Contaminated Objects – SCO [6]).

Preparing wastes for encapsulation often requires some level of pre-treatment (e.g. sorting, segregation), an encapsulation plant to immobilise the waste, a capping station to 'seal' the waste and a shielded store for 'unshielded waste packages'; this process is illustrated in Figure 4. For wastes encapsulated in concrete shielded waste packages the main difference would be the removal of the requirement for a heavily shielded store.

It should be noted that the plant, equipment and operations required for the above operations all give rise to secondary wastes that themselves require management.

[1] Croft Associates Ltd products

A new generation of waste containers has been introduced [5] to the UK. These robust self-shielded containers (RSCs) are manufactured in ductile cast iron (DCI) and called Ductile Cast Iron Containers (DCICs); examples are shown in Figure 3. These containers meet the performance requirements for disposal (e.g. impact and fire) without reliance on the wasteform. In terms of process, the different steps for the use of RSCs are illustrated in Figure 4 in the right hand block. It can be seen that these containers offer a much simpler process to the use of traditional encapsulation processes.

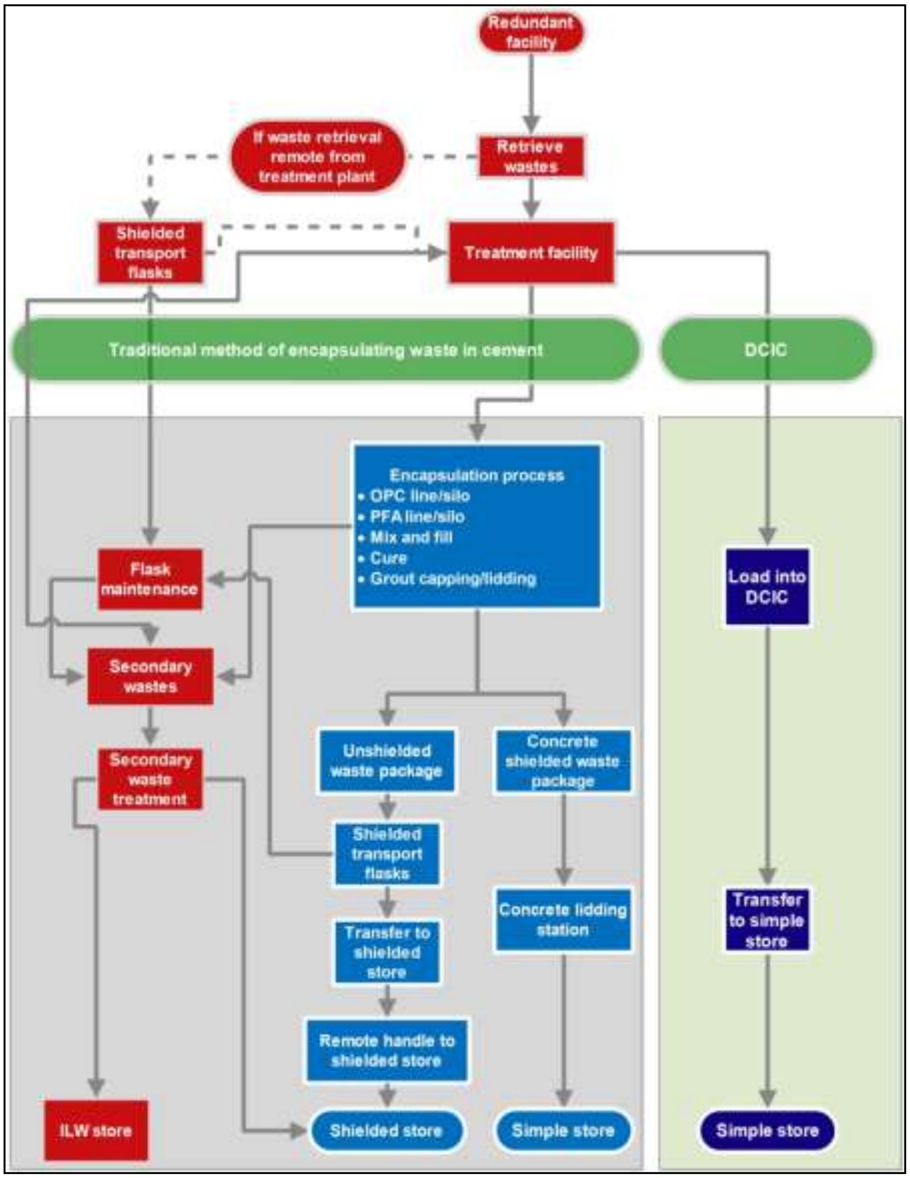

Figure 4. Illustration of different process steps for traditional encapsulation and use of DCICs

The benefits of DCICs are:

- savings in terms of reduced programme duration and cost to implement through the reduction in capital plant requirements; e.g. eliminates need for encapsulation plant integral to waste packaging operations;
- relative to thin-walled unshielded containers, savings in terms of shielded stores, shielded transport container infrastructure and remote operations;
- elimination of lengthy and costly research and development programmes required to establish waste and encapsulants behaviour;
- negating need to design, build, construct, operate and ultimately decommission secondary waste treatment facilities;
- achieving rapid hazard reduction through early retrieval and packaging of legacy wastes;
- overall reduction in waste produced as decommissioning of encapsulation plant and heavily shielded store not required;
- offer the ability for future retrieval and processing of materials; they do not foreclose future options;
- versatile to accommodating mixed wastes;
- packaging of some problematic wastes that are not compatible with cement encapsulation techniques; and
- relative to shielded concrete containers, a reduction in the number of containers required and therefore associated costs of transport, storage and disposal. This is because ductile cast iron is a more effective shielding material than concrete and therefore for a given external package size more waste can be stored and disposed of in a DCIC leading to fewer total packages.

In assessing packaging options for transport, storage and disposal of ILW, cost is not the only factor. Other attributes have to be considered such as safety, technical performance (with practicability and feasibility), social and ethical and security [7]. However, cost clearly plays an important part in deciding a strategy for packaging ILW [8].

> "Ultimately cost (based on total cost of procurement and storage for 100 years) is a primary consideration in reviewing package options. Minimising cost while ensuring cost-effectiveness and/or value is one of the key challenges in selecting the optimum waste package option"
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> *Source: Engineerlive, "Waste interim storage: the cost efficiency challenge", 21st February 2013*

COST CONSIDERATIONS FOR PACKAGING STRATEGIES

The cost of DCICs is generally regarded as higher than that of alternative unshielded or shielded waste packages. However, when the costs associated with the encapsulation of wastes, the build, operation and decommissioning of capital plant and the costs of transport, storage and disposal are factored into an LCC assessment then a very different relationship emerges.

The NDA illustrated this relationship considering only the different storage requirements for shielded and unshielded waste packages (see Figure 5 below). Clearly when other costs associated with encapsulation are also factored in the cross over point will move further to the right.

Figure 5. Indicative cost comparison of the cost of storage for RSCs (DCICs) and unshielded waste packages [4]

The economic viability of traditional unshielded or shielded concrete packages is further challenged when the cost of other essential elements is also factored into an LCC assessment:

- costs of continued asset care and maintenance for maintaining the safety of the facility awaiting decommissioning until waste packaging plant and processes are available;
- cost and programme extension for the design, construction, operation, maintenance and decommissioning of an encapsulation plant;
- cost and programme extension for the design, construction, operation, maintenance and decommissioning of an engineered shielded store;
- cost of packaging, transporting, storing and disposing of additional secondary wastes arising from operating and decommissioning additional plant and equipment;
- procurement, maintenance and operation of a fleet of shielded transport containers to move unshielded waste packages; potentially for both on-site and off-site transport movements; and
- maintenance and operational costs for plant and equipment associated with handling unshielded waste packages.

The discussion above largely considers arguments centred on possible effects within an LCC assessment of pre-treatment and encapsulation of wastes for shielded and unshielded boxes. What would also be important in ensuring cost effectiveness of a packaging option is the amount of waste that can be packaged into the container; the higher the packaging efficiency of a container, the lower the overall cost per m^3 of contained waste (more space for waste).

Iron is a much more efficient shield material than concrete due to its higher density and atomic number. Comparing the capacities of containers of the same external package volume that use concrete shielding (e.g. 2m and 4m ILW boxes and 6 cubic metre concrete box as shown in Figure 2), the DCIC offers an increase in waste capacity for comparable shielding efficiencies. This additional capacity means that DCICs offer the following additional benefits over concrete shielded boxes:

- fewer containers required;
- fewer packaging and handling operations;
- smaller store;
- reduction in transport movements (based on package volume);
- reduction in disposal costs (based on packaged volume); and
- reduced operational activities due to fewer containers, lower resource usage, reduced transport operations;

Such reductions may also assist in reducing overall radiation exposures to workers and members of the public due to fewer operations.

Within the nuclear industry in the UK there is a resurgent interest in using concrete boxes due to their potential low capital cost to manufacture. However, within the context of a life cycle assessment the initial higher cost of DCICs compared to concrete would be offset by savings when taking into consideration the other elements within the life cycle (e.g. eliminating waste encapsulation plant and the higher packing efficiencies afforded by DCICs).

Other factors that would need consideration in a waste packaging assessment comparing shielded concrete containers with DCICs are [9]:

- The technical maturity levels of each option (Technical Readiness Levels [10]). Particular waste management solutions may favour products that are at a more mature technical level; products at an early stage of development maturity may require considerable research and development effort to bring it up to a technical maturity level suitable for implementation.
- Suitability of the waste to be packaged e.g. the use of cementitious encapsulants may give rise to chronic waste evolution in some reactive wastes, potentially threatening waste package containment and performance. In waste packages where concrete is used for both shielding and containment functions, the properties of the waste form and its evolution characteristics could be highly constraining.
- Development and capital expenditure that may be required to demonstrate the suitability of concrete packages for long term storage, followed by transport and disposal.

- Risk mitigation may also be required when considering the use of a concrete container in case of non-compliance with transport requirements if it is to be approved as a transport package particularly after prolonged storage; an overpack may be required.
- If a concrete lid is to be cast on the concrete container, this requires facilities and capabilities necessary to do this remotely and to the required quality.

Consideration of all these factors from both a cost and a technical compliance perspective may lead to additional cost elements within an overall assessment of the life cycle costs of a particular waste strategy. Different scenarios are presented below to illustrate how a consideration of LCC can suggest a more cost effective solution when all elements of a waste packaging strategy are considered; a consideration of container cost alone would support one solution whilst a consideration of LCC might suggest another.

CASE STUDIES: WASTE CONTAINER OPTIONS

Case Study 1. Unshielded and shielded container options

The relative merits of packaging waste in an unshielded container (3 cubic metre box as shown in Figure 1) are compared to a shielded container of equivalent displacement volume (Croft 3m3 Safstore [11] which is a DCIC as shown in Figure 3). The assumptions regarding costs[2] are given in Table I (see Assumptions).

If container cost is singularly the most important factor in deciding between options then regardless of waste volume to be packaged the unshielded box would be the preferred option as the container cost is around 30% the cost of the equivalent DCIC (see Table I).

However, when other life cycle cost elements are built into the LCC model the relationships illustrated in Figures 6 and 7 emerge for a large and a small facility respectively; the LCC assessments include UK estimated costs for operational plant, transport to a geological disposal site and disposal. For significant volumes of waste as in a large facility it would be expected that processing and storage capacities and hence costs would be significantly larger than with processing smaller volumes of waste.

In both large and smaller facilities, and despite the initial higher cost of the DCIC, the assessment shows that there is a considerable total cost saving in using the DCIC option. As a store has a limited capacity as the waste volume increases that is processed additional storage capacity will be needed; this is shown as an increase in capital cost at 10,000m^3 for the larger facility and at 2,000m^3 for the smaller facility as an illustration.

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[2] All costs are indicative and presented for illustrative purposes only

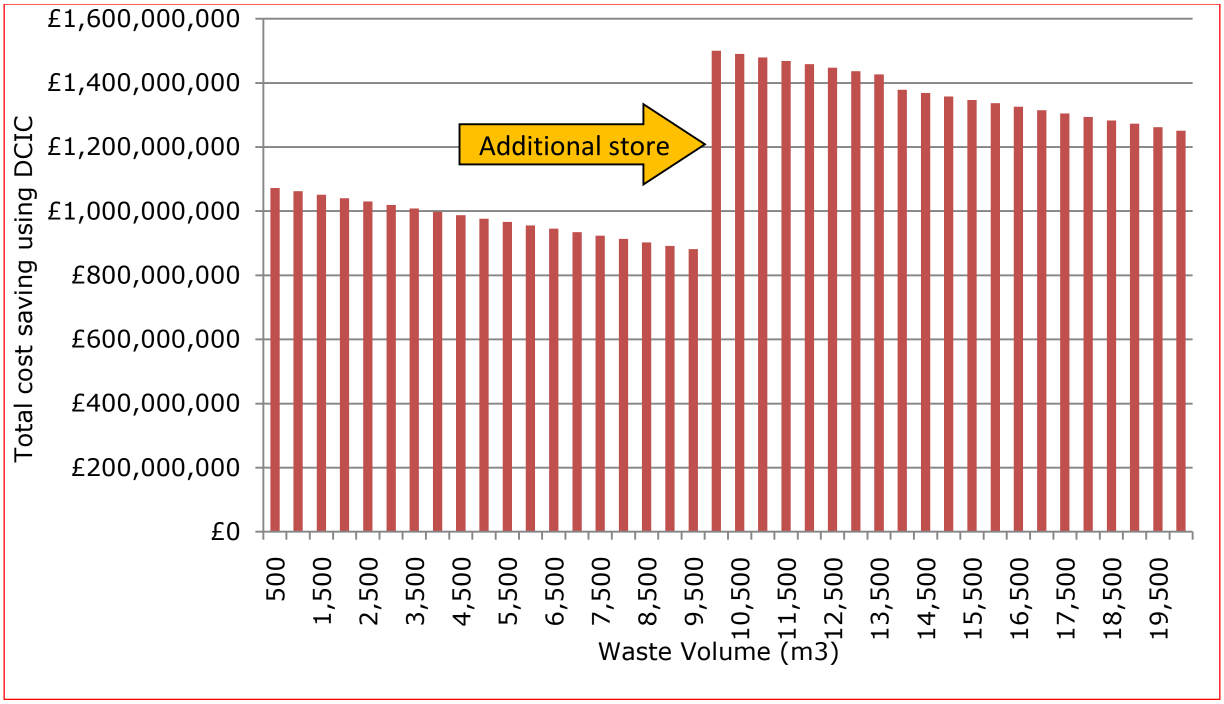

Figure 6. Indicative total cost saving using DCIC - Large facility

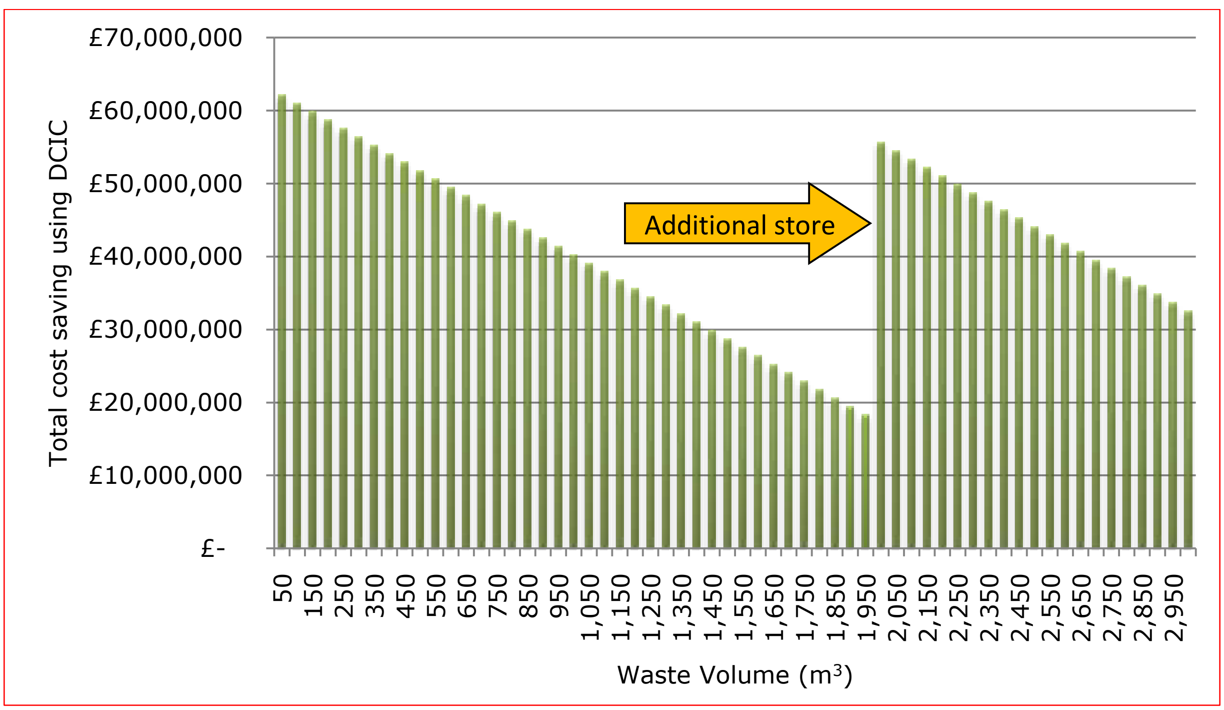

Figure 7. Indicative total cost saving using DCIC – Small facility

In these two cost LCC assessments it is the significant additional cost of the encapsulation plant and shielded store for the unshielded containers that, even when amortised over the number of packages processed, that adds significant cost to processing via this option. The lower capital cost of plant for processing waste in DCICs makes this the more cost effective option with significant cost savings over the unshielded/encapsulated process.

Any net savings and the point at which an option represents the most economic solution will very much depend on site specific requirements and waste volumes; the examples above are intended to show how other factors in an LCC assessment can support a different solution than when considering container costs alone.

Case Study 2. Shielded container options: concrete compared to DCIC

In this case study the cost of packaging waste into a shielded container is considered where shielding is provided either by iron or concrete.

The comparison is made between a 6 cubic metre concrete box [12] (concrete shielding) and a Croft 2m Safstore [11] (ductile cast iron – DCI - shielding); both have approximately the same displacement volume, although the concrete box is slightly larger. The costs attributed to this scenario are illustrated in Table II in the Assumptions. The Croft 2m Safstore provides shielding by nature of its ductile cast iron manufacture. With the concrete box the walls provide the shielding; the waste is still required to be encapsulated.

If a waste strategy is selected on container price alone, the selection would favour the 6 cubic metre concrete box as this is about 25% of the cost of the 2m Safstore. However, when other cost elements are considered in the LCC assessment the total cost savings of using the DCIC option emerge, as shown in Figure 8 considering processing, storage, transport and disposal cost elements. This cost saving using the 2m Safstore are largely due to the much larger capacity of the 2m Safstore, this has a internal capacity of around 50% more space for waste than the 6 cubic metre concrete box due to the more efficient shielding capacity of iron as compared to concrete. This means that more concrete boxes are required compared to DCIC. This represents a significant increase in the overall volume (displacement) of the concrete packages to be transported and disposed.

Excluding transport and disposal cost elements within the LCC assessment and considering only processing and storage costs, the relationship in Figure 9 emerges. Excluding these elements from the LCC assessment still shows that the 2m Safstore option provides the more economic solution with significant cost savings.

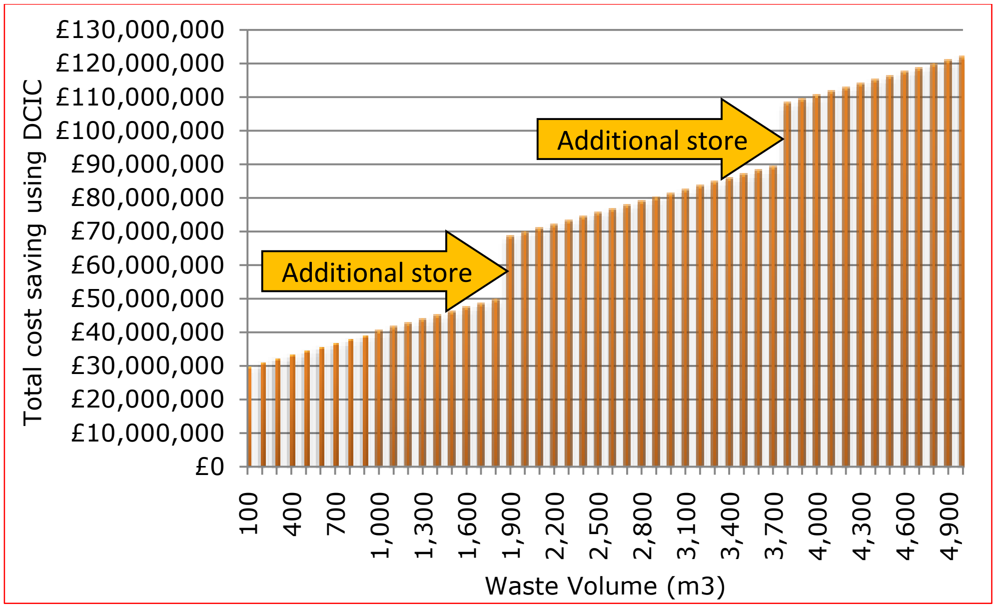

Figure 8. Indicative total cost saving using DCIC (iron) compared to concrete for shielding: costs include processing, storage, transport and disposal

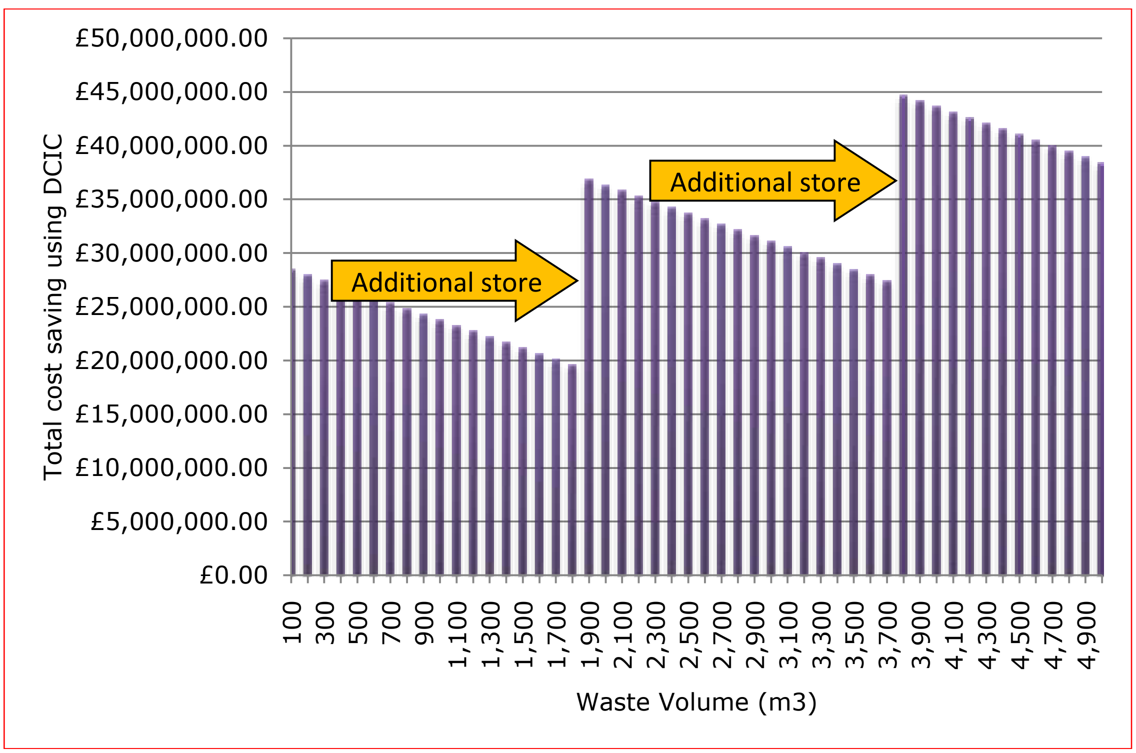

Figure 9. Indicative total cost saving using DCIC (iron) compared to concrete for shielding: costs include processing and storage, excluding transport and disposal

As in the previous case study, when considering all elements within an LCC assessment this can determine a more economic waste packaging strategy than in considering just the cost of a single element.

In addition other factors that could influence the choice of waste packaging option include:

- compatibility of the waste material with box internal storage environment;
- timescale for designing and building and gaining approval for an encapsulation plant and/or a heavily shielded store which might favour a quicker solution, e.g. for ageing legacy plant; and
- the requirements to carry out research and development on encapsulation processes might favour a quicker timescale and greater certainty.

Such issues might favour a lower risk strategy such as that offered by the use of DCICs; a lower risk strategy might also mean more certainty regarding timescales and costs to implement.

CONCLUSIONS

There may be a perception that when an *individual* project element within an *overall* waste management programme presents a cost saving over alternatives that this represents the most cost effective *optimum waste package option*; this saving may prove to be somewhat illusory when considering all elements within a LCC assessment of that programme. The examples given comparing DCICs (RSCs) with the more traditional methods are simply intended to illustrate this point. This is not to say that there is one specific waste packaging solution and there are issues other than cost to consider.

Removing the need for capital plant for waste packaging provides opportunities to accelerate clean-up and hazard reduction. DCICs also offer technical advantages for wastes not compatible with the traditional approach of encapsulation and shielding using concrete and, subject to appropriate design and materials selection, are compatible with a disposal strategy which can include a significant period of interim storage before final disposal.

Balancing cost and risk reduction are important regulatory drivers, particularly for dealing with legacy issues. Although each waste owner will consider their specific circumstances, in determining the optimal solution it will be important to consider:

- the estimated full life cycle costs of each alternative, including capital costs, operational costs, costs arising from increased programme length, decommissioning costs and transport, storage and disposal costs;
- the uncertainty associated with those estimates. Programme and project risk is increased by lower levels of product maturity, technical uncertainties requiring R&D (and therefore with no certainty of a solution) and the need for

large scale projects and ongoing operations, which by their nature may give rise to cost and schedule overruns; and

- issues such as safety, technical performance (with practicability and feasibility), social, ethical and security.
- Solutions that offer a greater certainty and future demonstrability of technical and regulatory compliance.

Two illustrations have been given; that of comparing use of DCICs to the more traditional approach of unshielded containers with waste encapsulation, and comparing use of DCICs to the use of concrete boxes where the concrete provides both shielding and encapsulation. This paper shows that whilst container costs for DCICs are higher than other options (concrete boxes and thin walled unshielded containers), DCICs nonetheless can offer a more economic solution when looking at an LCC assessment.

> "The LCC approach to strategic decision making encourages a holistic assessment of the investment decision-making process rather than attempting to save money in the short term by buying assets simply with lower initial acquisition cost."
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> *Source - International Journal of Project Management, Vol. 15, No. 6, pp. 335-344, 1997, Elserver Science Ltd and IPMA, Life cycle costing--theory, information acquisition and application David G. Woodward*

ASSUMPTIONS – CASE STUDIES

TABLE I. Illustrative costs for processing waste into unshielded and shielded containers for of same displacement volume

LCC element	Unshielded container	Shielded container
Description	**3 cubic metre box**	**DCIC**
Cost per container	£45,000	£140,000

	3 cubic metre box waste packaging option	DCIC waste packaging option
Treatment plant (sorting, segregation, loading)	£450,000,000	£100,000,000[3]
Design, construction & approvals of grout plant for encapsulating wastes		N/A
Maintenance and operation of plant - 10 years service	£100,000,000	£30,000,000
Decommissioning at end of service (assuming non-active)	£90,000,000	£20,000,000
STORE	Heavily shielded store	Simple store
Design, construction and approval of store	£450,000,000	£15,000,000
Operation of store	£20,000,000	£5,000,000
Maintenance	£70,000,000	£15,000,000
Decommissioning	£90,000,000	£1,800,000
CONTAINER INFORMATION		
Internal volume (m^3)	2.8	2.4
Displacement volume (external) (m^3)	3.7	3.7
Waste packing efficiency	50%	80%
TRANSPORT & DISPOSAL COSTS	(disposal in unshielded-container vault)	(disposal in shielded-container vault)
Transport costs per m^3 of displacement volume	£1,276	£1,276
Disposal costs per m^3 of displacement volume	£10,475	£3,921
Store capacity m^3	10,000	

Notes:

- Although the DCIC will have a slightly smaller internal cavity due to the shielding extending into the container cavity, the unshielded container will accommodated

[3] Cost of a pre-treatment plant to remotely load waste into RSC and unshielded box – an encapsulated plant not required as integral part of waste packaging operations

less waste due to the presence of the grout encapsulants; this is reflected in the waste packing efficiency.

- The DCIC will require some pre treatment but does not need to be encapsulated as an integral part of waste packaging operations.
- A pre treatment plant and an encapsulation plant will be required for the 3 cubic metre box
- The unshielded 3 cubic metre boxes will require storage in a heavily shielded store as they offer no significant shielding capacity.

- The DCIC requires storage in a much simpler store allowing man access and waste packages do not require remote handling TABLE II. Illustrative costs for processing waste in containers providing shielding in concrete and iron (DCIC) with similar displacement volumes

LCC element	**Concrete shielding**	**Iron shielding**
	6 cubic metre concrete box	**DCIC**
Cost per container	£30,000	£120,000

ENCAPSULATION PLANT	**6 cubic metre concrete box waste packaging option**	**DCIC waste packaging option**
Design, construction & approvals of pre-treatment plant	£35,000,000	£15,000,000[4]
Design, construction & approvals of grout plant for encapsulating wastes		N/A
Operation and maintenance of plant	£10,000,000	£5,000,000
Decommissioning at end of service	£7,000,000	£3,000,000
STORE (simple store)		
Design, construction and approval of store	£9,000,000	£9,000,000
Operation of store	£2,000,000	£2,000,000
Maintenance	£5,000,000	£5,000,000
Decommissioning	£1,800,000	£1,800,000
CONTAINER INFORMATION		
Internal volume (m^3)	5.0	8.7
Displacement volume (external) (m^3)	11.9	10.7
Waste packing efficiency	50%	80%
TRANSPORT & DISPOSAL COSTS	(disposal in shielded-container vault)	
Transport costs per m^3 of displacement volume	£1,276	£1,276
Disposal costs per m^3 of displacement volume	£3,921	£3,921
Store capacity (containers)	750	

[4] Cost of a pre-treatment plant to remotely load waste into RSC – an encapsulated plant not required for RSC

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